Reduce the noise of microwave amplifiers with a design method that makes use of Linvill and quadrant charts to simplify the mathematics. The charts also help choose the best trade-offs among other major parameters, such as stability, power gain and signal-handling ability. For the complete story, turn to page 54.
Gold-plated components conduct better, solder easier, reflect heat, and resist wear, corrosion, oxidation, galling.

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- (< 3 parts/10⁹/day optional)

Price: $1800

Want more information? Call or write your Hewlett-Packard field engineer for complete data, Hewlett-Packard, Palo Alto, Calif. 94304; Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

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Plug-ins for Militarized 880A

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- Functional Digital Circuits
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New from Sprague!

TRIGATE* PULSE TRANSFORMERS... the industry's lowest-cost SCR triggers!

Dependable enough for industrial equipment, yet priced for high-volume commercial applications

Here's good news for designers of appliances; lighting controls; air-conditioning and heating controls; industrial controls. You can actually cut costs while upgrading your present method of SCR triggering!

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Comsat down, Centaur up—a busy week in space

The disappointing failure of Comsat Corp.'s communications satellite, Lani Bird, to achieve synchronous orbit over the Pacific last week climaxcd 7 busy days in space.

The satellite, officially known as Intelsat 2 but nicknamed "Lani Bird," was to have been the first of two spacecraft to be launched this fall that would eventually have extended commercial space communications to two-thirds of the world.

Preceding the Comsat launching by 13 hours was the United States' successful first double ignition of a high-energy hydrogen-fueled engine in space.

During the early launch phases Lani Bird appeared to be functioning well; however, a motor aboard the satellite misfired in an attempt to put the satellite into stationary orbit 22,300 miles above the Gilbert Islands in mid-Pacific.

Another attempt to establish a commercial communications link across the Pacific Ocean is scheduled to be made later this month with the second of Comsat's satellites due for launch this fall. Had Lani Bird been successful, this second, unnamed spacecraft was to have joined Comsat's Early Bird spacecraft launched in 1965 over the Atlantic Ocean.

The new spacecraft will be twice as big as Early Bird but will have the same 240-circuit capacity. It will, however, have twice the power and expected lifetime. The extra power will enable the satellite to relay its radio signals to a much greater area than Early Bird (see illustration below).

In the earlier launching the upper stage of an Atlas-Centaur rocket was ignited twice to hurl a dummy model of a Surveyor spacecraft toward a predetermined point in space. The launching was a rehearsal for later Surveyor soft-landing missions on the moon.

Problems in taming hydrogen as a space fuel, including failures on two previous double-ignition attempts, had set Centaur's full development program back about three years.

The recent success, according to NASA spokesmen, will enable the U. S. to send heavy payloads to the moon and other planets.

During the same week the Soviet Union's Luna 12 sent back to earth the first Russian close-ups of the lunar surface from an orbiting probe. The pictures were reported taken from an altitude of 58 miles.

Meanwhile the United States announced that it had commanded its camera-carrying spacecraft, Lunar Orbiter 1, launched last August, to crash into the far side of the moon. The purpose was to keep the spacecraft's radio signals from interfering with a new U. S. Lunar Orbiter set for next month.

As the week neared a close NASA officials announced that the first three-man Apollo space flight would be postponed at least a month, because of "unresolved engineering problems." It had been scheduled for early December. Preparations are now underway to launch the four-day Gemini 12 mission, which will conclude the Gemini manned space flight program that was begun nearly two and a half years ago.

Chinese nuclear missile disturbs U.S. officials

Communist China's recent firing of a short-range, nuclear-tipped missile has surprised and disturbed American officials.

It demonstrated once again the unexpectedly rapid progress the Red Chinese are making in nuclear and missile technology.

According to a State Dept. spokesman, the development of an atomic warhead small enough to ride on a missile and still produce a large explosive yield represents one of the most difficult challenges of atomic technology.

One leading rocket designer noted that developing a nuclear warhead required the use of brains but relatively little engineering skill. A rocket, he added, requires a high degree of competence to solve the myriad problems of bringing tens of thousands of components together in a workable vehicle.

Defense Secretary Robert McNamara estimated earlier this year that China would be capable of launching a nuclear attack on countries within 500 miles of her borders within two or three years, and against the United States within a decade. So far this estimate has not been revised. There is some specula-
tion, however, that the Chinese missile blast might hasten the development of an operational Nike X antimissile system.

400 million ICs a year are foreseen by 1971

By 1971 the industry demand for integrated circuits will increase 15-fold to 400 million units annually, according to Ben Jacoby, marketing manager for RCA's integrated circuit division.

Addressing a recent Instrument Society of America meeting in New York City, Jacoby said that 150 million units of the 1971 total would be linear circuits, mostly for the control instrumentation market.

He listed some of the major industry-wide programs that are underway to improve linear ICs. They included:

- Extension of the frequency capability from 100 MHz today to 1 GHz in 1971.
- Reduction of low-frequency noise by a factor of 100.
- An increase in voltage capability from 50 to 100 volts.
- A rise in the component count per chip from 30 to 150.

Jacoby predicted that within five years the price of custom-made ICs, produced at the rate of 1000 units a year, would be between $10 and $25 a unit. General-purpose ICs, with production runs of 100,000 units annually, he said, will sell from $1 to $3 five years from now.

Jacoby forecast that specific integrated circuits for consumer applications and produced in quantities of two million a year would probably be sold to equipment manufacturers for as little as fifty cents each.

VSTOL planes called best hope for short hops

With rapidly increasing populations in the nation's urban areas, there is a growing need for an "air bus" to speed short-haul public transportation.

The vertical, short takeoff and landing (VSTOL) airplane appears to be the leading candidate for the 1970s, according to Jack Brewer, program manager for NASA's VSTOL program. He spoke at the Second International Congress on Air Technology that was held in Hot Springs, Ark.

By 1985, Brewer said, commercial airlines will be faced with a severe logistics problem in short hauls of cargo and passengers between cities. By then, it has been predicted, more than 130 million people will be living in super metropolitan areas.

Though many different VSTOL concepts have been studied and a few have even reached the prototype stage, a number of technical problems remain to be solved. A leading problem, according to Brewer, is the need to augment the aircraft lift with power, but without excessive use of fuel, during low-speed flight in the vicinity of the terminal area.

Nuclear missile contract goes to Boeing Co.

The Air Force has awarded a $235.8 million contract to the Boeing Co. for development and production of a nuclear-tipped, air-to-ground missile for use by U.S. strategic bombers.

Known as the SRAM (short-range attack missile), the weapon will be mounted on late-model B-52 bombers and on the strategic bomber version of the F-111 to be placed in service in 1968.

The missile will have a reported range of 50 to 75 miles.

Oxygen obtained from aircraft cabin moisture

Pilots and astronauts may some day be breathing oxygen obtained from the cabin moisture of their spacecraft.

A device, developed by the General American Transportation Corp., breaks down into its components (hydrogen and oxygen) the cabin moisture which is built up through the perspiration and respiration of the occupants.

In aircraft, its use would eliminate the need to use stored oxygen—usually in the form of liquid oxygen or "lox"—and a dehumidifier.

The most likely initial application, according to a company spokesman, is in military aircraft, which often require complicated liquid-oxygen generating and storage facilities at remote airfields.

Forget-Me-Not stars in Chicago

What is it? A new medical machine? A modern sculpture? A collection of junk? In a whimsical spoof of the science of automated calculation, the Honeywell Electronic Data Processing Div. in cahoots with Britain's celebrated cartoonist, Rowland Emett, presented it at the Business Equipment Exposition in Chicago as the "ultimate" computer—the Honeywell-Emett "Forget-Me-Not."

The four-dimensional "cartoon"—a moving, blinking, noise-making creation of bamboo, birds, door knobs, lamp shades, playing cards and measuring tapes—was first shown at London's Business Efficiency Exhibition. "Our commission to Emett to invent the Forget-Me-Not stemmed from a belief that there is room for some levity in an industry that has been taken so seriously for the past 20 years," explained Walter W. Finke, group vice president of Honeywell's Computer Group.
Be Prepared

Building digital systems can be tricky business. The parameters may change. Preliminary results may call for equipment modifications. It happens all the time. It's best to be prepared.

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The PAR Model 100 Signal Correlator provides a general purpose, high accuracy instrument of wide dynamic range that computes the auto- or crosscorrelation function of input signals and makes them available for continuous display. This system computes 100 points of the correlation function over total spans from 100 microseconds to 1 second. It operates by simultaneously multiplying one input signal by 100 separate delayed replicas of the second input signal. The resulting 100 products are individually averaged and stored in analog memory elements. Readout, which may be performed continuously as the correlation function is being computed, is accomplished by scanning the memory bank at a rate consistent with the speed of the external readout device, e.g., an oscilloscope or x-y recorder.

Correlation analysis — an extremely powerful signal processing technique in many areas of science and engineering — has heretofore been neglected, largely due to a lack of availability of suitable equipment. The PAR Model 100 Signal Correlator will be useful in such diverse fields as aero- and hydrodynamics, plasma physics, vibration analysis, radio astronomy, radar, lasers, medical physics and geophysics.

PAR Model 100 - Hundred Point Time Delay Correlator SPECIFICATIONS IN BRIEF:

**Total Delay Range:** 100 µSec to 1 Sec in 1, 2, 5 sequence.

**Input Signal Levels:** Peak-to-peak signals of 0.4 volts to 200 volts are accommodated without overload in each channel.

**Correlator Gain Factor:** At gain of 1 in each channel, 1 volt into each input will give 1 volt of correlated output. Gain for each channel is 0.01 to 5, in 1, 2, 5 sequence.

**Noise and Dynamic Range:** Base line noise with no signals, 10⁻³ volts peak-to-peak. Maximum correlated output, 3.5 volts.

**Frequency Response and Resolution:** Channel amplifiers flat to 1 megahertz. Resolution: 100 sampling points on output function.

**Averaging Time - Constant:** Nominally 20 seconds; May be changed to any value from 0.1 to 100 seconds.

**Accuracy:** Better than 1%.

**Readout:** 0-3.5 volts at sweep rates of 20 per Sec, 1 per 10 Sec, 1 per 50 Sec.

**Price:** Approx. $7500.00

For more information call (609) 924-6835 or write Princeton Applied Research Corp., Dept. E, P.O. Box 565, Princeton, N. J. 08540.

Typical Photograph of Crosscorrelation Function of Input and Output Signals of Complex Passive Network Driven by White Noise.
New uses for microwave power explored

Hundred-mile underground waveguides may one day carry billions of watts to distant cities

Peer Fossen
West Coast Editor

Right now, microwave power is used mostly to cook roasts in minutes or to run diathermy machines that cure sore muscles in the arm of a baseball pitcher. But billions of watts may yet travel underground in the form of microwaves to power industrial machines and to heat batches of materials.

Microwave power could travel hundreds of miles in foam-wave guides and even negotiate slight bends, according to Prof. Donald Dunn of Stanford University.

"The transmission of huge amounts of power in underground polyurethane waveguides has several advantages," he says. "No unsightly towers need mar the countryside, and the underground guide need not occupy the surface of valuable real estate. The microwaves do not interfere with radios, pose no danger of electrocution and are less vulnerable to bad weather and enemy attack."

Such a microwave guide would have a diameter of about five feet. The foam layer would surround a thin copper lining, the conducting material that actually guides the beam. The waveguide's inner surface would be protected by a low-loss dielectric such as Teflon. Air would be forced through the hollow tube to cool it.

"One of the flaws in this plan is the lack of a billion-watt power tube," says Dunn. "Million-watt tubes presently operate at around 8000 MHz. But since power transmission could use much lower frequencies, we should be able to boost power with no theoretical difficulty."

Once the beam is guided into a plant, it could be used directly in heating, cooking and curing processes. But if it is to do any form of mechanical work, it must power motors. According to Dunn, this might be accomplished two ways:

The microwave beam could be rectified and used by dc motors. Or microwave motors might be developed to use the beam directly.

A study of the feasibility of microwave motors is presently under way at Stanford. A program at Marquette University, Milwaukee, is under way to develop a motor with a built-in set of rectifiers. The rectifiers would be placed in the motor's armature, and would rotate with it.

At present the difficulty in using rectifiers to convert the microwave beam to dc is similar to that in making the beam: there is no theoretical restriction, but high-power, high-efficiency rectifiers have not yet been developed.

An increasing number of companies are investigating exciting microwave-energy applications, ranging from the removal of solvents in magnetic-tape production to powering helicopters. Among the leaders in this field are the Atherton Div. of Litton Industries, Palo Alto, Calif.; Cryodry Corp., San Ramon, Calif., a subsidiary of Armour & Co.; the Eimac Div. of Varian Associates,
(microwave power, continued)

Palo Alto, Calif., and Raytheon Co., Waltham, Mass.

Raytheon, for example, has been working on a microwave-powered helicopter. An antenna from the ground sends microwaves to the helicopter's antenna. The received energy powers an electric motor that turns the rotors. The company has made small working models and hopes to develop a full-size whirlybird that can soar to altitudes of 10 miles. The microwave helicopter could serve as a communications relay station.

Microwaves may some day power more conventional vehicles. At Rensselaer Polytechnic Institute, Troy, N. Y., Dr. Joseph Foa is working on plans for a microwave-powered rapid transit system. As the train approaches an antenna, it would radiate microwaves to the train.

Industrial uses rise

Recently there has been a spurt in industrial uses of microwaves. But these uses have capitalized more on the ability of microwaves to heat materials through and through.

Small microwave ovens operating at low power and low frequency can quickly cook any material with an appreciable relative dielectric constant. (Metals cannot absorb microwaves and thus do not lend themselves to such heating.) The first ovens were expensive, hard to maintain and their tubes didn't last long.

Most of the problems with these early ovens have been overcome in the new generation of microwave systems now going on line in processing plants throughout the world. The first manufacturers to make use of microwaves are in the food, drug, chemical and forestry-product fields. Others will be forced to look to microwave systems to remain competitive, and new fields are being explored every day.

Oddly enough, it was the successful use of microwave power in the final heating and drying process of potato chips that started moving this technology from the R&D laboratory onto the production floor.

The microwave ovens are fast and compact. And the potato chips seem to stay fresh days longer than those cooked in conventional ovens. According to Granny Goose, makers of the chips, microwave ovens, operating at 65 kW and 2450 MHz, can cook a potato at a much lower cost per chip.

While the final configuration varies from one manufacturer to another, each of the microwave systems contains certain basic building blocks:

- A power supply.
- A microwave (RF) generator.
- An applicator.
- A sensing device.
- Operating controls.

To these can be added a series of production accessories, such as waveguides, tuners, channeling devices and conveyor systems, for continuous processing.

The cost of microwave heat must be higher than the cost of heat from the combustion of natural fossil fuels. But its peculiar ability to heat volumes much more uniformly than other sources make it ideal for certain specialized jobs. For example, the protective coatings on plywood can be heated and dried quickly without the risk of scorching the outer layers of the wood.

A more novel use of microwave energy in the medical field can be credited to the University of Edinburgh. There, they simply stick the patient into a microwave oven and restore him to normal body temperature after low-temperature open-heart surgery. Because of the short time needed to attain the desired temperature again, more time can be spent in surgery.

Still another medical application: Blood plasma is quick-thawed as it is needed for transfusions. Conventionally the plasma expected to be used during an operation is drawn out of the blood bank and thawed well in advance. Whatever is not used has to be discarded. With microwave thawing, hardly a drop need be wasted.

The principle of microwave heating is simple. It is based on the electric dipole moment of the molecules of the substance being processed. As RF energy penetrates the substance, the molecules attempt to align themselves with the electric field. Subjected to a high-frequency alternating electrical field, the dipoles oscillate about their centers. Internal friction in the material converts the mechanical energy of the vibrating dipoles to heat.

The FCC has assigned six microwave frequencies for industrial, scientific and medical use—13, 30, 915, 2450, 5800 and 22,125 MHz. There are no power limitations on the propagation of electromagnetic
Fairchild Dual RTL integrated circuits are a new generation of multiple complexity devices. They pack twice the number of logic functions into a ¼” by ¼” flat pack. You get a quad 2-input gate into a space previously required for a dual. You also get Fairchild Planar® epitaxial processing, positive NOR or negative NAND logic, noise immunity of 300mV, typical propagation delays of 12nsec., hermetically sealed packaging, and full military range temperature capability. All Fairchild Dual RTL circuits are also available in industrial Dual in-line packaging, with a temperature range of 0 to 70°C. You can also get a dual J-K flip-flop in the DIP (see 9994 diagram). And this is only the beginning. A hex inverter, a four-bit shift register with parallel inputs, a four-bit shift register with complementary outputs, and other dual circuits will be coming your way soon. Get evaluation samples from your Fairchild Distributor. Or, get our data sheets. Get going.

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SPRAGUE COMPONENTS

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News

(microwave power, continued)

waves at these frequencies.

Though the use of microwave power—particularly radiation in the two highest-frequency channels—has not yet reached its infancy, there is more than enough interest in this peculiar form of power to justify the existence of a specialized society.

Form new microwave society

Formation of a new international technical society for the exchange of information on the applications of microwave power to industrial processes was recently announced by a group of Canadian and U. S. scientists.

The group, known as the International Microwave Power Institute (IMPI), will provide economic analyses on microwave power versus conventional fossil-fuel applications, and combinations of both. Details of particular microwave heating systems will also be made available.

The new society plans to publish annual technical proceedings and direct an information program. Its next annual symposium will be held at Stanford University, Palo Alto, Calif., March 29 to 31, 1967.

Microwave power pipeline section

made of plastic foam is displayed by Prof. Donald Dunn (right) and a graduate student, Walter Loewenstern, Jr., both of Stanford University. By converting the electric power to microwave energy, they believe such a pipeline could carry billions of watts for hundreds of miles underground to cities of the future.
Pulsed plasma engine runs 2 years on an ounce of fuel

A tiny rocket engine can develop 1/10,000 of a pound of thrust by accelerating clouds of plasma down a pair of parallel conducting rails, according to its inventor Dr. Aldo LaRocca, manager of advanced propulsion, General Electric, Philadelphia. The engine, complete with voltage converter, triggering circuit and fuel, weighs only 1.5 pounds. One ounce of fuel can power the engine for up to two years, according to LaRocca.

The key to the design of this extremely simple, lightweight space engine is the use of a passive fuel feed. This is nothing more than a wick that replenishes a thin film of the fuel, which must conduct electricity at least fairly well, physicist John Siviski explained.

Triggering electrodes pass 2000-volt pulses through this thin film of fuel. The fuel ionizes and then forms a cloud at the base of the two parallel accelerating electrodes. The current, $j$ (see diagram), flowing into these two rail-like electrodes, completes a closed path by flowing through the plasma.

This ion current interacts with the component (B) of the magnetic field that is perpendicular to the plane of the rails. This magnetic field is created by the current in the rails and the cloud of ions is propelled along the rails at supersonic speed by the force resulting from this interaction. The plasma is discharged from the engine at the end of the rails, and the momentum of each ion cloud provides the thrust that pushes the engine along.

The G. E. scientists have used fine aluminum particles suspended in silicone for the fuel. The silicone is normally an insulating liquid, but the colloid of aluminum particles in silicone conducts electric current. The scientists are presently experimenting with liquid inorganic polymers that are conductive.

Thrust is controlled by regulating the frequency and intensity of the pulses to the triggering and accelerating electrodes.

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IBM announces military/space version of the system/360

Complete capability over the data-processing spectrum is claimed by International Business Machines with the announcement of their new 4 Pi series of digital computers. The new family of compact computers has been named 4 Pi to reflect its relationship to System/360.

The “360” in System/360 refers to the number of degrees in a circle, emphasizing the system's ability to handle total data-processing requirements. 4 Pi, the number of steradians (3-dimensional radians) in a sphere, indicates that a new dimension has been added to this capability.

Read-only storage can be used in both System/360 and System/4 Pi to control logic operation so that a general-purpose computer can be adapted easily—without rebuilding logic circuitry—to a wide range of specialized applications.

The 4 Pi series makes the first ready for use in a tactical missile, the TC version of the 4 Pi consists of three major subassemblies: (from left) memory, input/output and central processor. Each subassembly consists of 13.25-inch-diameter assemblies of two multilayer interconnection boards and supporting aluminum plate. Mirror shows bottom side of assemblies.
Superior Pulse Response

with Time Domain Crystal Filters

Damon applies advanced insertion loss design techniques to realize Time Domain Crystal Filters with prescribed transient behavior. Overshoot and ringing can now be eliminated in pulse systems. Damon has supplied filters with Gaussian, Bessel and Thomson polynomial characteristics. Completely eliminated are the pitfalls inherent in attempting to obtain desired pulse behavior from "equivalent" steady state design. Damon Time Domain Filters are aligned and tested under pulse conditions simulating actual equipment operation. Applications include Pulse Doppler Radar, FM-CW Radar, Spectrum Analysis, Pulse Interference Rejection, and Pulse Data Communications Systems such as PCM, FSK.

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Gimbal-less gyros win NASA backing

NASA scientists favor the use of so-called "strapdown" gyroscope systems in spacecraft, as opposed to the more conventional gimbaled systems. They also advocate the use of a single, integrated, general-purpose computer—instead of several separate ones—to perform all of the computing functions aboard.

These trends in spacecraft design were reported by Dr. Winston Kock, outgoing director of NASA's Electronic Research Center at Cambridge, Mass., in a speech before the National Electronics Conference and Exhibition in Chicago. Beside reviewing the achievements of the two-year-old center, Dr. Kock announced that he had resigned, effective Oct. 1, to return to industry as director of research for the Bendix Corp. He has been replaced by James C. Elms, formerly NASA's Deputy Associate Administrator for Manned Space Flight.

The problem of gyro drift, complicated by rising costs for the fabrication of improved gimbaled gyros, was cited by Dr. Kock to explain why NASA favored strapdown gyro systems.

In the strapdown system—so called "because in it the gyroscope bearings are connected to the vehi-
cle without gimbals"—the problem of drift due to friction can be overcome, Dr. Kock said.

"With no gimbals to permit the gyros to remain oriented in their original direction as the craft rolls or yaws," he explained, "the gyros must move with the craft. This motion generates forces on the gyro bearings, and if sensors are provided to detect these forces, full information for guidance is still available."

With the advent of compact, lightweight, low-cost components, computers can now be built for use with the more complex strapdown system, Dr. Kock said.

"Strapdown guidance packages thus provide one of many examples of a trend in which substitution of electronic functions for mechanical ones can result in lower costs," he added.

Turning to other computer developments, Dr. Kock reported a new trend at NASA's Cambridge center.

Besides the guidance and control computers, he noted, some computers on spacecraft must assemble and store data from various sensors; others are used for telemetry.

"Thus there are many computer functions," he continued, "and the question has been: Should each function have its own computer, or should there be one integrated multipurpose computer network which can accommodate all of the needs of the spacecraft?"

Scientists at the center, Dr. Kock said, feel that "under some circumstances much can be gained in flexibility and reliability by following the multipurpose computer route."

Other areas that Dr. Kock touched on included:
- Microwave technology (NASA recently used a Gunn diode in a successful voice communication circuit).
- Solid-state materials (investigations are focusing on high-band gap materials: aluminum phosphides, aluminum antimonides and sodium nitrides).
- Microwave radiometry (the center has developed a modified Dicke radiometer that makes use of signal-comparison techniques from two lobes radiated from the same antenna).
- Holography (experiments are in progress to use it in an airport landing-simulation device).

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More computer traffic cops due

New York is installing the world's largest system, and smaller cities are following the trend.

Ron Gechman
News Editor

Within eight years New York City will have the world's largest central computerized traffic-control system. It will cost $100 million and will operate the signals at 9000 intersections.

In San Jose, Calif., traffic is already flowing smoothly under the control of an IBM 1710 Model II computer. Delays have been cut 14%, the city reports, and the probability that a vehicle will have to make a complete stop has been reduced by more than 17%.

The two sides of electronic traffic control—the planning and the results—were presented to the annual convention and exhibit of the Instrument Society of America. Among the speakers at the New York event were E. Vinson Hoddinott, chief of the Bureau of Signals and Communications for the City of New York, and O. I. Bermant, program manager of vehicular traffic systems for the International Business Machines Corp.

Recalling the rapid-transit strike in New York last January, Hoddinott noted that it caused an increase of 43% in the normal daily traffic of 550,000 to 600,000 vehicles in Manhattan. Traffic became so knotted that a 20-minute ride home for some office workers stretched into two to four hours. Without electronics, the city could expect jams almost as bad as this in eight years, Hoddinott told the convention. Studies indicate, he said, that traffic in Manhattan will increase 30% by then.

New York has already taken two steps toward easing the anticipated mass snarl: it has completed an engineering study of the feasibility of electronic direction of traffic, and it has awarded a $5-million contract to the Sperry Rand Co. to furnish the computer and control equipment. Early next year, Hoddinott reported, the third phase of New York's traffic modernization program will begin with the installation of the equipment in four boroughs.

New York's approach

The computerized signal system for the city will consist of a number
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ON READER-SERVICE CARD CIRCLE 17

ELECTRONIC DESIGN 25, November 8, 1966
of area systems, interconnected and coordinated by a central computer and sub-master computers. But all of the area systems will be linked into one citywide control system.

"Unlike most of the conventional systems, which use only one master control unit, ours will operate initially with ten," Hoddinott said. These will be solid-state digital computers, functioning as both master and sub-master units. They will operate without air-conditioning or humidity controls and within ambient temperature variations from 0° to 110°F.

Control sensors at selected locations on arterial streets throughout the city will measure speed and traffic volumes, and solid-state telemetry equipment will transmit the data to the master computers.

On the basis of this information, the computers will transmit signal-timing instructions to local intersection controllers.

Two types of control sensors will be employed. One operating on the radar principle, will transmit and receive reflected radio signals from vehicles passing the device. The other will function in a similar manner, but they will operate in the ultrasonic region. The sensors can be mounted either at the side of the roadway or directly over it. Both types will be supplied by the Sperry Gyroscope Co.

A unique feature of New York's system, Hoddinott reported, is that it will employ an entirely separate set of sensors to check on the accuracy of the control system.

Another feature is the critical intersection controller, which changes the signal lights. A non-electronic traffic controller at the intersection of two busy streets ordinarily sets the signals for a 50-50 split. In the New York system, the intersection controller may permit as little as 30% of the total green time to be allocated to either street, depending on the speed and volumes of approaching traffic.

Loop detectors in San Jose

In describing San Jose's system, IBM's Bermant said that the California city had added 320 loop detectors, used only to initiate a contact closure. The traffic detectors are connected by direct wire to the central IBM computer. The computer has a card input and output, a disk file, a printer and manual entry and display units. A display board depicts the green conditions of the intersections on a system map.

The programing system consists of a series of sub-programs, all under the control of a supervisory program, called the traffic monitor.

Each sub-program has a particular function to perform, such as scanning detector inputs, advancing controllers, checking the synchronization, allowing for operator intervention or logging data. The priorities under which these programs operate and the information flow between them are controlled by the traffic monitor. Each sub-program can be reloaded without affecting other sub-programs. In this way the decision-making function can be modified without changing the operational data-gathering or analysis elements.

Intersection control a problem

One decision any city must make is whether or not it should have a central computer system to control traffic intersections. Robert Doble of the Link Group of General Precision, Inc., told the convention of developments in advanced intersection control. One solution, he noted, is to control a majority of a city's traffic intersections through the central computer, which receives inputs from detectors all over the city. In the downtown areas of major cities where traffic is heavy all day long, this is desirable, since changes of offsets and cycle times must be closely coordinated.

However, in cities that have extended boundaries—like San Francisco and Los Angeles—signal lights and traffic are spread over large areas. While traffic is widely heavy at rush hours, it is relatively light the rest of the time. In these cases, Doble said, the efficiency of total computer control is doubtful, as well as costly.

He discussed two new methods of individual intersection control that do not use a central computer but do use more economical digital logic. One of the systems, called the variable clock reference method, has detectors 350 feet from an intersection and at the stop line. The controller therefore monitors the traffic arriving at an intersection and also the traffic passing over or waiting at the stop line.

Reference clock used

The reference clock runs at a predetermined speed and provides a series of subtractive pulses that are applied to a ring counter or similar

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**Diagram:**

Two-phase variable reference-clock controller has four basic system blocks: reference clock, phase counter, AND gate and signal-light control unit. External inputs come from the vehicle detectors and pedestrian buttons. More phases can be added, simply by connecting additional detectors, counters and gates to the reference clock.
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device. Vehicles running through an intersection on a green light actuate a detector to apply additive pulses to the counter. Vehicles approaching the cross street actuate detectors to introduce subtractive pulses to the total count. The difference between the additive and subtractive pulses determines when the clock runs out. When the clock reaches zero, the counter initiates a green-light signal, which is passed through an AND gate to the signal-light control unit to change the light condition.

Four basic units

The control system is composed of only four basic units: the reference clock card, phase counter card and gate card, plus the signal-light control unit. The number of phases at any intersection can be expanded merely by plugging in the appropriate selection of these units.

The reference clock is a voltage-controlled oscillator that provides a series of subtractive pulses. The pulses are applied to a ring counter, into which additive pulses from the detectors are also fed. Therefore, vehicles running through on the green light add to the count, while the clock pulses subtract from it. Also causing the counter to reach zero at a faster rate are subtract pulses from detectors on cross streets, where vehicles are waiting for a green light. When the count reaches zero, the counter issues a green-light terminating signal to the signal-light control unit through an AND gate. One AND gate is installed for each green phase available at the intersection.

The AND gates provide a means to skip a phase, if no vehicles are waiting for that particular phase to turn green. The gate requires two inputs: a green-light terminating signal from the counter, and a release signal generated by a vehicle passing over the detector associated with the next phase scheduled to get the green light. If no terminating signal is received, the outgoing gate passes the green terminating signal to succeeding gates, until one is found that does have a vehicle waiting.

The signal-light control unit performs the function of changing the lights on command from the signals received from the AND gates.

Loop-occupancy controller

The other new system for individual intersection control is called the loop-occupancy controller. The vehicle detector used in this system is a loop detector, consisting of a loop of wire buried in each approach lane and extending from the stop line back for 50 to 90 feet. The loop can inform the computer when a vehicle gets within it, when it leaves the stop line and whether another vehicle has followed the first one into the loop.

The loop-occupancy controller method is simpler in operation and circuitry than most other automatic-control systems. Without further complication, the system can be expanded to any number of phases, can automatically skip phases when no vehicles are present, and can be wired to provide phase overlaps — such as left turns from opposite directions — to any extent required.

In the absence of any cars in the intersection, all lights are red. A typical loop extends 65 feet from the stop line. When a car enters, the light turns instantly to green. It remains green while the vehicle travels through the loop. Immediately after the vehicle has passed the stop line, the signal cycles through amber to red.

Should a number of cars enter the loop, the light remains green so long as there is continuous occupancy of the loop. Cars approaching the intersection from the cross street must wait until there is a break in traffic. Cross-street traffic, therefore, is slipped in between main street gaps.

This system can handle traffic volumes greater than other systems because it does not allow any unused green time to appear.

To eliminate the possibility that a continuous flow of traffic will keep the light permanently green in one direction, a time-delay circuit is added to terminate the green after a predetermined time.

The proceedings of the ISA Convention can be obtained from the Instrument Society of America headquarters, 530 William Penn Place, Pittsburgh, Pa. • • •

Camera stores image on plastic film

A new electronic reconnaissance and surveillance camera records images on a plastic film that has no magnetic surface and needs no chemical development. The film records images by storing electric charge in its dielectric surface.

The film is a flexible cronar tape that is coated with gold-copper alloy. This conducting layer is, in turn, coated with arsenic selenide (a photoconductive material). A thin layer of insulating material protects the working surface when the film is rolled on a spool.

Just prior to exposure, the tape is erased by a flood of electrons, which bring the dielectric sandwich to a constant potential over its entire area. While the image is being exposed to the film, another flood of electrons charges every point in proportion to the amount of light falling on it. During read-out an electron beam scans the film's surface and measures the charge density of the conducting layer.

The tape can be erased simply by being flooded with electrons. It can be read over and over, once the image is recorded, until it is erased. Moreover, the tape can either be carefully and slowly scanned by a very fine beam to obtain a high-resolution image, or it can be quickly scanned by a broader beam for a lower-resolution image.

It can store high-density information for long periods of time, and is extremely radiation-resistant. Combined with a color filter system, the dielectric camera can map objects in full color.

The tape and camera system were developed for NASA by the Radio Corporation of America, Princeton, N. J. • •
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Here's the first practical laser device you can order for less than $100.00. It's G.E.'s new gallium arsenide infrared laser diode—the H1D1. Typical peak output power at room temperature: 5 watts. Typical peak current: 100 amps.

Now you can afford lasers for dozens of military, commercial and industrial applications never before considered. Wireless communication links, isolated coupling, instrumentation, and measurement present excellent possibilities.

New low-cost H1D1 pulsed room-temperature injection laser diodes—another General Electric first. Devices shown approximately twice actual size.

And plans are underway to use them for night surveillance, intrusion alarms, plant protection equipment and optical range finders.

Peak wave length of G.E.'s new H1D1 laser diode is 9,000 Angstroms at room temperature. Each is mounted in a TO-46 header and hermetically sealed in a metal can with a flat glass window at the top.

Test one yourself. H1D1's are available now from your G-E engineer/salesman or semiconductor products distributor. Circle Number 812.

Here are those new low-cost voltage reference diodes you've been waiting for

Prices run as low as 40 cents in volume quantities. New F16H1 temperature-compensated diodes are actually two diodes connected in series within a single pellet and with one common anode. Key features include:

- low temperature coefficient—$dv/dt<0.025%/°C$ max
- $V_z$ reference voltage—5.2v (typical)
- close thermal coupling

These new devices are designed for general purpose voltage reference and voltage regulator applications up to 15 milliamperes. Here are just a few of their industrial and consumer possibilities in addition to uses as temperature-compensated reference diodes:

- as symmetrical voltage reference diodes.
- as dual diodes with one common anode.

In standard G-E economy TO-98 packages (shown actual size)

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- as dual or single zener diodes.
- as premium voltage reference diodes.
- as variable capacitance matched diodes.

Circle Number 811 for more product and application information.

Speaking of Light-Emitting Devices

... have you checked into General Electric infra-red light-emitting diodes (LED's)? At room temperature they'll emit light at 9,000 Angstroms. This opens the door to many new uses for LED's. For example, they're a perfect spectral match for modern-day light detecting devices (such as G.E.'s new low-cost light-activated silicon controlled switch). Or you can use LED's for high speed reading of computer cards as LED's will follow a signal up to 2 megacycles. No more mechanical errors inherent with "feeler" devices.

Other distinct new advantages are possible for high-voltage isolation, optically coupled computer elements, photoelectric systems, and high-speed infra-red photography. Circle Number 813 for more details on these and many other devices in the G-E family of opto-electronic semiconductors.

These are just a few examples of General Electric's total electronic capability. For more information on all G-E semiconductor products, call your G-E engineer/salesman or distributor. Or write to Section 220-47, General Electric Company, Schenectady, New York. In Canada: Canadian General Electric, 189 Dufferin Street, Toronto, Ontario. Export: Electronic Components Sales, IGE Export Division, 159 Madison Ave., New York, N.Y., U.S.A.
Congress to favor science

'67-'68 to be banner science years

The White House Office of Science and Technology is predicting that the next two years will be the biggest so far in American history for officially supported science and technology. The forecast is also being made by almost all of the technology-oriented agencies and from both sides of Capitol Hill, as Representatives from "safe" election districts and Senators not up for re-election begin thinking about the upcoming 90th Congress. The next two years, all parties point out, may not see more money spent by the Government—unless something breaks in Vietnam to ease war budget pressures—but more emphasis, more talk, more legislation and more moral support are expected for technology than in the past.

Politically science is "in." The Republicans have called for Government use of aerospace types of systems management for all major Government programs, such as the war on poverty, attacks on pollution and transportation problems, medical research and urban redevelopment. The White House says that systems engineering already is at work in most of these areas. A major G.O.P. 1968 campaign issue is expected to be whether the Administration and the Democrats in Congress have done enough to bring science to bear on non-military, 'non-space problems and whether Federally-supported research is being translated rapidly enough into practical, mass programs. Last summer, knowing that a Republican policy committee was about to issue study papers on the application of technology to civilian problems, President Johnson beat the opposition to the punch by ordering concentrated efforts to get research results into the mainstream of national life sooner.

Despite a NASA-sponsored report indicating that new technology cannot be forecast and that, if it could, nobody apparently really wants to attempt it, the House Committee on Science and Astronautics wants to form a national commission that would largely have as its mission the forecasting of technological change.

Committee Chairman Emilio Q. Daddario (D-Conn.) says the proposed Technology Assessment Board would be an "early warning system" to alert the nation to undesirable by-products of new technologies: air and water pollution, atomic waste, collision hazards and other "evils" that temper the benefits of new technology. To predict the unwanted side effects, Rep. Daddario admits, the board would first have to forecast the development of new technology. The committee is expected to hold hearings on the proposal next year.

Subminiature connector hassle resolved

In-fighting among the military services and within the industry over standardization of subminiature cylindrical connectors has finally been resolved. A tri-services conference and the Defense Electronics Supply Center have adopted a design by the Amphenol Corp (Astro/348). Seven U.S. and one British concern presented designs in the competition. The chosen design does not meet every one of the criteria demanded by the three services, particularly with respect to air leakage. Nevertheless, a Navy spokesman for the tri-services conference said, the "over-all characteristics and performance" of the Amphenol design "were the closest to the criteria established by the three services."

No sooner was the announcement made, at a Naval Air Systems Command symposium on advanced techniques for aircraft electric systems, than a Navy spokesman revealed that the connector already was undergoing modifications to meet new requirements imposed by the military forces.

A spurt for high-speed transit R&D

Watch for R&D spending in the high-speed ground transportation program to speed up next year. The war in Vietnam is likely to make inroads into the total budget, but the Office of High-Speed Ground Transportation—now in the Commerce Department but soon to switch
to the new Transportation Department—has recently hired additional engineers and R&D administrators to monitor new programs. Programs deliberately held at a low spending level will be accelerated.

The entire program moves into a second phase later this year. Advanced technology, including electronics, will get more attention. The first phase consisted largely in organizing the office and in getting the Boston-Washington rail experiment set up. While railroad cars in the experiment are whizzing along stretches of the Pennsylvania’s tracks at up to 150 mph, gathering data, the Office of High-Speed Ground Transportation can reorient toward advanced technology needed for future systems. In the offing: development of data-acquisition, signaling, communications and control systems. Cryo-pumped tube vehicles and ground-effect machines that use smoothed, hardened earth paths as rights-of-way are under study. So are linear electronic motors and the vehicles that they would power.

Marines look into maintenance systems

Problems in Vietnam are showing the Marine Corps that maintenance systems that work on paper and that perform well in a well-defined, large-scale war do not necessarily work in brush fighting. The Marines are giving serious thought to redesigning their entire maintenance system. And they are looking for an R&D-oriented concern to provide the technical advice. So far there has been no official request for proposals, but companies that might be interested have been invited to outline their qualifications to do the job. Some of the thinking at Marine Corps headquarters is that more men can be put into fighting if front-line maintenance men are replaced by modularized, pull-out, plug-in equipment. Also, with present airlift capabilities, it may be cheaper and more effective to discard, rather than repair, much equipment; new equipment could be flown in. One thing is certain, the Marines say: automatic data processing will be applied throughout any new maintenance management system.

Industry warned to sharpen management

What does the Navy want most from the electronics industry? Navy Secretary Paul H. Nitze says that all of the cries for greater reliability, faster performance, lower costs, and longer equipment life boil down to two words—“better management.” He says:

“We continue to see vital and costly programs fall short of desired goals in time and performance, or even fail completely. The reasons for this are hard to isolate. We have seen the same company do an outstanding job on one program and fall short on another. We frequently see different companies unable to produce comparable results on the same or similar equipment. The causes are sometimes technical, sometimes costs, sometimes management. But even where management is not directly responsible, there are always overtones of management problems. Of all the improvements we can make, a creative approach to management offers the greatest prospect of return.”

Nitze’s comments were addressed to the electronics industry at a IEEE Aerospace and Electronic Systems Convention. They were part of a speech that emphasized that the Navy was moving toward more advanced electronic systems. Observers saw them as a warning that the Navy might take over some in-plant management or drop some of its contractors.

Navy studies shipboard systems costs

Any proposed changes in shipboard systems will in future probably have to measure up to a new set of standards. These standards are the result of a survey of the costs of performing a variety of jobs aboard naval vessels, which has just been completed by the Office of Naval Research (ONR). The Maritime Transportation Research Board of the National Academy of Sciences-National Research Council cooperated with the ONR to study operations—including radio and electronic—on board 20 ships. The data that they collected form the basis for a new data collection system, which they suggest should be used to evaluate proposals for modifying on-board systems or installing new ones.

The main points of the new data collection system are contained in a report on the study made of one of the 20 surveyed ships. The report is entitled: “Shipboard Systems Costs: A Functional Analysis of Work Aboard Ship, MTRB Ship Number 5—A Tanker in Domestic Service” (Order AD-637 786). Copies may be obtained for $2.00, or 50¢ in microfiche, from the Commerce Department Clearinghouse, Springfield, Va. 22151.
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Deeper probe of ionosphere due

Penn State to use improved equipment, better techniques to study RF signals

Ron Gechman
West Coast Editor

Improved high-frequency radio equipment and a relatively new technique for measuring the effect of disturbances on signals may soon add significantly to our understanding of the ionosphere.

The dual approach is being pressed by Pennsylvania State University engineers, who are installing a new transmitter, antenna array and improved receiving equipment to probe deeper into the ionosphere. The equipment is scheduled to be in operation by December and will, according to one of the university's investigators, Dr. Anthony Ferraro, aid in answering such questions as these: How did the ionosphere form? What disturbs it? How can long-range radio communications be improved?

Of prime importance to researchers is the ionosphere's ability to reflect radio signals back toward earth. Because ionization depends primarily upon the sun, and the sun displays strange behavior (sun spots and flares), the reflective ability of the ionosphere varies. This causes radio fading. Also affecting the ionosphere are man-made disturbances, such as those caused by atomic explosions. The area that appears to pose the greatest problem to long-range radio transmission is the lower, or D-region, which extends from 30 to 60 miles up.

To study the effects on radio transmission, researchers needed a way to monitor quickly and continuously the electron density of the ionosphere at all altitudes and to investigate what happens to the density when it is disturbed by the transmission of radio signals. Two Penn State Engineers—Dr. Ferraro, an associate professor, and Dr. Hai-Sup Lee, assistant professor, both in the Dept. of Electrical Engineering and members of the university's Ionosphere Research Laboratory—developed a technique called phase interaction. It requires two ground-based radio transmitters, a receiver and an array of antennas.

Two high-frequency radio signals are aimed into the ionosphere, so they will intersect at a particular altitude in the D-region. On entering the ionosphere the first signal warms the electrons in its path only (continued on p. 36)

Ionospheric-disturbance experiment is conducted by Penn State engineers with high-frequency radio signals. One signal, beamed into the ionosphere, causes a change in phase of a second signal, by heating the electrons in the ionosphere at the intersection point.

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Fluidic navigator guides Army on March

With a five-pound fluidic navigator hooked to his belt, a soldier can pound the forest turf in darkness and be sure of his location.

A bellows attached to one foot sends a puff of air surging up to the navigation unit each time the soldier takes a step. Two permanent magnets in a liquid-filled case track magnetic north, and the unit's fluidic logic calculates the soldier's new position after each step.

The unit, developed by the Martin Marietta Corp. of Baltimore, is said to be jam-proof. However, if the soldier is dragged any appreciable distance, the unit must be reset.

NEWS

(ionosphere, continued)

slightly. The second signal, transmitted at a higher power, greatly warms the electrons, causing a change in phase of the first signal. This change is measured on the ground.

Ferraro and Lee experimented with their technique over a year ago, but when the new equipment goes into operation, many questions about the ionosphere, especially those concerning radio-wave propagation, will hopefully be answered, Ferraro says.

Situated near University Park in the center of Pennsylvania, two transmitters are synchronized with each other. The first, called the "wanted" station, broadcasts 80 pulses per second at 2.2 MHz. The output power of this station is 10 kW. The wanted signal is beamed into the ionosphere, reflected back to earth and recorded at the receiving station.

The precise altitude where the signal is reflected can be calculated from the time span between the transmission and reception of the pulses.

A second transmitter, called the "disturbing" station broadcasts at 40 pulses per second at 4.5 MHz. The power output is 500 kW, but when the new antenna array is installed, the effective power will be raised to 15 MW. Pulses from the two stations are synchronized, so the signals will intersect in the ionosphere at a point below the altitude where the wanted signal was reflected back to earth (see diagram).

The high power of the disturbing transmitter greatly warms the electrons in the path of the signal. The disturbance created at the intersection of the two signals causes a greater change in phase of the wanted signal. This change is recorded on the ground and compared with the signal received before its disturbance.

The Penn State engineers have designed and built an elaborate system to help the receiver distinguish changes in the wanted signal, even against a background of a continuously changing ionosphere. The system continually adjusts the two transmitters, so the signals will intersect at varying altitudes within the D-region.

Using an earlier system for measuring the effects of disturbances, the two engineers found they could continuously sweep the entire D-region in about an hour. If the sweeping rate could be significantly increased, all changes in the ionosphere due to either natural or artificial disturbances could be continuously monitored, the Penn State engineers reasoned. This is why the Office of Naval Research, sponsor of the program, authorized Ferraro and Lee to improve their equipment. The new equipment will allow the entire D-region to be continuously and precisely swept in less than 30 seconds, Ferraro asserts.

In another ionospheric experiment, scientists at the Cornell Aeronautical Laboratory are preparing to measure electron densities in the D-region during a total eclipse of the sun on Nov. 12.

They will collect scientific data before, during and after the eclipse. Equipment is now being set up in Brazil to transmit signals into the ionosphere to obtain electron density profiles. The profiles will be analyzed to determine the effective electron production and recombination rates.
Roger Smullen is a 30-year-old malcontent. He came to Fairchild six years ago in Quality Assurance. Then, he became a Production Foreman. Then, Production Engineer Supervisor. Now, he's Product Manager in the Custom Integrated Circuits department at Fairchild. He can never leave well enough alone. We need three more like Roger. If you're not content, contact Jack Sheets at Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, California.

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NEW

Ruby laser process controls resistivity

A new ruby laser process is being used to adjust, in a predictable and controllable way, the electrical values of the tiniest available microelectronic thin-film resistors. Unlike other laser trimming methods, in which material is burned away, the new process alters film resistivity. This is achieved by momentarily heating the thermally alterable film above a threshold temperature.

The process is being investigated by the Univac Defense Systems Div. of the Sperry Rand Corp., St. Paul, Minn. A major advantage of their method, the researchers say, is the ability to localize the point of impact of the minute laser light on the surface of the hybrid circuit. Their hope is that ultimately it will be practical to automatically adjust resistors about one-fifth the width of a human hair.

Adjustment of resistivity is achieved when light from a ruby laser (left) is aimed at the resistor on a one-eighth-inch-square hybrid circuit, mounted at the right of the apparatus. By precise regulation of the beam, Univac researchers can predict and control subtle changes in the electrical values of the resistor, to meet the strict electrical requirements of a given circuit.

Zinc-air battery cuts weight sharply

A practical zinc-air battery has been developed for space and military applications, and several commercial laboratory units look very promising.

The single biggest advantage of the zinc-air battery is its high energy-per-weight (watt-hours/pounds) figure. Batteries of 150 watt-hour/lbs have been developed—about twice the figure of a conventional silver-zinc battery—and the theoretical limit is 450.

Zinc-air batteries also operate well at low temperatures—as low as \(-40^\circ F\).

These details were disclosed at a news conference in New York City by Leesona Moos Laboratories of Great Neck, Long Island, N. Y., developer of the new battery. Dr. Stewart M. Chodosh, Product Manager-Batteries of the company, displayed several developed zinc-air batteries, described further development work, and briefly explained the working mechanism of the zinc-air battery.

In producing power, the zinc anode is converted into zinc oxide. The cathode, meanwhile, remains unchanged, acting to form hydroxyl ions from the oxygen combining with the electrolyte of potassium hydroxide.

At present zinc-air batteries can be obtained either as primary or mechanically rechargeable batteries. The mechanical recharge consists of replacing the zinc anode (the only part that "wears") with a fresh one.
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NEWS

AF memory unit 'programs' attacks

The Air Force is testing a new Integrated Armament Control System that lets the pilot "program" his pattern of attack before he reaches the target and then carry it out with a flick of a switch.

Current fighter-bombers often have entirely different controls and displays for each family of weapons, including nuclear and conventional bombs, dispensers and tanks, the Air Force says. The new system gives the pilot a consolidated armament control panel. A readout display shows the type of weapons carried, where they are located and the status of each—armed or safe.

A unique feature of the system is its memory-selection capability. With buttons on the control console, the pilot can program several different types of attack before takeoff or while he is en route to the target. He chooses the number of weapons he wants to release, the stations they will be released from, interval between releases, delivery mode and other conditions.

Several choices available

One program, for example, might call for several passes over the target, with two bombs released on each pass. Another might specify a salvo attack, with all bombs falling on one small target during a single pass. A third might call for a combination of weapons.

The pilot can select the most suitable program from the memory unit just seconds before starting his attack. He merely moves a selector switch to it, aims and touches his bomb-release button. If none of the pre-selected programs is suitable, he can quickly establish a new program to fit the target situation.

The system has a built-in test capability. To find out if all circuits are working, the pilot presses a button on the control console. If there is a major malfunction, the panel indicates the source.

The prototype for the system was developed by the Technical Measurement Corp. of North Haven, Conn. Tests are under way in an F-105 fighter plane at Kirtland Air Force Base, N. M.
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**Just plug in at any tree**

Sir:

You printed a letter from Charles A. Klimko [ED 17, July 19, 1966, p. 38] which accused ED of frivolity in publishing a photograph of Michel Yardney about to plug his electric car into a tree receptacle [ED 13, May 24, 1966, p. 17]. This is not so far in the future as it may seem.

In August, 1964, we parked our travel trailer by the town park of Manti, Utah, and were delighted to find outlets on several trees, provided by the town fathers for travelers such as we. This idea should spread to any town that wants to attract travelers, for trailering has become very popular and a source of extra income for hospitable towns.

Robert W. Blanchard
Design Specialist
Lockheed Missiles/Space
Sunnyvale, Calif.

**Scientific happiness draws an objection**

Sir:

Your editorial of August 30, 1966 ["Man looks to science for his future happiness," ED 20, p. 31], does not present a complete picture.

While it is quite true—as Lester Hogan says—that “science and engineering, more than any other forces, are responsible for removing the isolation between men and nations,” this removal has not always been beneficial. The same science that makes worldwide communications possible also makes possible a worldwide nuclear holocaust.

You point out that “increasingly complex controls are needed by a minority if it wishes to fool most men most of the time,” but as a matter of fact these complex controls are available to minority groups in power. Witness managed propaganda in the U.S.S.R. or by the Johnson Administration in the U.S.

Science can provide the tools, but it is in itself a tool. It is not, nor can it ever be, the place of science to establish values—good or bad.

If we are to consider the totality of man’s existence, we must look...
HAPPINESS IS AN n-CHANNEL (HIGH-GAIN) 50¢ UNIBLOC* FET!

Your customers will believe it when they discover the drift-free, low-distortion, low-noise audio you’ve achieved in your newest product — when you design with Motorola’s new, low-cost field-effect transistors.

You’ll be happy with the big initial savings you get with Motorola FET types MPF103-05 at 50-cents each (1,000 quantities) — plus the added savings you’ll find when you can use smaller, lower-cost capacitors, due to the high input impedance of a FET (like a tube).

You’ll also be happy about the design simplicity you get because your high-gain Motorola n-channel FET allows for direct pickup from the transducer, provides outstanding power gain and does not load the driver device. (Think about assembly time saved and the reliability of performance, too.)

Top this off with the knowledge that you’re getting reliable Unibloc one-piece plastic-package transistors that provide long-life, rugged performance and you see the total happiness picture!

Here’s a look at the performance-rated specifications that make it all possible:

<table>
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<tr>
<th>Characteristic</th>
<th>Device Type</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
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<td>pF</td>
</tr>
</tbody>
</table>

*Trademark of Motorola Inc.

Your nearest Motorola semiconductor distributor has units for immediate evaluation. For complete details on how you can find happiness with Motorola’s new 50¢ FETs, call your local Motorola district office or send for our data sheet.

—where the priceless ingredient is care!
beyond science. Science may be necessary, but it certainly is not sufficient for man's happiness.

For man to look to science as the necessary basis for his happiness is a false hope. He is not taking a total systems approach by considering only one aspect of his existence as the basis for his future.

What factors are sufficient? This is the subject for another discussion.

Arnold Larson
Engineering Specialist
Philco WDL
Palo Alto, Calif.

Engineers can guide product development

Sir:

In reference to Dr. B. Martin Steiger's letter ["Engineers cannot govern quality," ED 21, Sept. 13, 1966, p. 44], I would like to make a few comments.

Your published interview with the men of the green beret [ED 18, Aug. 2, 1966, p. 36 ff.] was most informative and helpful to the engineers at AEL. In most organizations such as ours, it is the engineering staff which is the essential management, for it is its ingenuity and originality which dictates [to] the vice-presidents and stockholders the companies' capabilities as well as the quality of the products produced. The engineers are the individuals who write the technical proposals and who produce the final product. Knowing the problems of the men in the field aids us in producing items which most readily meet their needs. "A quick and dirty design job" reflects back upon the company and engineers and forms an image which I believe no organization would desire to own.

I believe that more articles and interviews of this nature should be published, directed to the engineers, for it is they who can most directly help their sons and brothers in the field.

Robert D. Goldblum
American Electronic Laboratories, Inc.
Systems Division
Colmar, Pa.
Since 1958, Varian has powered most of the world's satellite communication systems.

During these years Varian scientists and engineers have worked hand-in-hand with America's leading ground terminal designers to build up the most thorough knowledge, capability, and technology in the entire microwave tube industry.

For example, this close working relationship resulted in Varian's VA-884B CW amplifier, a 14 kW power output tube tunable between 5.925 and 6.425 GHz. This tube is an important part of most satellite ground terminal stations in use today.

Another example of this ability to help industry develop the most advanced klystron amplifiers is Varian's VA-925, a state-of-the-art tube which delivers over 8 kW CW power output and is tunable from 7.9 to 8.4 GHz. This tube will be used to power the latest satellite communication projects now under development.

There will be other examples soon because Varian is continuing to develop new and more sophisticated microwave tubes for new and more sophisticated satellite communication systems.

May we help you extend the state-of-the-art in your industry?

Write: Varian Palo Alto Tube Division, 611 Hansen Way, Palo Alto, California.
In Canada: Varian Associates of Canada, Ltd., Georgetown, Ontario, Canada.
In Europe: Varian A.G., Zug, Switzerland.

varian
The first JAN voltage-variable capacitor!

TRW's newest addition to the broadest line of voltage-variable capacitors... JAN 1N4801A-1N4815A Varicaps to MIL Spec 19500/329B!

Outstanding characteristics are extremely low leakage (less than 0.005 µA at MWV) and the widest capacitance change per volt available anywhere!

Optimum uniformity and tracking is assured by TRW proprietary alloy junction process—ideal for VCO, VCXO and delay lines. Capacitance range from 6.8 to 100 pF nominal.

Contact any TRW distributor or TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif. 90260. Phone: 679-4561.
Wasteland revisited: Must CATV be an electronic 'rubber stamp'?

When Newton Minow, then chairman of the Federal Communications Commission, called television “a vast wasteland” some years ago, one television executive whimsically retorted that it was a “conservative estimate.” Today community-antenna television systems (CATV) pluck this conservatively estimated vast wasteland from the air and feed it to 6.6 million viewers in this country.

At present there are 1600 CATV systems in operation, 250 under construction, 650 franchises in preparation and 1300 pending. Two million households subscribe to a CATV service. These franchises turn a handsome profit, often between 50 and 100 per cent. But what does CATV do for the paying viewer?

A CATV franchise provides its subscribers with a clear, interference-free image of conventional broadcasts. When stock is sold and the wires are installed, the CATV directors are quite content to transmit nothing but regularly scheduled broadcasts. This, they say, is part of the terms of their franchise. They contend they are not licensed to compete with television, but rather to implement it.

This is the lazy, slothful attitude of an industry mesmerized by excessive profits. It is true that the FCC regulations strictly forbid CATV from transmitting programs that it originates itself. But those same regulations contain “white space.” That is, a loosely defined clause that allows CATV operators to originate straight information in the public interest.

CATV could provide its subscribers with educational programs, in-depth news broadcasts, and transportation and weather information. Separate channels could even carry time standards, newswire services and technical programs for engineers and scientists. Its selective distribution makes it ideal for dissemination of specialized knowledge to narrow interest groups. For example, it could supply doctors with medical information, and police with law-enforcement information. In addition its closed-loop, jam-resistant wires could make it an invaluable tool for civil defense and military communications.

CATV holds the promise of fulfilling many a politician’s dream: it can give each person just what he wants. But to its public it will never be worth the copper in its wires unless it abandons its present policy of taking the ambient, electronic air pollution and simply feeding it through its lines.

Here is an ideal chance for engineers to raise their voices as citizens. A letter to Congress or to the FCC can help turn the trick—if enough responsible engineers take the trouble to write.

ROGER KENNETH FIELD
New Industrial Op. Amplifiers

±20 Volt Output

<table>
<thead>
<tr>
<th>SPECIFICATIONS</th>
<th>FIELD EFFECT TRANSISTOR TYPE</th>
<th>BIPOLAR TRANSISTOR TYPE</th>
<th>UNITS</th>
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<td>dB</td>
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<td>Gain Bandwidth Product(1)</td>
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<td>±10</td>
<td>µV/°C</td>
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<tr>
<td>Current Drift (max)</td>
<td>±25</td>
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<td>nA/°C</td>
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<td>Output (min)</td>
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<tr>
<td>Price (1-4)</td>
<td>$77.50</td>
<td>$70.00</td>
<td></td>
</tr>
</tbody>
</table>

(1) Internally stabilized by 6 dB/octave rolloff.  
(2) 50pA @ 25°C; doubles every 11°C.

Select the amplifier to give you best performance/price and call your UNION CARBIDE ELECTRONICS Distributor today.

1.5" x 1.5" x 0.4" (max.)
Linvill charts simplify design of low-noise microwave amplifiers. Page 54.

Inexpensive and stable RC oscillators are possible with unique design approach. Page 88.

Improve A/D converter performance with inexpensive off-the-shelf microcircuits. The unit described here combines both simplicity and low cost. Page 96.

Also in this section:

- Saturating chokes and SCRs team up in inverter applications. Page 66.
- FET devices provide fast, stable digital switching. Page 72.
- Predict line regulation accurately in your next high-current regulator. Page 82.
Design amplifiers for low-noise by carefully considering device selection, circuit configuration and parameters essential to optimum performance

Bipolar transistors yield the lowest noise figure in microwave amplifiers—provided they are used in the right circuit configuration and the proper trade-offs are taken care of. The design procedure must be carefully mapped out, to achieve the best balance among the other important parameters, like gain, power, stability and signal-handling ability.

To show that indeed the bipolar transistor is the best device for low-noise microwave amplification, let’s consider the other possibilities; that is, FETs and MOSFETs. The examination of the relative merits of the devices requires the development of certain fundamental considerations.

For a precise description of noise performance, the source immittances and bias conditions must be specified.

The configuration becomes important, because at microwave frequencies (above 500 MHz), the common-emitter and common-base noise figures are not the same. External package parasitics contribute a great deal to the noise figure at these frequencies.

The selection of the best device should start with an examination of Fig. 1 which shows the optimum noise figure, as a function of frequency, for FETs, MOS-FETs, bipolar pnp germanium and npn silicon transistors. These devices are the ones that are most frequently considered for low-noise microwave amplifiers. Schottky barrier diodes are usually employed as microwave mixers at the high end of the spectrum. The curves show the optimum performance in each group.

Even though junction FETs and MOS devices are shown together, the MOS is, in general, slower. Since present MOS devices are about two orders of magnitude below their theoretical speed limit, however, their development may be spectacular. Bipolars are almost at their theoretical limits. The really major difference between silicon and germanium bipolar noise figures is in the region above 1 GHz. In the case of the junction FET, noise figures lag somewhat behind silicon.

Bias conditions affect noise figure

In a comparison of noise performance it is necessary to mention bias conditions and their effect. The internal noise mechanisms in a bipolar junction transistor can be represented in terms of an external noise-voltage generator, Eq. 1, and an internal noise-current generator, Eq. 2:

\[
\begin{align*}
(n_v^2)^{1/2} &= \left[2kTB r_e' + 4kTB r_b' + 2kTB \right] \left(\frac{\beta_o r_e'}{\beta o}\right)^{1/2} \\
(n_i^2)^{1/2} &= 2kTB \left[1 + \left(\frac{f}{f_a} \sqrt{1 - \alpha_e}\right)^2\right] / \beta o r_e'.
\end{align*}
\]

The first term in Eq. 1 is due to the emitter-base shot noise, the second term to the thermal noise in the base and the third term to the collector-base diode noise. Low-noise amplification with bipolar transistors requires:

- As low a value of \( r_b' \) as possible.
- A high value of \( \beta_o \) since the noise sources are inversely proportional to \( \beta_o \).

The FET is subject to the same types of noise that are found in bipolar transistors; however, its gate-to-source capacitance tends to couple the output noise back to the input and thus to modify the noise figure.

The noise figure of bipolar transistors is given by Eq. 3 while the one used for FETs is given in Eq. 4:

\[
F_{HF} = 1 + \left(\frac{r_b'}{R_o}\right) + \left(\frac{r_e}{2R_o}\right) + \left[\left(\frac{r_e + r_b' + R_o}{2\alpha o R_g r_e}\right)\right] \left[\left(\frac{f}{f_a}\right)^2 + \left(\frac{I_{o}}{I_{o}}\right)^2 + 1\right],
\]

\[
F = 1 + 2\omega \left(C_{ps} + C_{pd}\right)/\left(g_m + \lambda / g_m\right) \left[G_s - \omega(C_{gs} + C_{gd})/G_s\right],
\]

The noise figure of bipolar transistors tends to increase as the emitter current is decreased below the optimum level. As the emitter current is increased, on the other hand, thermal noise and collector-base noise become increasingly prominent.

The comparison of noise figures among the various device types is permissible, even though the bias currents are not identical. Each type optimizes at different current levels, determined by constants that change according to the intend-

George D. Johnson, Section Head, Microwave Circuit Dept., Texas Instruments, Inc., Dallas, Tex.
Noise figures of devices capable of microwave amplification indicate optimum performance for each type. The data were taken with bias currents and source immittances that yield the best results for each device.

1. Noise figures of devices capable of microwave amplification indicate optimum performance for each type. The data were taken with bias currents and source immittances that yield the best results for each device.

Noise figure depends on source immittance

Source immittance must always be given to specify the noise figure adequately. Equation 5 can be used for both bipolars and FETs:

$$ F = F_0 + R_n (Y_s - Y_s^{(opt)})^2 / \text{Re}(Y_s). $$

The plots of optimum source conductance and susceptance for a bipolar germanium planar FET are shown in Figure 1. For example, many germanium bipolar low-noise transistors have optimum noise performance in the current region about 1.5 mA, while some silicon bipolars may optimize at about half this value. Junction FETs, by contrast, may optimize at currents as high as 4 mA.

Definition of symbols used in the article

- $e_n$ = root mean square external noise-voltage generator
- $i_n$ = root mean square internal noise-current generator
- $k$ = Boltzmann's constant = $1.380 \times 10^{-23}$ J/K
- $T$ = absolute temperature in degrees Kelvin = 300°C at room temperature
- $B$ = noise bandwidth ($\Delta f$)
- $r_e$ = emitter resistance
- $r_b$ = base resistance
- $b_o$ = low-frequency transistor current gain
- $f_a$ = alpha cutoff frequency, the frequency at which $\alpha = 0.707 \alpha_0$
- $\alpha$ = common-base current gain
- $\alpha_0$ = $\alpha$ at zero frequency
- $R_{g(\text{opt})}$ = optimum generator resistance for noise figure
- $M_n$ = noise measure
- $G$ = available power gain
- $f_A$ = upper noise corner frequency
- $i_{ne}^2$ = mean square value of emitter-base diode thermal and shot noise current
- $i_{nc}^2$ = mean square value of noise current in the collector-base junction
- $i_{nc}^2$ = mean square value of noise current in the base
- $i_{ne}^2$ = mean square correlation term noise source between emitter and collector currents
- $e$ = electronic charge
- $i_{ms}^2$ = mean square source noise current
- $Y_{1e}$ = small-signal input admittance for ac short-circuited output
- $Y_{re}$ = small-signal reverse transfer admittance for a short-circuited input
- $Y_{fe}$ = small-signal forward transfer admittance for a short-circuited output
- $Y_{ee}$ = small signal output admittance
- $C_S$ = inherent stability factor
- $Y_{11}$ = $Y_{22}$, the real part of the short-circuit input admittance
- $G_{oc}$ = power delivered to $\text{Re}(Y_L)$ divided by the power delivered to the input of the two-port, where $Y_L$ is conjugately matched to $Y_{22}$.
- $K$ = circuit stability margin
- $P_1 = \text{Re}(Y_{11})$
- $Y_{re}$ = external input admittance
- $Y_{fe}$ = external output admittance
- $\rho_{12}$ = $\text{Re}(Y_{12})$, the real part of the input immittance
- $\gamma_{11}$ = the input immittance
At microwave frequencies the optimum source immitances for low noise differ for common-emitter and common-base connections. The transistor is a bipolar germanium planar device.

Parasitics make a difference

The difference in CE and CB noise figures at microwave frequencies is caused by parasitics. Degenerative feedback lowers the gain of the CE connection but also lowers its noise figure. Regenerative feedback in the CB connection decreases stability, which can cause arbitrarily high gain, but also increases the noise figure over the CE value. The parasitics which have the most effect on the noise figure are:

- Common lead inductance.
- Feedback capacitance.

Since both of these parameters have an effect on gain and stability it is important that they be included in the calculations.

It is evident from the above discussion that there is an interdependence between gain and noise figure at microwave frequencies. To specify noise performance for a single stage in terms of both noise figure and gain, use Eq. 6:

$$M_E = \frac{F - 1}{1 - \left(\frac{1}{G}\right)}.$$  (6)

The noise figure of a cascade of identical stages, where $G$ is very large, in terms of $M_E$ is given by:

$$F = M_E + 1.$$  (7)

Here $F$ is the noise figure of the cascade. $M_E$ therefore determines the best over-all system noise figure that is attainable with a particular active device. It can be optimized by suitable circuit transformation to produce the same cascaded noise figure for all three configurations, since $M_{E(opd)}$ is invariant under reciprocal lossless transformation and interchange of terminals. $M_E$ is thus a more comprehensive comparison of noise performance than $F$ alone.

Two factors limit bipolars

The fundamental noise performance of bipolar transistors is limited by two phenomena: thermal noise in $r_e$ and uncorrelated portion of the collector shot noise ($f_a$ limit).

The noise caused by base resistance may be reduced by:

- Heavy doping under the base contacts (applicable to both Si and Ge).
- More complex geometry to produce parallel paths.
- Very shallow diffusions.

The uncorrelated portion of the collector shot noise is directly related to $f_a$. Since $f_a$ is itself directly related to the transit time for minority
carriers through the base, it is not possible to consider \( f_a \) without also considering \( r_\alpha \). It is obvious that shallow diffusions produce thinner bases and higher \( f_a \) but they also increase \( r_\alpha \). Thus, a compromise must be found between these two quantities. At present, germanium \( f_a \) is limited to about 8 GHz while silicon \( f_a \) is limited to about 5 GHz.

An accurate prediction of the noise figure of microwave transistors can be made by use of a suitable equivalent circuit that includes package parasitics. An equivalent circuit for germanium planar microwave transistors in L-band is shown in Fig. 3. The values of the parameters are for a germanium transistor, TIXM101, in a stripline package, with a \( V_{cb} \) of -5 V and an \( I_g \) of 1.5 mA.

The total collector depletion capacitance, \( C_{c1} + C_{c2} \), is determined from 1-MHz capacitance measurements. The value of \( r_F \) is obtained by comparison of calculated \( y \)-parameters from the equivalent circuit with measured values obtained from the transfer function bridge. The value of \( f_r \) is determined from \( h_{fe} \) at approximately 400 MHz. It is good to check this, too, with a transfer function bridge. The value of \( r_F 'C \), is determined by measurement of \( h_{re} \) at 319 MHz. Some care must be taken here, because correction must be made for header capacitance—the prime cause of parasitics. This correction may be made by subtracting the package feedback capacity. From \( h_{re} \) and \( r_F ' \), the value of \( C_{c1} \) may be obtained. The most difficult but most important parameter to determine is \( f_a \). Perhaps the most accurate method is to compare the calculated noise figure with the measured one at a number of frequencies above \( f_{re} \) (the frequency at which \( h_{re} = 0.707 h_{ie} \)).

The values of the different noise sources are:

\[
\begin{align*}
\overline{\tau}_{ie} &= 4kT \Delta f \Re \left( Y_e \right) -2eI_g \Delta f \\
\overline{\tau}_{ae} &= 2eI_e \Delta f \\
\overline{\tau}_{ae}^* &= 4kT r_F ' \Delta f \\
\overline{\tau}_{ae}^* \overline{\tau}_{ae} &= 2kT \alpha Y_e \Delta f \\
\overline{\tau}_{ae}^2 &= 4kT \Re \left( Y_e \right) \Delta f
\end{align*}
\]

The output noise of the FET at high frequencies and for a short-circuited input is the sum of the low-frequency noise and the thermal noise of \( |g_{12}| \). The limiting noise of the FET at low frequencies is attributed to the thermal noise of the channel resistances \( r_s \) and \( r_d \). The increase in thermal noise at high frequencies has been attributed to \( |g_{12}| \), the high-frequency conductance between gate and drain. The high-frequency input conductance, \( g_{11} \), also exhibits full thermal noise. It may be shown that \( g_{11} \) and \( |g_{12}| \) both vary as the square of the frequency. Therefore, \( g_{11} \) and \( |g_{12}| \), along with \( r_s \) and \( r_d \), represent parameters which limit the high-frequency noise performance of the FET.

In summary, we may conclude that germanium bipolar transistors still lead in noise performance at microwave frequencies. The common-emitter connection, rather than common-base, presents a better compromise between the quantities:

- Noise figure.
- Stability factor.
- Power gain.

In the case of FETs, the common-gate configuration represents the best compromise between gain, noise figure, cross modulation and stability. On the other hand, if noise figure is the sole consideration, common-source connection is recommended.

Regardless of the device, designers should be careful in selecting the type of parameters (ie—\( y \), \( h \), etc.). The \( h \)-parameters represent a better description of the active device at low frequencies. The \( y \)-parameters are better at high frequencies. Scattering parameters present the best description of the active device at microwave frequencies. It is not advisable to convert one set to another through matrix manipulation at microwave frequencies. Inaccuracies will be introduced because of the different effect that the package has on each configuration. In other words, a measured set of common base data at microwave frequencies will not, in general, agree with a set of common base data obtained by performing a simple matrix transformation on measured common emitter data.

The design of the amplifier itself involves many trade-offs, but fortunately there is a graphical method that considerably simplifies the procedure.

**Linvill chart highlights trade-offs**

With the Linvill chart, the circuit designer can quickly determine the input and output impedance that will establish a specified margin of stability and alignability while maintaining a specified amount of gain. Any trade-off in these quantities is displayed graphically.

The actual design procedure may be divided into four steps:

1. Measure the terminal parameters of the active device.
2. Construct the Linvill chart.
3. Design the input network for minimum noise figure.
4. Determine the actual circuit stability margin.

The design of a 450-MHz amplifier will serve as an example. It is assumed that the bandwidth is narrow and that the \( y \)-parameters at 450 MHz are unchanged through the band. The \( y \)-parameters of the 2N2415 450-MHz amplifier are:

\[y_{ie} = 29.7 + j14.3\]
4. Linvill chart is a set of constant-gain circles superimposed on a Smith chart. The centers of the circles lie on the straight line. The maximum available gain (10 dB) is

\[ Y_{re} = -0.38 - j2.0 \]
\[ Y_{fe} = 10.3 - j50.2 \]
\[ Y_{oe} = 0.93 + j5.31 \]

The measurement of the terminal parameters is the most important step of all, since inaccuracy at this point invalidates all the remaining work.

The stability factor is defined as:

\[ C = \frac{\| Y_{12} \|}{\| 2 g_{11} g_{22} - \text{Re}(y_{12} y_{21}) \|} \]

where

\[ Y_{12} = 105 / [2(29.5)(0.93) - (-97)] = 0.69. \]

It must be less than 1 for unconditionally stable operation. If it is larger than 1, it means the stage is potentially unstable and that a set of terminations can be found that will cause the circuit to oscillate.

The value of \( G_{oo} \) may be calculated for the linear active network by means of the expression:

\[ G_{oo} = \frac{\text{Power delivered to } \text{Re}(Y_L)}{\text{Power delivered to input of two-port}}, \]

where \( Y_L \) is conjugately matched to \( y_{22} \).

The value of \( G_{oo} \) may be calculated for the linear active network by means of the expression:

\[ G_{oo} = \frac{\| y_{12} \|^2 / 4 g_{11} y_{22} - 2 \text{Re}(y_{12} y_{21})}{(C/2) |y_{21}/y_{12}|} \]

\[ = (0.69/2) |51.3/2.0| \]
5. Gain and stability vs frequency curves for a common-emitter transistor configuration point up the fact that the maximum stable gain can be practically obtained only with a negative real termination.

\[ \text{Gain} = 9.4 \text{ dB} \]

A Linvill chart for the 450-MHz amplifier is shown in Fig. 4. The circles indicate lines of constant gain and any point on a circle represents a load that will produce that gain. The centers of the constant-gain circles lie on the straight line that passes through the center of the Smith chart. The maximum gain occurs at a single point on this line if the device is unconditionally stable as it is in Fig. 4.

For the input network, \( Y_{s}\) is calculated with the aid of Eq. 5. The mismatch loss with \( Y_{s}\) for the CE configuration usually results in about a 1.5 dB reduction in gain. This is another trade-off, where power gain is sacrificed in favor of lower noise figure.

It is advisable to use as few components in the input circuit as possible in order to minimize component losses which add directly to noise figure.

The last stage is to evaluate the actual circuit stability margin, \( K \). The mathematical expression is:

\[ K = \frac{\left| 2(P_1 + \rho_{11}) \left( P_2 + \rho_{22} \right) - \text{Re}(\gamma_{12}\gamma_{21}) \right|}{\gamma_{12}\gamma_{21}} \]

where

- \( \gamma \) = complex general parameters, either \( y \), \( h, g, z \), or \( ABCD \),
- \( \rho_{11} = \text{Re} \gamma_{11} \),
- \( P_1 = \text{Re} \gamma_{12} \),
- \( P_2 = \text{Re} \gamma_{21} \).

Examination of Eq. 16 points to the fact that an increase in \( K \) leads to a drop in the gain. \( K \) increases through \( P_1 \) and/or \( P_2 \), which means larger loads at the terminals. A \( K \) value of 2 has proved to be a good compromise between stability and gain in cases where the circuit is not subjected to environmental stresses or replacement of transistors.

If large temperature variations are expected, \( K \) may have to be as large as 4. Values above 5 are rarely needed.

Another way of looking at Eq. 16 is to let \( P_1 \) be equal to the real part of \( Y_{s} \) and find \( K \) for the input termination that yields the lowest noise figure. In this case the designer obtains optimum noise performance and knows the level of circuit stability at once.

Therefore, the Linvill chart technique is a valuable tool in the design of low-noise microwave amplifiers. It allows the analysis of tradeoffs between power gain, stability, bandwidth and, with the aid of Eqs. 3 and 5, noise figure.

To illustrate some practical results, consider the curves of gain and stability vs frequency for a germanium transistor in Fig. 5. Note that the maximum stable gain:

\[ G_{\text{max}} = \frac{|y_{21}|}{|y_{21}|}, \]

is only obtainable with negative real termination.

\( G_{\text{max}} \) may, however, be lower than can be safely obtained in circuits that are designed in the region of potential instability. The region of potential instability for bipolar transistors in the common-emitter connection is shown in Fig. 6. The two critical frequencies are approximately given by:
\[ f_1 = \frac{1}{r_e C_c} \]

and

\[ f_2 = \frac{f_1 r_e}{2r_b} \]

The C-factor for a common-emitter germanium transistor is shown in Fig. 7.

In a common-base configuration, the transistor is potentially unstable to a frequency approximately equal to \( f_t \). It is evident that CE is superior to CB from a stability standpoint.

If \( C \) had been greater than unity, the value of \( G_{\text{max}} \) would have been unbounded. If \( C = 0.69 \), \( G_{\text{max}} \) is finite and may be calculated by evaluating \( K_o \) and multiplying by \( G_{\text{oo}} \):

\[
K_o = 2[1 - (1 - C^2)^{1/2}]/C^2 = 1.15;
\]

\[
G_{\text{max}} = (K_o)(G_{\text{oo}}) = (1.15)(8.7) = 10 \, \text{dB}.
\]

While the gain in this example is very low by more recent microwave transistor performance, it should be remembered that in many cases it is not necessary to have much more than 10- to 15-dB power gain in the RF amplifier. Usually this is sufficient to negate the noise figure contribution of the mixer. In some cases, large gain is actually undesirable, since it is usually more economical to develop the overall gain in the IF portion of the system.

The load for a maximum gain of 10 dB is given as:

\[
G_x + jB_x = G_L + jB_L + y_{22}
\]

Solve for \( G_L \):

\[
G_L = G_x - \text{Re} \, y_{22}
\]

From the Linvill chart, \( G_x \) is equal to \( 3 \, \text{Re} \, y_{22} \) for maximum gain.

\[
G_L = 3 \, \text{Re} \, y_{22} - \text{Re} \, y_{22} = 1.86 \times 10^{-3} \, \text{mhos}
\]

Now evaluate the reactive part:

\[
B_L = B_x - \text{Im} \, y_{22}
\]

From the Linvill chart, \( B_x = 0.7 \, \text{Re} \, y_{22} \) for maximum gain.

\[
B_L = 0.7 \, \text{Re} \, y_{22} - \text{Im} \, y_{22} = -4.65 \times 10^{-3} \, \text{mhos}
\]

The load should be \( 1.86 - j4.65 \) mmhos to yield a 10-dB gain. The transformation from 50 ohms may be done with the aid of an admittance-impedance chart. One possible form of the network is shown in Fig. 8, where the capacitor offers dc isolation and impedance matching. The values of the components are obtained through conventional impedance transformation techniques.

Locate the 50-ohm load on the impedance coordinate system, Fig. 9, using a scale factor of one unit as 200 ohms or \( 0.5 \times 10^{-2} \) mhos. This point is on the horizontal axis where \( R = 0.25 \). The value of the series capacitive reactance is added as a vertical line down from 0.25. The reactance necessary to transform 50 to 540 ohms is obtained by moving down from 50 ohms to the constant conductance circle marked \( G = -0.37 \), since:

\[
G = 200/0.37 \, \Omega = 540 \, \Omega
\]

At this point the transformation from 50 to 540 ohms is completed, but the terminal value is rather capacitive. To neutralize this, it is necessary to include a tuning capacitor of 6.5 pF and an inductance that resonates at 450 MHz (0.02 µH).
11. Quadrant chart, superimposed over the Linvill chart, allows a rapid analysis of the input imittance. The Linvill chart shows a gain of 10 dB at $G_2 = 3 \text{ Re } y_{22}$ and $B_2 = 0.7 \text{ Re } y_{22}$. 
sary to add \(-jB\) to the \(+jB\) due to the transformed value of the series capacitor. However, the Linvill chart indicates that a complex load is necessary to achieve \(G_{\text{max}}\), so the desired load point has the components:

Real part: \((1.86 \times 10^{-3}) / (0.5 \times 10^{-2})\)
\[= 0.37 \text{ units;}
\]
Imaginary part: \((-4.65 \times 10^{-3}) / (0.5 \times 10^{-2})\)
\[= -0.93 \text{ units.}
\]

Now, instead of stopping at the horizontal axis, the process is continued until the point \(0.37 - j0.93\) is reached.

Solve for \(X_e\):
\[X_e = (0.8)(200) = 160 \Omega;\]
\[C = 2.2 \text{ pF at 450 MHz.}\]

When solving for the amount of shunt inductance, it is necessary to move to the desired load point on the constant-conductance circle, \(G = 0.37\):
\[X_L = 200/2.03 = 98 \Omega \text{ (where 2.03 = 1.1 + 0.93);}\]
\[L = 0.034 \mu\text{H at 450 MHz.}\]

To allow tuning of the network, a shunt capacitance is added. It is calculated by selecting a fractional bandwidth of 0.1:
\[FBW = 0.1 \text{ (45 MHz).}\]

By definition:
\[Q_L = 10 = \omega CR_e = (540)(6.28)(450 \times 10^6)C;\]
\[C = 10 / [(540)(6.28)(450 \times 10^6)] = 6.5 \text{ pF.}\]

The inductance required to resonate with 6.5 pF is 0.02 \(\mu\text{H}\) at 450 MHz. The complete output network appears as in Fig. 10.

**Input network is found with quadrant chart**

Before the input networks are designed, the value of the input admittance must be obtained for the specified load.

A quick way has been devised which not only reduces the amount of complex algebra but allows a rapid analysis of input admittance. The input admittance is:

\[Y_{\text{in}} - y_{11} = G_1 + jB_1. \quad (18)\]

If a quadrant chart is placed over the Linvill chart (Fig. 14) and rotated so that its real axis lies parallel to the gradient line, the input impedance may be evaluated. Reading the values of:

\[G_1 / |y_{11} y_{21}/2 \text{ Re } y_{22}| = 0.52;\]

and
\[B_1 / |y_{12} y_{21}/2 \text{ Re } y_{22}| = -0.39;\]

and
\[|y_{12} y_{21}/2 \text{ Re } y_{22}| = (105 \times 10^{-3}) / [(2)(0.93 \times 10^{-3})] = 56.5 \times 10^{-3},\]

which are indicated by the point of maximum gain, we may calculate the value of \(Y_{\text{in}}\). The substitution in Eq. 18 yields:

\[Y_{\text{in}} = (0.52)(56.5 \times 10^{-3}) - j(0.39)(56.5 \times 10^{-3})\]
\[+ 29.7 \times 10^{-3} + j14.3 \times 10^{-3}\]
\[= 59.1 \times 10^{-3} - j7.7 \times 10^{-3}.\]

Therefore the input admittance of the terminated stage at 450 MHz and the input network to match the generator to this admittance are as shown in Fig. 11. The circuit includes dc return for the base and dc block for the input.

In designing the input network, use 1 unit-50 ohms or 0.02 mmhos. The input admittance is 59.1 - \(j7.7\) mmhos, which becomes 2.9 - \(j0.385\) units. Locating this on the admittance chart (Fig. 12) establishes the starting point. Notice that the input admittance is automatically converted to a series combination simply by reading the rectangular co-ordinates at this point.

The first component in the desired network is a series \(C\) which requires a move straight down the chart from 2.9 - \(j0.385\) until the constant-conductance circle of 1 is intersected (shown in color in Fig. 12). This is the value to which 16.8 ohms is transformed. The value of \(X_e\) required is:
\[X_e = (0.58)(50) = 29 \Omega;\]
\[\therefore C = 12 \text{ pF at 450 MHz.}\]

Moving around the constant-conductance circle
from $B=1.25$ to $B=0$ requires the addition of a shunt inductance to the network. Its value is:

$$X_L = \frac{50}{1.25} = 40 \, \Omega;$$

$$L = 0.014 \, \mu H \text{ at } 450 \, \text{MHz}.$$ 

The input network of Fig. 11 is set for a conjugate power match. For CE, however, it is adjustable for minimum noise figure; that is, for an input admittance of $Y_{s_{opt}}$. 

Reference:

Bibliography:


New miniature tantalum capacitor for microcircuits

The Mallory TUR is a miniature solid electrolyte tantalum capacitor designed for use with integrated circuits, thin film and other micro-electronic circuits. It is supplied un-encapsulated to provide extremely small size per rating. It is intended for use with microcircuits where it will be encapsulated after assembly.

The TUR has a new configuration which provides maximum capacity per unit volume. It's a square chip, only .225" to .325" square, and .04" to .170" thick depending on rating. It is supplied with an electrically insulating coating on the positive side of the case, so it can be stacked or placed directly on the circuit chip or board prior to encapsulation. When properly pre-dried and encapsulated, it withstands MIL environments.

CV (capacity x voltage) product is extremely high. Ratings range from 47 mfd., 6 VDC to 15 mfd., 50 VDC. Temperature rating is -55°C to +85°C, de-rated linearly to ¾ voltage at 125°C. DC leakage is low. Three configurations keyed to lead position are available. Standard units are polarized; non-polarized units on special order. Leads are gold-plated ribbons, can be welded or soldered.

Reducing costs with Mallory packaged rectifier circuits

You can save both on component costs and on assembly costs, with Mallory rectifier packages. Each of these factory-connected circuits costs less than what you would pay for an equivalent number of separate rectifiers. The four-rectifier bridge package costs less than four separate rectifiers, and the full-wave and doubler packages cost less than a pair of rectifiers.

Savings in assembly come from reduction in number of soldered connections which you need to make. ... one less on a doubler or full-wave circuit, two less on a bridge. You can figure it out for your own conditions, but here's a typical analysis. At a labor rate of $1.60 per hour, the saving is about $300 per 25,000 doubler packages, or $600 per 25,000 bridge packages. Extra reliability due to fewer solder joints is a plus value.

Cold-case encapsulated circuits include Type FW full wave bridge, Type VB voltage doubler, Type CT full-wave center tap with either positive or negative polarity ... all rated for 100°C, in PRV values from 50 to 600 volts. Bridge circuits, Type FWZ, are also supplied with an integral, factory-connected zener diode across DC output terminals; all standard zener voltage ratings are available in this configuration.
Improved heavy-duty performance now provided by Mallory Alkaline Batteries

Recent refinements in Mallory Alkaline Batteries increase their ability to deliver long life at higher values of current drain, and further improve their advantage over conventional zinc-carbon batteries both in service dependability and cost per hour.

This added capability is the result of new internal construction which increases the effective anode area in relation to cell volume. Internal impedance of the cell is reduced, particularly at low temperatures. At 70°F ambient, the Mallory alkaline system delivers up to 7 times more hours of service on continuous heavy drain than ordinary batteries (see chart). At 32°F, the improvement in performance is even better.

Added refinements in case and seal construction have also been made to insure reliability of the seal under even the most severe vibration. Mallory Alkaline Batteries with the new construction are available in a broad range of standard cell configurations.

Circuit breaker-switch now available on Mallory controls

The OCB breaker-switch eliminates the need for a separate circuit breaker by combining overload protection and line switch into a single, compact unit. It’s an extra convenience idea for television and stereo equipment, for instruments and any products which require overload breakers under 5 amperes.

To reset the breaker after it trips, you simply turn the switch back to OFF, then to ON. You cannot hold the breaker closed against an overload.

Holding current is factory-set to your specifications; standard range is 1.25 to 1.9 amperes, with special models available up to 5 amperes.

Break current is 50% higher than holding current. The OCB switch will withstand a 10% overload for 4 hours at 65°C ambient. It will take a 50 ampere surge, peaking in 1.6 millisecond decaying to normal in 3 milliseconds, without opening or being damaged.

The OCB is supplied attached to standard Mallory volume controls as a rotary on-off switch, or can be supplied as a separate breaker switch. As a combination control-switch-breaker, it offers savings in total component and assembly cost.

Circuit breaker-switch attached to volume control.

Diagrams show operation of breaker mechanism: at left, in MAKE position; at right, in BREAK position.
Team saturating chokes with SCRs to improve inverter performance and at the same time reduce circuit complexity.

The saturating choke and the SCR appear a rather unlikely pair when it comes to electronic matchmaking. Yet, with a little application ingenuity, the two can form a potent combination in SCR circuits—such as inverters—that use self-quenching for SCR turnoff. Both improved performance and circuit simplification are possible with a variety of configurations.

Technique simplifies self-quenching circuits

Many SCR circuits employ series resonant LCR elements in a self-quenching configuration. The most familiar form of this circuit is probably the series inverter, but resonant quenching is also frequently used in other types of SCR circuits, such as chopper regulators.

The basic action of the series inverter circuit is illustrated by the simple circuit of Fig. 1. Capacitor C is initially discharged. When the SCR is triggered, ringing occurs in the circuit, causing C to be charged to something greater than the supply voltage. The current drawn by C is approximately sinusoidal, and when this attempts to reverse (C to discharge), the SCR extinguishes. The circuit of Fig. 1 is essentially single shot, in that there is no means of removing the accumulated charge on the capacitor. In all practical arrangements some other circuit is provided to do this; for example, the push-pull configuration of the simple series inverter shown in Fig. 2.

The use of saturating inductances in series with the SCRs in circuits like that of Fig. 2 offers two benefits. These are:

- The high initial inductance delays the rise of current.
- The desaturation of the inductor may be used to provide a pulse when the SCR is about to extinguish. Each of these benefits will be dealt with separately.

Current limiting provides protection

The use of small inductors, saturating or nonsaturating, has been described as a means of reducing the rate of rise of current in the SCR during the turn-on time. These applications normally involve switching into capacitive loads, where the rate of rise of current could be very high, possibly causing device failure due to local breakdown burnout of the SCR. Similar precautions are not required for conventional high-power series inverters, since they are limited in frequency to about 10 kHz and have sinusoidal current waveforms. Consequently they have relatively long rise times. With time-sharing inverters, which are combinations of basic series inverters, the operating frequency is increased by at least an order of magnitude. Initial current buildup must therefore be considered with respect to device failure and power rating. As the turn-on time of an SCR tends to be independent of operating frequency, the transient dissipation experienced during turn-on becomes increasingly important as frequency rises. This is illustrated in Fig. 3, where it is assumed that the voltage across the SCR falls linearly during the turn-on period and remains at 1 volt for the rest of the conducting time. The current is taken to be a sinusoid starting as soon as the voltage starts to fall.

It can be appreciated from Fig. 3 that there is a

---

very real incentive to reduce this transient dissipation in high-frequency inverters. And delaying the start of current with saturable chokes is a simple method of doing this. Unfortunately the savings gained are not as great as might be expected. This is mainly due to the fact that, while the voltage across the SCR initially falls before any appreciable current flows, there is a tendency for it to rise again when the current starts to increase. This is shown in the oscilloscope tracings of Fig. 4. These show the voltage across the SCR and the current through it. The current pulse is one half-cycle of 125 kHz and has a peak value of 20 A. The SCR is a 16-A device and is switching 40 V.

In Fig. 4a no choke is used, while Fig. 4b shows the effect of a saturable choke in delaying the rise in current and allowing the voltage to fall. As the delay in Fig. 4b is under a microsecond, however, the voltage rises sharply again when the current builds up. A method of increasing the delay in current rise without having to increase the number of high-current turns on the choke is to apply bias amp-turns by means of another winding. This technique has been used to vary the delay, and its effect is shown in Figs. 4c and 4d.

As the delay in current rise is increased, the voltage rise across the SCR is reduced. Comparison of Figs. 4a and 4b shows that the effective turn-on time increases if the SCR current is kept low. Ideally the delay must be much greater than the turn-on time with no choke, although useful savings in device dissipation may be obtained with delays less than this. While these savings could be appreciable, in many cases the incentive to use saturating chokes will not be current limiting, but rather the generation of trigger pulses.

Technique generates trigger pulses

When an SCR switches on, most of the circuit voltage is developed across the saturable inductance, if one is used. This inductance proceeds to store energy until it saturates, and then, when the current falls again, the energy is fed back into the circuit. This pulse of energy can be coupled out of the core of the saturable inductance by a secondary winding and used as an SCR trigger source.

Figure 5 shows a typical waveform from a saturable inductance in a series inverter. The waveform can be coupled from the inductance by means of a floating winding, and hence is ideal for triggering SCRs, particularly those that do not have grounded cathodes. The low dc resistance of

3. Variation of SCR dissipation and permissible current rating as a function of voltage fall time shows that transient dissipation can be a particularly severe problem at high frequencies.

4. Curves show SCR voltage and current waveforms during turn-on. In (a) no choke is used to delay the current. In (b) a saturable choke is used, but the voltage tends to rise again when the current builds up. In (c) and (d) bias turns are used on the choke for the purpose of increasing the current delay.
the winding results in good temperature and \( \frac{dv}{dt} \) performance.

The other important feature of the pulse is that it occurs at a time suitable for use in many circuits, such as that of Fig. 2. If \( L_1 \) and \( L_2 \) in Fig. 2 are mutually coupled, a saturable choke may be used to provide a trigger pulse for one of the SCRs. This is shown in Fig. 6.

When \( SCR_1 \) of Fig. 6 is triggered, inductor \( LS \) saturates after the initial delay. Diode \( D_1 \) protects the gate of \( SCR_2 \) from excess reverse voltage while high voltage is being developed across \( LS \). When \( SCR_1, L_1, R \) and \( C \) have completed the half-cycle of operation, \( LS \) desaturates, feeding a trigger pulse to \( SCR_2 \). This fires \( SCR_2 \), and completes the extinguishing of \( SCR_1 \) by the transformer action of the coupled inductors \( L_1 \) and \( L_2 \). A second saturating choke may be associated with \( SCR_2 \) to fire \( SCR_1 \), with the circuit free-running once one SCR has been fired.

**Trigger pulses desirable for high-frequency use**

The technique of Fig. 6 is a valuable simplification of inverter triggering. In more complex circuits, such as time-sharing, high-frequency inverters, the use of this type of triggering is even more desirable. These circuits require not only suitable pulse generators, but also circuitry such as ring counters to obtain a suitable sequence of pulses.

A six-SCR inverter is shown in Fig. 7. This is basically three series inverters of the type shown in Fig. 2 feeding, in turn, to a common load. The firing order is indicated on the load waveform. For simplicity, only one triggering choke has been shown. In practice five of the SCRs would have interconnected triggering. The sixth would be triggered from a separate timing circuit. This allows the circuit to be run at a constant frequency, with variations in tuning of the resonant circuits merely causing a timing error in the waveform once every six half-cycles. If this error is not acceptable, which may be the case when the load has a variable reactance, more external triggering may be introduced. For instance, it would be convenient to take pulses from either side of a multivibrator and trigger SCRs 1 and 2.

While the utility of this form of triggering is best illustrated by more complicated circuits, it should be remembered that many other inverters and chopper circuits use resonant quenching and could employ saturable choke triggering.

**Acknowledgment:**

The author wishes to make acknowledgment to the directors of The Plessey Co., Ltd., for permission to publish this article.

**References:**


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FETs make digital switching a snap.
Logic circuits employing J-FETs and MOS-FETs are fast, stable, need few components and are easily designed

Part 2 of a two-part article
Field-effect devices are well suited to digital circuits that require high fan-out, low power and good temperature stability. Both the junction type (J-FET) and metal-oxide semiconductor version (MOS-FET) provide these characteristics in logic designs.

NAND and NOR gates, half-adders, flip-flops and other digital switching networks are quickly and easily built with FETs. FETs feature moderate switching speeds (tens of nanoseconds), can be combined for complementary design purposes, and exhibit low component counts. What's more, the MOS-FETs are compatible with microelectronic technology; some of these logic designs are already available in integrated-circuit form.

The second part of this article deals with the actual design of FET digital switching subsystems and shows how the advantages of FETs can be exploited.

Inverter—fundamental FET switching block
The basic digital circuit is the inverter circuit already discussed.* Two J-FET inverters connected in series form a NAND gate (Fig. 1a). Reversing the definitions for logical 1 and logical 0 makes this circuit a NOR circuit. The disadvantage of this series arrangement can be seen from the equivalent circuit for the ON condition (when \( A = B = 1 = +V \)) in Fig. 1b. For the 2-input NAND gate, the logical 0 voltage will be the combined voltage drops across \( r_{ds1} \) and \( r_{ds2} \). For NAND gates of higher order, the logical 0 voltage can become large.

The series combination of \( r_{ds} \) also reduces the noise margin of this circuit. For example, with an \( n \)-input NAND gate:

\[
e_{n(0)} = V_{1(TH)} - [V_{DD} \cdot nr_{ds}/(R_D + nr_{ds})],
\]

where \( e_{n(0)} \) is the noise margin, \( V_{1(TH)} \) the threshold voltage, \( n \) the number of inputs, \( V_{DD} \) the bias supply, \( R_D \) the drain resistance, and \( r_{ds} \) the drain-to-source resistance of the J-FET. Note how the margin is reduced by the series-connected \( r_{ds} \) values.

The other basic logic gate is the NOR circuit. A parallel NOR gate is illustrated in Fig. 2a. Again, if the definitions for logical 1 and 0 are reversed, the NOR gate becomes a NAND gate. In the parallel arrangement, the logical 0 level is derived from \( n \) paralleled channel resistors. This gives a low logical 0 level, and a high 0 noise-immunity level. The disadvantage of the parallel arrangement comes from the parallel leakage currents when the gates are OFF.

Figure 2b shows an equivalent circuit for the logical 1 condition. For the parallel case the logical 1 noise margin is reduced by the combined \( I_{D(off)} \) currents appearing in the load. This is given by:

\[
e_{n(1)} = V_{DD} - n I_{D(off)} R_D - V_{0(TH)}. \tag{2}
\]

Note that \( V_{0(TH)} \) here refers to the threshold of the 1 state.

Another disadvantage of the parallel NOR gate becomes apparent when only one of the parallel devices is ON while the rest are OFF. By means of the common drain resistor \( R_D \), the single ON device must conduct the current normally handled by the rest of the FETs. For example, a 5-input gate designed for a current of 1 mA in each gate must handle 5 mA when only a single gate is conducting. As the width of the gate is increased, the current handled by a single device becomes larger and the maximum \( V_{DD(on)} \) increases. Another disadvantage is that the output voltage varies with the number of parallel devices that are conducting.

Normally these problems are not serious when constructing more complex circuits. With shift registers and adders where only two or three input gates are required, the J-FET NAND and NOR gates are suitable.

Summing NOR gates yields half-adder
When a number of NOR gates are paralleled, the result is a half-adder circuit (Fig. 3a). This type of subsystem requires complementary inputs,
1. **NAND gate** is formed by connecting two J-FET inverters in series (a). If the truth table definitions of logical 1 and 0 were reversed, a NOR gate would result. Equivalent circuit for ON state of NAND gate appears in (b).

2. **NOR gate** uses two J-FETs in parallel (a); equivalent circuit for logical 1 state is exhibited in (b). Noise margin for one state is reduced by the parallel combination of OFF leakage currents.

3. **Half-adder** is constructed with parallel NOR gates (a). Truth table (b) and logic diagram (c) show that complementary inputs are required. Note that the J-FETs are all n-channel types.

As is made clear by the truth table (Fig. 3b) and the logic diagram (Fig 3c). If the complementary signals are not normally available, a slightly more complex half-adder must be constructed (Fig. 4). In this circuit a two-input NAND gate followed by an inverter replaces one of the NOR's of Fig. 3a. This subsystem does not require complementary inputs.

Flip-flops using J-FETs can also be made by the Eccles-Jordon approach. A set-reset (R-S) flip-flop built on this principle is shown in Fig. 5. The design equations for the R-S flip-flop are the same as the classic Eccles-Jordan equations for vacuum tube flip-flops. With conventional triggering schemes, the R-S flip-flop of Fig. 5a can be transformed into a J-K flip-flop (Fig. 5b). The J-K version offers conventional trailing-edge triggering.

Consider the condition $J = K = 1$ with the J output at ground. With the J, K or clock inputs grounded, the trigger capacitors cannot charge, since all the diodes clamp the intersection of $C1$ and $R1$ at ground. When the J and K inputs go positive, their diodes disconnect. However, the

---

4. Complementary inputs are not required by this half-adder. Comparing it with Fig. 3a, we see that a NAND gate and an inverter have replaced one of the NOR gates. Note that this is an n-channel J-FET circuit exclusively. It may be observed that the NAND gate and the inverter are represented by the AND gate symbol in the logic diagram. Thus the slight increase in the circuit complexity is not obvious from the logic diagram alone.

5. Flip-flops are easily built with J-FETs by vacuum tube design techniques. The reset-set (a) and J-K (b) multivibrator versions demonstrate this. One benefit of these circuits over their bipolar-transistor counterparts is their lower power dissipation. This is because J-FETs don’t draw base (gate) current; bipolars do. Moreover, noise immunity is higher and temperature stability is slightly better with J-FET devices.

- Good noise immunity.
- Temperature performance considerably more stable than that of conventional junction-transistor circuitry.
- Less radiation sensitivity.
- Lower power dissipation than conventional junction-transistor circuits because no base (gate) current is required.

MOS-FET digital superior to J-FET

Attractive as the J-FET may appear in
6. MOS-FET inverter circuit (a) is a superior digital design to both its J-FET and bipolar counterparts. Stability, minimal power needs and circuit simplicity are characteristics of this complementary network. Switching performance (b) demonstrates little variation in time parameters with temperature change. Here $V_{DD} = 10 \text{ V}$, $V_{GS} = 10 \text{ V}$, $C_{IN} = 10 \text{ pF}$ and the fan-out refers to the ratio of load capacitance to input capacitance. Also, $t_r$ is the rise time and $t_{d1}$ the turn-on delay time. Note that $t_{d1}$ variation over the ambient range $-40$ to $+125^\circ \text{C}$ is imperceptible.

7. Three-input NAND gate using MOS-FETs (a) has p-channel units in parallel and n-channel devices in series. Truth table (b) shows that output is always high (at $+\text{V}$) except for the condition of $A=B=C=1$.

contrast to a bipolar, for digital applications it runs second to the other basic field-effect device, the MOS-FET. Comparatively, the main benefits of MOS-FET switching circuits are:

- Circuit simplification.
- Higher thermal stability.
- Far less stringent power requirements.

The capacitive input to the MOS-FET lends itself to direct-coupled circuitry—a saving in component count and circuit wiring. In addition, the MOS-FET is innately more stable with temperature than the J-FET. And when complementary MOS-FET designs are used, power is dissipated only during the switching interval.

Several families of MOS-FET logic have been proposed. For this discussion, attention will center on complementary logic. The basic complementary inverter circuit is shown in Fig. 6a. This circuit has the unique attribute of dissipating almost no power in either stable state.

With the input at zero, the upper p-channel MOS-FET is fully ON. The load capacitance $C_L$ is charged to $+\text{V}$ through the p-channel MOS-FET. Once $C_L$ is at $+\text{V}$, the only current flow in the circuit is the $I_{oss}$ of the p-channel unit. This $I_{oss}$ is in the picoampere range, since the 2N4351 with a zero gate voltage is completely OFF. The voltage drop across the 2N4352 is simply the $I_{oss}$ of the 2N4351 times the channel resistance of the 2N4352 (about 300 $\Omega$). The voltage drop across the 2N4352 is therefore approximately 3 nV.

With the input at $+\text{V}$, the n-channel 2N4351 is fully ON and the p-channel is cutoff; $C_L$ discharges to ground and the 2N4352 then limits current flow to picoamperes. The voltage drop across the n-channel MOS-FET is again in the nanovolt region.

Figure 6b shows the switching performance of the MOS-FET complementary inverter as a function of the fan-out. Fan-out is defined as $C_L/C_{IN}$ where $C_{IN}$ for the 2N4351-2N4352 pair is about 10 pF. Thus, for example, the rise time with a fan-
out of 10 when $T_a = 25^\circ C$ is 70 ns and the delay time is 13 ns. At a fan-out of 100, representing a load capacitance of 1000 pF, the rise time is about 650 ns with a 100 ns delay time.

The temperature variation of this circuit is also displayed in Fig. 6b. At a fan-out of 10, the variation in rise time over the temperature range of $-40^\circ C$ to $+125^\circ C$ is only 20 ns. There is no appreciable change in the delay time over this temperature range. Turn-off is much the same as turn-on, since one device of the pair is always turning ON.

The complementary NAND gate is formed as in Fig. 7. The p-channel devices are connected in parallel and their n-channel complements are connected in series. The truth table for the 3-input NAND gate is also shown. For the NAND function, the output is always high, unless all three inputs are high. If any one or any pair of inputs is high, one or more of the p-channel FETs will be held ON by the remaining low inputs, and the common output bus will be at $+V$. When all three inputs are high, all three series n-channels will be ON, and the output is low.

**Little leakage in MOS-FET NAND gate**

This configuration does not suffer from the noise-margin problems of the series J-FET NAND gate. The zero output level is developed across three series elements. The leakage current from all three of the p-channel devices, however, is in the picoampere range, resulting in nanovolt output levels even for very large gates.

For example, at $+125^\circ C$, the leakage current of the p-channel 2N4352 is about 100 nA and the channel resistance of the n-channel 2N4351 at a 10-volt bias and $+125^\circ C$ is about 130 $\Omega$. For a 50-input gate the total leakage current is 5 $\mu$A. The series output resistance is 6.5 k$\Omega$, resulting in an output voltage of 0.325 V, an extremely low value. A limitation of the width of the NAND gate exists: switching speed decreases and power dissipation increases as the width increases.

The complementary NOR gate appears in Fig. 8. Here the order has simply been reversed. The p-channel devices are connected in series and the n-channel are in parallel. If any one of the inputs is high, one of the parallel n-channels will be ON, and the output will be low. Only when both inputs are low will both series p-channels be ON, allow-
ing the output to go “high.” Thus the conditions stated in the truth table are satisfied. The same comments about size apply to the NOR gate as to the NAND gate.

As a practical example of the use of the NOR gate, a half-adder configuration using three NOR gates is shown in Fig. 9. The carry digit is taken from the NOR gate handling the complement inputs, while the sum digit is picked up from the NOR gate that sums outputs from the first two NOR gates.

Referring back to Fig. 6b, which shows the switching times of the complementary pair, consider the carry digit in the half-adder to the next stage as a fan-out of one, and the input to the sum-digit NOR gate as a fan-out of one. The carry NOR gate now faces a fan-out of two. For a fan-out of two, according to Fig. 6b, the rise time at room temperature should be 15 ns. Therefore, the propagation delay from the input to the carry digit is 15 ns.

Assume a fan-out of two for the sum-output complexity, this circuit has longer propagation delays. It should therefore be used only when complementary inputs are not available.

10. This half-adder requires no complementary inputs because a NOR gate in the half-adder of Fig. 9 has been replaced by an AND gate. In addition to its greater complexity, this circuit has longer propagation delays. It should therefore be used only when complementary inputs are not available.

11. Complementary R-S flip-flop employs eight MOS-FETs. Note the direct-coupling between stages.
MOS-FET flip-flops are direct-coupled

The complementary R-S flip-flop requires a more complex design approach than simply cross-coupling gates (Fig. 11). One of the major advantages of MOS-FET logic is that it makes it possible to design highly reliable, direct-coupled circuits. Care, however, must be exercised to avoid "sneak-paths" that are a hazard of direct-coupled circuits.

The R-S flip-flop is a case in point. If the set and reset lines are applied directly to the basic flip-flop gates, the output is driven directly from the set and reset lines. Logically, therefore, all that is needed to accomplish this feat is the circuit wiring. An additional complementary pair is required for both the set and reset lines, Q1, Q2, Q3 and Q4, to isolate them from the load. The circuit of Fig. 11 then becomes the basic flip-flop circuit for complementary MOS-FET logic.

By a suitable triggering scheme, the basic flip-flop can be made into a J-K flip-flop (Fig. 12). To steer the trigger pulse for the $J = K = 1$ condition, a complementary pair is used to sense the output of the opposite side. Additional single device gates are used to gate the J, K and clock inputs.

Consider the J output grounded. The $J = K = 1$ condition is to toggle the flip-flop. With the J output low, the p-channel of the right-hand sensing pair is biased ON. While the K output is high, the n-channel of the left-hand sensing pair is kept ON. High inputs at the J and K inputs turn ON their respective gates. When the clock input comes "true" (or high), the $+V_{DD}$ is propagated.
through the clock gate, through the K input gate, through the right-hand sensing gate, and to the K output gate, toggling the flip-flop.

The trigger signal does not propagate through the left-hand sensing gate since it is blocked. Naturally, this scheme requires a narrow clock pulse. The clock pulse must not be present when the K output has switched, since the left-hand sensing pair would then become inadvertently biased ON.

Without excessive precautions with the circuit layout and device selection, the J-K flip-flop of Fig. 12 can be operated at frequencies from dc to about 5 MHz. Tighter control of layout and device matching should make it possible to construct circuits operable above 10 MHz.

Integration of MOS-FETs easily realized

Obviously, the MOS-FET design approach is much more amenable to integrated-circuit techniques than the J-FET method. Integrated MOS-FET circuitry arrays are being increasingly used. Already logic families built with single-polarity devices have been marketed. The complementary MOS-FET pair has particularly noteworthy low power dissipation, fast switching times, and very stable temperature characteristics.

The MOS-FET fabrication process is simpler and inherently more reliable than conventional triply-diffused junction-transistor integrated circuitry. The MOS-FET has a size advantage over conventional integrated circuits. The use of active load resistors in place of conventional diffused resistors also further reduces the size of MOS-FET integrated circuits. Because of this smaller size, and of the higher yields of the MOS-FET process, the complexity of integrated circuits can be increased by an order of magnitude or more. Whole shift-registers, 16- and 32-word memory units, and eight-bit full-adders can now be projected for integrated circuits.

This present presentation of J-FET logic circuits has been limited to rather straightforward RTL-type circuitry and is intended merely as an example of J-FET switching circuits. The RTL circuits described, however, achieve lower power dissipation levels than conventional junction-transistor RTL circuitry and are not so susceptible to current-hogging problems. There is some doubt about the integration of J-FET circuits. To date, none has been marketed, largely because of processing difficulties.

Although the switching behavior of FETs is difficult to characterize, and many interesting logic schemes have yet to be explored, the FET, by virtue of its unique characteristics of inherent stability, low power consumption, and potentially very high reliability, will be a permanent member of the digital device family.
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ON READER-SERVICE CARD CIRCLE 41

ELECTRONIC DESIGN 25, NOVEMBER 8, 1966
Airpax double-pole double-throw electromechanical choppers, Types 2550-1 and 2555-1 (for 60 CPS operation) and Types 2750-1 and 2755-1 (for 400 CPS operation) are designed for synchronous modulator-demodulator functions, stabilized DC instrument amplifiers, shared channel applications and null seeking servos. In some instrumentation applications it is desirable to have different dwell times on the individual sections of a DPDT chopper. Typically, a longer dwell is used on the modulator section than on the demodulator portion. Types 2555-1 and 2755-1 are designed to have a 165° dwell on one set of contacts and 120° on the second set. This prevents even slight contact bounce from affecting the demodulated output.

<table>
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<tr>
<th>TYPICAL CHARACTERISTICS</th>
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Electronic Design 25, November 8, 1966
Predict line regulation accurately in high-current regulators by including output conductance in your calculations.

Output conductance is so low that it is generally ignored in calculating line regulation for most transistor series regulators. But this parameter cannot be overlooked when high-current silicon power transistors are used as pass elements. Here then are two methods—one exact, one approximate—of making the calculations.

The reason why output conductance \( h_{oe} \) is so important to the operation of a pass transistor is clear when we analyze how a silicon transistor performs as a pass device. The high saturation voltage drop of a silicon transistor makes it necessary to locate the operating point of a silicon regulator close to the “knee” of the characteristic curve in order to keep internal power dissipation at a minimum. Since this “knee” is the point at which the characteristic curve becomes nonlinear, \( h_{oe} \) increases considerably so that it cannot be omitted from calculations.

The line regulation may be calculated from one of two equations, one an approximation, one exact. The approximate solution employs a voltage divider model and, though simpler to work with, will often make the regulator look as though it has poor line regulation. Down to a line regulation of 5% the more precise analysis will improve calculated line regulation by a factor of two.

Exact approach improves line regulation

In the typical series regulator shown in Fig. 1, pass transistor \( Q \) is defined by the following relationships:

\[
\begin{align*}
  h_{FE} &= \text{dc current gain}, \\
  h_{fe} &= \text{small-signal current gain}, \\
  h_{oe} &= \text{output conductance}, \text{ and} \\
  R_o &= \text{dynamic base resistance} = V_{be}/I_{out}.
\end{align*}
\]

The error amplifier is assumed to be a linear amplifier that has infinite input resistance and these characteristics:

\[
\begin{align*}
  A &= \text{unloaded open-loop voltage gain}, \\
  g_m &= \text{transconductance}, \text{ and} \\
  R_o &= \text{output resistance} = A/g_m.
\end{align*}
\]

The regulation of this series regulator is affected by three major factors:

- Load resistance change—specified as source resistance \( R_s = \Delta E_{out}/\Delta I_{out} \) at a constant input voltage \( (e_{in}) \) and temperature.
- Temperature change—specified as temperature sensitivity \( (\Delta E_{out}/\Delta T) \) at a constant input voltage and load resistance.
- Input voltage change—specified as line regulation \( \lambda = \Delta E_{out}/\Delta e_{in} \) at a constant load resistance and temperature.

Line regulation is obtained by calculating the effects of input voltage changes \( (\Delta e_{in}) \) on the circuit in Fig. 1. This change must be absorbed by the change in the voltage across \( Q \) \( (\Delta V_{ce}) \) and \( R_{load} \). The voltage change \( (\Delta V_{ce}) \) is found by evaluating the transistor characteristics shown in Fig. 2.

In Fig. 2, the total collector current change is separated into two parts where \( \Delta I_{ce} \) is simply \( h_{oe}\Delta V_{ce} \) and \( \Delta I_{c1} \) is \( h_{fe}\Delta I_{B} \). Since \( \Delta I_{0} = \Delta I_{B} + \Delta I_{S} \), the change in output current becomes:

\[
\Delta I_{output} = \Delta I_{B} = h_{oe}\Delta V_{ce} - (h_{fe} + 1)\Delta I_{B}.
\]

Rearranging this expression and using \( \Delta E_{out} = \Delta I_{out} \cdot R_{load} \) gives:

\[
\Delta V_{ce} = [\Delta E_{out}/R_{load} + \Delta I_{B}(h_{fe} + 1)]/h_{oe}.
\]

To find \( \Delta I_{B} \), consider the voltage change across \( R_o \) caused by an output voltage change \( (\Delta E_{out}) \), where:

\[
\Delta I_{B} = [(1 + A)/R_s]\Delta E_{out} + [R_s/R_o]\Delta I_{out}.
\]

Since \( \Delta e_{in} = \Delta E_{out} + \Delta V_{ce} \), the line regulation \( (\lambda = \Delta E_{out}/\Delta e_{in}) \) becomes:

\[
\lambda = \Delta E_{out}/(\Delta E_{out} + \Delta V_{ce}) = 1/(1 + \Delta V_{ce}/\Delta E_{out}),
\]

and, using Eqs. 2 and 3:

\[
\lambda = 1/[1 + (1/h_{oe}R_{load}) + [1 + A + (R_s/R_{load})]/(h_{fe} + 1)]/h_{oe}R_s].
\]

Rewriting \( \lambda \) in terms of the source resistance, \( R_{so} \), makes the equation easier to handle. From the definition of source resistance and by use of Fig. 2, it can be shown that:

where

\[ \lambda = H_T h_{oe} R_{SPL} \]  \hspace{1cm} (7)

and

\[ R_{SPL} = \frac{R_{LOAD}}{R_{LOAD} + R_s} \]  \hspace{1cm} (9)

\( H_T \) may vary from 0.4 to 1.0. Equation 7 indicates the trade-offs that are possible between \( h_{oe} \) and the product \( H_T R_{SPL} \). In most cases, \( R_s \) is approximately equal to \( R_{SPL} \).

### Approximation assumes conductance is constant

The approximate solution for line regulation (\( \lambda' \)) is obtained by considering a simpler model of the series regulator where only first order effects are considered. In this model, \( R_{LOAD} \) is replaced by \( R_s \) in parallel with \( R_{LOAD} \), and \( Q \) is represented by a transistor having a linear characteristic in shunt with a conductance, \( h_{oi} \). Since the transistor, because of its "flat" characteristic, appears as a constant generator in parallel with \( h_{oe} \), it can be omitted. This yields the model in Fig. 3.

The calculation of line regulation now becomes merely a voltage divider analysis:

\[ \lambda' = 1 / [1 + 1/h_{oe} R_{SPL}] \]  \hspace{1cm} (10)

The percentage error of this approximation is:

\[ \frac{(1 - \lambda')}{H_T - 1} \times 100\% \]  \hspace{1cm} (11)

and the relationship between the exact value of \( \lambda \) and \( \lambda' \) is:

\[ \lambda = H_T \lambda' / (1 - \lambda') \]  \hspace{1cm} (12)

From Eq. 10, it is apparent that \( \lambda \) can be more or less than \( \lambda' \), depending on the specific value of \( H_T \) and \( \lambda' \).

Figure 4 shows line regulation for a range of values for the product \( h_{oe} \cdot R_{SPL} \). The dashed curve represents the approximate solution where \( H_T = 1 \). Other plots for exact values of \( H_T \) ranging from 0.1 to 1.0 are also shown in this figure. When the regulation is greater than 5\%, the exact solution should be used.

To determine the effect of line resistance, the resistance between the source and the collector of the pass transistor, as shown in Fig. 5, is included in the following relationship, where \( \lambda \) is the
4. Line regulation as a function of the parameters and for various values of \( H_T \). For any given regulation the best over-all line regulation:

\[
\Delta = \frac{E_{\text{OUT}}}{e_{\text{source}}}, \quad (13)
\]

\[
\Delta = \frac{\lambda}{1 + h_{oe} R_{\text{LINE}} (1 - \lambda) + h_{ie} R_{\text{LINE}} \left( \frac{h_{fe}}{h_{fe} + 1} \right) \left( 1 - \lambda - \frac{H_T R_{\text{RPL}}}{R_{\text{LOAD}}} \right)} \quad (14)
\]

The desired over-all line regulation of a transistor series regulator is realized by selection of an appropriate combination of \( R_s \) and \( h_{oe} \) (for a given \( R_{\text{LOAD}} \)) from Fig. 4. The \( R_o \) of the amplifier can then be designed for a suitable \( H_T \) to yield the required line regulation, \( \lambda \). Using this and \( R_{\text{LINE}} \) in Eq. 12, the over-all line regulation, \( \Delta \), can be determined. If the output of the bias voltage supply varies with line-voltage variations, the line regulation will also be affected. In this analysis, it has been assumed that the operation of the amplifier is not affected by changes in the bias supplies. In any experiment or test, it is important to identify the portion of the output voltage error that accrues as a result of amplifier bias voltage variations. When these variations occur, they can be controlled by amplifier design, feedback, and better regulation of the bias voltage itself.

Design example regulates 75 amperes

As an example, take the design of a 6-V, 75-A series regulator with a line regulation of 0.5%. Assume the pass transistor selected for the application has these characteristics:

\( h_{oe} = 5 \text{ mhos; } R_s = 10 \text{ m} \Omega; \ h_{fe} = 10. \)

The first step is to select an arbitrary value of \( H_T \); assume \( H_T \) is equal to 0.5. From Fig. 4, \( h_{oe} R_{\text{RPL}} \) becomes \( 10^{-2} \) when \( \lambda = 0.5\% \). Thus,

\[ R_{\text{RPL}} = 10^{-2}/5 \text{ mhos} = 2 \text{ m} \Omega, \]

and

\[ R_{\text{LOAD}} = 6 \text{ V}/75 \text{ A} = 80 \text{ m} \Omega. \]

From Eq. 8, the value of \( R_o \) (the output resistance of the error amplifier) is calculated to be 110 m\( \Omega \).

From Eq. 9, the value for \( R_s \) becomes 1.95 m\( \Omega \). These values are inserted in Eq. 6 and the equation is solved for the error amplifier gain, \( A \). For these particular values, the gain turns out to be 99 and is well within the capabilities of most amplifiers.
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Don’t pay too much for stability in oscillators. A different approach to amplifier stabilization yields inexpensive and stable RC oscillators.

Usually RC oscillators are not considered for precise frequency generation. But an unusual design technique makes them unbeatable as inexpensive, easy-to-reproduce frequency sources and time-base generators.

The design approach differs from the conventional in that it uses a precisely adjusted amount of excess loop gain, rather than some form of multicycle level control, to achieve stable operation. The choice of a stable twin-T network and a gain-stabilized amplifier results in an oscillator that has better than 0.1% accuracy and a short-time stability of a few parts in 10^8. The temperature range is from -55 to +71°C.

Such oscillators are useful in many communication, switching or channel-selection applications, and in telemetry systems for subcarrier or composite signal generation. Stable time-base generators are also finding increased use in settable digital electronic timers for both civilian and military equipment.

The design approach has been carried out at 1000 Hz, although frequencies between 100 and 10,000 Hz may be generated by the choice of appropriate network components.

Why RC oscillators?

Inductance-capacitance oscillators were investigated first because they have already been used as precise audio frequency sources. An LC resonator, furthermore, presents favorable impedance interfaces to the amplifier in the frequency range of interest. But there are some practical difficulties that arise with this approach.

For small size, a permeable-core inductor must be used (usually toroidal) along with film capacitors of the wound type. Extensive testing has indicated that control of the temperature coefficients of these elements to the required accuracy would be extremely difficult on a production basis. To obtain 0.1%, an average LC temperature coefficient of 10 ppm/°C must be held to cover a temperature range of 100°C. Permalloy dust cores and polystyrene dielectric capacitors that approach this stability are available, but it is likely that each one of them would have to be tested individually.

Under shock and spin, both of these circuit elements may change typically as much as 0.25%, even when protected by special potting techniques.

These basic limitations make RC oscillators preferable. Precision wire-wound resistors are widely available with uniform temperature coefficients of less than 10 ppm/°C over the military temperature range. Coefficients as low as 2 ppm/°C can be obtained. Aging of wire-wound resistors of proper design is as low as 0.003% per year. Highly stable capacitors of suitable size with porcelain or ceramic dielectric are available from several commercial sources. One source supplies capacitors with specifications indicating 0 ±25 ppm/°C temperature coefficient.

Capacitors of this type may also be obtained with the same temperature-coefficient tolerance but with temperature coefficients of +105 or -65 ppm/°C. Aging tests on these capacitors, conducted by the National Bureau of Standards and others show variations less than 0.1% in 10 years. Most of this variation has been found to occur in the first few months (following a time-logarithmic pattern) and may be considerably reduced by accelerated aging treatment.

The wire-wound resistors and ceramic capacitors withstand high setback accelerations with negligible changes, when appropriately potted.

Twin-T for frequency selection

There are two alternative frequency-selective networks in general use: a twin-T or a Wien bridge. The twin-T outperforms the Wien bridge in
several areas.

- Input and output have a common terminal, which may be grounded.
- Input and output are less sensitive to loading, since the amplifier's input impedance does not appear directly across a single frequency-determining element.
- The twin-T may work directly into an emitter-follower that presents an input capacitance of $C_{bc}$, whereas the Wien bridge with the necessary common emitter input presents a $C_{bc}$ multiplied by the gain factor of the input stage. The base-collector junction of the input stage for the twin-T thus has a low signal voltage impressed across it compared with the large ac voltage for the Wien bridge (equal to about one-third of the output voltage times first-stage gain).
- The twin-T network permits the use of a dc, unity-gain, direct-coupled amplifier which results in a high degree of bias stabilization. This can be achieved for the Wien bridge only with highly stable decoupling components that are relatively expensive and large, by a push-pull output, or by a three-terminal power supply.

A photograph of the 1000-Hz oscillator is shown in Fig. 1, with an unpotted unit in the center and the individual circuit boards at left (twin-T network) and right (amplifier). A potted unit of this type has a volume slightly greater than 1 cubic inch. A hybrid amplifier with integral film resistors, chip transistors, and slightly smaller network resistors can reduce the volume to about 0.5 cubic inch.

Low-cost transistors preferred

Inexpensive epoxy-cased transistors are recommended because they are extremely rugged and can be obtained with very high betas. They are very reliable and convenient for experimental high-shock design. Field-effect transistors have higher input impedance, but their ruggedness, stability, uniformity and cost need further improvements.

The circuit schematic for the oscillator is shown in Fig. 2. It consists of three sections: a regulator-filter, a twin-T frequency-selective network, and an amplifier. This circuit was designed for use with a power supply voltage of $15 \pm 3$ V. An emitter-follower regulator-filter, using $Q_5$, and the base-emitter junction of $Q_6$ as a zener diode, along with a 10-µF capacitor, isolate the oscillator from the power supply's voltage and impedance variations.

**1. Stable RC oscillator** (center) consists of two major stages: The twin-T network is at the left and the amplifier is at the right. The volume of the potted unit is slightly more than 1 cubic inch.

**2. Twin-T network** is inserted into the negative feedback loop of the amplifier. The regulator-filter ($Q_5$ and $Q_6$) isolates the oscillator from the power supply. The oscillator circuit is adaptable to monolithic techniques.
The base-emitter junctions of these transistors, when used as zener diodes, have extremely sharp break points down to 1 µA, and more than half of them have straight curves beyond the 400-µA maximum current required. The voltage change at the output of the regulator-filter is less than 1 V over the temperature range. A low-cost, rugged regulator-filter is thus obtained with isolation much better and response rate much faster than a simple RC filter. A resistor of several hundred ohms may be added in series with the 15-V lead, to protect against accidental burn-out of the regulating circuit if the battery polarity is reversed.

The oscillator proper consists of two parts—the twin-T filter network shown to the left of the dashed line in Fig. 2, and the amplifier, consisting of Q1 through Q4.

**Twin-T into feedback loop**

The phase-inverting, unbalanced, symmetrical twin-T, is inserted into the negative feedback loop of the amplifier. At dc, the network has nearly zero attenuation, which results in a dc amplifier gain of unity with high bias stability. At the notch frequency, the phase inversion in the network and the phase inversion in the amplifier result in the positive feedback necessary for oscillation. The network is unbalanced by changing R3 or C3 or both from their balanced values of 2R3=R1=R2 and C3=2C1=2C2.

For the balanced, symmetrical condition, the notch frequency is given by:

\[ F_n = \frac{1}{2\pi R1 C1}. \]  

The general equation for the complex transmission loss of a twin-T network is lengthy and much has been written about its analysis and performance. The above simple equation may be used with the specified R and C ratios to obtain approximate values for R1 and C1. Ordinarily, capacitors have been specified to ±5% and resistors to ±1% for the network elements. Fine tuning can then easily be done by adjusting the shunt arms of the network.

For phase inversion, the impedance in the resistive shunt arm (R3) must be slightly less than the impedance of the capacitive shunt arm (C3). Optimum over-all stability was obtained with a notch attenuation voltage ratio of about 50:1. Typical values for R3 are about 70 kΩ and C3 totals approximately 2200 pF at 1000 Hz.

To adjust the frequency, increase C3 by capacitors C+r and C-r. R3 may be adjusted by series resistors Rr and Rv which give an attenuation that is slightly less than the amplifier's gain at the desired frequency.

The network has maximum selectivity or phase sensitivity in the symmetrical state, but the curve is rather broad with respect to ratios of R1, R2, R3 and C1, C2, C3. The amplitude and phase response is very sensitive to the degree of balance and reaches its peak as a null is approached. The equivalent Q of such a network, when compared with the phase response of a single tuned circuit, is about equal to the network loss (or amplifier gain) divided by four.

The importance of a high network Q is shown by the equation giving the fractional change in network drive frequency required to compensate for a change in amplifier phase shift:

\[ \frac{df}{f} = \frac{\theta}{2Q}, \]  

(θ is in radians).

It may be used to compute the change in oscillator frequency resulting from phase changes in the amplifier. For a one-degree phase change in the amplifier, a fractional frequency shift of about 0.0006 would result for a network Q of 15.

**Amplifier stages are direct-coupled**

The amplifier is designed to have a minimum effect on the oscillation frequency. The amplifier has a wide bandwidth and thus small excess phase shift at the working frequency. Its input impedance is very high (20 MΩ) with respect to the output impedance of the twin-T; and its output impedance is very low (200 Ω) with respect to the input impedance of the twin-T filter. Thus, changes in these amplifier parameters with respect to variations in temperature or supply voltage result in minimum changes in the oscillation period. This design simplifies adjustments and is stable over the temperature range.

The amplifier consists of two cascaded emitter-followers, followed by a common emitter stage and an output emitter-follower. The stages are all direct coupled, which minimizes the number of components and provides excellent bias stability, because of the unity dc feedback through the...
Because of the dc coupling, the emitter voltage of $Q4$ is approximately the same as the base voltage of $Q1$. This voltage is essentially the sum of the base-emitter drops of $Q1$, $Q2$, and $Q3$, which is about 1.7 V. The voltage on the collector of $Q3$ must be this voltage less the base-emitter drop of $Q4$, or about 1.1 V. This voltage determines the maximum ac voltage swing of $Q3$ without clipping. Since this voltage will vary considerably over the temperature range, the ac output will vary proportionately. This variation may be actually desirable for driving shapers or trigger circuits, since it helps compensate for threshold variations in the driven stage.

The ac gain of the amplifier is achieved in $Q3$ and is approximately equal to the effective load resistance divided by the total emitter resistance ($R_e + r_e$), or about 65 at 25°C.

The stage currents are approximately 10, 25, 200, and 300 $\mu$A respectively, for $Q1$ through $Q4$. The regulating diode of $Q6$ draws about 200 $\mu$A at 15 V, which results in an over-all drain of about 735 $\mu$A.

**Excess loop gain stabilizes oscillator**

The excess loop gain is the difference between the amplifier gain when it operates in the completely linear region and when it operates under a steady-state oscillating condition with the gain clamped by the collector saturation of $Q3$. In the latter case the gain of the amplifier is equal to the loss of the twin-T network and the gain around the loop is equal to unity, or zero dB.

The total period change over the temperature range is shown in Fig. 3 as the amplifier gain is varied and the excess gain is about 20% (1.6 dB). The maximum period stability occurs at a gain of about 60 dB. Moderate temperature deviations in either direction have only minor effects on the stability.

The excess gain can be computed if the value of the supply voltage where oscillation starts is known, since the gain is a function of the emitter current of $Q3$. The excess gain may be adjusted with $R3$, to change the period (Fig. 4). At any given temperature the variation of the period with the amplifier gain is less if the excess gain is not over 2 dB. For positive period-vs-temperature-slopes over-all compensation can be achieved by an increase in the excess gain. However, small gain variations could cause undesirable changes in the period.

To give the period maximum independence from the amplifier properties and yet ensure reliable starting, an excess gain of 1.5 to 2 dB seems optimum. If the excess gain is too low, the loop gain may drop below unity, and oscillation cannot start. For the circuit of Fig. 2 the proper gain occurs with a bus starting voltage of 5 V, or a supply voltage of about 5.5 V. This value allows for a 0.5-V drop in the emitter circuit of the regulator, which operates below the zener-controlled point.

The excess gain may be expected to increase at low temperature. It can be accounted for by decreases in the intrinsic emitter resistances, $r_e$, and the collector resistances, $h_{ce}$, or $h_{oc}$, of the transistors. Variations in other transistor parameters tend to decrease the gain.

The principal cause of gain variation is believed to be the variation in the internal emitter resistance of $Q3$. A thermistor could be used to make up a part of $R_{es}$ to improve gain stability. Because of the small change in gain and its significance, this expedient would prove useful only if high-stability resistors were used in the emitter.

The excess loop gain may be adjusted with $R_s$ and $R_g$. Their values must be selected simultaneously with $C_s$ and $C_g$, to yield the correct period of oscillation.

If the oscillator is to be potted, $R_g$ and a resistor $R_s$ (about 80 ohms and in series with the ground end of the emitter resistor of $Q3$) are left outside the potting compound. $R_g$ is used to adjust the period and $R_s$ to adjust the gain. After the fine adjustments these resistors may be potted. Since both of these resistors are grounded and have low impedances, they may be left unshielded.

An electrostatic shield is needed to isolate the high input impedance of the twin-T network and to permit precise calibration. A thin metal case, tied to ground, is acceptable and it may also serve as a potting container.

The potting material should have good mechanical properties, low and stable dielectric constant and low dissipation factor. Long, straight leads, cordwood construction and spaghetti should be avoided.
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Tests prove stability

The measured amplifier phase shift was 181.0 degrees at 1000 Hz. This 1° variation from the nominal 180° value at dc will change somewhat with temperature. These changes thus have a slight effect (about 0.02%) on the oscillator frequency, but are fairly predictable and may be compensated for. More favorable or more stable amplifier properties may be obtained only with considerably more complex circuitry.

Temperature variations in the electrical properties of the potting material, rather than a lack of very high amplifier input impedance, may impose a lower limit on the usable frequency.

The amplifier seems easily adaptable to miniaturization by hybrid techniques and perhaps also to monolithic integrated form.

If all temperature compensation is to be effected by choosing the net TC of $C_3$, the worst-case for attenuation change results if all $R$s and all other $C$s have the same TC sign. One may assume all $R$s have $+10 \text{ ppm/°C}$ and all $C$s $+25 \text{ ppm/°C}$. $C_3$ has a zero TC. The period shift from $+25° \text{C}$ would then be $-2.21 \mu$s, the attenuation change would be $-0.08 \text{ dB}$ at $-55° \text{C}$. To correct the period change to zero at $-55° \text{C}$, the net TC of $C_3$ must be chosen to be $-106 \text{ ppm/°C}$. This will result in a network attenuation change of $-0.49 \text{ dB}$ in going from room temperature to $-55° \text{C}$. If the TCs are linear, an equal upper temperature excursion causes an attenuation change of equal magnitude but opposite sign. The $\pm106 \text{ ppm/°C}$ for $C_3$ represents also the maximum net TC required of $C_3$ if all other randomly selected parts of the network have TCs of opposite sign within the specifications above, namely, $\pm10 \text{ ppm/°C}$ for resistors and $\pm25 \text{ ppm/°C}$ for capacitors.

In any large-quantity purchase of network components that are specified for zero TC tolerance, it is likely that about one-half of the items will have coefficients at either side of zero. Thus a simple pairing of favorable combinations could reduce both the attenuation changes with temperature and the net TC requirement for $C_3$ to a small percentage of the above values.

Typical period-versus-supply-voltage performance of oscillators with voltage regulators was less than $0.02 \mu$s change between 10 and 20 V. The period increased $0.15 \mu$s when supply voltage was changed from 6 to 10 V.

Without the voltage regulator, the variation in period is less than $0.5 \mu$s from 6 to 20 V or about $+0.02 \mu$s (0.002%) per volt. The regulator decouples the oscillator from phase-coherent interference, which might result in frequency pulling.

The start-up time for the oscillator with the regulator-filter attached is less than 0.8 ms (5-cycle excess with power applied at zero time, compared with a steady-state sampling).
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ON READER-SERVICE CARD CIRCLE 851
Shrink A/D conversion costs and size and improve converter performance by using inexpensive off-the-shelf microcircuits.

Mix the old principle of ramp voltage comparison with modern integrated-circuit technology, and the result can be a fast, accurate, simple and cheap analog-to-digital converter.

The simplicity and low cost of this IC A/D converter make it especially suitable for multichannel applications. Conventional multichannel converters require some form of analog channel switching (commutation) to allow the various input signals to be connected to the processing circuitry. Using inexpensive ICs, one converter can be allotted to each channel, thus saving the cost of multiplexing and eliminating the errors usually generated in electronic commutators.

The accuracy of the multichannel IC converter is better than ±0.05% of full scale at room temperature, and the conversion rate is typically 1000 per second per channel. Parallel operation makes the conversion rate comparable to conventional high-speed converters.

Counter helps generate sawtooth

The block diagram of the complete n-channel analog-to-digital converter and required storage circuits are shown in Fig. 1. The storage circuits are usually already provided in special-purpose digital computers for input signal buffering.

The n-channel version of the converter comprises only one sawtooth generator, n-comparators, and n-differentiation circuits. Each of the n-input voltages $V_{x1}$ to $V_{xn}$ is connected to one input of a comparator, while the sawtooth voltage $V_s$ is connected to the other input. When $V_s$ is larger than $V_x$, the output of the comparator, $t_x$, is $+V_o$; when $V_s$ is smaller than $V_x$, the output level is zero. The comparator output is connected to a differentiation circuit, which produces a narrow pulse at the trailing edge of the $t_x$ pulse signal. The start of this narrow pulse, which is coincident with a clock pulse, is used to parallel-transfer the content of the master counter into the appropriate storage circuit. This occurs just after the clock has changed the master counter. In the block diagram one m-bit shift register is provided in the digital computer for each conversion channel. These storage registers can be arranged to provide either serial or parallel output.

Most conventional sawtooth generators use analog integrators. The amplitude of the resulting sawtooth waveform, $V_s$, is thus a function of the integrating resistor, $R$, and capacitor, $C$, since:

$$V_s = 1/RC \int_0^T V_c dt = V_c T/RC, \quad (1)$$

where $V_c$ is a constant voltage and $T$ a constant time interval.

Herman Schmid, Senior Engineer, General Electric Co., Johnson City, New York

1. Off-the-shelf microcircuits lower the cost of this multichannel analog-to-digital converter. The sawtooth generator is freed from the need for an accurate, variable time constant by a D/A converter and a master counter.
2. Binary digital outputs from this master counter drive the D/A converter which generates the sawtooth voltage.

To overcome this dependency on components, and especially to eliminate the need for a precision capacitor, a sawtooth generator has been designed. It consists of a counter and a digital-to-analog converter.

The master counter operates continuously and provides as outputs binary digital signals that represent a linearly increasing number—from 000...00 to 111...11. Here 000...00 represents a maximum negative value, 111...11 a maximum positive value and 100...00 represents zero. A continuously operating counter can be regarded as a digital sawtooth generator, since it resets itself to 000...00 after it has reached 111...11.

The conversion from the digital number to an analog sawtooth voltage is performed with a conventional D/A converter. With appropriate biasing, the output of the D/A converter swings between the negative reference voltage, $-V_r$, and the positive reference voltage, $+V_r$. Besides generating the sawtooth, the master counter outputs are also gated into the digital computer storage circuits. The number in the counter increases linearly with time; so the number transferred out at any given time is proportional to the time that has elapsed since the start of the counting cycle. By gating the controls of the master counter into the shift register at the end of the $t_o$ pulse, whose width is proportional to $V_r$, a number proportional to $V_o$ is transferred into the register.

Careful circuit selection is a must

There are five basic circuits used in building the A/D converter:

- Master counter
- D/A converter
- Comparator
- Differentiator circuit
- Digital storage circuits

The circuits used were carefully selected to obtain the optimum trade-off between cost and performance. The features considered were:

- **The master counter** must be capable of operating with a clock frequency of at least 4 MHz, must have a resolution of at least 12 bits and should operate synchronously with clock frequency. Each output of the master counter must be capable of driving $n$ digital loads and one analog switch in the D/A converter. A typical design of such a counter with Sylvania's SUHL logic circuits is shown in Fig. 2. It requires a total of 15 off-the-shelf digital integrated circuits.

- **The D/A converter** may be any one of three types: resistor ladder network, weighted voltage or current divider. Each has the basic speed and accuracy capability and similar limitations. The weighted voltage D/A converter shown in Fig. 3, using discrete components, is the most economical.
The ramp-conversion principle

The conversion from a dc voltage, $V_x$, to a digital signal, $X$, can be effected, as shown in the figure, by converting $V_x$ first into a pulse-width signal, $t_x$, and then into a digital signal, $X$.

The dc voltage to pulse-width conversion is obtained by comparing $V_x$ with a sawtooth voltage, $V_s = tV_R$. The output of the comparator is a rectangular wave with an ON-time $t_o$, and a repetition period $T$. The ON-time $t_o$ is proportional to the voltage $V_x$, since:

$$V_x = t_x V_R \quad (1)$$

and

$$t_o = V_o / V_R \quad (2)$$

where $V_R$ is a reference voltage.

The conversion from $t_o$ to $X$ is accomplished by either counting the clock pulses during $t_o$ or by transferring the contents of a master counter (which is synchronized with the sawtooth voltage $V_s$) into a storage circuit.

The narrow pulse (waveform B) generated by the differentiation circuit is used to transfer the content of the master counter into the appropriate storage circuit.

Electrical DESIGN 25, NOVEMBER 8, 1966
voltage at the output of the operational amplifier that is linearly proportional to the parallel binary input. The output of the amplifier must be able to drive the inputs of $n$ comparators.

The comparator, shown in Fig. 4, is an integrated differential amplifier (Fairchild µA 710). When the voltage on the noninverting input is larger than +1 mV, and when the inverting input is connected to ground, the output voltage is approximately +3 V; when it is smaller than 1 mV, the output voltage is approximately −0.5 V. The input impedance, $Z_i$, of this comparator is a function of the input voltage, $V_i$; when $V_i > 0$, $Z_i$ is small; when $V_i < 0$, $Z_i$ is high; and when $V_i = 0$, $Z_i$ is typically 10 kΩ.

To make the input impedance more uniform a 5-kΩ resistor was connected in series with each of the two inputs. In addition, a small capacitor was connected directly across the two inputs to reduce the effect of noise on the input voltages.

The differentiation circuit, shown in Fig. 5, consists of three NOR or NAND gates interconnected to produce a narrow output pulse when the input signal, $A$, and the clock pulse change from zero to positive. The length of the output pulse, $B$, is determined by the delay in the three gating circuits. When the input signal, $A$, changes from positive to zero, the circuit resets, and is ready to generate the next narrow pulse. NOR gate N1 must be chosen so that it can drive the $m$ parallel transfer switches in the digital storage circuit.

The digital storage circuits are not a physical part of the A/D converter and are, therefore, not described in detail.

Unit has high conversion rate

Complete converter performance data were obtained with off-the-shelf linear integrated circuits (Fairchild µA 709 operational amplifier, the µA 710 comparator). The transistor switches were built with discrete components. The data were also taken with a conventional sawtooth generator, where the time constant had to be trimmed to the desired value. Finally, the circuit tested consisted of only three conversion channels.

With a sawtooth frequency of 1 kHz, the static accuracy at room temperature was better than 0.05% on all three channels. Over-all accuracy vs temperature tests have not been performed; however, the transfer characteristics of the µA 710 comparator have been examined both at high (+125 °C) and at low (−55 °C) temperatures and were found to shift by no more than 10 mV; i.e., no more than 0.1% of the full-scale input signal. In the D/A converter, the output amplifier and, to a lesser degree, the switches and resistors are the only other circuits that can produce an error. Past experience has shown that the accuracy of the D/A converter can be maintained to within ±0.25% of full scale over a wide temperature range. Therefore, the complete A/D converter should operate from −55 °C to +125 °C with a static accuracy of better than ±0.5%.

No dynamic tests were performed. Dynamic performance, however, is largely a function of the sawtooth frequency: the higher the frequency, the higher the resulting band pass of the converter. In the system described the maximum possible sawtooth frequency is determined by the speed of the master counter and the D/A converter, and by the rate limitation of the D/A output amplifier. With a 1-kHz sawtooth frequency, the converter performs 1000 conversions per second per conversion channel. If the converter were to have 20 conversion channels, it would have an equivalent conversion rate of 20,000 conversions per second, comparable to some of the fastest A/D converters.

Once the first channel of the converter is built, it is possible to add additional channels at a cost of only $8.00 per channel, when the microcircuits are purchased in quantities of 100 or more. ■ ■

Reference:


Conventional A/D conversion

Today's high-speed analog-to-digital (A/D) converters employ the successive approximation technique, which sequentially compares the unknown voltage $V_X$ with a binary fraction of the reference voltage $V_R$. This type of A/D converter is a complex piece of equipment made up of a high-speed comparator and summing amplifier, an error threshold detection circuit, a shift register, a digital-to-analog converter and digital logic circuits to control the sequential operation. Usually converters of this type can only be afforded for a multiplicity of input channels. Time-sharing of any A/D converter requires an electronic analog commutator, which connects the various input voltages to the converter sequentially in time. Such a commutator consists of a set of analog voltage switches with their associated drivers, a timing generator, one or several dc buffer amplifiers and control logic.

The size, weight and cost of such a converter-commutator combination depends largely on the required accuracy and speed, on the environmental specification, and on the number of voltages to be converted. Prices range between $2000 and $20,000. Size and weight often exceed that of the special-purpose digital computer they are built for, since only a small portion of the converter and commutator can be built with ICs.
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The use of EASTMAN 910 Adhesive is not suggested at prolonged temperatures above 175°F., or in the presence of extreme moisture for prolonged periods.

### SHEAR STRENGTH OF BONDS

<table>
<thead>
<tr>
<th>Bond Type</th>
<th>Time to Firm Set (minutes)</th>
<th>Representative Shear Strength(^1) (psi)</th>
<th>Age of Bond</th>
<th>Bond Type</th>
<th>Time to Firm Set (minutes)</th>
<th>Representative Shear Strength(^1) (psi)</th>
<th>Age of Bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum-Aluminum</td>
<td>2</td>
<td>1,484(^2)</td>
<td>10 mins.</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>114(^3)</td>
<td>15 mins.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2,188(^2)</td>
<td>1 hr.</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>178(^3)</td>
<td>2 yrs.(^2)</td>
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<tr>
<td></td>
<td>2</td>
<td>2,700(^2)</td>
<td>48 hrs.</td>
<td>Neoprene-Polyester</td>
<td>(\frac{1}{2})</td>
<td>112(^3)</td>
<td>15 mins.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2,800 (Tensile)</td>
<td>24 hrs.</td>
<td>Neoprene-Polyester</td>
<td>(\frac{1}{2})</td>
<td>136(^3)</td>
<td>2 yrs.(^2)</td>
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<td>Steel-Steel</td>
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<td>10 mins.</td>
<td>Nylon-Nylon</td>
<td>1</td>
<td>327</td>
<td>10 mins.</td>
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<tr>
<td></td>
<td>2</td>
<td>2,224(^2)</td>
<td>3 hrs.</td>
<td>Nylon-Nylon</td>
<td>1</td>
<td>1,460</td>
<td>48 hrs.</td>
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<td>10</td>
<td>5,030 (Tensile)</td>
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<td>Phenolic-Phenolic</td>
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<td></td>
<td>(\frac{1}{2})</td>
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<td>Polyurethane</td>
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<td>647</td>
<td>10 mins.</td>
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<td>1,007</td>
<td>1 hr.</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>136</td>
<td>2 yrs.(^2)</td>
</tr>
<tr>
<td></td>
<td>(\frac{1}{2})</td>
<td>1,653</td>
<td>1 hr.</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>112</td>
<td>2 yrs.(^2)</td>
</tr>
<tr>
<td>Butyl Rubber-Butyl</td>
<td>(\frac{1}{2})</td>
<td>51(^1)</td>
<td>10 mins.</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>114(^3)</td>
<td>15 mins.</td>
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<tr>
<td></td>
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<td>63</td>
<td>4 yrs.(^2)</td>
<td>Butyl-Phenolic</td>
<td>(\frac{1}{2})</td>
<td>178(^3)</td>
<td>2 yrs.(^2)</td>
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<tr>
<td>Butyl Rubber-</td>
<td>1</td>
<td>52(^1)</td>
<td>10 mins.</td>
<td>Neoprene-Polyester</td>
<td>(\frac{1}{2})</td>
<td>112(^3)</td>
<td>15 mins.</td>
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<tr>
<td>Steel</td>
<td>1</td>
<td>76(^1)</td>
<td>10 mins.</td>
<td>Neoprene-Polyester</td>
<td>(\frac{1}{2})</td>
<td>136(^3)</td>
<td>2 yrs.(^2)</td>
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<tr>
<td>Butyl Rubber-Aluminum</td>
<td>1</td>
<td>73(^1)</td>
<td>10 mins.</td>
<td>Nylon-Nylon</td>
<td>1</td>
<td>327</td>
<td>10 mins.</td>
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<tr>
<td></td>
<td>(\frac{1}{2})</td>
<td>69(^1)</td>
<td>4 yrs.(^2)</td>
<td>Nylon-Nylon</td>
<td>1</td>
<td>1,460</td>
<td>48 hrs.</td>
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<tr>
<td>SBR Rubber-SBR</td>
<td>(\frac{1}{2})</td>
<td>90(^1)</td>
<td>10 mins.</td>
<td>Polyurethane-Aluminum</td>
<td>1</td>
<td>207(^3)</td>
<td>6 mos.(^4)</td>
</tr>
<tr>
<td></td>
<td>SBR Rubber-SBR</td>
<td>56(^1)</td>
<td>4 yrs.(^2)</td>
<td>Polyurethane-Aluminum</td>
<td>1</td>
<td>192(^3)</td>
<td>1 yr.(^4)</td>
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<tr>
<td></td>
<td>(\frac{1}{2})</td>
<td>89(^1)</td>
<td>4 yrs.(^2)</td>
<td>Polyurethane-Aluminum</td>
<td>1</td>
<td>200(^3)</td>
<td>2 yrs.(^4)</td>
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<tr>
<td>Neoprene Rubber-</td>
<td>(\frac{1}{2})</td>
<td>54(^1)</td>
<td>10 mins.</td>
<td>Polystyrene</td>
<td>2</td>
<td>327</td>
<td>10 mins.</td>
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<tr>
<td>Neoprene Rubber</td>
<td>(\frac{1}{2})</td>
<td>45</td>
<td>4 yrs.(^2)</td>
<td>Polyurethane</td>
<td>2</td>
<td>70</td>
<td>1 yr.(^4)</td>
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<tr>
<td>Natural Rubber-Natural Rubber</td>
<td>(\frac{1}{2})</td>
<td>46(^1)</td>
<td>10 mins.</td>
<td>Polyurethane</td>
<td>2</td>
<td>447(^1)</td>
<td>10 mins.</td>
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<tr>
<td>SBR Rubber-Butyrate</td>
<td>(\frac{1}{2})</td>
<td>95(^1)</td>
<td>10 mins.</td>
<td>Polyurethane</td>
<td>2</td>
<td>327(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td></td>
<td>SBR Rubber-Butyrate</td>
<td>110(^1)</td>
<td>2 yrs.(^2)</td>
<td>Polyurethane</td>
<td>2</td>
<td>411(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td></td>
<td>(\frac{1}{2})</td>
<td>112(^1)</td>
<td>30 days, salt spray cycle (ASTM B 1117-577)</td>
<td>Polyurethane</td>
<td>2</td>
<td>447(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td>SBR Rubber-Polyester</td>
<td>(\frac{1}{2})</td>
<td>105(^1)</td>
<td>10 mins.</td>
<td>Polyurethane</td>
<td>2</td>
<td>180(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td></td>
<td>SBR Rubber-Polyester</td>
<td>110(^1)</td>
<td>2 yrs.(^2)</td>
<td>Polyurethane</td>
<td>2</td>
<td>411(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td>Butyl Polyurethane</td>
<td>(\frac{1}{2})</td>
<td>102(^1)</td>
<td>15 mins.</td>
<td>Polyurethane</td>
<td>2</td>
<td>447(^1)</td>
<td>24 hrs.</td>
</tr>
<tr>
<td></td>
<td>Butyl Polyurethane</td>
<td>154</td>
<td>2 yrs.(^2)</td>
<td>Polyurethane</td>
<td>2</td>
<td>447(^1)</td>
<td>24 hrs.</td>
</tr>
</tbody>
</table>

\(\frac{1}{2}\)Laboratory test results  \(\frac{1}{2}\)rubber failure  \(\frac{1}{2}\)weathered outdoors  \(\frac{1}{2}\)plastic failure  \(\frac{1}{2}\)50% Relative Humidity and 75°F.  

*In certain cases, most notably those involving polystyrene, pickled or dissimilar metal surfaces, bonding with EASTMAN 910 Adhesive is sometimes slow. EASTMAN 910 Surface Activator is designed to restore the rapid polymerization of the adhesive. It is also quite valuable in maintaining consistent results in production line bonding situations. Further information on this product is available.

Other materials that can be bonded successfully with EASTMAN 910 Adhesive are: polyurethanes, acetal resins; most hard woods; brass, copper. Recent work indicates that polyolefin and acetal plastic bonds are significantly improved by flame treatment of the plastic material prior to bonding (shear strengths up to 500 psi).

If you have applications in which extreme speed of setting is needed, or where design requirements involve small joining surfaces, complex mechanical fasteners, or heat sensitive assemblies, EASTMAN 910 Adhesive may save you many man-hours of production time. Send $10 for a trial kit to use on your toughest bonding job. Kits and further information are available from Armstrong Cork Co., Industry Products Division, Lancaster, Pennsylvania, or from Chemicals Division, EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, Kingsport, Tennessee.

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A DIVISION OF HONEYWELL

HONEYWELL INTERNATIONAL—Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.
Flexible circuit probe fits in small places

Here is a technique for fabricating a flexible probe that can simplify measurements on small assemblies. The probe is made from standard alligator clips and printed-circuit strips, and provides two separate connections to a common point.

It is often very difficult to connect circuit probes to miniature switch assemblies for measuring contact resistance. The difficulty stems from the fact that such resistance is usually measured by metering the voltage drop and current separately. The accuracy of such measurements is increased by using separate contact points for each meter, which, effectively, gives a four-wire metering system. Most conventional means for four-wire hookups to very small assemblies are either too cumbersome or unreliable.

A convenient way to circumvent this problem is to use a homemade probe (see illustration) made from miniature alligator clips and double-clad flexible printed-circuit material. The flexible printed-circuit material (approximately 0.010 inch over-all thickness) should be gold-plated on both sides and cut into strips narrow enough to slip inside the jaws of the alligator clip.

One side of the clad material is soldered to the jaws, and an insulating sleeving is slipped over both leads. The inside surface of each copper-clad strip then becomes an electrically isolated conductor. Meter leads may be soldered to the free end of the strip. The alligator clip thus provides two separate connections to the contact terminal when it is attached.

Fred W. Kear, Engineer, Sparton Southwest, Inc., Albuquerque, N. M.

Double flip-flop has constant output impedance

In several applications involving reference-voltage switching, such as digital-to-analog conversion, it is desirable to have a flip-flop whose output impedance is low and does not depend on the state that the flip-flop is in. Such a circuit is made possible by the addition of two extra transistors to the conventional flip-flop (see illustration).

The circuit output switches between the plus and minus supplies and provides an output impedance of about 10 ohms in either state. The cross-coupling network is arranged so that only one npn stage (Q3 or Q4) can be ON at a time. When one npn is ON, its associated pnp is OFF, and vice versa.

If only one output is to be used, one of the pnp transistors (Q1 or Q2) can be replaced by a

---

Flexible circuit probe is made from standard alligator clips and double-clad flexible printed-circuit material.

Low output impedance is maintained by the double flip-flop regardless of its state.

VOTE FOR 110

Electronics Design 25, November 8, 1966
Whose dual in-line 930 DTL?

Only your purchasing agent knows for sure!

ITT offers all series 930 DTL circuits in a dual in-line package. Circuits manufactured by ITT are identical to and perfectly interchangeable with the other leading brand.

If you're convinced that dual in-line packaging is your answer — if you want the lower component insertion cost, heavier leads and all-ceramic construction that only dual in-line can give you, evaluate ITT.

You can order any series 930 DTL in dual in-line today! Call your ITT distributor or factory representative.
resistor. Triggering can be accomplished by any conventional method, such as diode steering.

The technique, although shown for a flip-flop, is also applicable to the design of monostable and astable multivibrators.

**Walter J. Guinon, Consultant, Boston, Mass.**

**Operational amplifier attenuates faster with three added devices**

Doubling the attenuation rate of an operational amplifier, from 20 dB/decade to 40 dB/decade, can be achieved merely by the addition of one capacitor and two resistors to the feedback loop of the amplifier. The circuitry is much simpler and less expensive than the usual buffer stages that are employed.

The conventional operational amplifier (Fig. 1) attenuates at the 20-dB/decade rate and has the transfer function:

\[ A = \frac{E_o}{E_{IN}} = 1/\left(1 + j\omega C \right). \]

Rheostat \( R_1 \) is a simple gain adjustment.

Addition of the three components shown in Fig. 2 increases the attenuation rate to 40 dB/decade, while the simple gain adjustment is retained. The transfer function for this circuit is:

\[ A = K_1 \left[\frac{1 + j\omega R_3 C}{(1 + j\omega K_2 C)^2}\right], \]

where
\[ K_1 = \frac{1}{R_2 R_3 + R_3^2/R_1}, \]
\[ K_2 = 2R_2 R_3/(R_3 + 2R_2), \]
\[ K_3 = R_2. \]

To obtain 40 dB of attenuation for the first decade above the desired corner frequency, \( K_3 \) must be at least 10 \( K_2 \) and the transfer function then becomes:

\[ A = K_1 \left[\frac{1 + j\omega (0.1 K_3 C)}{(1 + j\omega K_2 C)^2}\right]. \]

This represents a low-pass filter that has a corner at \( \omega c_1 = 1/K_3 C \) and attenuates at a rate of 40 dB/decade to the second corner, \( \omega c_2 = 10^9/K_3 C \).

Above \( \omega c_2 \), the attenuation rate is 20 dB/decade. At frequencies very much less than \( \omega c_1 \), the gain is equal to \( K_1 \).

This circuit is being used to condition data, prior to A/D conversion and computer analysis, that are acquired from animals and humans subjected to acceleration and impact.

**Paul L. Kittenger, Engineer, Systems Research Laboratories, Inc., Dayton, Ohio.**

**Small flasher circuit uses few and inexpensive components**

A unijunction relaxation oscillator is the key element of a small, reliable flasher circuit, suitable for control panel indicator lamps. The circuit enables the lamp to give warning of malfunctions, indicate if an operation is complete, and show limits.

The oscillator, \( Q_1 \) in the Figure, drives the base of a switching transistor, \( Q_2 \). The frequency of oscillation is determined by \( R_1 \) and \( C_1 \) in the emitter circuit of \( Q_1 \). The given values yield a frequency of 2 Hz, which is quite adequate for most purposes. The pulses at base 1 drive \( Q_2 \) into saturation—provided, of course, that the emitter of \( Q_2 \) is returned to ground through the secondary indicator lead. When \( Q_2 \) saturates, the base of \( Q_3 \) is returned to ground through \( R_4 \) and \( Q_2 \), reducing the base drive on \( Q_3 \) and extinguishing the indicator lamp. Capacitor \( C_2 \) in the base of \( Q_3 \) increases the time required to extinguish the lamp. When the circuit is initially energized, there is a delay in the turn-on of \( Q_3 \) because of the time constant of \( R_5-C_2 \) and emitter resistor \( R_7 \). This

**VOTE FOR 111**

**VOTE FOR 112**
Who says 1-amp epoxy rectifiers can't stand humidity?

Write for free water-soaked samples from ITT:

Choose the PRV rating that fits your application best and write for samples. We'll ship them immersed. You'll find that ITT epoxy rectifiers exceed the humidity requirements of MIL-STD-750. While you're at it, check for cool operation, low thermal impedance and extreme stability. All are made possible by ITT's patented* "double nail-head" design. Send for your free bottle of ITT rectifiers today!  *Patent No. 3081374

ITT SEMICONDUCTORS
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Please send me a pair of water-soaked 1-amp silicon epoxy rectifiers with the PRV rating I have indicated.

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CITY .............................. STATE ............ ZIP ............
Resistor cuts saturation voltage of switching transistors

Reduce the saturation voltage of a switching transistor by putting an additional resistor into the circuit. In many switching applications it is necessary to produce a voltage level (V1 in Fig. 1) by a simple voltage divider, and then to switch this output to zero volts. However, the troublesome saturation voltage keeps the zero output level at V_{sat} for this basic shunt switch.

The conventional solutions include selection of a transistor with a low V_{sat} (which is usually expensive), matching a complementary compensating pair, or making R2 adjustable by returning it to a negative supply, which requires another resistor between the collector of Q1 and the junction of R1 and R2.

The simplest and easiest solution is to use a very ordinary switching transistor with the addition of R4 as shown in Fig. 2, where (R3 + R4) replaces R1. When Q1 is OFF, the circuit functions exactly as that in Fig. 1. When Q1 is ON, the saturation voltage at the output is now attenuated to:

\[ V_1 = V_{sat} \cdot \frac{R_2}{R_2 + R_4} \]

In a typical application, six of these circuits were used as inputs to an operational amplifier, which summed and amplified logic combinations of six dual-state V1 levels. Because the attenuation of V_{sat} by 10:1 in the ON state is so simple and cheap, shunt-switching for A/D conversion proved to be practical.

Circuit values are: R3 = 33 kΩ, R4 = 21 kΩ, R2 = 2 kΩ, E = 28 V, V1 is at 2 V when Q1 is OFF and at 0.03 V when Q1 is ON. Q1 is a 2N910 transistor.

The only restriction seems to be that the attenuation of V_{sat} is limited to the ratio \( E / V_1 \) (OFF). Therefore V1(OFF) should be designed to a lower grounded through the secondary indicator leads. Simple regulator (R6, CR1, CR2) assures proper timing.

Jack K. Hickman, Engineer, Texas Instruments Inc., Dallas.

VOTE FOR 113
No other RF transistors can offer this performance at these prices!

<table>
<thead>
<tr>
<th>RCA Type</th>
<th>2N4259</th>
<th>2N3933</th>
<th>2N3932</th>
<th>2N3478</th>
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<tbody>
<tr>
<td>Min. Power Gain @ 450 MHz</td>
<td>11.5 dB</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Max. NF @ 450 MHz</td>
<td>5 dB</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Min. Power Gain @ 200 MHz</td>
<td>—</td>
<td>14 dB</td>
<td>11.5 dB</td>
<td>11.5 dB</td>
</tr>
<tr>
<td>Max. NF @ 200 MHz</td>
<td>—</td>
<td>4.0 dB</td>
<td>4.5 dB</td>
<td>4.5 dB</td>
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<tr>
<td>NF @ 60 MHz</td>
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<td>3 dB max.</td>
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<td>Max. Cc</td>
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<td>0.55 pF</td>
<td>0.55 pF</td>
<td>0.70 pF</td>
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<tr>
<td>hFE</td>
<td>60-250</td>
<td>60-200</td>
<td>40-150</td>
<td>25-150</td>
</tr>
<tr>
<td>Min. BVCEO</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Pr @ 25°C Ambient</td>
<td>200 mW</td>
<td>200 mW</td>
<td>200 mW</td>
<td>200 mW</td>
</tr>
<tr>
<td>Price*</td>
<td>$1.60</td>
<td>$1.40</td>
<td>$1.25</td>
<td>$1.15</td>
</tr>
</tbody>
</table>

*In quantities of 1,000 and up.

RCA covers the communications spectrum from 27 MHz to 500 MHz. Every type available for immediate delivery in production quantities. These silicon epitaxial planar transistors for VHF and UHF communications are packaged in hermetically sealed 4-lead metal cases. Check the noise figure and the power gain… then check the price! You get top performance, top value, and immediate delivery in production quantities—a unique combination that no other commercially-available RF transistor can offer! For complete information, pricing, and delivery, call your RCA Field Representative. For technical data sheet, write: RCA Commercial Engineering, Section EG 11-2, Harrison, N.J. 07029.

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IDEAS FOR DESIGN

2. A resistor, $R_4$, attenuates the saturation voltage. The amount of attenuation is limited by the ratio of $E$ and $V_1$ (OFF).

$R_3$ optimizes $I_c$ in the range of lowest $V_{sat}$ from the $V_{sat}$ vs $I_c$ curves.

Charles H. Karr, Senior Engineer, Martin Co., Baltimore.

VOTE FOR 114

Variable square-wave generator combines IC with 4-layer diode

An integrated-circuit flip-flop and a multi-layered diode are the major components in this variable-frequency, square-wave generator. Cost, size, simplicity are some of the circuit advantages.

Any flip-flop could possibly be used, though the particular one shown in the schematic (Fig. 1) was selected for its high speed and edge triggering capabilities. The familiar relaxation oscillator, using a four-layer diode, is compatible with the rise-time requirements of the flip-flop; the flip-flop has a clock input rise-time specification of 150 ns max and the output of the oscillator has a 100-ns rise time, or less, depending on the circuit conditions.

To operate the flip-flop in a continuous counting mode, the $J$ and $K$ inputs (pins 3 and 5) were placed at the logical “1” level. Also, in order to sustain oscillation, $V_1$ must be kept higher than the firing voltage of $CR_1$, and the minimum value of $R_1$ must be large enough to prevent the current through $CR_1$ from reaching a “holding” value.

The completed generator is built on a one-inch-square printed-circuit board and costs about $12 in single quantities. The output waveform (Fig. 2) has a rise time of 100 ns and the square-wave frequency can be varied from 1 hertz to 200 kilohertz by choosing appropriate values of $V_1$, $R_1$, and $C_1$. By adjusting the $R_2$-to-$R_3$ ratio, the clock driving voltage may be varied without affecting the operating frequency.

Since this particular flip-flop can sink currents as large as 14 mA, the circuit is found extremely useful in a variety of switching and control applications.

C. Joseph Buttemeier, Senior Engineer, Litton Guidance and Controls Systems Div., Woodland Hills, Calif.

VOTE FOR 115

Optical diodes trigger stepping counter

A simple circuit permits the use of light as a control signal in electronic circuits. The circuit (see figure) employs the principle of a stepping type of frequency divider, except that it uses optically controlled SCRs as the bistable elements and is controlled by light pulses rather than volt-
Digital Equipment Corporation's PDP-8 programmed data processor, in which these modules are used, is a compact general purpose digital computer with a high speed, random-access, magnetic-core memory for engineering, scientific, and educational applications.

Allen-Bradley hot molded resistors have established such a consistently superior performance record over the years that Digital Equipment Corporation uses them exclusively in their computers—with no substitutes permitted under any circumstances!

While Allen-Bradley quality is the number one reason for this standardization, Digital reports that excellent service from Allen-Bradley is an advantage of vital importance to them, too. For example: “Recent expansion of FLIP CHIP production to meet the demand for PDP-7 and PDP-8 computers quadrupled our component needs. With Allen-Bradley’s help there wasn’t a single hitch in the production speedup.”

The unvarying quality of Allen-Bradley resistors—million after million, year in and year out—results from an exclusive hot molding process. The precision automatic equipment developed and used only by Allen-Bradley produces such uniform properties that long term resistor performance can be accurately predicted. Please note, Allen-Bradley hot molded resistors have never been known to fail catastrophically in service.


HOT MOLDED FIXED RESISTORS are available in all standard EIA and MIL-R-11 resistance values and tolerances, and can usually also be furnished in values above and below standard limits. Shown actual size.

‘‘When we use A-B hot molded resistors instead of some other make, it’s one less component we have to worry about’’

Digital Equipment Corporation
Light pulses replace voltage pulses as triggers for this stepping counter.

Operation is as follows: If all the light-controlled diodes are initially OFF, the first light pulse will trigger the first diode and extinguish before the voltage across the capacitor has built up enough to fire the next diode. This voltage will have built up by the time the next light pulse arrives, thus firing diode number two, and so on down the line until the last diode triggers the transistor, turning all the stages OFF to start over again.

Because of pulse deterioration down the line, this type of circuit is limited to about five stages for reliable operation, although it will operate at speeds up to 400 pulses per second, the limit of the General Radio “Strobotac” used as the light source.

Robert C. Hayler, Design Engineer, New Shrewsburg, N.J.

Capacitor increases speed of transistorized core counter

A capacitor in the collector circuit of a transistorized counter enables it to count pulses up to 30 kHz.

To analyze the circuit’s operation, assume that trigger pulse p activates core I2 through winding n_p, making it appear as a logic 1. Let core I1 be a logic 0. When the first input pulse arrives, I2 returns to the 0 state because of the magnetic field generated by winding n_{c2}, and the transistor becomes conductive. The collector current divides between two paths, according to the ratio of R1 and R2. Assuming that \( R1 < R2 \), the current through windings \( n_{c1}, n_{c1}, C \) and \( R1 \) becomes much larger than the current through \( R2 \). Time constant \( CR1 \) should be about one-third of the duration of the output pulse of the transistor. The magnetic field of winding \( n_{c2} \) couples to the base winding \( n_{b2} \), maintaining the 0 state of core I2 and the conductive state of the transistor until the next input pulse. After the capacitor is charged to a voltage of about \( V_{cc} \), all the current passes through \( R2 \) for the remainder of the duration of the pulse.

The next input pulse cuts off the transistor and the capacitor discharges, with a time constant of \( CI(R1 + R2) \), through the collector windings \( n_{c1} \) and \( n_{c2} \), placing cores I1 and I2 into state 1. The transistor remains cut off, since the base windings are still activated. The second trigger pulse maintains the state of I2. The next input pulse to be counted returns both cores to the 0 state. The third trigger pulse starts the procedure all over again. Resistor \( R3 \) damps out undesired voltages due to the possible asymmetries of the base winding.

Dejan V. Glusac, Design Engineer, New Belgrade, Yugoslavia.

Transistorized magnetic core counter uses a storage capacitor to count pulses at frequencies up to 30 kHz.

IFD Winner for Aug. 2, 1966

Bert Pearl, Project Engineer, Hallicrafters Co., Chicago, Ill.

His Idea, “UJT, bipolars in compact, versatile generator,” has been voted the $50 Most Valuable of Issue Award.

Cast Your Vote for the Best Idea in this Issue.
Signetics goes farther than anyone ever has before to anticipate technical questions and provide meaningful written design data. In addition to worst case figures, Signetics SE400J series data sheets provide System Design Limit Curves. These allow a designer to predict readily how a specific system design will function under conditions other than worst case. With such information at hand, the hidden costs of design—extensive in-house characterization, and lengthy specification negotiations—are eliminated. Operative designs can be made with a minimum of meetings and phone calls. As efficient as their data sheets, the SE400J series require 40% to 70% less power than comparable devices while maintaining equal or greater speed and noise immunity. Ideal in aerospace applications where high density packaging and the ability to drive high capacitances are important, the series features a dual 5MHz Binary Element operating on less than 9mW per flip-flop, and includes a Dual NAND Gate, Dual Driver-Buffer and a Quad NAND Gate.

Please send me your unique data sheets on the SE400J series.

Name
Company
Address
City
State
Zip
Mail to: Signetics, 811 E. Arques Ave., Sunnyvale, California
Have fare, will travel

Speak to any good top executive, and he'll tell you that every minute of a business trip can be used to advantage—both the company's and you own. The following tips, gathered during thousands of miles of business travel, may not be the ultimate in good advice, but they have served the writer well and represent some conservative guidance for beginners at the travel game:

• Before you start out, notify all parties with a stake in your trip. If there are local sales offices or representatives in the city that you are visiting, advise them in advance that you are coming. Let employees in your own offices know where you are going. Once on the road, spend some time with company representatives or their customers. Some on-the-spot technical advice can make you a hero to them and to the company.

• Plan your schedule. Sketch out a rough calendar and plan the seminars, sessions and exhibits that you will attend, if you are going to a convention. Then stick to your plan. Discipline yourself to work a full day. Slack afternoons can be usefully employed to scout the competition, consolidate your notes, contact your home office, etc.

• Keep good notes. Many in the home office didn't go to the convention. Your notes, either delivered at an informal session when you return or typed and circulated, will spread the benefits of your experiences to all associates. Note product features and prices displayed by the competition, and, if possible, collect data sheets for analysis by the technicians at your company.

• Be sure significant people can find you. Nothing is more frustrating than trying to locate somebody in a large city, especially if the need has been generated by some emergency in your family or at your office. Tell your hotel operator when you will return, tell your associates where you are going, and leave notes when you cannot speak with somebody. If you have been out of contact for more than a few hours, call your hotel for messages or call your office long-distance. Most times there will be no messages, but if there are, you'll be on top of any situation that develops.

• Keep a careful diary of expenses. Accounting departments are notoriously reluctant to accept your blanket assurances that you spent $300 in the "line of duty." They need actual receipts, statements of whom you met, and what you discussed. In many instances the exact locations of the meetings are required information. It may be a chore, but it is a necessary one. Remind yourself always to get a receipt and keep careful accounts.

• Enjoy yourself too. Every city has its own history, culture and problems. The list of things to see and do is endless. Weekends are never long enough to take it all in. And if you miss "sampling" the city you visit, you have cheated yourself, because this is another way to expand your horizons.

• Be courteous and considerate. We rarely give conscious thought to these traits, but politeness and consideration of others—service people, residents, other delegates at the convention, etc.—goes a long way to making your visit more enjoyable.

Richard L. Molay
Mountain View, Calif.

---

Job seekers, unite

We have, in our modern society, computerized utility bills, computerized banking, computerized airline reservations, even computerized matchmaking to ensure that newly-weds will be compatible—so why not computerized job hunting?

For $12 (the annual membership fee) and the time it takes you, as a job applicant, to draft a résumé, you can become part of a massive filing system that matches prospective employee capabilities with prospective employer requirements in minutes.

The system, called Personnel Information Communications System, was recently announced by Western Union. It combines two capabilities: high-speed, real-time data processing (filing, sorting and seeking data) and a widely distributed

---

Reported monthly earnings of EEs*

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*Summer 1966. Reprinted with permission of Information Science, Inc. © 1
It's no fun to sit still. If your career has stalled, do something about it now. It's too easy to get sidetracked into a secondary role; the next thing you know, you're lost in the ranks. If your present position doesn't provide: (1) a genuine creative challenge, and (2) a reasonable chance for advancement, perhaps it's time to look around. When you do, look first at LTV Electro-

systems. At our Garland Division, we've structured an environment specially suited for the talented engineer. There's plenty of room and opportunity for you to grow just as far as your capability and appetite for success will take you. You'll be part of a creative team, yet find plenty of latitude for individual expression. And when you begin a project, you'll follow through, from concept to conclusion, then go on to another, equally challenging. Programs include: electronic warfare, communications, specialized antennas and RF systems, automatic controls, guidance systems, space systems, large-scale precision antennas, automated display systems and more. R & D programs are augmented by a complete antenna range facility, well-equipped EMI laboratories, complete environmental test facility— including an L-200 shaker, and metallurgical and chemical laboratories. Two IBM computer systems (360-50 and 360-65) support the complex research and computation involved with each project. Garland Division headquarters is located in Garland, Texas, a major suburb of Dallas. In Garland you'll find all the cultural, recreational and educational advantages of a metropolitan location and still enjoy the spaciousness, hospitality, low cost of living and excellent school system of a suburban area.

Right now, a new world of professional and personal opportunity is waiting for qualified specialists in these disciplines:

- RF CIRCUITS DESIGN
- RF SYSTEMS ANALYSIS
- DIGITAL SYSTEMS ANALYSIS
- DIGITAL CIRCUITS DESIGN
- ANTENNA SYSTEMS DESIGN
- ELECTRO-MECHANICAL PACKAGING
- SERVO-MECHANISMS DESIGN
- FLUIDS CONTROLS DESIGN

Please write or send resume (including telephone number with dates and times we may reach you) to: Mr. B. G. Hickey, Professional Placement, P.O. Box 6118, Dallas, Texas 75222.

GARLAND DIVISION
LTV ELECTROSYSTEMS, INC.
A SUBSIDIARY OF LING-TEMCO-Vought, INC.

AN EQUAL OPPORTUNITY EMPLOYER M/F

Electronic Design 25, November 8, 1966 113
Interesting opportunities open for Circuit Design Engineers with experience in integrated circuits, high speed switching circuits, and A/D-D/A circuitry. Each of these positions offers considerable responsibility and growth potential. Your interest is invited. Send resume in confidence or call collect: Martin Dorfman (617) 235-6220.

Honeywell

COMPUTER CONTROL DIVISION
OLD CONNECTICUT PATH, FRAMINGHAM, MASSACHUSETTS
An Equal Opportunity Employer

Bits and Pieces CONTINUED

network of telegraph offices to collect the data rapidly.

Here's how the Personnel Information Communications System works. You, the job seeker, call Western Union and ask for Operator 77. She records your name, address, telephone number and occupation. Within a few days, information about the service, and a set of forms on which you list your background are sent to you. These resumés are returned to Information Services, Inc.—the company that developed and operates this service through Western Union—and the information is transferred to a central computer.

Employers get in touch with the system by dialing Operator 88. They in turn receive and fill out "recruitagrams," which detail job specifications, salary, required skills, etc. This information is coded and fed to the computer system, which sorts through the resumés and develops a list of qualified individuals. The selected individuals receive a detailed description of the job, if their salary requirements are met. The interested employer simultaneously receives their resumés. Though complete, these resumés omit the individual's name and present employer and are only referred to by a code number. If the company wishes to interview the applicant, and he does not object, his identity is then disclosed.

Aside from the membership fee, there are no placement fees for applicants. Employers, however, pay a fee for each computer run and an additional fee for each résumé-rerequirement match. As an additional service, members receive a quarterly report of salaries, as they relate to age, experience, profession and education. An abstract of part of this report is shown in the accompanying table.

Western Union is now undertaking an extensive development program to eventually transform itself into a national information utility. A network of computer centers will program process, store, retrieve and distribute the data on a real time basis.
CAREER INQUIRY – confidential

Respond to the career opportunities advertised in this issue. Fill out and send us this handy resume. Electronic Design will do the rest – neatly typed copies of this form will be mailed to the companies of your choice, indicated by the circled Career Inquiry Numbers at the bottom of this page.

<table>
<thead>
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| Home Address (Street) | City | State | ZIP Code |

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**Employment History** – present and previous employers

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**Education** – indicate major if degree is not self-explanatory

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**Additional Training** – non-degree, industry, military, etc.

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Fluidics


This book was written by eight students at the Harvard Business School. It was intended primarily as a market survey of the field. Yet it does introduce anyone interested to a fascinating and useful field.

The first chapter describes fluidic devices and systems in detail. Though the language is simple and devoid of mathematical notation, it provides, very appropriately, a clear and lucid description of these conceptually simple and straightforward devices. Diagrams give an easy understanding of these devices and how they operate.

The manufacturing procedures, designs, and materials are covered carefully in the second chapter.

The bulk of the book is an estimate of the present and future market of these devices. Various areas are thoroughly and completely covered, i.e., consumer appliances, automotive equipment, aerospace systems, materials handling, machinery, and medical tools. The possible uses for fluidics in each of these areas is investigated, and the potential growth of all these areas is taken into account. One of the conclusions the book makes is that by the mid-1970s fluidics will be a several-hundred-million-dollar-

(continued)
High Speed Data Communications
Terminal—unique system extends computer processing facilities to remote locations via broadband transmission.


Here are a few ways General Electric engineers are advancing the state-of-the-art in communication products.

Come advance with us.
This steady stream of successes has built up a backlog of orders that keeps our engineers thinking; adapting systems to customer needs; constantly working on ideas for product improvements and applications. Small wonder our staff keeps increasing. And increasing. And that's where you come in. That is, if you really see yourself taking your place beside some of the best engineers in the business, pulling your weight, and maybe nudging the state-of-the-art even further ahead. Do you?

Engineers—Quartz Crystal . . . With manufacturing or design experience to participate in the design and production of a wide range of crystal types. Opportunities range from design of advanced products through process engineering to volume production.

Electronic Engineers . . . Circuit and system design engineers for microwave radio relay, cable carrier and data communication equipment development. BSEE/Physics.

Manufacturing Engineers . . . Challenging products and project oriented assignments to support assembly and component manufacturing activity. Develop and put into use new processes, techniques and equipment. Coordinate introduction of new products with manufacturing and engineering. Degree in engineering and/or apprentice graduate—tool and die making. 4 to 6 years experience sheet metal, electronics assembly, quartz crystal, or system; knowledge time standards, planning and general production functions.

Project Engineers—Digital Systems . . . For data communication and processing equipment design application and manufacturing. Responsible for equipment and software design, support and integration. BSEE/Physics.

Plant Engineer . . . To provide technical engineering as required to maintain present and new plant facilities, utilities and services, buildings, and equipment. Counsel all functions in the application of techniques in support of plant production improvement programs. BSME/EE/CE.

Microwave Sales Engineers . . . Sales engineering experience in the area of commercial and government microwave telecom system sales. BSEE or strong equivalent in microwave technology required. Must have sales management capabilities and ability to sell at both technical and management levels. Experience in microwave systems, planning and proposal work desirable. Willingness to travel is a requirement.

Systems Engineers—Mobile Radio . . . To analyze customers' mobile communication requirements and design effective systems. Must have good understanding of marketing approach and ability to speak and write well. BSEE/Physics with 3 to 5 years' experience, of which 2 years should have been spent in mobile radio.

IF YOU THINK YOU ARE “AMONG THE BEST”—or want to be—and meet any of the above requirements, let us know about it. Write full details, in confidence, to Mr. Walter J. Kelly, Room 58-L, Communication Products Dept., General Electric Co., Mountain View Road, Lynchburg, Virginia.

An Equal Opportunity Employer (M/F)

COMMUNICATION PRODUCTS DEPT.

ELECTRONIC DESIGN 25, NOVEMBER 8, 1966

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lar industry. A technical appendix contains 14 important papers in a field about which little has so far been published in book form.

—Roger Kenneth Field

Semiconductor electronics


This senior-graduate-level book, requiring a background of modern physics and differential equations, is designed to be used as the basic textbook for a course in semiconductor electronics. Its purpose is to give a direct heuristic description of the physics of semiconductor electronics, together with an analysis of a wide variety of devices. The analytic approach used emphasizes the physical approach to the various devices and gives the student an appreciation of how to estimate the magnitude of a result which is to be expected, and further, how to refine this estimate to the desired degree of accuracy.

Computer operations


This book helps you to learn about computers the easy way. It shows you through 28 low-cost construction projects the use of transistors in computers and describes the various individual computer operations in detail. Along the way it gives details for constructing actual working models of the computer circuits described. At the end of the book, construction details are given for a ten-stage adder/subtractor, complete with readout lamps.

Feedback circuit analysis


This book is devoted to a detailed study of feedback theory as applied to linear electronic circuits. It has been written with two objectives in mind: first, to develop a generalized feedback theory which doesn't rely on the separation of a feedback circuit into an amplifier and feedback network component, but yet is capable of accounting for all the effects associated with feedback; second, to provide a broad view of stability and its relation to the closed-loop transient response, open-loop frequency response and driving-point impedances of the feedback circuit. This text is written at a level suitable for a final year electronics undergraduate or a postgraduate student. A list of references is included at the end of each chapter.

Electric machines


This text is basically in two parts. The first gives a unified, analytical approach to the steady-state machines and the dynamic operating characteristics of rotating electric machines. The second is devoted to the selection and application of electric machines in engineering problems.
including feedback control systems. The authors provide a detailed and integrated mathematical description of the steady-state and dynamic terminal characteristics of machines by using a universal circuit model. This provides the student with a basic understanding of the operating characteristics that are important in the application of machines to engineering problems.

Electric networks


This book is designed for a second-year course in electric network theory for students who have completed a first course in network analysis. The basic approach is to develop a background in fundamental concepts through detailed discussion of each topic. Emphasis is placed on seven topics which are covered in depth: network functions; synthesis of two-element-kind one-ports; introduction of two-ports; filter design; network analysis; lattice networks; and network transmission characteristics.

Optimization


This book of original articles discusses recent analytical studies and presents new practical methods of optimization. The results of the application of these methods to real life problems are presented. Actual working programs are described and their operation discussed. The articles cover two broad areas. The first involves design optimization of "static" systems, leading to nonlinear programing problems. The other involves performance optimization of dynamic systems leading to problems in the calculus of variations, dynamic programing and others. A bibliography of optimization techniques is included.

DO YOU MAKE THESE FIVE COMMON MISTAKES IN EVALUATING CAREER GROWTH OPPORTUNITIES?

1. Do you consider only the largest companies in your particular field? Size of opportunity is not necessarily proportional to size of company. Many medium size companies, such as ECI, offer faster achievement of professional recognition and personal satisfaction than do the "industry giants."

2. Do you fail to consider breadth of product/customer base? It's difficult to achieve career stability in a company that is closely tied to a narrow range of products and technologies and which sells them to a limited number of customers. You'll do better at ECI, where major projects in VHF/UHF communications, multiplex, space instrumentation, microelectronics, systems integration and advanced communications techniques are in progress simultaneously. ECI's broad customer base includes Army, Navy, Air Force, Marine Corps, NASA and foreign governments.

3. Do you consider joining a company which has insufficient R&D programs? Lack of aggressive R&D could mean future trouble for the company... and you. ECI has a wide range of Company and customer-funded development programs, particularly in the promising fields of microelectronics, telemetry, space instrumentation and digital switching systems.

4. Are you overly impressed with "boom" growth conditions? Growth that's too fast can point to future instability. Look for a record like ECI's, where years of stable, predictable growth demonstrate management's ability for both sound planning and successful execution.

5. Do you settle for less-than-optimum living conditions in the name of opportunity? You needn't! In addition to all the foregoing advantages, a career at ECI will let you and your family enjoy life to the fullest in St. Petersburg, Florida. This segment of Florida's Gulf Coast offers an unequalled combination of sunshine, beaches, golf, boating, and fishing plus cultural, educational and professional engineering opportunity.
BOOK REVIEWS

**Introductory text**


Important topics, techniques and terminology of modern electrical engineering are discussed in an integrated treatment of circuits, electronic devices, electromechanical devices and systems. The author emphasizes fundamental principles to provide a basis for further work and includes examples to provide motivation for students with various interests. A new physical concept is examined, its application in a device and the behavior prediction of an engineering system incorporating the device. Emphasis is given to the modeling process. Each chapter begins with an introduction and ends with questions, problems and exercises for 3 years' use without repetition.

**Using your television**

*101 Ways To Use Your Color-TV*, Robert G. Middleton (Howard W. Sams & Co., Inc., Indianapolis), 160 pp. $2.95.

This edition describes the many uses for various color, pattern, sweep and marker generators, and other equipment used to pinpoint color-TV problems more quickly. It takes up each type of equipment and shows the ways it can be used. Included are photographs of the waveforms that occur at various points and discussions of defects. Test setups, procedures and results are described and illustrated in detail. This book also tells how to test all types of circuits found in color-TV receivers.

**Cryogenic engineering**


This text contains 76 papers delivered at the Eleventh National Cryogenic Engineering Conference, held August 23-25, 1965, at Rice Uni-

(continued)
New Class B amp gives 94 db gain at 4.5 Vcc, has over 50% efficiency

...and it can beat discrete in the price/performance tradeoff

Here's the best commercially available Class B audio amplifier in silicon! It's the new Westinghouse WC 183. This universal low-level IC audio amplifier gives high gain throughout the Vcc range from 1.5 to 9. Minimum gain with a single battery cell is 60 db.

And here's a stopper...you can buy the WC 183 in TO can or flat package for only $7.50 in quantities of 50!

How does Westinghouse do it? We start the circuit with a three stage Class A preamplifier. There's your high gain. We follow it with a Class B output stage. That gives high efficiency. The entire 8-transistor balanced circuit with internal DC feedback draws only 5 ma. at a minimum output power of 3 mw.

The quiescent current is extremely low too. It's only 0.9 ma. at 1.5 Vcc. This means vastly extended battery life in most applications. It also makes possible a broad range of new battery-powered IC applications.

You'll find the WC 183 ideal for hearing aids, paging systems, dictating equipment, phone amplifiers, and dozens of other voice communication applications. You can also put it to work in phonographs, tape recorders, and other uses where you want flat frequency response extending beyond the audio range.

Reliability? Every chip undergoes storage bake at 150°C, 20,000 G centrifuge, and hermeticity tests. Life tests indicate less than 0.01% failure rate per 1000 hrs.

Call your Westinghouse distributor. Or write Westinghouse Electric Corporation, Molecular Electronics Division, Box 7377, Elkridge, Maryland 21227.

You can be sure if it's Westinghouse
The Micro Instrument Model 5202 is a dc to 20 MHz DVM that never forgets — and won't let you forget! Actually, it's three instruments in one: a dc DVM; a single or repetitive pulse peak-reading DVM; and a sample-and-hold DVM.

The Model 5202 can be gated to accept any 50 nanosecond or longer segment of a waveform, hold it indefinitely, and digitize it for readout on its 3-digit Nixie® tube display. And it makes no difference whether pulses are single or repetitive.

Check the following features. You'll see why the all solid-state Model 5202 is your best buy when it comes to monitoring random occurring transients and other voltages.

- No dead-time or loss of input, even during reset
- High input impedance — to 10 megohms
- Added flexibility through either ac or dc coupling
- Analog recorder and printer outputs
- 10-, 100-, and 1000-volt ranges

All of the Micro Instrument Model 5202's exceptional features are fully described in our technical literature. Send today for your copy of our 4-page brochure covering the theory of operation and specifications. No obligation, of course.

The Model 5202 illustrated is also available in rack-mounting configuration for $1495.

BOOK REVIEWS

Understanding capacitors

ABC's of Capacitors, William F. Mullin (Howard W. Sams & Co., Inc. Indianapolis), 96 pp. $2.25.

Written in everyday language, this book explains how various types of capacitors are constructed, their characteristics and applications, points to consider when selecting replacements and several methods of testing and measuring capacitors. This text is directed at those who work with electronic circuits or anyone who needs an understanding of capacitors as an aid in troubleshooting, designing, or constructing electronic equipment. The author has provided a text which bridges the gap between engineering technology and circuit theory — making this a reference for technicians, servicemen, students.

Adaptive control systems


The basic method of approach in this volume is to identify the characteristics of a control system problem with those of a statistical game. This permits the engineer to employ some of the game theoretic results in the solution of the control problem. A knowledge of engineering statistics equivalent to graduate level is necessary.
IBM can show you hundreds of ways to cut your design time.

Find out for yourself.

FORTRAN—lets you work in the engineer's language. You write instructions algebraically. FORTRAN helps you simplify design of components, circuits, control systems, machinery, power systems, and many more. We'll send you details on how you can use FORTRAN.

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Scientific Subroutine Package/360—combines almost 200 tested computational shortcuts—pieces of FORTRAN programs that let you race through circuit analyses, formula evaluations, simulations. Special problems? Chances are you'll find an IBM subroutine for them.

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Company________________________________________
Address_________________________________________

Computers—for component design, control system design, analysis and evaluation. IBM computers are working for companies like yours. Send for our booklet, "The role of computers in electrical engineering." You'll get some interesting ideas.

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112 East Post Road, White Plains, N.Y. 10601

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Title____________________________________________
Company________________________________________
Address_________________________________________

Systems Summary—Basic equipment and program information are available for the following IBM systems: □ 1130—low-cost, compact computer oriented to individual use. □ 1800—high-performance system for data acquisition. □ SYSTEM/360—all-purpose system—many models for diverse scientific and engineering requirements.

IBM Data Processing Division, Dept. 735-EDD
112 East Post Road, White Plains, N.Y. 10601

Name__________________________________________
Title____________________________________________
Company________________________________________
Address_________________________________________
MODEL 901 DC SERIES: Available with \( \frac{3}{5} \% \) and \( \frac{4}{5} \% \) accuracy, self-shielding mechanism, exceeds ASA C39.1 specification requirements. Many multi-range combinations in stock.

MODEL 1477 ELECTRONIC DC MILLIVOLTS/MICROAMPS & AMPLIFIER: A portable electronic test instrument supplied in either potential or current ranges as low as 1 MV and 10 UA full scale. Typical self-contained range combination 1,000/500/200/100/50/20/10/5.2/1 Millivolts. Similar microammeters with ranges as low as 10 UA. Special feedback type amplifier assures extreme stability with virtually no energy drain from the input circuit. Terminals provided for 1 MA full scale output (on any range) into resistances as high as 5,000 ohms.

MODEL 904 AC SERIES: \( \frac{3}{5} \% \) accuracy with shielded radial vane, moving iron mechanism. Multi-range voltmeter available with self-contained ranges 750/300/150/75/30/15/7.5/3 Volt full scale. Multi-range ammeter self-contained with ranges 200/100/50/20/10/5/2 amperes full scale. Other ranges and sensitivities available from stock.

MODEL 905 AC/DC SINGLE PHASE WATTMETERS: \( \frac{3}{5} \% \) accuracy true electrodynamometer shielded mechanism. Rated accuracy on AC or DC provides useful "transfer instrument". Full scale ranges from 5 Watts.

MODEL 931 DC SERIES: \( \frac{3}{5} \% \) accuracy shielded type instruments stocked in many single and multiple range combinations. The most reasonably priced portable on the market for the quality and performance that is provided. Matching instruments also available for AC current, voltage and single phase power measurements.

MODEL 934 ELECTRONIC DC MILLIVOLTS/MICROAMPS: Portable microammeter, self-contained, available in ranges as low as 1 MV and 10 UA full scale. Typical range combination 1,000/500/200/100/50/20/10/5.2/1 Millivolts. Special feedback type amplifier assures extreme stability with virtually no energy drain from the input circuit. Terminals provided for 1 MA full scale output (on any range) into resistances as high as 5,000 ohms.

MODEL 935 PRECISION DC SERIES: \( \frac{3}{5} \% \) and \( \frac{4}{5} \% \) accuracy. Shielded permanent magnet mechanism. Many assorted range combinations from 5 UA full scale and up. Typical self-contained 20 range DC Volt-Milliammeter (1/2% accuracy): 750/300/150/75/30/15/7.5/5/3.5/2 Millivolts; 100/50 Millivolts; 3,000/1,500/750/300/150/75/30/15/7.5 Milliamps. Special RMS type thermocouple instruments with plug-in couples also available.

These portables have made over 250,000 lasting friends

Yes, Weston has sold more than a quarter million of these portable instruments. Some of the reasons are apparent in these specs which cover a portion of Weston's broad line. Other reasons: year-after-year reliability (key to your zero-defect program) and distributors who carry in stock the industry's widest portable line. Call your Weston distributor today. He has complete information—and the instrument you need.

Weston Instruments, Inc., 614 Frelinghuysen Avenue, Newark, N.J. 07114

WESTON® prime source for precision...since 1888

ON READER-SERVICE CARD CIRCLE 60
Interlocking cast bends snap together to simplify the assembly of waveguides. Page 194

Micromin molded tank circuits represent 80% size reduction over TO-5 units. Page 186

IC logic modules in tilt-out racks, are used exclusively in a new 16-bit, 960-ns computer. It is designed for a variety of real-time, on-line applications. Page 126

Also in this section:

Complex digital ICs save dollars and inches over single-function ICs. Page 142

Reactive ratio divider is driftless to 1 ppm with 0.3-ppm resolution. Page 162

RF power transistor guarantees 50 W at 50 MHz. Page 180
Small-scale control computer has all-IC logic, 960-ns cycle time

Honeywell Inc., Computer Control Div., Old Connecticut Path, Framingham, Mass. Phone: (617) 879-2600. P&A: $25,000 (with ASR-33 teletype); 90 days.

Computer Control Corp., the first concern to produce an all-integrated-circuit, general-purpose computer, joined Honeywell this May. The first product of the merger is a fast, low-cost IC computer for real-time and control applications. It is being shown at the Fall Joint Computer Conference in San Francisco and delivery is promised in 90 days.

The 16-bit, 960-ns DDP-516 is a third-generation all-IC computer. Its “250 program” software package has been proved in the field with Honeywell’s existing DDP-116 in more than 125 real-time, on-line applications.

The DDP-516 features fully parallel organization, indexing, multi-level indirect addressing and a 72-command instruction repertoire, including byte manipulation capability. The memory capacity is 4,096 words, expandable to 32,768, and the cycle time is 960 ns. The standard main-frame includes two full-word arithmetic registers, a hardware index register, a “priority interrupt,” power-failure protection and individually buffered I/O channels. Two-cycle I/O commands select device, test status and transfer data without I/O hold-off. The mainframe consists of three vertical leaves that contain the system power supply, central processor and the memory. Tilt-out construction provides easy access to both modules and inter-wiring. The entire computer may be rack-mounted in a standard 19-inch rack. The MTBF is two years under normal 40-hour week operations, or 4,000 hours.

Options include a direct multiplexed channel option to give multi-station, time-shared I/O capability. Direct memory access is available when I/O word transfer rates of 1 MHz are needed. Other options are a high-speed arithmetic package, including hardware, double-precision memory lockout for program protection, memory parity and a real-time clock. All options are plug-ins.

The standard software program package includes a FORTRAN IV one-pass compiler that operates with a minimum of 8,192 words of core memory. A symbolic language assembly program (DAP-16) translates from the programer’s language to machine language. A realtime monitor program automatically time-shares the computer between real-time and free-time tasks. A unique “desectorizing” loader allows the programer to address directly all of the memory, without regard for sector boundaries. A complete library of support programs is provided, including input-output selector routines, which allow for deletion, insertion or replacement of source programs.

Desk-top computer is jack-of-all-trades


In business, scientific and industrial use, the model 480 is designed to process both binary and decimal data. Standard features include variable word length, as many as 4 data channels, and an 8-µs core memory 1024 x 10 to 65,536 x 10. The 480 also accepts a wide range of input-output devices.

Modular multiplexer scans 20 channels


A modular multiplexer, Model 902, scans up to 20 bipolar analog channels in either synchronous or asynchronous mode at speeds from 1 cps to 10 kHz. Max leakage current is 0.06 µA worst-case. Channel skipping speed is 4 µs/channel with normal switching speeds of 20 µs. Channel skipping can be controlled by either the front-panel switch or externally.
Modutrim microminiature ceramic variable capacitors offer micromodule and hybrid circuit designers a choice of wide Δ Cs in extremely small and stable units. MT 200 Series measures only 0.208 in. x 0.281 x 0.120 in. thick.

The excellent stability inherent in all MT Series is due to a unique rotor design utilizing a special proprietary ceramic material in a monolithic structure. Electrical characteristics are outstanding for components of this size and type—Q in excess of 500 measured at 1 MC for those values under 50.0 pf.

- MT 100 Series' design is specifically for channel-mount and cordwood applications, as well as many other micromodule packages.
- MT 200 Series offers further miniaturization, an answer to high component density problems and various LC networks packaged in TO-5 cans.

In order to make available superior mounting techniques for printed and modular circuitry, JFD has created two new series—MT 300 and 400...

MT 300 Series' 4 terminal lead configuration provides optimum mechanical support and is specifically designed for printed, microminiature and module circuit applications.

MT 400 Series is designed for cordwood and module applications. This configuration has 8 terminations for easy connection above and below the capacitor substrate.

Write for Bulletin MT-65-2.
**Ebert Guaranteed**

**Reliability**

**NEW EBERT Hi-Power METAL TUBE**

**MERCURY RELAYS ARE GUARANTEED TO PROVIDE LONG, MAINTENANCE-FREE LIFE EVEN IN PROBLEM ENVIRONMENTS**

**FACT:** Ebert Hi-Power Mercury Relays are available in 1, 2 and 3-pole units. Load ratings up to 40KW or 100 Amps. Load voltages up to 550 V.A.C. They are unmatched for continuous in-use reliability, durability, compactness and ease of installation.

**FACT:** Their hermetically sealed, mercury-to-mercury action eliminates contact problems.

**FACT:** Their epoxy-clad, metal tube construction withstands physical shock or rough handling.

**FACT:** Once you've tried an Ebert Hi-Power Relay you won't be satisfied with any other!

**WRITE FOR FREE MANUAL AND 30-DAY FREE TEST DETAILS**

---

**Components**

**1 µF capacity in 0.0135 cu-in. case**

U.S. Capacitor Corp., 2151 N. Lincoln St., Burbank, Calif. Phone: (213) 843-4222.

A ceramic dielectric is used to deliver capacitance up to 1.0 µF in the miniature C12 line. For values of 0.18 to 0.47 µF, case measurements are 0.300-in. square by 0.1-in. thick. From 0.47 to 1.0 µF the thickness is increased to 0.150-in. Working voltages are 50 V at 125°C for values from 0.18 to 0.27 µF and 25 Vdc for 0.33 to 1.0 µF. Tolerances are 5%, 10% and 20% with 10% standard.

**CIRCLE NO. 121**

**Log transconductors have 6-decade range**

Philbrick Researches Inc., Allied Dr. at Route 128, Dedham, Mass. Phone: (617) 329-1600. Price: $59-$227.

With an over-all wide range of at least 6 decades, a series of adjustable log transconductors provide an accuracy of ±0.5% dB over at least 4 decades. The units are packaged in a wire-in module measuring 1-1/8 square by 5/8-in. deep. Applications include conversion of linear-scale instrumentation to log, power, decibel dBm scales and analog conversion of log-compressed signals.

**CIRCLE NO. 122**

**Nulling-circuit trimmer solves phasing problems**

Techno-Components Corp., 7803 Lemon Ave., Van Nuys, Calif. Phone: (213) 781-1642.

A solution to the problem of correct phasing for nulling circuits is offered by the model 193 dual trimmer. The miniature unit has a single adjustment screw for two in-phase resistance elements. Wire-wound resistance elements are available in a range from 10 Ω to 50 kΩ with a tolerance of ±5%. TC is rated 50 ppm/°C max and operating temperature range is −65°C to 175°C.

**CIRCLE NO. 123**

**Magnetic tape head guaranteed 2000 hours**

Ferroxcube Corp. of America, Saguerties, N.Y. Phone: (914) 246-2811.

All-glass bonding is credited with extending the life of the 4R5 ferrite recording head to over 2000 hours. The 7-track, IBM-compatible head is offered for standard record/reproduce tape applications. The all-glass bonding process combines pole pieces of the 4R5 ceramic ferrite and glass into a homogeneous structure with an all-ferrite recording surface. Neither relapping nor recrowning is involved in the 2000 hour life.

**CIRCLE NO. 124**
Relay Reliability in 3-Gram Packages

You can cut problems down to size with the Bourns TRIMPOT® Model 3100 SPDT and Model 3101 DPDT relays. These proven units give you MIL-Spec reliability and 160 mw sensitivity in a package size of less than 1/20 cubic inch. Punish them with 150G shock or 40G, 3000 cps vibration, and you still get the performance that's on the published data sheet. Features include highly efficient magnetic circuit, rotary balanced armature, hermetically sealed case and self-cleaning contacts. Environmentally they exceed requirements of MIL-R-5757D.

With these relays, there is little chance of "infant mortality" in your circuits. Bourns double-checks each unit with a 5000-operation run-in followed by 100% final inspection for all important characteristics, including mass-spectrometer leak testing. Furthermore, Bourns tests samples quarterly in the famous Reliability Assurance Program that it created for TRIMPOT potentiometers. In short, you can trust the name TRIMPOT in relays, too.

Other TRIMPOT relay products available from Bourns: Model 3105 subminiature AC DPDT and a full line of miniature adjustable time-delay and voltage-sensing relays and modules. Delivery is immediate. Write today for complete technical data.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Specifications</th>
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<tr>
<td>3100</td>
<td>SPDT Relay</td>
<td>Size: 0.2&quot; x 0.4&quot; x 0.6&quot;&lt;br&gt;Max. operating temp.: 125°C&lt;br&gt;Contact rating: 1.0 amp resistive, 26 VDC&lt;br&gt;Pickup sensitivity: 100 mw (Model 3100)&lt;br&gt;Standard coil resistances: 50 to 2000Ω (Model 3100)</td>
</tr>
<tr>
<td>3101</td>
<td>DPDT Relay</td>
<td>Size: 0.2&quot; x 0.4&quot; x 0.6&quot;&lt;br&gt;Max. operating temp.: 125°C&lt;br&gt;Contact rating: 1.0 amp resistive, 26 VDC&lt;br&gt;Pickup sensitivity: 160 mw (Model 3101)&lt;br&gt;Standard coil resistances: 65 to 2000Ω (Model 3101)</td>
</tr>
</tbody>
</table>

TRIMPOT® AND PRECISION POTENTIOMETERS — RELAYS — MICROCOMPONENTS: TRANSFORMERS, INDUCTORS, RESISTORS AND CAPACITORS
CHOOSE A NUMBER FOR YOUR
HIGH POWER · HIGH ORDER · SINGLE DIODE
FREQUENCY MULTIPLIERS
(EVEN PRIME NUMBERS)

P/N M-2-1-32-8
UNDER $450 IN QUANTITY

Typical Results: 1.5 watts from our X8 Multiplier at 2250 MHz. Spurious signals down at least 30dB-mid-band efficiency typically 25%

P/N M-4-2-30-12
UNDER $750 IN QUANTITY

Typical Results: Our C Band unit gives 1 watt output, X12 mid-band efficiency typically 16%

P.S. SIMILAR RESULTS WITH AS LOW AS 50 MW inputs.

COMPONENTS

Multiturn 7/8-in. pot designed for industry

Military features are standard in the type 8400 potentiometer. The multiturn wirewound component has a molded thermo-plastic case with grooved interior and a low-TX wire element to provide 0.25% independent linearity. Resistance values are 100 ohm to 100 K with ±5% tolerance. Temperature range is −55° to +105°C with a rating of 2.0 W at 25°C.

CIRCLE NO. 125

Solid-state commutator meets IRIG standards

Integrated circuit logic is said to allow the Series 2080 high-level commutator to adapt readily to various input channel configurations meeting IRIG telemetry standards. Up to 90 high-level inputs are converted to standard PAM, PDM and PPM output formats. Overall reliability is cited as particularly attractive in satellite testing, launch vehicles and aircraft testing.

CIRCLE NO. 126

For further information regarding trade-offs on multiplication factor, bandwidth, efficiency, output power, form factor, etc. contact Mr. Joseph Brumbelow, Director of our Solid State Department, at the address below.

WRITE FOR OUR FREE CATALOG ON SOLID STATE CIRCUITS

MICROWAVE DEVELOPMENT LABORATORIES * INC.
87 Crescent Road • Needham Heights • Massachusetts 02194
Telephone: 617-449-0700 • TWX 617-444-2695

ON READER-SERVICE CARD CIRCLE 64
Adlake Mercury Wetted Relay — Application Data

Capacitance of Adlake Mercury Wetted Contact Relays Applicable for Low Signal Applications

Typical Capacitance in Picofarads — Graphs illustrate typical capacitance values for Adlake AWCA-16000 series relays. Fig. 1 is for unshielded relays. Fig. 2: Electro-statically shielded switch brought out to a separate pin. Fig. 3: Electro-statically shielded switch with case and shield tied together at a common pin. Inter-electrode capacitance across contacts of a bare switch, without external wires, is less than 1.0 picofarad.

Abbreviation COMM. stands for the Combination of the Armature and Normally Closed Contact. N.O. is the abbreviation for Normally Open Contact; whereas the symbol # is the mean average for the 5 relays. Graphs are available on other styles of Adlake Mercury Wetted Contact Relays upon request. (Please state wiring configuration.)

Data was obtained using a Brooton Electronics Corporation Capacitance Bridge, Model 75-A-8 at 1MHz.

Backed by sound research and disciplined engineering, Adlake applies the industry's broadest line of mercury displacement and mercury wetted relays to the creative solution of design circuit problems. However unique or special your application, Adlake can assist you in developing it. For prompt, personal and knowledgeable attention to your relay needs, contact the one source that is the complete source in the mercury relay field. Contact Adlake today for catalog and further information.

THE ADAMS & WESTLAKE COMPANY
Dept. 1116 Elkhart, Indiana, U.S.A. 46514 (AC 219) 264-1141
TRANSPORTATION EQUIPMENT • ARCHITECTURAL PRODUCTS • MERCURY RELAYS • DOORS AND ENTRANCES • CONTRACT MANUFACTURING ON READER-SERVICE CARD CIRCLE 65
Electronic Design 25, November 8, 1966 131
Specify American Circuit-Tronics

We can produce almost any p.c. board you'll ever want—standard, multi-layer, precious metal, module header, flexible, you name it! We'll meet your specs. Leadtime is cut because all manufacturing is done at one location. Prototypes are usually to you in less than 48 hours!

American Circuit-Tronics is also your immediate source for electronic assemblies and small, intricately shaped flat metal parts

Write today for your free brochure

American Circuit-Tronics Corp.
4229 Cass Avenue
Detroit, Michigan 48201
Telephone 313/831-6226

ON READER-SERVICE CARD CIRCLE 66

COMPONENTS

Variable air capacitor makes not a whisper


These variable air capacitors provide improved rotational life, "noiseless" contact during adjustment, greater stability under shock and vibration, broader operating temperature range and easier soldering. The 5200 series features: capacity, 0.8 - 10 pF; working voltage, 250 Vdc (test voltage, 500 Vdc); temperature coefficient, 0-30 ppm/°C; Q at 100 MHz > 3000; sinusoidal vibration > 60g; random vibration > 2.0g/cps shock > 275g (6 milliseconds).

CIRCLE NO. 127

Arbitrary function units have 10 breakpoints

Philbrick Researches Inc., Allied Dr., at Rte. 128, Dedham, Mass. Phone: (617) 329-1600. P&A: $195; 3 wks.

Ten breakpoints for straight-line approximations of algebraic functions are provided by the SPFX series of arbitrary function transconductors. The diode-resistor nets are available in both positive- and negative-going models and both are adjusted through potentiometers housed in the SPFX case.

CIRCLE NO. 129

Solid-state timer operates 1 million times

Hi-G Inc., Windsor Locks, Conn. Phone: (203) 623-2181.

A reliability factor based on a life expectancy of 1 million operations is provided in conventional timing operations by the Series 1850 type fixed timer. The new units have microsecond reset times with a timing range of 10 µs to 10 seconds. Operating temperature range is -55° to +85°C and unit's weight is 0.7 ounces.

CIRCLE NO. 128

Divider module scales HF sweepers to LF


Your standard HF sweeper or signal generator can be converted for use as a signal source in vlf, sonar or audio work through the SD-10 divider. Outputs are either 1/10, 1/100, or 1/1000 of input. This division is said to multiply the effective stability of your instrument in the process of translation, making narrow-band measurements feasible.

CIRCLE NO. 130

Electronic Design 25, November 8, 1966
Dense between the ears—but what an I.Q.*!!

Between the ears of the A-MP* 750 Series Box Contact Connector are 100 contacts in a space of less than 4 inches—that’s pretty dense! Yet this connector offers you the industry’s lowest per line applied cost for a highly reliable two-piece printed circuit connector—that’s economy plus Installed Quality!*!

High density is achieved with two rows of 50 box contacts located on .075" centers. Receptacle contact tails are staggered to permit larger spacing between printed circuit wiring paths. Headers contain channel shaped pins which are latched in the header and have flat tails for easy connection to daughter boards.

The 750 Series Box Contact Connector provides economy in overall applied cost. Socket contacts are highly flexible allowing wide margins of misalignment of pins and eliminating the need for costly precision card guides. Low insertion and extraction forces permit mating of a large number of contacts without mechanical screws or cams. The 750 Series connector has contacts which can be easily replaced without removal of the connector.

High electrical integrity is assured by four elliptical spring beams arranged at right angles forming a box. These beams provide four areas of contact on the mating pin, whether it is square, round, rectangular, or channel shaped. The walls of the housing limit spring deflection and prevent over stressing of the contacts, even when subjected to severe shock and vibration.

This adds up to a rugged, tolerant miniature connector for your most demanding applications. Examine these unduplicated features:

- Contacts on .075” centers
- High misalignment tolerance
- Latched-in contacts can be easily replaced
- Gold over nickel plated beryllium copper contacts
- Polarized housings
- Sturdy diallyl phthalate housings
- Four redundant contacts for high reliability
- Resistant to vibration and shock
- Low installed cost

If your design calls for tight specifications requiring a tolerant, reliable, high density connector—all with an eye on economy, then the A-MP 750 Series Box Contact Connector is for you. Write immediately for complete details.

*Trademark of AMP INCORPORATED

ELECTRONIC DESIGN 25, November 8, 1966

ON READER-SERVICE CARD CIRCLE 67
Even if your non-linear function looks like the Playmate of the Month in profile, Duncan can build a pot to match it. All you have to do is use the new "DUNCAN DO-IT-YOURSELF NON-LINEAR FUNCTION KIT," which we'll send you without obligation if you'll fill out and mail the coupon below. The kit includes a fabulous French curve* plus all other necessary ingredients and instructions. You supply us with the non-linear trace of your function and other supporting data. We'll feed it to our high-speed computer and analyze the data defining the pot's desired function. Then we'll enter the output tape into our servo-controlled machines to produce the variable-pitch winding to meet your function.

To be sure the output of the pot conforms to the specified tolerances, we'll compare it with the theoretical function on our unique conformity tester.

The result? A precision, accurate pot exactly to your specifications.

Our applications engineers can help solve your problems quickly and economically. In many cases they'll be able to match your function using pre-calculated data from our extensive tape library.

So forget about cams, differentials, and non-linear gears. For the direct approach to a complicated non-linear potentiometer problem — for airborne data computation or matching thermocouple curves — depend upon Duncan. You'll have more time to check out other interesting curves!

Send for your free Duncan "do-it-yourself" kit today. For literature only, circle the appropriate number and mail the inquiry card enclosed in this magazine.

---

**DUNCAN ELECTRONICS INC.**

Please send me my free "DUNCAN DO-IT-YOURSELF NON-LINEAR FUNCTION KIT" and complete technical literature on Duncan's family of non-linear potentiometers.

I understand that there is no obligation on my part.

Name ___________________________ Title ___________________________

Company________________________

Address________________________

City___________________________ State __________ zip____________

*French curve ruler by Birule Co.
Amphenol metal-film trimmers outperform cermets and wirewounds

Compare metal-film trimmers to cermets and wirewounds and you get a picture like the one above. It makes a convincing story for Amphenol metal-film.

First note that Amphenol metal-film provides the temperature coefficient and noise characteristics of wirewound trimmers. (Check the high TC and noise levels of cermets.) Next note that metal-film offers the essentially infinite resolution of cermets. Put the two together and you've got yourself quite a trimmer—one, for example, like Amphenol's 2901 metal-film trimmer. It's the only infinite resolution trimmer with a TC as low as 50 ppm/°C and zero noise level at the trimmed position. You just set it and forget it.

Other features of the half-inch square 2901 include a humidity-, vibration- and shock-proof case (it maintains setting through 50 g's). Silicon "O" Ring shuts out dust and humidity. Precious metal contact assures low contact resistance.

The 2901 is now available from your Amphenol Industrial Distributor. For more technical information, call your Amphenol Sales Engineer. Or write us in Janesville, Wisconsin.

NEW LOW-OHM VALUES
Amphenol has just added three new low-ohm values—50, 100, and 200 ohms. The chart above shows how wirewound trimmers lose resolution rapidly in the lower ohmic values. Yet metal-film maintains infinite resolution across the entire resistance range.
NEW MAGNETIC RELAY
plugs into your PC board!

NO Springs, NO Wiring,
NO Sockets, NO Soldering,
NO Mechanical Linkage

Printact®
Standard Series G
Latching Series LS/LD

Plated Conductors on Your PC Board are the Fixed Contacts

Save space, money and manhours with these new small, lightweight, highly reliable Standard and Latching PRINTACT Relays.

Available with Bifurcated Palladium or Gold Alloy contacts for more than 10 million cycle 2 or 3 pole switching. Handles up to 3 amp. res. loads. Coils for 6, 12, 24 and 48 vdc at 500 mw.

Operating temperature -30°C to +95°C. Operate time 7 ms. The little gem is an 0.8 oz. ⅜" cube.

Quality features include: double-break contacts; balanced armature, enclosed housing, plug-in application; encapsulated coil; self-wiping contacts and inherent snap-action — and the cost is lower than you think!

COMPONENTS

Digitubes can line up on 0.8 inch centers

Baird-Atomic, 33 University Rd.,
Cambridge, Mass. Phone: (617) 864-7420. Price: $4.95 (for 1000).

These new tubes have an envelope width of 0.75 in. allowing the tubes to be arranged at less than 0.80 in. center to center. All "840 series" digitubes are long life and side viewing. The BA-840 is a 10-character display tube, numerals 0 to 9; the BA-841 is a 10-character display tube, numerals 0 to 9 with an independent decimal point to the left of the numerals; the BA-842 is a 10 character display tube, numerals 0 to 9 with an independent decimal point to the right.

Time delay relays boast instantaneous return

Relay Specialties Inc., 3 Goodwin Ave., Fair Lawn, N. J.

Series MTRH 8 time delay relays feature instantaneous return time and accurate recycling periods obtained by utilizing both the heating and cooling time of a thermal element. The relay has a drop out time of only five milliseconds and may be immediately reoperated with virtually 100% rated time delay period.

Metal film resistors can handle 1/2 watts

Continental-Wirt Electronics Corp.,
26 W. Queen Lane, Philadelphia, Pa.
Phone: (215) 848-7700.

Meeting MIL-R-10509, this line of metal film resistors includes both the T-1 model (TC/°C ±100 ppm) and the "D" characteristic (TC/°C +200, -500 ppm). MIL sizes of 1/8 watt, 1/4 watt, 1/2 watt are available. The body of the resistor is coated with multiple layers of epoxy. A high degree of stability is attained through improved methods of controlling film thickness during the deposition of the thin, evaporated, metallic film on the ceramic core in a vacuum chamber.

Trig function units are accurate 0.1%

Philbrick Researches Inc., Allied Dr., at Rte. 128, Dedham, Mass.
Phone: (617) 329-1600. P&A: $195; 3 weeks.

Output currents proportional to the sine or cosine of the input voltage are provided by the SPSIN or SPPOS transducers in an operational amplifier circuit. In such applications as conversion of coordinate data from rectangular-polar presentation or conversion of linear-scale to angular displacement readings, the units have a response speed of 5° phase shift at 100 kHz and an accuracy of 0.1%. 

Electronic Design 25, November 8, 1966
NEW STRIP-CHART WRITING TECHNIQUE:

Ends pen clogging, ink drying
Gives clear, clean traces
Provides new economy

New Hewlett-Packard electrosensitive paper, available as a standard option on Moseley 680 and 7100 Series Strip-Chart Recorders, ends the problems associated with pen-and-ink writing techniques... at an economical price and without the disadvantages inherent in other available electric writing methods.

The Hewlett-Packard electrosensitive paper is a special electro-chemical coated chart paper. The coating is current sensitive, changing to a dark brown trace with application of voltage from the recorder stylus. The new technique eliminates the familiar arc method of electric writing on carbon-backed paper.

With Hewlett-Packard electric writing, you can use your strip-chart recorders for long-term, unattended monitoring, with increased performance at slow writing speeds, as well as at high writing speed. It is non-pressure sensitive, so that you can't damage or obscure your recordings.

Here's another advance in recording capability from Hewlett-Packard. Call your Hewlett-Packard field engineer for information on converting your strip-chart recorder to maintenance-free electric writing. Or write for information: Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

Data subject to change without notice.
Interference suppressor blocks AF noise

Narda Microwave Corp., Plainview, N. Y. Phone: (516) 433-9000.

In measurements in the 0.01 to 12.4 GHz region, the Microline audio interference suppressor is said to effectively eliminate audio leakage along the transmission line. In effect, the unit is designed to increase measurement signal-to-noise ratios. Insertion loss is 0.5 dB and max vswr ranges from 1.3 to 1.5 max.

CIRCLE NO. 177

Multiplier diode yields X10 action in one stage

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $45 (in quantity); 2 wks.

An input of 15 W at 200 MHz nets 2 W at 2 GHz with an HPA 0300 step recovery diode. One of many applications for the new diode is expected to be 2-GHz telemetry. The devices are epitaxial, surface-passivated silicon construction with very abrupt junctions. Max power dissipation is 15 W at 50°C case temperature and the latest revisions of MIL-STD-750, MIL-STD-202 and MIL-S-19500 are met.

CIRCLE NO. 179

Lumped-element hybrid is 1/8 in. diameter


"The Pellet," a 1/8-in. diameter quadrature hybrid, operates at 2.1 to 2.3 GHz in such applications as image rejection mixers, phase comparators, SSB modulators and discriminator nets. Designed especially for PC use, it is available alone or inside the QHM-2 connector shown above. Specs include: bandwidth 10%, output equality ±0.3 dB, insertion loss typically below 0.3 dB and power at 5 W average.

CIRCLE NO. 178

Impedance plotters range to 12 GHz

Texascan Corp., 51 S. Koveba Lane, Indianapolis, Inc. Phone: (317) 632-7351.

Both coax and waveguide units are available in a Smith-chart automatic impedance plotter line. Coax models cover a 3 to 1 frequency range with the highest frequency unit operating to 3000 MHz. Waveguide models begin at 350 MHz and cover the range to 12 GHz with each unit covering a full waveguide frequency band. The plotter kits include cables and accessories.

CIRCLE NO. 180

1-mW oscillators operate 4 to 13 GHz

International Microwave Corp., River Rd., Cos Cob, Conn. Phone: (203) 661-6277.

A line of precision, mechanically tunable tunnel-diode oscillators operate in the 4- to 13 GHz range. These units have FM noise equal to 2 or 3 Hz/kHz in a slot 70-kHz removed from the carrier. Frequency stability over the temperature range of -30 to 60°C is 0.02% min. Pushing figure is 0.1 MHz per 10% applied-voltage change and pulling is 0.01% into a short.

CIRCLE NO. 205

Two commercial lasers first of complete line

Hughes Aircraft Co., 11105 S. La-Cienega Blvd., Los Angeles. Phone: (213) 670-1515. P&A: $4000 and $5000; 60 days.

Two completely packaged pulsed lasers, first of a commercial and industrial line, produce outputs in the blue-green at 5146, 5017, 4965, 4880, 4765 and 4579 Å simultaneously. They are packaged in two units consisting of laser head and power supply, both using singly-ionized argon gas sources. Model 3040H provides 1 W power out and model 3041 provides 10 W. Both have pulse lengths of 50 μs.

CIRCLE NO. 206
For critical chopper applications... RCA's new MOS transistor will even work

RCA's new 40460 is an N-channel, depletion type, insulated-full-gate MOS which, because of its symmetry, can be operated "upside down"... works equally well with either positive or negative incoming signals... does the work of two bipolar transistors.

RCA's full-gate MOS is especially useful for chopper applications at extremely low voltage levels... handles input signals from microvolts to volts. It has an inherent offset voltage of zero. This means that the RCA 40460 has none of the tracking problems of matched bipolar devices, caused by temperature changes and extended operation.

A high "off" resistance of 1000 megohms and a low "on" drain-to-source resistance of only 250 ohms make the RCA 40460 perform like a mechanical chopper, without its drawbacks. And you get all the advantages of solid-state reliability. In addition, long-term stability is assured by a fully metallized gate and a hermetically sealed JEDEC TO-72 4-lead metal case.

TO GET THE MOST FROM YOUR RCA 40460 CHOPPER, use the new RCA 40461 MOS transistor in your chopper amplifier stage, as well as for other critical audio and wideband applications.

Try these devices and see how they improve your chopper design. Check your RCA Field Representative for complete information. For technical bulletins, write RCA Commercial Engineering, Section CG.11-2, Harrison, N. J. 07029.

ALSO AVAILABLE THROUGH YOUR RCA DISTRIBUTOR

RCA's New 40460 MOS Transistor Features ZERO OFFSET VOLTAGE*

*Thermocouple effects and contact potentials may cause erroneous readings

RCA ELECTRONIC COMPONENTS AND DEVICES

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Permanently effective Netic and Co-Netic are the recognized world standard for dependable shielding. About 80% of all magnetic shield designs in use originated here. Netic and Co-Netic are insensitive to ordinary shock, have minimal retentivity, never require periodic annealing. Total quality is controlled during manufacture. Design assistance gladly given.

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This automatic machine was developed to assemble Clinch-Loc Terminals with variable and flexibility for volume users. With an alternate track any Clinch-Loc Terminal can be used in this machine.

**S-band amplifier uses avalanche diode**

A low noise, compact solid-state S-band parametric amplifier uses an avalanche diode oscillator as a pump source. Designated the AEL model PAR 1612A parametric amplifier, this device is tunable over the 2.2 to 2.3 GHz telemetry band and has a maximum noise figure of 2.5 dB. A single, low level dc input of 60 V at 20 milliamperes operates the avalanche pump and provides bias for the parametric amplifier varactor.

---

**MINIATURE ATTENUATOR RANGES DC TO 18 GHz**
Weinschel Engineering, Gaithersburg, Md. Phone: (301) 948-3434. Price: $88 (Model 3) and $125 (Model 4).

Miniaturization without the sacrifice of electrical specs is the lead feature of the models 3 and 4 fixed coax attenuators from Weinschel. The new units are said to be completely comparable to the older models 1 and 2 but the package has been reduced to 1.45 x 0.35-in. diameter. Each attenuator is supplied with a certificate of calibration stating accuracy, insertion loss and vswr.

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**MICROWAVES**

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**MICROWAVES CONTINUED ON P. 194**
Coors Beryllium Oxide Ceramic offers you the bonus of 10 times the thermal conductivity of aluminum oxide ceramic—approximately the heat transfer qualities of aluminum metal. Ordinarily, beryllia is thought to be too expensive, except for designs where maximum heat dissipation is an essential. However, we find the additional cost of using beryllia in small metallized assemblies adds only a few cents to the total cost of the completed part. For an “extra two-cents worth” Coors offers a beryllia-to-metal assembly that allows you to use more power...or allows you even further miniaturization than with alumina...or gives you longer component life—or a combination of all three. When you design micro-substrate assemblies—Consider Coors Metallized Ceramics—and get the bonus of beryllia’s thermal conductivity. Write for Coors Metallizing Data Sheet 9502, or call the Coors “hot line”—303/279-4533, Ext. 351.
Bulova forks solve low frequency problems

Let the experience behind 300,000 forks per year help you!

American Time Products forks are now available up to 25 kc, thanks to years of experience plus new design techniques developed by Bulova. (Including the tiny forks for Accutron® electronic timepieces, Bulova made 300,000 last year alone!)

Result: ATP units provide lower cost, smaller size, lighter weight and greater long term stability in such applications as Computers, Navigation Systems, Doppler Radar, Motor Drives, Encoders and Timers. Accuracies of up to 0.001% are available.

Bulova fork oscillators offer the added advantage of simplicity of design and circuitry. Fewer components mean greater reliability. Finally, Bulova fork products are uniquely capable of withstanding severe shock and vibration environments.

Write or call for specifications on Bulova's complete line of tuning fork products. Address: Dept. ED-16

Reduce circuit size and cost with complex function ICs

Texas Instruments Inc., P. O. Box 5012, Dallas, Texas, 75222. Phone: (214) 235-3111. P&A: (lots of 100 to 999) $5.75 for SN7482N; $8.15 for SN7483N; $8.30 for SN7492N; $8.30 for SN7493N; $10.50 for SN7441N. Evaluation quantities available immediately.

More for your money is the theme of Texas Instruments' latest product announcement—a line of complex function integrated circuits mounted in low-cost molded plastic packages.

An extension of the Series 54/74 digital ICs also manufactured by TI, the new additions are: Dual Adder (SN7482N); Quad Adder (SN-7483N); 16-12 Counter (SN-7492N); BCD-to-Decimal Decoder/Driver (SN-7441N). Using Transistor-Transistor Logic (TTL), the circuits are suitable for high-frequency operation. General characteristics include a noise immunity of 1-V, an operating temperature range of 0° to +70°C, and a 5-V, 5% supply voltage. Inputs are specified as “0” if $V_{in}$ is less than 0.8-V and “1” if $V_{in}$ is greater than 2.0-V. Outputs are “0” when $V_{out}$ is less than 0.4-V and “1” when $V_{out}$ is greater than 2.4-V.

The dual-adder (see Fig. 1a) adds a two-bit number, $A,B$, to another two-bit number, $B,B$. Provisions are included for a carry input, $C_0$ and a carry output, $C_2$; the carry from bit-one to bit-two is internally performed. Total time for a serial carry through both additions is 15-ns.

The monolithic chip for the dual adder (see Fig. 1b) is small enough to permit bonding two such chips into a single package. By appropriate interconnection this forms the SN7483N Quad Adder, which can add two four-bit numbers. The operation of this adder is otherwise similar to the dual adder. The serial carry propagation time for the four addition stages is 30-ns.

The Divide-by-12 Counter (SN7492N) is a single monolithic silicon chip that divides frequencies up to 15 MHz by twelve, six, three or two. A feature on this device is the simultaneous independent operation of a divide-by-six and a divide-by-two counter.

The Four-bit Binary Counter (SN7493N) can divide frequencies up to 15 MHz by either sixteen, eight, four or two when operating as a ripple through divider. Also possible is simultaneous independent division by eight or two.

The BCD-to-Decimal Decoder Driver (SN7491N) takes a BCD input, decodes it, and drives a gas-filled readout tube. The output driver transistors are guaranteed for 65-V operation and can be tied directly to the cathodes of the readout tubes.

Bulova American Time Products

ELECTRONICS DIVISION
OF BULOVA WATCH COMPANY, INC.
61-20 WOODSIDE AVENUE
WOODSIDE, N.Y. 11377, (212) DE 5-6000
ON READER-SERVICE CARD CIRCLE 77
Does AE make the world's prettiest dry-reed switches?

Some of our customers think so. They go for the chic look of our PC Correeds on a printed circuit board. Our designers are flattered. But they point out that the beauty of a PC Correed is more than skin-deep.

Take the contact leads. We keep them separate from the terminals—to eliminate strain. The terminals themselves have “I-beam” strength. They are longitudinally ribbed for extra rigidity—for easy insertion in PC boards.

The contact terminals are welded, not soldered. This makes a better electrical connection.

We filled the plastic bobbins with glass, to prevent moisture absorption. And to boost structural strength. You can pack these smart-looking switches as densely as you like. Because of their low profiles, magnetic shielding, and standard PC terminal spacing (multiples of .200”).

PC Correeds are available with 1, 2, 3 and 5 reedcapsules, in contact forms A, B, C and magnetic latching. You can get many of these modules right from stock. So it's easy to put a little beauty in your life. Want some helpful new design information? Ask your nearest AE representative for Circular 1070-B. Or drop a line to the Director, Electronic Control Equipment Sales, Automatic Electric Company, Northlake, Illinois 60164.
who said plugwires can’t be interchangeable between systems?

MAC Panel’s series 140 are!

MAC Panel’s new Series 140 Plugwires are interchangeable with most existing systems. Another important engineering feature is the Ball-D-Tent design. It prevents accidental dislodging of the plugwires, and yet provides closely controlled extraction forces. Won’t mar insert surface, either.

The complete line of Series 140 Plugwires is available in color-coded lengths ranging from 5 to 35 inches, and is available with Gold or Nickel plating in the following types:

**GOLD PLATED 140 WIRES**
- Manual Single Conductor
- Stack Plugs
- Manual 3 Pin Common
- Manual 4 Pin Common
- Manual 6 Pin Common
- Manual Dual Conductor
- Manual Single Conductor Shielded
- Two Conductor Shielded
- Three Conductor Shielded
- Four Conductor Shielded

**NICKEL PLATED 140 WIRES**
- Manual Single Conductor
- Stack Plugs
- Manual 3 Pin Common
- Manual 4 Pin Common
- Manual 6 Pin Common
- Manual Dual Conductor
- Manual 4 Pin Common
- Manual 6 Pin Common

**ORDER NOW... AVAILABLE FOR IMMEDIATE DELIVERY**

---

**IC op-amp moderately priced**

*Amelco Semiconductor, 1300 Terra Bella, Mountain View, Calif. Phone: (415) 968-9241. Price: $46.80 (100 lots).*

With a typical input offset of 1.0 V and 20 μA, the 807BE integrated operational amplifier is designed for high-performance applications. The circuit package is TO-5 or 10-pin ceramic flat-pack. Specifications of the devices include a typical common mode input range of ±1 V ($V_{oc}=±15$ V) and a typical input impedance of 100 kΩ.

**CIRCLE NO. 866**

**IC counters use J-K flip-flops**

*Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. Phone: (617) 876-2800. P&A: from $45.05; stock.*

J-K flip-flops provide counting rates up to 5 MHz in a line of DTL circuits. The line includes binary counters up to 8 stages of serial counting and a variety of 2, 3, and 4-stage combinations. The in-line packages are assembled on two-sided PC cards with edge-mounted connections. They are designed to be incorporated directly into data processing and formatting systems, computers, process controllers and display equipment.

**CIRCLE NO. 867**

**General purpose amp sits on a single chip**

*Amelco Semiconductor, Div. of Teledyne, 1300 Terra Bella Ave., Mountain View, Calif. Phone: (415) 968-9241.*

A new general purpose amplifier is constructed on a single monolithic silicon substrate. The amplifier is well suited for applications that require high input impedance, high output voltage swing, high gain, low offset and low drift. Specifications of the unit include an input impedance range from a minimum of 100 kΩ, with 500 kΩ typical; maximum input offset current is 200 nA. Open loop dc gain (no load) is typically 20,000 with 10,000 minimum; open loop bandwidth is typically 10 MHz.

**CIRCLE NO. 868**
Announcing the Brush Mark 250, first strip chart recorder for the perfectionists of the world.

Meet the fastest, most accurate strip chart recorder on record: The new Brush Mark 250. When you read about all the features you'll know why we call it the first recorder for the perfectionists of the world!

1. Unmatched frequency response. Flat to 10 cycles on full 4½" span! Useless response to 100 cycles. Nobody has a strip chart recorder in the same league.

2. Wide selection of signal conditioners. Choose from 21 interchangeable preamps. Use one today; plug in a different one when your recording requirements change.

3. Crisp, clean rectilinear writing. Patent, pressurized inking system puts smudge-proof trace into the paper not just on it.

4. Contactless, non-wearing feedback system. Same one used in our multi-channel Mark 200 recorders. (No slide wires!) Accuracy? Better than 1/5!

5. Multiple chart speeds. Pushbutton choice of twelve... from 5 inches/second to 1/10 of an inch/minute (up to 8 days of continuous recording).

6. Portable or rack mounting. And either way you get the exclusive new dual position writing table.


See what we mean? The Mark 250 is for the perfectionists of the world. Ask your Brush Sales Engineer for a demonstration, Or, write for chart sample and specifications. Clevite Corporation, Brush Instruments Division, 37th & Perkins, Cleveland, Ohio 44114.

CLEVITE

The Brush Mark 250 First recorder for perfectionists
Need a small 1, 5 or 10 mc crystal oscillator for use in synthesizers, timing systems, counters, communication systems, time-code generators, tape systems, or some other small black box?

Think TRACOR®

Shown half actual size
TFA 766

Volume 19.1 in.³
That's about the size of it.

For further information:
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Austin, Texas 78721
Phone: 512-926-2800

SULZER DIVISION

We are looking for EE's, ME's and Physicists for design consultation or systems development in ASW and undersea problems—experience in penetrations aids—design studies, tests, analysis and reports on electronic and mechanical systems. Your reply strictly confidential.

ON READER-SERVICE CARD CIRCLE 81

MICROELECTRONICS

Flat pack covers need one solder joint


Metal covers for sealing IC flat packs eliminate alignment problems and need only one solder joint rather than two as when a preform is used. The lids are Kovar with gold-tin eutectic solder (280°C) clad on one side and pure gold plated or clad on the other side. The covers can be held to a flatness as close as 0.0005-in. Also available are lids with gold-germanium eutectic solder (356°C) clad on one side.

CIRCLE NO. 894

IC breadboard accepts 14-pin dual in-lines

Motorola Semiconductor Products, P. O. Box 955, Phoenix. Phone: (602) 273-6900. P&A: $140 (over 25); stock.

For use with 14-pin, dual in-line plastic packages, the 16-socket XC73 breadboard permits rapid IC design and evaluation without damaging individual circuits. Little or no soldering is required. Continuous voltage planes on each side provide even voltage distribution and reduce signal crosstalk for high-frequency operation. Eleven BNC coax connectors and one 22-pin edge connector are provided.

CIRCLE NO. 896

100-MHz RF amplifier prices cut to $1.75

Radio Corp. of America, Electronic Components & Devices, Harrison, N. J. Phone: (201) 485-3900. P&A: $1.75; stock.

The price of RCA's CA3005 (100-MHz RF amplifier) IC has been reduced from $3 to $1.75 each in quantities of 1000 and up. The CA3005 is operable over a frequency spectrum from dc to over 100 MHz, and over a temperature range from -55 to 125°C. It can be used for mixer, limiter, modulator, age, detector, wideband and narrowband amplifier, RF, IF, and video amplifier and cascode-amplifier applications. Typical characteristics are: 20-dB cascode power gain at 100 MHz, 16-dB differential power gain at 100 MHz, 101-dB common-mode rejection ratio at 1 kHz and -60-dB age range at 1.75 MHz. The linear ICs are packaged in a TO-5 case.

CIRCLE NO. 897
CHEMICALLY MILLED MAGNETIC LAMINATIONS & SMALL METAL PARTS

Chemical milling permits faster delivery of prototypes and far lower re-designing costs. The process produces flat, thin, burr-free, close tolerance parts which are too thin to produce by normal stamping methods.

Typical precision metal parts in gages from 0.0002" to 0.020" include miniature transformer and recording head laminations, mechanical and semiconductor strain gages, micromodules with integrated circuitry used in the new flat packs, metal and glass masks used for semiconductor product manufacturing, electrical motor laminates and electrical contacts. Other precision devices made by this process are tube grids and CRT screens, alpha-numeric symbols and letters for electronic display tubes and devices, light attenuation masks (optical filters) and photographic shutters. The process also lends itself to fabrication of small metal parts using non-magnetic materials such as Beryllium Copper, Tungsten, Kovar and Alloy 52.

THE ARNOLD ENGINEERING COMPANY, Main Office, MARENGO, ILL.
BRANCH OFFICES and REPRESENTATIVES in PRINCIPAL CITIES

ON READER-SERVICE CARD CIRCLE 82

Electronic Design 25, November 8, 1966
Transmission Line Wiring
Systems with controlled characteristics

- Impedance
- Propagation velocity
- Cross-talk
- Capacitance

Minimize problems and reduce modifications in electronic package wiring by applying the uniformity and predictability inherent in aci Signaflo Transmission Line Systems with controlled characteristics. The combinations of signal transmission are limitless. Our ability to build controlled characteristics into aci Signaflo systems is the result of pioneering and continuing research in dielectric materials, conductor and shielding metallurgy. Approach your application with new aci concepts!

Send for Bulletin E-6.

"Acknowledged leader in flat cable systems."

aci DIVISION OF KENT CORPORATION
206 Industrial Center, Princeton, N. J. 08540
Telephone 609-924-3800 TWX: 609-921-2077

MICROELECTRONICS

Dual RTL ICs shrink digital systems

Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. Phone: (415) 962-2530. P&A: $10 to $10.70 (100 to 999); stock.

A family of multiple complexity dual RTL ICs consists of four planar epitaxial monolithic circuits. They feature high noise immunity (300 mV), low propagation delays (12 ns) and positive NOR or negative NAND logic, hermetically sealed packaging and military or industrial temperature range capability.

Units include a quad 2-input gate (9991), a quad 2-input expander (9992), a dual 2-input gate and dual expander (9993) and a dual buffer, dual 3-input gate (9995). They are rated over -55 to 125°C in the 1/4 x 1/4-in. flat pack and over 0 to 70°C in the ceramic dual in-line package. The entire family is designed for system operation with supply voltage of 3 V ±10%.

CIRCLE NO. 147

Regulated sources mount on IC cards


A simple way to distribute regulated dc to IC cards is offered by 250 series regulators. The 1.5 x 2 x 3-in. units mount directly on the cards and the power distribution system handles only unregulated dc. Output ratings up to 3 A are available. Voltage regulation is to 50 mV for a 10-V change. Voltage ripple is reduced 100 to 1 min with 200 to 1 cited as typical.

CIRCLE NO. 148
The DCP 800 Power Supply is a high performance, solid state DC power supply with exceptional versatility. It is a digitally programmed unit suitable for automatic test equipment. It provides automatic crossover from regulated voltage to regulated current.

**POWER INPUT:**
105-125 Volts — 50-63 cps — single phase.

**CONTROL INPUT:**
Voltage — Binary Coded Decimal Five Digit Programming in 1 mv steps.
Current — Binary Coded Four Digit Programming in 1 ua steps with 10 to 1 and 100 to 1 range expansion. The DCP-812 only has a 10 to 1 range expansion.
Excitation — Provided by 24 Volts to Reed Relay Input Circuit.

**OUTPUT:**
- **DCP-812**: Voltage 0-100V, Current 0-0.1A
- **DCP-813**: Voltage 0-50V, Current 0-1A
- **DCP-814**: Voltage 0-100V, Current 0-1A
- **DCP-820**: Voltage 0-50V, Current 0-0.5A
- **DCP-821**: Voltage 0.1V, Current 0.5A

**ABSOLUTE VOLTAGE ACCURACY:** 0.1% or 1.5 milv. Includes:
- Line regulation measured for an input voltage step change of 105-125 Volts at 50-63 cps.
- Load regulation measured for a no load to full load or full load to no load change within range.
- Stability for 8 hours after 30 minutes warm-up.

**ABSOLUTE CURRENT ACCURACY:** 0.35% or 0.25 uamp. Includes:
- Line regulation measured for an input voltage step change of 105 to 125 Volts at 50-63 cps.
- Load regulation measured for 100 Volt step change increase or decrease.
- Stability for 8 hours after 30 minutes warm-up.

*Write for more information.*

THE ROWAN CONTROLLER COMPANY • ELECTRONIC MEASUREMENTS DIV.
OCEANPORT, NEW JERSEY 07757

Electronic Design 25, November 8, 1966
Circular connector needs no retention clips
Amp Inc., Harrisburg, Pa. Phone: (717) 564-0101.

Rotating a ring on the rear of the CH-AMP connector simultaneously locks all of its contacts against a rated minimum of 15 pounds push-out force. The design also permits contact release and extraction without tools. The size 16 shell CH-AMP houses 58 #22 contacts on a 0.085-in. spacing. A single insert accepts AWG #22 to #30. Another insert accepts either submin coax or wire sizes from AWG #16 to #20.

CIRCLE NO. 149

Wedge-action relays miss once in 10 million
Electro-Tec Corp., P. O. Box 667, Ormond Beach, Fla. Phone: (305) 677-1771.

"Wedge-action" relays boast a failure rate of one in 10 million cycles. Contact resistance is 0.012 to 0.015 mΩ, constant within 15 mΩ for more than 100,000 operations. In the "Wedge-action" design, each moving contact is mounted between two stationary contacts. They drive into the stationary contacts, developing a positive wedge/wipe action that increases contact pressure during overtravel.

CIRCLE NO. 152

Current regulator operates in series

Operating in series with the current line, a new constant-current regulator needs no reference to ground. The unit is all silicon solid state. Temperature coefficient is 0.03%/°C, threshold is at 8 V, current stability to voltage change is 1% and max power dissipation is 8 W. Current level is factory set to 50 to 250 mA ±1%.

CIRCLE NO. 151

Decoder/driver modules use TTL integrateds

Considering its scarcity, control-panel space seems a logical place for IC logic. Following this line, the NL-M100 decoder/driver and NL-M201 decimal counter/driver use monolithic TTL logic. The M100 decodes 4-line BCD signals and drives a numerical read-out tube. The M200 is a 15-MHz decimal counter that displays directly on its read-out tube. Both require 200 V for tube drive and accept logic 1 voltage 5 V with logic 0 at ground.

CIRCLE NO. 153

Submin 4pdt toggles 40,000 times
C&K Components Inc., 103 Morse St., Watertown, Mass. Phone: (617) 926-0800.

In data processing, communication and computer systems applications, model 7401 submin toggle switch is rated for a 40,000-cycle minimum life. Bat-handle operating levers are standard for the model but plastic caps in 10 colors are available. Initial contact resistance is 20 mΩ at 2 to 4 dc, 1 A. Contact rating is 5 A resistive and contacts and terminals are coin silver.

CIRCLE NO. 154

MIL-R-27208 wirewound size reduced by 30%
IRC Inc., 401 N. Broad St., Philadelphia. Phone: (215) 922-8900. P&A: $3.56 (100 lots); 4 wks.

Without sacrificing MIL-R-27280 specs, the "thin-line" type 400-20 wirewound trimmer represents a 30% size reduction over the manufacturer's present RT-11 military style. The trimmer has offset PC pins and is completely interchangeable with the RT-11. Type 400-20 is available from 10 n to 50 kn with a ±5% tolerance and is rated 1 W at 70°C.

CIRCLE NO. 155
INSTRUMENTATION SPECS in 250 KC tape recording

...now start at under $9966

(7 CHANNELS, 6 SPEEDS, DIRECT MODE)

The design approach that made possible Sanborn true IRIG instrumentation performance at lower cost in low bandwidth tape recording is now available in intermediate band systems. Sanborn Models 3917B and 3924B 7- and 14-channel systems record and reproduce data up to 250 kc in direct mode, to 20 kc in FM mode. Pulse mode enables digital information as short as 2 µsec wide to be recorded and reproduced. A complete 6-speed system ready for direct recording/reproducing costs $9966 for 7 channels, $15,977 for 14 channels. (Same systems may be ordered with fewer tape speed plug-ins, at correspondingly lower costs.)

These new systems have the same improvements in performance, reliability and operating ease as the low bandwidth models, for instrumentation tape recording with complete IRIG compatibility. The tape transport, key to superior system performance, is of a rugged and simple Hewlett-Packard design which reduces costs without sacrificing uniform tape motion; six electrical speeds are pushbutton-selected (1% to 60 ips) without idler or capstan change. Other standard features include provision for edge track for voice commentary, adjustable input/output levels, built-in 4-digit footage counter accurate to 99.95%, and easy snap-on reel loading. The transport needs no maintenance except occasional cleaning of the tape path.

Check the system specifications here and call the H-P Field Engineer in your locality for complete technical data and application engineering assistance. Offices in 43 U.S. and Canadian cities, and major areas overseas. Sanborn Division, Hewlett-Packard Company, Waltham, Massachusetts 02154, Europe: Hewlett-Packard S.A., 54 Route des Acacias, Geneva, Switzerland.

<table>
<thead>
<tr>
<th>Tape Speed</th>
<th>Bandwidth</th>
<th>Frequency Response</th>
<th>S/N Ratio (Nominal)</th>
<th>Minimum RMS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 ips</td>
<td>300-250 KC</td>
<td>±3 db</td>
<td>35 db</td>
<td>29 db</td>
</tr>
<tr>
<td>15 ips</td>
<td>100-62.5 KC</td>
<td>±3 db</td>
<td>32 db</td>
<td>27 db</td>
</tr>
<tr>
<td>1½ ips</td>
<td>50-7 KC</td>
<td>±3 db</td>
<td>30 db</td>
<td>26 db</td>
</tr>
</tbody>
</table>

*Measured with bandpass filter at output with an 18 db/octave rolloff

FM MODE

<table>
<thead>
<tr>
<th>Tape Speed</th>
<th>Bandwidth</th>
<th>Frequency Response</th>
<th>FM Center Frequency (Nominal)</th>
<th>S/N Ratio</th>
<th>Total Harmonic Distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 ips</td>
<td>0-20 KC</td>
<td>+0, -12 db</td>
<td>108 KC</td>
<td>45 db</td>
<td>1.5%</td>
</tr>
<tr>
<td>15 ips</td>
<td>0-5 KC</td>
<td>+0, -12 db</td>
<td>27.0 KC</td>
<td>45 db</td>
<td>1.5%</td>
</tr>
<tr>
<td>1½ ips</td>
<td>0-625 cps</td>
<td>+0, -14 db</td>
<td>3.38 KC</td>
<td>40 db</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

*Noise measured over full bandwidth, min. rms at zero freq. dev., with lowpass filter placed at output. Filter has 18 db/octave rolloffs.

TAPE TRANSPORT

Maximum Interchannel Time Displacement Error: ± 1 microsecond at 60 IPS, between two adjacent tracks on same head.

Tape Speeds: 60, 30, 15, 7½, 3⅞, 1½ ips standard; 0.3 to 120 fps optionally available.

Tape: 3600 feet, 1.0 mil, 1½" (7 channel), 1" (14 channel).

Controls: Line (Power), Stop, Play, Revers, Forward (fast) and Record are pushbutton relays. A receptacle at the rear of the transport is provided for remote control operation.

Drive Speed Accuracy: ±0.25%.

FLUTTER

<table>
<thead>
<tr>
<th>Speed</th>
<th>Bandwidth</th>
<th>Flutter (p-p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 ips</td>
<td>0-200 cps</td>
<td>0.2 %</td>
</tr>
<tr>
<td>30 ips</td>
<td>0-200 cps</td>
<td>0.2 %</td>
</tr>
<tr>
<td>15 ips</td>
<td>0-200 cps</td>
<td>0.25%</td>
</tr>
<tr>
<td>7½ ips</td>
<td>0-200 cps</td>
<td>0.5 %</td>
</tr>
<tr>
<td>3⅞ ips</td>
<td>0-200 cps</td>
<td>0.8 %</td>
</tr>
<tr>
<td>1½ ips</td>
<td>0-200 cps</td>
<td>1.2 %</td>
</tr>
</tbody>
</table>
**CHANGE YOUR RECORDING RATIO QUICKLY / EASILY**

Record at any object-to-image ratio from 1:1 to 1:0.5 without extra lenses with the Beattie-Coleman MIIA Oscillotron. This highly versatile camera also offers these plus features:

- Rugged construction for field test instrumentation.
- Fully enclosed electric shutter actuator and lens.
- Records ultra-high speed traces.
- Synchronous electric shutter.
- Polaroid and 4 x 5 backs.
- Hinged at CRT to swing away for unobstructed viewing when not recording.
- Data recording optional.
- Shutter-open indicator light.

43 different models. Send for catalog.
Coleman Engineering Co. Inc.,
Box 1974, Santa Ana, Calif. 92702

BEATTIE-COLEMAN OSCILLOTRON
OSCILLOSCOPE CAMERAS

---

**COMMENTS**

**Solid-state device converts for sin, cos**


As a replacement for mechanical resolvers and synchro computing servos, Model 670 function generator responds to dc inputs representing angles of 380° of arc. Output is ±10 Vdc, proportional to the sine and cosine of the input. Conformity is rated better than 15 minutes.

Among other applications cited for the unit are replacement for a conventional sine-cosine pot, coordinate axes rotation and rectangular/polar transformations.

**Digital phase shifter for 1500-W S-band use**

Microwave Associates, South St., Burlington, Mass. Phone: (617) 272-3000.

An array of these digital phase shifters replaces conventional electromechanically driven antennas. The MA-8357-881S features reciprocal operation and high power capability at 15-kW peak and 500-W average operating power levels with a burnout level of 30 kW. Phase accuracy is maintained at ±3° and bandwidth is 10% within any 2- to 4-GHz range. Pin diodes are mounted iteratively and switched in combinations to provide a maximum of 360° phase shift in a minimum of 22.5° increments. Insertion loss is 2 dB max and 1.5 dB average; vswr is 1.35 max and 1.15 average.

**1-W glass zeners are lifetime guaranteed**

International Rectifier, 233 Kansas St., El Segundo, Calif. Phone: (213) 678-6281. Price: $0.73 & (100 to 999); stock.

Glass zener voltage regulators G3 through G12 are designed for regulator and other applications where stable long-term operation is required. The glass configuration offers small size (DO-7) for high density packaging applications. The 1-W voltage regulator series offers a nominal zener voltage range from 3 to 12 V with tolerances of ±20, ±10 and ±5%.

**Thin-clad laminates for knotty problems**

G. T. Schjeldahl Co., Electrical Products Div., Northfield, Minn. Phone: (507) 645-5633.

While most circuit routings are somewhat simpler, these ultra-thin laminates could be tied in knots without breaking their electrical integrity. The laminates are 0.5-oz. electrodoped or hard-rolled copper on polyester film from 0.001 down to 0.00015-in. thin. Dielectric strength for the 0.0015 film is 1500 V.
what's in it for you?

Just this... 15 times the winding length and 10 times the resolution in the Clarostat Series 76JA Trimming Potentiometer... and it looks and mounts like any ordinary trimmer pot. That's the kind of superb engineering you've come to expect from Clarostat. Naturally, it's designed for your needs; production time is reduced by eliminating critical mechanical settings, and you enjoy more mechanical freedom than with bulky multi-turn pots. Completely interchangeable with other trimmers. But most important... resolution is ten times better than you can get from ordinary trimming potentiometers.

SPECIFICATIONS: Mechanical Travel: 12 turns approximate;  ■ Effective travel: 11 turns (±¼);  ■ Resistance Range: 100 ohms to 20,000 ohms;  ■ Resistance Tolerance: ±5%;  ■ Power Rating: .75 watts @ 85°C. derated linearly to zero power @ 150°C.  ■ Available with printed circuit or solder lug terminations.  ■ Your local Clarostat Authorized Industrial Distributor has the Series 76 in stock ready for immediate delivery.
it must be nice to have money to burn...

if you're using mil spec. when industrial units will meet your needs...

Methode Electronics can supply you with Reli-Acon printed circuit connectors from the largest to the smallest sizes with a variety of contact designs.

If you require the super-precision of military specifications...you get it from Methode with our usual prompt delivery.

If an industrial grade will fill your particular requirements, Methode can save you money.

We invite your inquiry.

Methode Electronics, Inc.
7447 W. Wilson Ave.
Chicago, Illinois 60656 • 312-867-9600
ON READER-SERVICE CARD CIRCLE 88

COMPONENTS

Tapped delay lines solidly encapsulated
Stanford Applied Engineering, 340 Martin Ave., Santa Clara, Calif. Phone: (408) 243-9200.

Optimum pulse performance from the S-series tapped delay lines is said to be provided by a careful adjustment of phase and amplitude characteristics. Though no larger than your thumb, the components meet the requirements of MIL-STD-202A. Typical specs run: 250-ns delay within ±10 ns, max rise of 25 ns, bandwidth of 16 MHz and working voltage at 300 Vdc.

CIRCLE NO. 138

MIL-C-11015C capacitor stands X15 overvoltage
American Components Inc., 8th Ave., at Harry St., Conshohocken, Pa. Phone: (215) 828-6240.

Voltage breakdown is said to run as high as 15 times the rated voltage of the ceramic C-02 capacitor. The component is molded uniformly for use in automatic-insertion equipment and specifications meet MIL-C-11015C. Capacity ranges are from 100 to 2200 pF and 2700 to 470 pF at 100 and 50 V respectively with operating temperatures from −55 to 125°C.

CIRCLE NO. 139

Electronic Design 25, November 8, 1966
Belden has it...

Every electronic and electrical wire you need—from the finest drawn magnet wire to the most complex multi-conductor cables.

There is a Belden wire or cable in every insulation and shielding to meet your application and design needs. Here is just part of this complete line. Available from stock. Ask your Belden electronics distributor for complete line information or write for catalog. Request also a copy of A Buyers' Guide to Specifying Electrical Wire and Cable.

3 REASONS WHY Belden is the most specified line

1. Basic Manufacturer—Belden draws its own wire—compounds its own insulations for complete quality control.
2. Research and Testing—All Belden wire and cable are laboratory tested to guarantee insulation and conductor efficiency. Lab test data available.
3. Design and Engineering Service—Belden has a completely staffed design and engineering department to help customers meet unusual wire application or design requirements.

Belden

Belden MANUFACTURING COMPANY • P.O. Box 5070-A • Chicago, Illinois 60680
COMPONENTS

Submin industrial relay meets MIL-R-5757D
Bourns Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

Though designed as a low-cost industrial relay, the model 3118 meets the environmental specs of MIL-R-5757D. The 1/6 crystal-can relay also features a balanced armature design, rated for 50-G shock and 10-G vibration. Action is dpdt with a contact rating of 1 A and a pick-up sense of 200 mW max. Operating temperature range is -25 to 85°C in an unsealed plastic enclosure.

CIRCLE NO. 140

Rotary thumbwheel indexes 16 positions
Engineered Electronics Co., 1441 E. Chestnut Ave., Santa Ana, Calif. Phone: (714) 547-5651.

An indexing system of sixteen 22.5° positions is the latest addition to the manufacturer's 200 series. Compatible wheel marking permits this switch to be used with 8, 10 and 12-position switches of the same line. All standard options of the series apply to the new addition as well.

CIRCLE NO. 141

Infinite resolution pot has vernier-lead screw

Infinite resolution with a vernier lead screw adjustment is provided by the RM11 rectilinear trimmer potentiometer. Based on a thin-film resistance element, MystR, the units provide resistance ranges from 500 Ω to 50 kΩ at ±10% and from 51 kΩ to 1 MΩ at ±20%. They are housed in plastic casings and have neither pressure or solder connections.

CIRCLE NO. 142

Tuning-torque varies in piston capacitors

A tensioning device varies the tuning-torque of a line of glass-piston capacitors, allowing easy tuning but preventing subsequent detuning by shock or vibration. Max above-the-board mounting height of the components is 1.235-in. Capacitive ranges run 2.5 to 9 pF to 2.5 to 60 pF. Suggested applications are in the areas of instrumentation, communications and systems.

CIRCLE NO. 143
Put out because you can't get a reliable 10 amp magnetic latch relay?
Next time call Leach!

Our 10-amp, 2 pdt, cl Series is just the answer. Of course we can't deliver bundles right now (it’s just going into production), but we can meet your prototype requirements. And immediately.

This relay not only meets MIL-R-5757, but it’s been tested against all your previous magnetic latch relay complaints. And it more than stands up to all of them.

For example, the cl magnetic assembly is a closed loop design which minimizes interaction with magnetic fields or other relays. And it only takes a 15msec pulse to switch and hold—no continuous power is required. It’s the smallest (1.100 high). The lightest (1.6 oz.). And directly interchangeable with other magnetic latch relays.

The cl Series is rated at 50g shock; 30g at 2000 cps vibration. Pretty tough. And construction is all welded and sealed, contaminant free, with an electron beam.

So don’t be soured by other types you might have tried. Order ours. You’ll get them. No ifs, ands, or...

Call Leach Corporation, Relay Division, 5015 Avalon Blvd., Los Angeles, California 90003.
Phone Area code (213) 323-8221
Export: Leach International, S. A.
One of the two slides supporting this man weighs less than the telephone!

Chassis-Trak ultra-thin aluminum slides are engineered for application where weight is a critical factor. Available in tilt, non-tilt, and lock slides... the Model D-600 extruded aluminum slide weighs only 4 1/2 pounds, but readily supports up to 125 pounds... even when fully extended. That is why the telephone, weighing almost 5 pounds, is actually heavier than one slide.

All slides are coated with exclusive Poxylube 75 dry-film lubricant, providing permanent lubrication while protecting against atmospheric corrosion. For information on the Model D-600 extruded aluminum slides, call or write today.

A Package for Every Major Missile Project from ...  
525 South Webster Ave., Indianapolis, Indiana  
ON READER-SERVICE CARD CIRCLE 92
100 µv full-scale sensitivity from this new 20Hz-4MHz solid-state ac voltmeter

The highest level of performance available today is yours with the new HP 400F/FL General-Purpose AC Voltmeters. Measure 100 µv to 300 v full scale on an individually calibrated linear meter that lets you measure as low as 10 µv with 1 µv resolution. The 400FL, $285, offers a linear 12 db log scale with accuracy of 1% of reading. Specified accuracy of the 400F is ±2% of reading + ±2% of full scale. The 400F, Option 01., puts the db scale uppermost for greater db resolution ($10 extra).

As a low-distortion amplifier, the 400F/FL has a noise spec <5 µv referred to input, typically 3.5 µv. The instrument can be battery operated through rear-panel terminals. The 1 v ac output is available on all ranges.

The low-pass 100 kHz filter, activated by a front-panel switch, reduces the effect of unwanted high frequencies for low-level audio measurements. The 11074A Voltage Divider Probe (10:1) is available.

The front panel shows the ease of use that's yours with this truly state-of-the-art ac voltmeter. Ideal for low-level audio, servo, communications measurements... one instrument for the widest variety of applications. For complete specifications... or for a demonstration... call your Hewlett-Packard field engineer. Or write Hewlett-Packard, Palo Alto, Calif. 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

Data subject to change without notice. Prices f.o.b. factory.
DC amplifier has automatic gain switch

Teledyne Telemetry Co., 12964 Panama St., Los Angeles. Phone: (213) 398-6229.

In data acquisition systems measuring input signals over a wide dynamic range, the DA-45 dc amplifier automatically ranges its gain in three discrete steps. This automatic stepping operation allows the amplifier gain to remain known at all times, aiding in the reduction processing. These amplifiers are direct-coupled and accept inputs in the 10-to-400-mV range. Bandwidth is 200 kHz.

CIRCLE NO. 160

Phase/time detector uses signal comparison


Using signal comparison rather than conventional detection, 206B3-4 phase and time detectors are said to avoid errors due to meter lag and circuit-element tolerance. One input is shifted 90° by a variable waveguide delay line, then fed to a sum/difference net. A second input is fed directly to the net. Isolated sum/difference outputs are rectified and fed into an appropriate null detector. Type 206B3 operates at X-band and 206B4 is Ku-band.

CIRCLE NO. 211

Spectrum analyzer covers 10 MHz to 40 GHz

Polarad Electronic Instruments, 43-20 34th St., Long Island City, N. Y. Phone: (212) 392-4500. P&A: $6300; 30 days.

With primary accent on price, the model 2882 spectrum analyzer covers applications in the 10- to 40-GHz range with nine dispersion ranges from 10 kHz to 100 MHz. The instrument is modular in design and compatible with the seven other types in the manufacturer's line. Among the important features of the 2882 are its automatic bandwidth selection and calibrated crystal markers.

CIRCLE NO. 161

Insulation tester barely a handful


An instrument for insulation and continuity measurements, the Metromh, is packed in a 20-oz. plastic case that fits easily into one hand. By mounting the movement on filaments rather than pivots, the Metromh withstands an acceleration of 40 G in three planes. Four models are available from 1 kV to 100 V with ranges of 0 to 50 to 0 to 10 MΩ.

CIRCLE NO. 212

50-MHz counter goes to X-band with plug-ins


This low-cost 50-MHz counter can measure to 12.4 GHz with available plug-in heterodyne frequency converters. It has a full compleiment of gate times from 1 µs to 1 s. The counter can measure directly up to 350 MHz with a precaler plug-in, operate with a 1-mV sensitivity with a preamp plug-in (basic counter sensitivity is 100 mV), normalize readings with a preset counter plug-in, or measure time intervals from 1 µs to 106 s and make digital voltage measurements to 1000 V with two other plug-ins. Input impedance of the dual FET amplifier input is 1 MΩ shunted by 25 pF for all signal levels up to 1 V independent of frequency to 50 MHz. With the constant high input impedance, vswr is low when the input is connected to a terminated line and it is possible to use a scope-type probe when voltage attenuation or a 10-MΩ, 10-pF input is desired.

CIRCLE NO. 213

Circuit printer has accuracy to 0.002 in.


This machine prints circuits onto ceramic substrates with an accuracy of registration to within ±0.002 in. Each of two lines has a speed of 1500 print strokes/h. The ceramic substrates are loaded into two hoppers and carried along the bed to the print station. Here, they pass over holes in a vacuum plate which, when covered, have a progressive braking effect.

CIRCLE NO. 214
**Portable computer expands to 20 amplifiers**

*Systron-Donner Corp., 888 Galindo St., Concord, Calif. Phone: (415) 682-6161. P&A: $7300 (12 amplifiers); December.*

Designed to simplify patching computer circuits to match more sophisticated computers, the ±100-V SD10/20 has built-in digital logic, electronic mode control and slaving capability. The removable problem board has visual computer circuits to aid new operators. The design permits full trade-in to the larger 84-amplifier SD40/80.

*CIRCLE NO. 162*

**Analog simulator for lab, plant training**


Designed for undergrad courses, Model 600 is also suitable for in-plant training in analog computer techniques. The ±10-V unit features 10 amplifiers, 2 multipliers, 10 coefficient pots, voltage references and null pot. Two or more computers can be slaved together for problems of greater complexity.

*CIRCLE NO. 163*

---

**Ballantine AC-DC Digital Voltmeter**

**Model 355**

**Price: $620**

**1/2% Accuracy f.s. for AC & DC Voltages up to 500 and for mid-band AC Frequencies**

**Measures Full Scale ac to 10 mV ...ac & dc from 0 to 1,000 V**

Ballantine's Model 355 is the only digital voltmeter of its type in the U.S.A. ... with a versatility that makes it ideal for production line and quality control applications.

Use the 355 in place of analog instruments, for example, in reducing personnel errors, for speeding up production. You can depend on Ballantine's high standards of accuracy, precision, and reliability to reward you with savings of time and money the first day you place it in service.

The instrument features a servo-driven, three-digit counter with over-ranging ... combines many virtues of both digital and analog voltmeters in one small, compact, economical package. Its large, well-lighted readout with illuminated decimal point, range and mode information, allows fast, clear readings, while the indicator can follow and allow observation of slowly varying signals. The position of the last digit can be interpolated to the nearest tenth, thus avoiding the typical "±1 digit" restriction of a fully digitized display.

Desire even faster production? An optional foot-operated switch of the Model 355 retains voltage readings, and enables you to cut materially the time between readings. Another aid in reducing personnel errors is provided by an over-range indicator that signals excessive input of the wrong polarity.

**PARTIAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full scale, most sensitive range</td>
<td>0 to 1000</td>
<td>0 to 1000</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>30 Hz to 250 kHz</td>
<td>DC</td>
</tr>
</tbody>
</table>

Optional Model 600 Resistors are available for measuring current directly in volts.

<table>
<thead>
<tr>
<th>Accuracy in % of Full Scale</th>
<th>AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mV</td>
<td>1/4%, 50 Hz to 10 kHz</td>
<td>1/4%</td>
</tr>
<tr>
<td>to 12%</td>
<td>30 Hz to 50 kHz</td>
<td></td>
</tr>
<tr>
<td>to 1%</td>
<td>500 V</td>
<td>5%, 50 kHz to 250 kHz</td>
</tr>
</tbody>
</table>

**Power Requirements**

- 115/230 V, 50-60 Hz, 52 W

**Relay Rack Version**

Model 800 rack mounting kit is optional.

*Write for brochure giving many more details*

Member Scientific Apparatus Makers Association

---

*BALLANTINE LABORATORIES INC.*

Boonton, New Jersey

CHECK WITH BALLANTINE FIRST FOR DC AND AC ELECTRONIC VOLTMETERS/AMMETERS/OMMETERS, REGARDLESS OF YOUR REQUIREMENTS. WE HAVE A LARGE LINE, WITH ADDITIONS EACH YEAR. ALSO AC-DC LINEAR CONVERTERS, AC-DC CALIBRATORS, WIDE BAND AMPLIFIERS, DIRECT-READING CAPACITANCE METERS, AND A LINE OF LABORATORY VOLTAGE STANDARDS FOR 0 TO 1.000 MHz.

*ON READER-SERVICE CARD CIRCLE 94*
SOME GEARHEAD SERVO MOTORS GET HOT UNDER THE COLLAR

One continuous stainless steel case houses both motor and gearhead in Harowe integral-gearred servo motors. There are no joints to block heat flow; no dissimilar metals to expand unevenly. Result is cooler motor operation and excellent thermal stability.

Harowe builds motors and gearheads together to work together . . . and to give you one-source responsibility and industry's fastest deliveries.

New catalog lists 61 standard ratios for sizes 8, 10, 11, 15, and 18 motors and motor-generators. (Special ratios readily available.)

Request your copy from—

Harowe
Servo, Stepper & Synchronous Motors
Motor Generators • Synchros
Resolvers • Pancakes • Gearheads

HAROWE SERVO CONTROLS, INC.
40 Westtown Road
West Chester, Pa. 19380
(215) 692-2700

TEST EQUIPMENT

Reactive ratio divider driftless to 1 ppm


Accuracy of the model RB-504T is basically a function of the number of turns of wire on the solidly encapsulated reference element.

The instrument functions similarly to a Kelvin-Varley divider; it is described as the equivalent of an autotransformer with 100,000 taps.

A handy feature of the RB-504T is an optional transformer that provides negative (phase reversed) ratios. When the unit under test has a neutral point, negative ratio capability allows plotting through the phase reversal point.

Basic accuracy is rated at 1 ppm, traceable to NBS, and the instrument spans a ratio range of -1.111110 to +1.111110 with 0.3-ppm resolution.

Among the features of the unit are relative immunity to temperature changes, low output impedance and high input impedance (200 kΩ).

Output impedance rises from a max of 8.5 Ω without the transformer, to a max of 10 Ω when the transformer is introduced. Phase shift with or without the transformer is less than one minute of arc.

Applications include measurement of gain, phase shift, and linearity of amplifiers and repeaters, measurement of attenuation and frequency response of filters and other networks, developing variable ac reference voltages from stable frequency sources and checking resolvers.

Chip probing system completely automated


From first test to completed wafer, semiconductor testing is fully automated by the model 2818 probing system. Operating at four steps/second, it uses a grid-mask and photo detector to position the chip within 0.0002-in. Chips up to 2-in. in diameter can be accommodated. When a negative result is taken, the system punches a card, the card is placed over the wafer and the wafer inked through the punch to mark it.
An extensive research and development program coupled with the industry's most complete selenium facility has produced the Uni-Sel—a high temperature, high density selenium cell, superior to all other types.

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

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

Write For Literature
TEST EQUIPMENT

Microvolt-ammeter
drifts 0.1 µV/day
Keithley Instruments; 12415 Euclid, Cleveland. Phone: (216) 795-2666. Price: $825.

Particularly useful as an IC lab instrument, model 150B microvolt-ammeter has 14 overlapping voltage ranges from 0.3 µV full-scale to 1 V on a zero-center meter. Meter accuracy is ±2% full-scale and voltage output is ±1%, 1 V or 100 mV. Zero drift is 0.1 µV/day, non-cumulative. As an ammeter, range is 3 x 10^{-10} to 10^{-3} A on 14 ranges with an accuracy of ±3% on the meter and ±2% at the output terminals.

CIRCLE NO. 218

Strip-chart recorder
engineered for people
Keithley Instruments Inc., 12415 Euclid Ave., Cleveland. Phone: (216) 795-2666. P&A: $895; 30 days.

Model 370 recorder has its operating controls on the front of the panel, as are the input posts. The chart is driven over a sloped Mylar writing surface. General specs run: ten speeds, 0.5-s response, ±1% of full scale linearity, 6-in. rectilinear chart with an active width of 4.5-in., chassis-to-ground isolation of 10^{10} Ω shunted by 500 pF and a float capability to ±500 V. Input is a minimum 1 V at 1 mA.

CIRCLE NO. 219

Electronic Design 25, November 8, 1966
What marking job can we help you do better?

These are only a few of hundreds of marking jobs you can do more efficiently and more economically with Markem machines. So why waste time improvising and experimenting?

Call in a Markem man and get acquainted with today's broadest line of marking equipment. New high-speed color banding machines — some capable of putting three tiny bands on a miniature diode. Machines that combine sequential numbering with identification. Type so small you can print 14 characters plus trademark in an 0.125" diameter area. Quick-change type for short or pilot runs. New techniques combining special ink with flash-curing to help you meet severe durability specs. A production-speed imprinter so gentle you can safely mark flat pack ceramic components. And many other machines, specialty inks and printing elements.

Right now our research engineers and chemists are working on even better ways to mark components. We'd like to be working with you. Markem Machine Company, 319 Congress St., Keene, N.H.
NEW MODELS NOW AVAILABLE

* 2 KVDC @ 0.7 Ma. & 6.3 VAC for CRTs
* 1 KVDC @ 1.5 Ma. & 6.3 VAC for CRTs
* 1 KVDC @ 3.0 Ma. — programmable for BWOs
* 4-6 VRMS @ 300 Ma. — 4-6 KC sq. wave for VFO Telemetry
* 500 VDC @ 6.0 Ma. for Decade Tubes
* 12 VDC @ 250 Ma. for Strain Gages

PLUS . . . 12 NEW MODIFICATIONS
including an RFI version to MIL-1-26600, Class 1.

There's now a wider selection than ever to choose from in the HIGHER POWER 'THIN-VERTER™ Series—voltages from 3 Volts to 20 KV, up to 40 watts . . . AND they are small!
Be sure you've got all the specifications on AMC's small Power Conversion Equipment.

ARNO LD MAGNETICS CORP.
6050 W. Jefferson Blvd., Los Angeles, Calif. 90016
Telephone: 837-5313; 870-6284 (213)
TWX: 213-836-0430

ON READER-SERVICE CARD CIRCLE 181

TEST EQUIPMENT

Frequenzer, discriminator functions up to 10 MHz

Rapid frequency deviations in signals can be measured quickly by the 5210A analog frequency meter. The instrument functions as a wide-band discriminator that demodulates signals in the 3-Hz to 10-MHz range at deviations up to 1 MHz. As a discriminator, linearity is over 0.025% of full scale to 100 kHz. Frequency readings are typically 1% accurate with 0.1% accuracy quoted for difference readings.

CIRCLE NO. 220

Economy scope ranges to 25 MHz

Offered as a low cost addition to the manufacturer's 43 series, the S43a is a general-purpose, single-beam scope for both lab and production applications in the 25-MHz region. The instrument is based on the manufacturer's S43 design. It uses a 4-in. flat-face CRT with an edge-lit graticule and it will accept standard Data Instruments amplifiers.

CIRCLE NO. 221

IC tests made with one socket insertion
Continental Device Corp., 12515 Chadron, Hawthorne, Calif. Phone: (213) 772-4551. P&A: $1495; 1 to 4 wks.

A "dynamic" test socket, in conjunction with the manufacturer's integrated circuit testers, allows direct measurements of both response and dc parameters with a single insertion. Frequencies available in the standard ac test head are 1 MHz with 500-µs pulse width, 100 kHz with 1-µs pulse width and 10 kHz with 1-µs pulse width.

CIRCLE NO. 222

Portable ammeter ranges 1 µA to 10 A

A broad range of current measurements from 1 µA full-scale to 10 A full-scale can be made with the model 500VS101-22. The instrument incorporates a filament-suspension movement and a non-parallax light beam pointer. Your choice of 0.5% or 0.25% accuracy is offered in the same portable design.

CIRCLE NO. 223

Electronic Design 25, November 8, 1966
This solid-state instrument is an electronically swept VHF-UHF wide-sweep and marker generator which accepts a variety of UHF plug-ins to provide extended frequency ranges and sweep widths. With its plug-ins, the 121-C covers a range of 500 KHz to 1700 MHz, offers octave-wide sweeps at low UHF frequencies where most generators in this range are limited to narrow widths. Narrow sweep and wide sweep plug-ins cover special applications such as UHF-TV — full 440 to 920 MHz in a single wide sweep. A digital frequency dial provides smooth center frequency control and remarkable vernier adjustment for narrow sweep operation.

Performance characteristics include line-lock, cw, manual and variable sweep rates, and external input.

External modulation from dc up to more than 15 KHz, a built-in detector and switched attenuator are standard features.
I see a West-Cap® ceramic capacitor in your future (I hope!)

CAPACITANCE VALUES from 5pf to 10μf
VOLTAGE: 50 to 500 VDC
TOLERANCE down to 5%
TEMPERATURE RANGE: —55°C to 150°C
MEETS OR EXCEEDS MIL-C-11015

SAN FERNANDO ELECTRIC MFG. CO.
1509 FIRST STREET  □ SAN FERNANDO, CALIFORNIA 91341
TELEPHONE: (213) 365-9411  □ TWX: (213) 764-5963

ON READER-SERVICE CARD CIRCLE 183

I C BREADBOARD AND TEST PANELS
TIME SAVING  •  FLEXIBLE

PANELS FOR:
Flat Packs
TO-5 Case size units
Dual-In-Line packages
T.I. Mech Pak Carrier
- Solderless interconnection concept throughout
- 10 to 50 patterns standard
- Fast loading and operation — easy IC interchangeability
- Single pattern units and wire jumpers provide unlimited flexibility
- Power and ground connection at each pattern
- Panel plugs into 36 position edge connector with contacts spaced on .156 centers
- 6” x 17” panels (50 patterns)

Request catalog 364

AUGAT INC. 31 PERRY AVE., ATTLEBORO, MASS. 02703

ON READER-SERVICE CARD CIRCLE 184

TEST EQUIPMENT

ULTRASONIC BONDER HANDLES HYBRIDS, ICs
Hughes Aircraft Co., 500 Superior Ave., Newport Beach, Calif. Phone: (714) 548-0671. Price: (without optics) $4100.

Model 2905 production bonder, designed for wire bonding of hybrid circuits, can also handle bonding and die mounting of transistors and ICs. Leading feature is a movable work station which can be manipulated over a 1.1-in. square. Pushbuttons allow the station to be rotated 360° in either direction and templates can be used to locate bonding points rapidly.

CIRCLE NO. 164

EIGHT-CHANNEL TAPES VERIFIED AND DUPLICATED
Tally Corp., 1310 Mercer St., Seattle, Wash. Phone: (206) 624-0760. P&A: $6995; 8 wks.

Whimsically called the “Super-Duper,” a perforated tape verification and duplication system handles tapes from one through eight channels in any code structure at a speed of 120 characters/second. The station operates in five different modes: duplicate, verify, verify/duplicate, bit echo/duplicate and bit echo. The system consists of 2 readers, a perforator and logic module.

CIRCLE NO. 165
program your Tektronix
Type 561A or 564 oscilloscope
for DC-to-15 MHz applications

Here's new convenience for many Type 561A or
564 applications.

You can program the Tektronix oscilloscope for
6 measurement setups—using the new Type 263
Programmer and the Types 3A5 and 3B5 Auto-
matic/Programmable Plug-In Units.

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

**AUTOMATIC SEEKING**
In this mode upon SEEK command from the probe or the plug-
ins, the oscilloscope automatically presents an optimum display.
The SEEK command to the plug-in units automatically adjusts
the time and amplitude settings and automatically checks the
trigger logic—switching to auto trigger mode, if not correctly
triggered, to present a stable display whenever possible. Indi-
cators on the plug-ins light automatically to show the time and
amplitude settings. Measurements can then be made quickly
and accurately from the CRT display. In **AUTOMATIC SEEKING**
mode, the deflection factor is 10 mV/div to 50 V/div and sweep
range is 5 s/div to 0.1 µs/div.

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

Programmable Functions: from Type 3A5—V/div, 10X
probe indication, and AC, AC Trace Stabilized, or DC
coupling, by program card jumper connection ... vertical
positioning by program card potentiometer setting; from
Type 3B5—Time/div, X10 or X100 magnifier, trigger mode
with coupling, and trigger slope, by program card jumper
connection ... horizontal positioning, trigger level, and
magnifier delay, by program card potentiometer setting.

Tektronix, Inc.

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

Electronic Design 25, November 8, 1966

U.S. Sales Prices f.o.b. Beaverton, Oregon
Two-channel recorder
4 speeds, will travel
Techni-Rite Electronics Inc., Techni-Rite Industrial Pk., Warwick, R. I. Phone: (401) 737-2000. P&A: $995; 15 to 30 days.

Primarily intended for use in the lab, hospitals or on the production line, TR-722 recorders cover a frequency range of dc to 125 Hz on two channels. The instrument records in rectilinear coordinates on heat-sensitive recording paper. The portable package measures 4-3/4 x 10 x 14-in. and weighs 25 pounds. Chart speeds range from 1 to 100 mm/s.

On-line computer
reduces random data
Technical Measurement Corp., 441 Washington Ave., N. Haven, Conn. Phone: (203) 239-2501.

A simplified digital computer, the CAT 900 uses signal averaging for on-line reduction of random data. Signal-to-noise improvement is attained by storing digital samples in a core memory where random background is cancelled, isolating the intelligence. Standard features include dual-input provisions, ±0.2% linearity, an internal CRT and outputs for analog or digital recording.

Data printer has
integral digital clock
Spectra-Strip Corp., P. O. Box 415, Garden Grove, Calif. Phone: (714) 892-3361.

This 2-line/s data printer incorporates a digital clock and reads out and prints out either simultaneously or separately. The printer accepts any 4-line BCD code, any 10-line input, any logic level, any logic polarity and any inhibit level at any polarity. All semiconductors are silicon, and the roll-fed inkless unit prints up to 36 columns.

Plotting system accepts
digital data directly
Houston Omnigraphic Corp., 4950 Terminal Ave., Bellaire, Tex. Phone: (713) 667-7403. P&A: $3725; 45 days.

Model 6710 digital plotting system operates directly from computers, counters, DVMs, or any source generating parallel binary or BCD data. Three decades are presented on a 10-in. x 144-ft. "fan-fold" recording surface with 0.1% resolution. The system requires 1.5-μs data access as it incorporates a 3-decade single-point memory. A maximum of 1200 points/min. may be plotted with 0.2% full-scale accuracy.

Frequency response
analyzed with tester
Procydyne Corp., 221 Somerset St., New Brunswick, N. J. Phone: (201) 249-8347. Price: $13,950.

A new frequency response analyzer operates in the range of from 1 Hz to 50 kHz. The analyzer simplifies the frequency response analysis of systems and devices including, filters, equalizers, amplifiers, transformers, servo-mechanisms, and all other audio devices. Operating as a two channel device, the model FR-201 gives as an output, the phase shift between two sinusoids, the amplitude ratio for the two sinusoids, and the frequency. The phase angle and the amplitude ratio are available both as direct readings on a meter, and as dc outputs for recording purposes.

Color pulse generator
measures envelope delay
Videometrics Inc., P. O. Box K, Brightwaters, N. Y. Phone: (516) 665-9231.

A new color pulse generator, permits the direct measurement of envelope delay between luminance and chrominance channels using existing oscilloscopes as the sole detector or measuring device. Its measurement resolution if ±10 nanoseconds with delays down to 30 nanoseconds. The company believes this generator will save time and expense as compared to previously available envelope delay measuring equipment.
OHMICONE® SILICONE-CERAMIC COATED AXIAL LEAD RESISTORS

two Choices from OHMITE

SERIES 88 • MOLDED OHMICONE®
Coating is uniformly thick, dense and smooth. Meets 1000 VAC insulation test. Consistent form and size make these resistors highly suitable for rapid automated assembly techniques and also permit firm mounting in clips for significant heat-sink advantages. Available in commercial, military, precision, and non-inductive types. Can be provided to meet new Char. U of MIL-R-26. Solderable or weldable leads. (Bulletin 101)

Wattages (Commercial): 1.5, 2.25, 3.25, 6.5, 9, 11 watts at 25°C.
Resistances: 0.1 to 226K ohms.
Tolerances: To 0.05%; standard commercial, 3%.
Low Temperature Coefficient of Resistance: 0 ± 20 ppm/°C, 10 ohms and above.

SERIES 44 • CONFORMAL OHMICONE®
Same basic high quality wire-wound resistor as above, but with a conformal coating (1000 VAC rating). While it does not have the uniform shape and dimensions of the molded Series 88, the Series 44 is available with the same close, standard tolerance and low TC. It is supplied in commercial and high precision types. Can also be furnished to meet MIL-R-26 requirements. (Bulletin 109)

Wattages (Commercial): 1.5, 3.25, 6.5, 11 watts at 25°C.
Resistances: 0.1 to 442K ohms.
Tolerances: To 0.05%; commercial, 3% for values above 1 ohm.
Low Temperature Coefficient of Resistance: Standard is 0 ± 20 ppm/°C for 10 ohms or more.

OHMICONE Silicone-Ceramic—Not just a conventional silicone coating, but rather silicone combined with a ceramic compound. Blending the two materials provides a coating which has the best characteristics of each. Developed and patented by Ohmite, Ohmicone envelopes a wire-wound resistor in an unusually tough, resilient jacket that has high moisture resistance and excellent dielectric properties, plus good stability and low temperature coefficients. Choose either the molded or conformal coating in accordance with your requirements.

RHEOSTATS • POWER RESISTORS • PRECISION RESISTORS • VARIABLE TRANSFORMERS • RELAYS
TAP SWITCHES • TANTALUM CAPACITORS • SEMICONDUCTOR CONTROLS • R.F. CHOKE

OHMITE MANUFACTURING COMPANY
3643 Howard Street • Skokie, Illinois 60076
Phone: (312) ORchard 5-2600

Electronic Design 25, November 8, 1966
Ken Stockman, Iron Worker, Survived His Heart Attack

Like most heart attack victims, Ken Stockman survived his first attack and went back to his job. Three out of four now do! Heart Fund dollars invested in research have helped make such progress possible through advances in diagnosis, treatment and rehabilitation.

But heart attack still kills 550,000 in the U.S. annually. Fight this Number 1 killer with the best weapon you have — a generous gift to your Heart Fund volunteer.

Give... so more will live
HEART FUND

Contributed by the Publisher

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This FET Voltmeter is jack-of-all tests

Texasan Corp., 51 S. Kowebaba Lane, Indianapolis, Ind. Phone: (317) 632-7351. P&A: $239; 4-6 weeks.

In one portable instrument, the DV-93 combines the features of a VOM, a VTVM and an ohmmeter. It is a dc voltmeter, an ac voltmeter, an RF millivoltmeter and an ohmmeter. dc bandwidth is 3 MHz at full accuracy but usable to 5 MHz. Most sensitive scales are 50 mV full-scale for dc, 15 mV for ac, and 25 ohms mid-scale for resistance. Meter is taut-band, mirror-backed.

CIRCLE NO. 133

Plug-in scales-down MW sweep generator


The manufacturer's HP sweep oscillator can be converted to RF-level operations through the model 8698A plug-in. The plug-in covers the frequency range from 100 kHz to 110 MHz in two 110-1 ranges. Instrument performance features such as flexible sweep functions, variable sweep-rates, tuned markers, and leveled outputs are not affected. Sweep linearity is 99.5% accurate.

CIRCLE NO. 134
PNP silicon transistor

\[ BV_{CEO} = 200\text{-}500V \]
\[ HFE = 30 \text{ min.} \]
\[ f_T = 30 \text{ Mc/s min.} \]

plus

NPN

\[ 300V \text{ TO } 1000V \]
\[ 50\text{Mc GBW} \]
\[ 5-15 \text{ WATTS} \]
Generator pulses into 12 output channels

Adar Associates Inc., P. O. Box 27, Lincoln, Mass. Phone: (617) 623-3131. Price: $5600.

As a clock and controller in any sequencing system, the SQ-260 provides pulses on 12 parallel output channels. Programming is accomplished by diode pins in a 12 x 16 matrix. Stepping rates are 10 MHz to 1 KHz. The cycle can be started by either an external pulse or a built-in 1 MHz to 10 Hz clock. The step-repeat switch has an "endless" position allowing an operator-controlled long step or pair repeat period.

CIRCLE NO. 135

Lead compensator resolves to 0.1 milliohms

John Fluke Mfg. Co., Inc., P. O. Box 1428, Seattle, Wash. Phone: (206) 774-2211. P&A: $245; 90 days.

Lead compensation, where ratios between standard and test dividers are as great as 4000:1, is possible with the model 721A compensator. A mode switch reverses the divider terminals so that dividers can be connected without regard to the divider with the higher resistance. Resolution is rated 0.1 milliohms and max allowable lead resistance is 150 milliohms. Max divider voltage is 1500 Vdc or peak ac.

CIRCLE NO. 136

AF response meter covers 20 Hz to 20 kHz


In testing frequencies from 20 Hz to 20 kHz, the 620B audio response meter needs neither markers nor physical connection between generator and meter to draw accurate response curves. The instrument module combines a log frequency meter and a log volt meter. Readout is provided by a fan type meter with 0 dB center. Analog dc voltages for both signal frequency and voltage are brought out for drives, recorders or scopes.

CIRCLE NO. 137

SMALL, LIGHT, QUIET
FRACTIONAL-HP MOTORS

15 millihorsepower to as high as 1/2 hp

General Electric single- and three-phase small induction* motors are ideal for applications requiring extra-high motor output in a really compact package.

They provide dependable, long-life operation and save on space, weight, and freight.

*Synchronous motors also available in 3-inch and 3\frac{1}{4}-inch diameters.

FREE BULLETIN—Technical information on types, ratings, dimensions, and characteristics.

Write for bulletin GEA-7300 to Section 727-06; Specialty Motor Dept., General Electric Co.; Fort Wayne, Ind. 46804.

Progress Is Our Most Important Product

GENERAL ELECTRIC

ON READER-SERVICE CARD CIRCLE 189

174 ELECTRONIC DESIGN 25, November 8, 1966
Fast, convenient direct reading measurements of impedance and phase angle 500 kHz to 108 MHz...

THE 4815A RF VECTOR IMPEDANCE METER

This new Vector Impedance Meter is a versatile instrument that provides fast, direct reading measurements of impedance and phase angle over the frequency range from 500 kHz to 108 MHz. It is continuous tuning over this frequency range, and does not require balancing or data interpretation. Thus, it is an extremely useful tool for the evaluation of the complex impedance of both active circuits and components. The convenience of probe measurement, ease of operation, and direct reading features make the instrument equally useful for laboratory, receiving inspection or production line measurements.

The 4815A is a convenient and powerful measuring tool for any application involving measurements over a band of frequencies or in-circuit measurements. It may be used to determine the self-resonance point of capacitors, the series and parallel resonance points of crystals, or the characteristics of high frequency transformers and transducers. Price: $2650 f.o.b. factory. For complete specifications, contact your local Hewlett-Packard field engineer or write Hewlett-Packard, Rockaway Division, Green Pond Road, Rockaway, N. J. 07866; Europe: 54 Route des Acacias, Geneva.

Advantages:
- Fast, continuous tuning from 500 kHz to 108 MHz
- Provides data directly in impedance and phase angle, 1 ohm to 100K ohms 0 to 360°
- Convenient probe for in-circuit measurements
- Analog outputs permit permanent data recording
- Self calibration check provides measurement confidence
- Low-level test signal minimizes circuit disturbance

HEWLETT PACKARD
An extra measure of quality
It’s hard to contact you if you don’t contact us.

It isn’t that we don’t have a phone or men out beating the bushes. It’s just that, if you don’t let us know about any electrical contact or sub-assembly problem you might have, we may not find you. And that would be a shame. You’d be depriving yourself of the opportunity of dealing with people who have seen enough contact problems to realize that yours may well be different from all the others. And, people who know what to do about your problem!

Once a solution is reached, it is executed with the finest, most modern, and in many cases, exclusive facilities in our industry. That’s another reason it would be a shame not to get in touch with us. Two more are service (and our eager approach to it) and delivery (we break our necks to be prompt). So do us a favor by doing yourself a favor. Next time the subject of contacts comes up, contact Deringer. It’s your best bet for quick, economical service.

Planar audio transistors are tiny and quiet
Amperex Electronic Corp., Slattersville, R. I. Phone: (401) 762-9000.

Microminiature silicon planar epitaxial audio transistors, types A151, A152 and A153, feature a noise figure of 1.5 dB and leakage of 10 nA. The small package size (0.078 x 0.071 x 0.071-in.) makes them ideally useful in hearing aids, tape heads or phone pick-ups. The current gain characteristics are maintained over a range of collector currents from 20 to 2000 µA. Mounted on a ceramic substrate, the units have been designed with extra rigid leads.

Miniature pnpn switch up in power and voltage

Miniature, except in ratings, recent additions to the Unitrode four-layer diode line have continuous current ratings as high as 1.5 A and firing voltages as high as 100 V. Typical of the Unitrode line, these new devices have terminal pins metallurgically bonded to the silicon element. Operating efficiency is said to be unaffected by continuous overloads or by temperature cycling within a −195 to 300°C range.
Only the CORNING®
GLASS-K
can cram
100,000 pf into this

Now the stability you associate only with glass comes to you from
1,000 to 100,000 pf in a size even smaller than conventional CK types.

We treat our high-dielectric-constant glass to a heating to produce a
micocristalline structure in the Glass-K material. The dielectric has
no room for holes, so we can slice it thinner, put more pf in a smaller case size.

No holes also means more environmental stability, less chance for failure.

Capacitance change after load-life with the Glass-K unit is less than 2%
and dissipation factor is less than 1.0% for values to 20,000 pf.

With all its obvious material advantage, the Glass-K has a
price that's competitive.

Why risk an entire system on a capacitor that can't give you the assurance of
Corning dielectric stability? Get complete Glass-K Capacitor data
in our new CORNING® Glass Capacitor Guide. Send to Corning Glass Works,
3909 Electronics Dr., Raleigh, N. C.
J-FET pair for linear amplifiers, switches

Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. Phone: (408) 245-1000. P&A: $14.90 (100-up); stock.

The 2N4339 / FP4339 and 2N4340 / FP4340 complementary n and p-channel junction FET pairs are designed for zero-offset source followers, low spiking choppers and controlled resistors. They feature a narrow three-to-one range of V_r = 0.05 V and g_r ; each pair is matched in to 5% and in V_P to 30%. Maximum V_P is 1.8 and 3 V, minimum currents are 0.5 and 1.2 mA; minimum g_r values are 800 and 1300 mho. Each device is packaged separately, in a TO-18 and a TO-72.

Double-gate MOS-FETS outdo bipolars at uhf


Developmental insulated double-gate MOSFETS, type TA7010, are intended for vhf/uhf communications receiver amplifiers at frequencies up to 500 MHz. The internal circuit configuration and performance of these devices are similar to those of two vacuum tube triodes in a “cascode” arrangement. They feature extremely low gate leakage currents, feedback capacitance in the order of 0.01 pF, high conductance (10,000 µhmo at a drain current of 7 mA) and a square-law transfer characteristic which makes them superior to bipolars as far as cross-modulation.

The TA7010 is an n-channel, depletion-type silicon transistor packaged in a four-lead TO-72 can. At 200 MHz typical power gain is 20 dB and noise figure is 2.8 dB. At 400 MHz typical gain is 13 dB and noise figure is 4.5 dB. These characteristics make the device exceptionally well suited for receiver front-end and IF amplifier circuits.

FET doubles as switch or SCR

Atlantic Instruments & Electronics Inc., 103 N. Beacon St., Boston, Mass. Phone: (617) 254-0465.

Aimed at the industrial and commercial markets, the Fieldtron FET type 15P1 operates as a switch or an SCR. Switching “on-time” is in the order of 1 µs and “off-time” is 0.1 µs. Since the device acts as a diode in the conducting state but as a cutoff pentode when pinched, it can also double as a proportional controller. Among the important specs are a continuous current rating of 10 A, break capability over 15 A and duty voltage of 150 V.

New Free Handbook on Servo Packages

Getting our new Servo Package catalog is almost like getting a servo design engineer through the mail. It gives you details about integrators, in-line servos, geared assemblies, data converters, synchronizers, and custom units, pre-engineered by Cedar. Write or call us for your free copy.

A NEW IDEA IN P-CLIPS!

Only nine (9) sizes of P-Clips will fit all loop diameters from 1/8" through 2"; each size can be adjusted within a specified range. Does away with inventory problems, permits quantity purchases and controls the tension. Molded of non-corrosive, non-conductive, virgin nylon. Applications include: cables, bundles of wires, components, pipes, tubing—wherever a clamp, strain-relief or strap is required. Send for free samples.

OTHER ELECTROVERT PRODUCTS: Cradleclip; strapping; cable ties; spiroband; markers; grommet strip; wavesoldering systems.
How to decide if you need an automatic test system for modules and ICs that will save you over $100,000...

Make a quick check! Answer these four questions:

1. Are your test specifications based on present test equipment capability, rather than true performance of the unit under test?
2. Are results of your present testing free of human errors and subjective evaluation?
3. Will present test equipment hamper your future billings schedules, due to more complex test requirements?
4. Does your present test routine require 30 minutes or more to adequately test a printed circuit card or integrated circuit?

If you answered “yes” to any one of those questions, you probably need a 553 Dynamic Test System.

Now it's your turn to ask questions. We have test instruments and systems to help you save testing time and money. Contact your nearest TI Field Office, or get in touch with us at the Industrial Products Group, 3609 Buffalo Speedway, Houston, Texas 77006. If you're in a hurry, our phone number is 713-782-9661.

Texas Instruments Incorporated

ON READER-SERVICE CARD CIRCLE 196
Model T-60
60 KHZ Time Code Receiver
Round The Clock WWVB 60 KHZ Binary Time Code Broadcasts • Most Accurate Time Signal Available • Can Be Recorded Continuously
Radio Station WWVB is broadcasting complete time information using a level shift carrier time code (10 db level changes). This code, which is binary coded decimal (BCD) is broadcast continuously and is synchronized with the 60 khz carrier signal. $480.00
Model T-60A Rack Model (3½" H x 19" W x 5" D)

Model SR-60
Price: $850.00
Model SR-60a WWVB-60 khz. Will calibrate any local standard up to 5-10' within a short period. Can be easily operated by any technician and performs in any part of the Continental United States.

Model SFD-6R
Modular Construction:
A complete system for distribution of standard frequency throughout a plant. All solid State—fail safe—reasonably priced. Price depends upon Modules selected ($90.00 each). Several Modules available.

Model WVTR
Mark 11 All Silicon Transistor
Five different models of Receivers for WWV and WWVH are available. They receive all frequencies transmitted by WWV and are all crystal controlled double conversion superheterodynes. $590.00

Special Antenna Assemblies for both VLF and HF are in stock.

Model WVVT
$590.00
Mark 11
All Silicon Transistor
Over All Size
7½" x 9⅛" x 5"
Approx. Weight
7 lbs.

Model 45
$98.50
A pocket size battery powered Time Base Calibrator, complete with internal battery.

Send for complete specifications, Prices and specifications subject to change without notice. P.O.B, Woodland Hills, Calif.

SPECIFIC PRODUCTS
P. O. Box 425 / 21051 Costanso Street
Woodland Hills, California
Area Code: 213 340-3131

ON READER-SERVICE CARD CIRCLE 197

SEMICONDUCTORS

Diode pin eases component insertion
Co-Ord Switch, 102-48 43rd Ave., Corona, N. Y. Phone: (212) 899-5588. P&A: $0.76; stock.

Components are easily inserted into two level (X-Y) matrix program boards when mounted in these holders. They feature a 0.106-in. diameter, 0.5-in. long pin with high bending resistance. The diode is crimped into the pin, thus eliminating diode failures due to soldering heat. Maximum component size installable is 0.16-in. diameter x 0.37-in. long.

CIRCLE NO. 230

Silicon thyristor diodes fire at 40 to 300 volts
Unitrode Corp., 580 Pleasant St., Watertown, Mass. Phone: (617) 926-0304. P&A: $5 to $15, 1 to 2 wks.

High power, high voltage thyristor diodes are available with voltages from 40 to 300 V. Continuous current is 1.5 A and short duration surges as high as 500 A can be withstood, with an 8.3-ms surge rating of 15 A. The body size is less than 0.25-in. long with 0.085-in. diameter. They are constructed using two cylindrical metal pins bonded to both faces of a silicon die.

CIRCLE NO. 231

Hot carrier diodes are quiet beyond 8 GHz
Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $29.75 to $79.05 (10 to 99); 2 wks.

In mixer/detector service beyond 8 GHz, series 2600 hot carrier diodes have maximum ssb noise figures of 7 or 7.5 dB with a 1-mW local oscillator and a 30-MHz, 1.5-dB IF amplifier. The diodes are metal/silicon Schottkies for use through 10 GHz, intended to replace point contact diodes. Cw power dissipation at 25°C is 125 mW.

CIRCLE NO. 232

Power transistor offers 50 W at 50 MHz
Motorola Semiconductor Products, P. O. Box 955, Phoenix, Ariz. Phone: (602) 273-6900. P&A: $22.80 (100-up); stock.

Type 2N3950 RF power transistor provides a guaranteed 50-W continuous power output at 50 MHz with a minimum power gain of 8 dB. The device is characterized for Class C operation, but can also be operated Class A or B to meet high-power single sideband requirements through 76 MHz. The multiple-emitter transistor is mounted in a grounded-emitter TO-60 package.

CIRCLE NO. 233

ELECTRONIC DESIGN 25, November 8, 1966
THIS LITTLE THREAD HELPS OUR AIR-SPACED COAX DO BIG THINGS FOR IBM

Our coax can do the same for you! A spiral of flame-retardant polyethylene thread air-spaces the center conductor of Brand-Rex Turbo® 209A Coaxial Cable. The result: a tough, miniature coax, with excellent electricals for high-speed transmission, at moderate cost. We first developed the Turbo 209A for use in the IBM Computer/360, but you may find this space-saving performer useful in a variety of data processing and communications applications. It is available as single cable, cemented ribbon cable (illustrated), or conventional round multiconductor cable. Substantially lower in price than standard 95 ohm High Temperature types, it also offers lower attenuation; higher velocity of propagation. A spiral drain wire under the shield simplifies termination.

Check the specs. Sound good? Write for full information.
Style 1354 (single), Styles 2384, 2385, 2386, 2387, 2388 (cable).
Nominal voltage: 600 volts rms.
Nominal impedance: 95 ohms, +6 - 4
Nominal capacitance: 13.5 pf./ft.
Max. attenuation: 14 db/100 ft at 400 Mc.
Velocity of propagation: 80%.
Inner conductor: #29 AWG silver-coated Turballoy C.
Cable core: Air-spaced, flame-retardant polyethylene, 0.072-0.078" O.D.
Drain wire: #29 AWG silver-coated Turballoy C spirally applied for flexibility and fatigue resistance.
Shield: #38 AWG tinned copper braid, providing 90% min coverage.
Jacket: High-density vinyl, 0.112" nom. O.D.; 0.122" max O.D. at drain wire points.

ON READER-SERVICE CARD CIRCLE 198
Micromin glass rectifiers withstand 50-A surges

New glass rectifiers feature a one-piece glass hermetic seal with diffused junction. Five JEDEC types, 1N4383, 4384, 4385, 4585 and IN4586, provide high forward conduction, low voltage drop and a 50-A one-cycle surge rating. Maximum recurrent PRVs are 200, 400, 600, 800 and 1000 V.

GaAs, Si Schottky diodes have tiny L and C
Gemini Semiconductor Inc., 482 Ridgedale Ave., Hanover, N. J. Phone: (201) 887-8181. Price: $200 (GaAs), $25 (Si).

Gallium arsenide and silicon Schottky diodes, rated at 10µA at 14 and 40 V respectively, have low package capacitances (0.22 pF) and inductances (0.05 nH). Noise figure of the AR2A35 GaAs diode at 35 GHz is 9 dB and cut-off frequency is 1200 GHz. Reverse current of the 2A414 Si diode is 1.6 x 10⁻⁵ µA.

JAN stud rectifiers available to 1000-V PIV
Electronic Devices Inc., 21 Gray Oaks Ave., Yonkers, N. Y. Phone: (914) 965-4400.

The 800 PIV and 1000 PIV 7/16-in. silicon stud rectifiers JAN 1N-3649 and 3650 are offered. Both cathode-stud and anode-stud polarity are available. Applications for the medium-power rectifiers include military communications equipment such as receivers, transmitters and low-power radar. The devices are also useful in signal generators and scopes.

FREE SAMPLE
Eccoshield SY
Conductive Plastic

Eccoshield SV is the flexible, compressible plastic with the electrical and heat conductivity of metal—available in many physical forms—sheets, rods, tubes. Easily fabricated and bonded to itself or other materials.

Write on your letterhead for free sample, technical data, and price information. Please state which product desired and intended application.

ON READER-SERVICE CARD CIRCLE 199
The Absolute Ohm

How a classic ESI system can bring you closer to the absolute in resistance measurement, and why it can be of more than academic interest in many electronic labs and plants.

The Absolute Ohm is a theoretical ideal, which can be ever more closely approached, but never attained.

Its legal value is the resistance standard maintained by The National Bureau of Standards. The accuracy of your resistance measurement depends on the degree of “direct traceability” to this NBS standard.

The ESI 242 Resistance Measuring System permits a chain of measurements to any resistance level from a single, directly traceable reference standard—with comparison accuracies of 1 ppm. Measurements can be made swiftly and simply; results are read directly, without calculation.

Even when you are not looking for greater accuracy in your resistance measurement and calibration, you may have good reason to consider our 242. It could help you speed up the pace of lab or quality control operations. Or increase reliability. Or get better results from less experienced people on your production line.

The 242 includes Ratio Bridge, Decade Standard, Generator-Detector and 4-Terminal accessories.

We can’t promise The Absolute Ohm in resistance measurements. But with the 242, we do offer The Definitive System. ESI, 13900 NW Science Park Drive, Portland, Oregon (97229).

Accuracy of 242 System over specified ranges.
Components

(continued from p. 158)

Miniature R-C networks to 22 MΩ, 0.2 mF

Globe-Union Inc., P. O. Box 591, Milwaukee. Phone: (414) 962-9200. Price: from $0.08.

Discrete components are assembled and then Durez coated and waxed, to form series R-C devices with high insulation resistance. A ceramic disc capacitor of 14 pF to 0.2 mF is combined with a 1.2-W resistor of 1 Ω to 22 MΩ. The 3-terminal disc-configuration network has voltage ratings from 16 V to 6 kVdc and capacitance tolerances from 5%. Disc diameter varies from 0.59 to 0.92-in. and thickness from 0.3 to 0.5-in.

Metallized polycarbonate sealed in metal

Gudeeman Co., 340 W. Huron St., Chicago. Phone: (312) 337-7400.

For high-temperature stability in miniaturized circuitry, a line of polycarbonate capacitors are available in hermetically sealed tubular metallic cases. Voltage ranges are from 100 to 400 Vdc and dissipation factor at 25°C is less than 0.3% at 1 KHz. No voltage derating is required over the unit’s operating range.

Sealed quartz crystals meet MIL stability specs

Tedford Crystal Labs., Inc., 4126 Colerain Ave., Cincinnati. Phone: (513) 542-555.

“Koldweld” quartz crystal units for frequency control are hermetically sealed in a nickel can with a nickel-plated, copper-clad Kovar base. The sealing process eliminates contaminants, prevents crystal frequency shift associated with solder heat and flux and provides ultrastable units with aging rates of 0.03 ppm/wk at 75°C. Frequency ranges are 1 to 30 MHz for fundamental types and up to 210 MHz for overtone types.

Reference junction is electrically compensated


Designed to replace ice baths and reference ovens, this electrically compensated reference junction will make ambient correction of an electrically established reference temperature within the measuring circuit. Measuring only 1 x 0.23-in. it is accurate to within 1% from −65 to 165°F. Power drain is 50 mW and excitation may be specified from 1 to 99 Vdc.
Babcock mercury-wetted relays... much more sensitive!

Power at a premium? You'll find Babcock Series BW Mercury-Wetted non-bridging relays more sensitive to your system requirements, providing billions of trouble-free operations on a mere 1.2 milliwatts or less. And more... the industry's most efficient magnetic circuit. Two independent permanent pole magnets are used, with separate induction bars for better magnetic field return. Whatever your system application—chassis or circuit-board components, or complete control board modules—you'll find a Series BW unit to your liking. Get the complete story today — write Babcock Relays, Division of Babcock Electronics Corp., 3501 Harbor Blvd., Costa Mesa, Calif; (714) 540-1234.

SPECIFICATIONS

MUST-OPERATE POWER: Low as 1.2 mw.
CONTACT ARRANGEMENT: 1 Form C
CONTACT RATING: 2 amps.
CONTACT RESISTANCE: 25 milliohms, Typ.
OPERATE SPEED: To 1 ms.

NO CONTACT BOUNCE
Snap-action slide switch is sub-submini

*F & F Enterprises, Chicago Switch Div., 2035 Wabansia Ave., Chicago. Phone: (312) 489-5500.*

The sub-subminiature “Mini-Slide Snap Switch” with a total stroke of 0.115-in., is designed for signal and moderate power circuits, and is claimed to be 1/4 the size of the next smallest. The spdt, 4-pin 1A, 1B or 1C circuits have a rated life of 250,000 operations. Contact rating is 2 A at 120 Vac or 0.5 A at 120 Vdc.

CIRCLE NO. 241

Micromin tank circuits are 1/5 TO-5 can size

*Piconics Inc., North Billerica, Mass. Phone: (617) 663-4862. P&A: $17.50; 2 wks.*

Weighing but 1/175 oz, low-cost tank circuits in a molded diallyl phthalate case represent an 80% size reduction over TO-5 size units. The stable capacitor and 65 ppm/°C inductor used give a typical temperature coefficient of 100 ppm/°C from –55 to 125°C. Frequency range extends to 250 MHz with an average Q of 60 at 60 MHz.

CIRCLE NO. 242

D/A converter cards supply 0 to 10 V

*Control Logic Inc., 3 Strathamore Rd., Natick, Mass. Phone: (617) 655-1170. P&A: $150 (CAC-101) and $345 (102); stock.*

Two D-to-A converter circuit cards, models CAC-101 and 102, are designed for analog interfacing in systems design or for A/D or D/A functions in instrument assemblies. Model CAC-101 converts with 0.05% accuracy; model CAC-102 at 0.01% over 0 to 50°C. In both, settling time is 10 µs/bit to rated accuracy.

CIRCLE NO. 243

**-120°F to +350°F on a bench!**

The New Improved Tenney Jr. Bench Model, Mechanically Refrigerated, High-Low Temperature Test Chamber features wider temperature range with ±1/2° F control throughout with indicator. Full 1,400 cu. in. test area. New, faster pull down, greater load dissipation. New fan guard. 26 per hour average operating cost! Hermetically sealed inside and out. Weighs only 200 lbs. Simple plug-in operation. Still priced at only $990 complete. Available immediately.

To order, or for more information, write to

**Tenney Engineering, Inc.**

1090 Springfield Road • Union, New Jersey

Western div.: 15700 S. Garfield Ave. • Paramount, Calif. 90723

Oldest and Largest Manufacturer of Aerospace and Environmental Equipment

ON READER-SERVICE CARD CIRCLE 785

**DISCOVER**

**TAPE-LIFT**

PRINTED CIRCUIT DRAFTING AIDS in flat 8" strips packaged in handy slip-pack boxes. Featuring our NEW Black Matte Finish, Clear Adhesive Centerless Donuts, Teardrops and Oval Pads in many new stock sizes, also Tees, Elbows, Fillets, Adapters, Register Marks, Drafting Film and Grids, Conductor line tapes in Matte or Creped finish in widths from 3/4" up.

Write for our NEW CROSS-REFERENCE DRAFTING AIDS GUIDE & PRICE LIST NO. P-41 – FREE SAMPLES.

**BY-BUK COMPANY**

4325 W. Pico Blvd., Los Angeles, Calif. 90019 • (213) 937-3511

ON READER-SERVICE CARD CIRCLE 786

Electronic Design 25, November 8, 1966
The Model 62PA side-adjust is a new easy-access cermet trimmer with these quality features: virtually infinite resolution; excellent high frequency characteristics; and standard resistance from 10 ohms to 1 megohm. Its rugged cermet resistance element gives you long, trouble-free life and freedom from sudden failure. Inside its plastic case is a sealed metal housing identical to the popular ¼" top-adjust Model 62P.

Focus in on delivery advantages, too... immediate stock availability. Call your Helipot sales rep for full specs.
**Conductive plastic pots offer center-tap option**

New England Instrument Co., Kendall Lane, Natick, Mass. Phone: (617) 655-1411. P&A: $11.55 to $19.55 (untapped), $2 to $5 extra (center tapped); stock to 1 wk.

Center-tap options are available in a line of low-cost conductive plastic potentiometers. Center taps can be maintained within 50% of the applied voltage, plus or minus the specified linearity tolerance. The "Econopot" line includes 18 models (9 servo and 9 bushing) with total resistances of 1, 5 and 10 kΩ.

CIRCLE NO. 244

---

**Silver/zinc batteries outdo Ni/Cd, Ni/Fe**

Epic Inc., 150 Nassau St., New York. Phone: (212) 349-2470. P&A: $7.50, $8.50, $11.50 (lots of 6); stock.

As a power supply for solid-state equipment, these chargeable batteries have solid pure silver and zinc electrodes. Energy storage capacity compared to Ni/Cd or Ni/Fe cells is 2.5:1. Internal resistance is low so that the cells can be overloaded. Three models are available with rated capacities of 50, 80 and 300 mA-hours and 1.5-V rated voltage.

CIRCLE NO. 245

---

**Tuning fork oscillator for long-term stability**

Fork Standards Inc., P. O. Box 177, West Chicago, Ill. Phone: (312) 231-3511. P&A: $29; 1 wk.

For high long-term stability with medium accuracy, this tuning fork oscillator replaces comparably priced RC and LC oscillators. It has a low TC tuning fork for long-term stability, all silicon transistors, and is hermetically sealed. Any frequency from 800 to 6000 Hz is available with accuracy of 0.02% at 25°C and 0.1% from 0 to 65°C. Output is an 8-V p-p square wave with a 12-V supply.

CIRCLE NO. 247

---

**Flatt-pack op-amp priced at $10**

K & M Electronics Corp., 102 Hobart St., Hackensack, N. J. Phone: (201) 343-4518. P&A: from $10; stock.

Low-cost operational amplifiers in a flat-pack are designed for industrial and commercial use in analog computers, high-gain/low-drift servo preamps, ac amplifiers, voltage comparators, and instrumentation amplifiers. Features of the KM-20 op-amps are input impedance of 500 MΩ, typical open loop voltage gain of $10^6$ and drift of 3 µV/°C.

CIRCLE NO. 246

---

**Solid-state control meter uses no relays or contacts**


Contactless, all solid-state control meters have a barrel length of 4.65 in. Using no relays, they are capable of full-wave spst switching at 3 A, 110 Vac. The units are suited for closed loop applications and have a zener regulation circuit to ensure accuracy despite ac line variations. The meters are available with taut band or pivot and jewel suspension.

CIRCLE NO. 248

---

**Tiny single-turn pot has top or side adjustment**

Bourns Inc., Trimpot Div., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700. P&A: $2.64 (100 to 249); 3 wks.

Single-turn micromin (3/16 x 0.105-in) potentiometers are available in two versions, 3317-P for top adjustment and 3317-W for side adjustment. Resistance range is 20-Ω to 5-kΩ with a ±10% tolerance and power rating is 0.2 W at 25°C. Multiple wire-welded terminations and flat leads improve solderability and weldability. Stops are provided.

CIRCLE NO. 249
Not angles. Temperature. Time. Wherever more accurate, more sophisticated high speed time-control devices are called for, as in critical process control applications, the new HAYDON QT Solid State Delay/Interval Timer is meeting the demands of design engineers. Completely interchangeable and compatible with the full line of HAYDON Panel Mounted electromechanical timers, the QT Solid State Timer assures such important advantages as accuracy specified at set value rather than full scale, and absolutely dependable accuracy at constant voltage and temperature. Unlike unijunction transistor and thyatron-controlled units, interruptions of timing do not cause momentary closing of relay contacts with resultant shortening of the next time interval.

As specialists in timing and application skills, HAYDON engineers are at your call—ready to assist you with any time problem. To put HAYDON and time to work circle the number on the card, phone or write today.

### Important Features
- Completely new approach to Solid State timing circuit design.
- Fully compatible with all HAYDON Panel Mounted timers. Complete interchangeability with other HAYDON units.
- Life expectancy 10 million mechanical operations.
- Voltages: 20VDC; 117,230 VAC, 50/60 cps. Power requirements approximately 3 watts.
- Comparatively insensitive to shock and vibration. Compensates for voltage variations.
- Not damaged by X-ray radiation or voltage spikes.
- Instantaneous reset even within a timing cycle. Repeat accuracy for Delay/Interval Timers is specified as "percent of set value" rather than the more customary "percent of full scale" with the resulting user benefit.
- Delay/Interval Timer: Full Scale—30 sec. maximum. Repeat accuracy —±2% of set value above 1 sec for temp range of 0° to 60°C, & operating line voltage within ±10% of rated value.

---

**HAYDON PRODUCTS / INDUSTRIAL CONTROLS DIVISION**
Thomaston, Connecticut

---

**GENERAL TIME**
Progress in the World of Time
Ceramic capacitors have tiny TC


"Zero TC Series" capacitors have a temperature coefficient of $0 \pm 25$ ppm over $-55$ to $125^\circ C$. Capacitance is unaffected by any change in ac or dc voltage or in voltage-temperature combination. Ratings of 50 and 100 Vdc in both radial-lead and cordwood styles are available from 1 to 10,000 pF. Dissipation factor is $0.2\%$ at 1 kHz and charge rating exceeds 5000 at 1 MHz.

CIRCLE NO. 250

10-turn servo mount pot measures 7/8-in. long


Wirewound 7/8-in. diameter, 10-turn servo mount pots measure only 7/8-in. long. Standard resistance values are 10 Ω to 125 kΩ with independent linearity of $\pm 0.2\%$ and standard tolerance of $\pm 3\%$. Power rating is 2 W at 40°C, derating to 0 at 85°C. Model 7263 has molded plastic housing and gold-plated terminals.

CIRCLE NO. 251

Vacuum pickup for micromin components

Erie Sobotka Co., Inc., 110 Finn Ct., Farmingdale, N. Y. Phone: (516) 293-9272. Price: $22.50.

In conjunction with a vacuum source, this pencil-shaped pickup is for moving, holding, and picking up small components. The aluminum pick up tool is operated with one hand. Thumb pressure on a spring-loaded valve adjusts the vacuum for pickup or release. An integral screen filter and plenums trap dust and dirt. Three interchangeable heads rotate through a 45° arc.

CIRCLE NO. 252

Self-coiling NEG'ATOR® metal readout scales simplify instrument design

The NEG'ATOR, a flat strip of prestressed spring steel, tends to coil at each end and resists uncoiling uniformly over the entire length of the strip.

When used as a printed metal readout scale, both ends are curled on bushings of equal size. Since the opposing forces (coils) are always in balance, the span between is held taut.

With its own built-in recoiling energy, the NEG'ATOR replaces large dial scales, long strips or drum scales, expanding readability while saving space!

Ask for Bulletin 310T containing full details.

CIRCLE NO. 255
Does a Bruning drafting machine really save time and labor? Here's proof!

The top two pictures were taken with a time exposure and lights on the wrist of a draftsman. Here are the number of movements necessary to make a simple drawing with a T square, straightedge, triangle, protractor and scale. Time: 2 hours, 11 minutes.

Here the same drawing was made with a Bruning Equipoise drafting machine. Note that considerably fewer movements were required. Greater accuracy was also obtained. Time: 1 hour, 31 minutes.

The Equipoise drafting machine (available in right- or left-hand models) is only one of several drafting machines made by Bruning. All of them save you time and labor. Want to find out more? Call your Bruning man. He's listed under Bruning or Addressograph Multigraph in the telephone directories of 155 major cities. Or write Dept. D, Mt. Prospect, Illinois.
Couched relays?

Use Couch 1/7-size Relays

Space/weight problem? The new Couch 2X 1/7-size crystal can relay gives you tremendous savings in space and weight. 0.1" grid — plus many outstanding specs — all in micro miniature. Thoroughly field-proven in electronics and space applications.

Portable stripping tool removes sheathing


This portable stripping tool removes metal sheath from thermocouple materials, heating elements and cables. The unit operates at 115 Vac with speed regulated by a "trigger control." Normal range of material that can be stripped is 0.04 to 0.25 in. OD. Interchangeable cutting heads and two types of holding devices, a Jacobs chuck or a two-piece clamp are available.

CIRCLE NO. 253

Metal/diamond spatula cleans contacts quickly

Electronic Space Products Inc., 854 S. Robertson Blvd., Los Angeles, Calif. Phone: (213) 657-5540.

The "Diacrom" is a metal spatula upon which diamond powder has been deposited on a layer of chromium. Since the cutting edges are very close to the layer, deep scratches cannot be produced. Contacts are cleaned and polished by a brushing motion. The shaft is flexible nylon for accessibility to awkward areas. The shafts are supplied in three different colors.

CIRCLE NO. 254

PC board racks built with do-it yourself kit


A "do-it-yourself kit" for prototype PC board racks contains side plates and support rods, card spacers and guides and connector brackets. Side plates can be adjusted to accommodate cards 3 to 4-1/2-in. high, with card guides 3 to 6-in. long in 1/2-in. increments. Support rods may be cut off to rack lengths up to 19-1/2-in. Aluminum or plastic spacers permit any center line dimensioning from 3/8-in. up.

CIRCLE NO. 255

Cut-and-form pliers for component leads

Henry Mann Co., P. O. Box 104, Cornwall Heights, Pa. Phone: (215) 639-4048. P&A: $15; stock.

Accurate "one-shot" forming and cutting of component leads is easy with this pair of pliers. The single cut-and-bend pliers has Delrin jaws to eliminate scratching, nicking or flattening of lead wires (there is no metal-to-metal contact). The pliers have cushion grip handles and a return spring. Replacement jaws are available.

CIRCLE NO. 256

Couched relays?

Use Couch 1/7-size Relays

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CIRCLE NO. 256
REEVES-HOFFMAN

"chips" away at the space problem with new COLD-WELDED CRYSTALS

Reeves-Hoffman's newest series of crystals, packaged in cold-welded TO-5 transistor cans, are designed for operation at frequencies from 3 to 125 MHz. Frequency tolerance over the temperature range from -55°C to +105°C is ±0.004%. (Upon special request, ±0.0025% can be provided.) Shock and vibration ratings exceed the requirements of MIL-Spec 30980. Aging at 65°C is 6 parts in 10⁶ per year.

Cold welding eliminates solder and attendant flux and heat, removes undesirable damping and corrosion, solves problems of thermal isolation. Leak rate is better than 10⁻⁹ cc of helium per second. The results: substantial increases in the reliability and stability of crystal units, oscillators and filters; further opportunity for miniaturization.

For example, by using microminiature circuitry "chips," it is possible to produce a cold-welded crystal oscillator that occupies the space normally used for the crystal alone. The oscillator shown at left, for example, is in the A-4 holder shown below. Can this new micromodule technique solve space problems for you? We invite your inquiry.
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CLARY MODEL AN16
Alpha-Numeric Strip Printer for Digital Systems
— with all of these features:
- COMPACT only 78 cubic inches
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- ONLY 14 MOVING PARTS
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- WEIGHT, less than 4 pounds
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- TAPE CAPACITY 75 feet
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CLARY CORPORATION
MILITARY PRODUCTS DIVISION
320 West Clary Avenue • San Gabriel, California 91776
Phone (213) 287-6111 • TELEX 674604

X-band switches have 10-ns rise and fall

Broadband solid-state spst switches have 10-ns rise and fall times and are useful from dc to 12.4 GHz. Insertion loss is 0.5 to 2 dB and isolation is 20 to 45 dB. The HPA 3540 switch consists of two oxide-passivated silicon pin diodes integrated into a broadband 50-Ω structure for use in 50-Ω stripline. Switching is accomplished by changing conductor bias.

CIRCLE NO. 257

MICROWAVES
(continued from p. 140)

Cast bends speed waveguide assembly
Datapulse Inc., Demornay-Bonardi Div., 1313 N. Lincoln Ave., Pasadena, Calif. Phone: (213) 681-7416. P&A: $5.50 (X-band); stock.

Interlocking cast bends featuring a "corral" design are snapped together to speed assembly of waveguide systems. The need for waveguide sections between bends is eliminated. Aluminum and beryllium copper types are available in 30°, 45° and 90° for E and H planes. Vswr is 1.06 max and insertion loss is 0.2 dB.

CIRCLE NO. 258
Phase shifters use flux transfer for low VSWR

Applying the principle of flux transfer, X-band phase shifters have extremely low insertion loss (0.06 dB) and low VSWR (1.2). The units are for use in phased-array radar where thousands of little dipole antennas are fed from a common source through the phased devices to obtain the sweeping action of a moving antenna.

The driver (control) circuit is part of the assembly. In operation, the shifters are signaled to a particular phase shift, remaining at that shift even though control power is removed. They must then be forcibly re-zeroed prior to applying a new phase shift command. The driver circuit must, therefore, match both the phase shifter control characteristics and the characteristics of the input command signal. The 2003X can handle 2 kW peak power and 20 W cw without cooling. C and S-band units are available.

CIRCLE NO. 259

Folding filter saves component space
I-TEL Inc., 10504 Wheatley St., Kensington, Md. Phone: (301) 946-1800.

Length is said to be the only important specification affected by folding a new microwave filter. With a unit weight of only 18 grams, the filter is specially designed to fold in the center as a convenience feature. Units are available in ranges from 60 MHz to 1 GHz. Special mounting can be provided and most common connector types are available.

CIRCLE NO. 260

High-sensitivity limiter has 100-ps recovery

The 100-ps recovery time of this UHF limiter is 100 times faster than that of existing solid-state limiters. In addition, limiting threshold (1 db above insertion loss at 0 dBm) is 10 times more sensitive. This combination compresses ns spikes to protect mixer diodes and insures instant response to low-level signals. Over 450 to 1050 MHz, insertion loss is less than 0.3 dB and isolation is 13 dB at 25 dBm input.

CIRCLE NO. 261

Coaxial attenuator operates dc to 6 GHz
Micron Electronics Inc., Roosevelt Field, Garden City, N. Y. Phone: (516) 741-4480. P&A: $68.75; 4 wks.

Power rating of the AT-00-1000 precision fixed coax attenuator is 1 W. Power surges to 2 kW can be handled by the 50-Ω unit with an operating range of dc to 6 GHz. Standard values are available at 1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30 and 40 dB. VSWR is rated at 1.1 to 1.3 through 6 GHz. Unit measurements are 1.245 x 0.5-in. diameter.

CIRCLE NO. 262
IF YOU CAN'T IDENTIFY THIS

IT'S NO WONDER, because you've probably never seen fiducial marks generated this way before.

HOW COULD YOU?
We used the TRW Model 46A Trigger Delay Generator, just coming on the market. It's brand new, with some inherited virtues of its predecessor, TRW Model 2A — nanosecond accuracy, high power trigger to override random noise, clear digital display, selectable triggering threshold — plus plug-in capability so you buy exactly the triggering input you need, exactly the sensitivity and spectral range your application calls for.

ASK US FOR A TECHNICAL DATA BULLETIN AND APPLICATION NOTES giving the characteristics of the TRW Model 46A and the plug-ins, and illustrating how you can use the TRW Trigger Delay Generator, as we did, to generate fiducial marks, to measure delay lines, calibrate oscilloscopes, and trigger the TRW Image Converter Camera or countless other laboratory instruments.

TRWINSTRUMENTS
139 Illinois Street, El Segundo, California AC 213, 679-9101 Extension 22884.

Developers and manufacturers of state of the art diagnostic instruments for basic and applied research.

ON READER-SERVICE CARD CIRCLE 824

Decapsulant removes epoxy nondestructively
Henry Mann Co., P. O. Box 104, Cornwells Heights, Pa. Phone: (215) 639-4048. P&A: $10/quart to $18/gallon; stock.

Cured epoxy or other thermosetting resins may be removed from encapsulated components without damaging them or corroding the metallic connections and lead wires. “Decap” causes the epoxy to flake off the component. Heat may be used as a catalyst. The solution may be re-used 3 to 4 times if the residue is filtered out.

CIRCLE NO. 263

Semi-rigid 50-Ω coax has 8-mil OD
Uniform Tubes Inc., Collegeville, Pa. Phone: (215) 489-7293.

Subminiature 50-Ω coax is designed for use in high-density circuits, particularly in computers, where complete RF shielding is necessary. The cable has an 8-mil solid jacket of drawn copper tubing and is flexible enough to bend on a 1/16-in. radius. Center conductor is 2-mil copper and insulation is Teflon. Capacitance is 29.3 pF/ft. The cable is available in lengths to 10 ft.

CIRCLE NO. 264

Nailhead diode lead eliminates preform discs
Alpha Metals Inc., 56 Water St., Jersey City, N. J. Phone: (201) 242-3320.
Replacing four parts with two in the manufacture of diodes, a solder-coated “nailhead” lead is said to eliminate the need for preforms between the lead and the chip. This process also insures that the solder completely coats only the head, preventing both “dry” and “shorts” due to too little or too much solder. Also, the absence of flux means a reduced chance of contamination.

CIRCLE NO. 265

High-temperature epoxy withstands 500°F
A two-part potting and encapsulating epoxy system is designed for high-temperature use. Where use temperatures are in the 400 to 600°F range, a step-wise cure yields optimum results. “Stycast 2762” withstands a 700°F environment for a few hours and a 600°F environment for much longer periods without deformation. Weight loss at 570°F is 0.3% in 3 days.

CIRCLE NO. 266

Etch resist, coating from the same can
Alpha Metals Inc., 56 Water St., Jersey City, N. J. Phone: (201) 242-3320.
A non-activated resin-base etch resist doubles as a solderable protective coating in PC board manufacture. Etchcoat #934 is applied as an etch resist after degreasing and tarnish-removal. After etching, boards can be soldered at once or stored for extended periods without any further treatment. Typical cure time is five minutes at 93°C. The material is available in quarts, gallons, or five-gallon containers.

CIRCLE NO. 267

MATERIALS
Ask Aladdin for a QFS*  
We not only know how to design and build filters, we handle your problems in a businesslike, straightforward way.  
Here are the steps in the plan that goes into action as soon as you send us a description of your requirements.  
First, the feasibility study. A free service. It amounts to a computerized analysis that tells whether one of Aladdin's "standard" types will meet your specs, using stock components.  
Second, if the feasibility study is affirmative, you receive a quotation on a sample lot of Aladdin filters which will meet your specs.  
Third, along with your quote and before we even make the samples—a quote on production quantities just like the samples. In short, we are not going to hem and haw and weasel word our estimate of the quote, even on a prototype design we have never made before. You know before you test the samples that if they turn out to be what you want you have a firm price on production quantities.  
Fourth—if you order the sample lot—quick service ... because we combine stock components and hardware with Aladdin tailored inductance values.

*Quick Feasibility Study

703 Murfreesboro Road, Nashville, Tennessee
Syntronic Yoke Specialists have more yoke knowledge and provide more engineering assistance than anyone else in the field.

The most extensive line of deflection yokes available is offered by Syntronic... in production quantities or custom designed to special requirements. See the BIG Difference for yourself the next time you specify a yoke.

10-A dc source needs no heat sinking

Power Designs Inc., 1700 Shames Dr., Westbury, N.Y. Phone: (516) 333-6200. P&A: $245; 3 to 4 wks.

Requiring no external heat sinking or blowers, this 10-A unit supplies 3, 4, 5 or 6 Vdc. The unit operates from 0 to 60°C. Regulation is 0.01% ±2 mV, ripple is below 1 mV p-p and output adjustment is ±1/2 V of programmed value. Stability is 1 mV/8 hours, using a high-voltage, temperature-compensated zener voltage reference and an integrated differential amplifier input.

Electrostatic supply yields 100 kV

Giannini, 12140 E. Rivera Rd., Whittier, Calif. Phone: (213) 723-3371. P&A: $3000; 30 to 120 days.

A portable electrostatic generator provides 100,000 V at 300 µA. The portable (under 50 lbs) unit is a dc generator of the drum type and uses no electronic conversion. High stability options are available to provide ripple as low as 0.001% and drift of 10 V/hr. In this configuration, a load regulation is 1 V in 100,000 and 0.01% for a 5% change in line.

wind your coils on Thermoform

complete line of high temperature tubing

Thermoform tubing is a scorching solution to high temperature coil problems—up past 180°C.—self generated or environmental heat. Diabolically made from a variety of materials; asbestos, glass, mica, polyamide. Wickedly wound to meet your specifications. Tempted to investigate? Write for technical data.

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wind your coils on Thermoform

complete line of high temperature tubing

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Electrostatic supply yields 100 kV

Giannini, 12140 E. Rivera Rd., Whittier, Calif. Phone: (213) 723-3371. P&A: $3000; 30 to 120 days.
Most new high-power 20 kW FM transmitters use the EIMAC 4CX15,000A tetrode for service as a Class-C amplifier. The tube features a new internal mechanical structure which minimizes rf losses, and is capable of operation at full power ratings to 110 MHz. EIMAC also recommends the 4CX15,000A for 220 MHz operation at lower power levels for VHF-TV transmitters. EIMAC's long experience in tube technology and ceramic-to-metal sealing leadership have combined to produce a tetrode of optimum design and structural integrity. That's why the 4CX15,000A is used in more new transmitters than any other ceramic tetrode with similar characteristics. For more information write Product Manager, Power Grid Tubes, or contact your nearest EIMAC distributor.

EIMAC Division of Varian
San Carlos, California 94070

15 kW tetrode offers high power gain for advanced transmitters

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<th>RADIO-FREQUENCY POWER AMPLIFIER OR OSCILLATOR</th>
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ON READER-SERVICE CARD CIRCLE 828
Offered only by api

API is the only manufacturer who offers ±1% tracking and frictionless taut-band construction as standard specifications for production-quantity meters, at no extra cost.

Precise tracking is the most useful attribute of a panel meter in modern electronic applications. Taut-band meters give truer readings, respond to smaller signals, resist damage from shock or vibration and do not deteriorate in operation.

Order from Stock

Best of all, API also offers quick delivery from stock of DC panel meters with the double-header bonus of taut-band plus 1% tracking.

You get all this in the most popular ranges of nine models in API's economically priced Stylist and Panelist lines (illustrated). Take your pick of these full-scale DC ranges:

<table>
<thead>
<tr>
<th>Microamperes</th>
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<td>0—20</td>
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<tr>
<td>0—50</td>
<td>0—10</td>
</tr>
<tr>
<td>0—100</td>
<td></td>
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</tbody>
</table>

(You also get the double header in the 0-25 millivolt range, but it isn't stocked.)

If precise tracking is a real fetish with you, don't forget that API can give you 0.5% tracking at reasonable extra cost. No other manufacturer features this "super-calibration" and backs it up with catalog prices.

Bulletin 47-A describes all API panel meters and pyrometers

api INSTRUMENTS CO.
CHESTERLAND OHIO - PHONE 216-423-3131

Sensitivity, noise figure rule

Receiver sensitivity and noise figure can be calculated using this slide chart. By choosing a video bandwidth from 0.01 to 1000 MHz, equivalent bandwidth for a quadratic detector or linear detector and corresponding radio bandwidth is found. For a tangential sensitivity between -120 and -20 dBm or 0.1 to 10,000 µV, noise figure is given for quadratic or linear detectors which range from 0.01 to 1000 MHz. HRB Singer, Inc.

CIRCLE NO. 270

CATV cable calculator

Seven scales determine attenuation and dc resistance for CATV cable on this three dial/cursor circular slide rule. Attenuation scales determine attenuation at any frequency, at any given length or at temperatures (-60 to 140°F) other than 70°F. Resistance scales determine dc resistance for any given length of a given cable. The reverse side of the calculator is complete with instructions for operation and sample problems and solutions. Jerrold Electronics Corp.

CIRCLE NO. 273

Power supply design

This guide is aimed at designers of system power supplies. In addition, it is intended to aid in writing specs that are free from loop-holes and "bugs." The cost factor is covered and suggestions are offered for minimizing expense. Circuit and block diagrams aid in the discussion. Trio Laboratories, Inc.

CIRCLE NO. 274

Arc welding handbook

The "Miniature Precision Arc Welding Handbook" describes the application of tungsten inert gas arc welding to the joining of small and thin electronic parts. The 54-page handbook illustrates typical applications of miniature precision arc welding and provides basic arc welding theory. Materials suitable for the process are discussed. Costs are considered and compared to other joining processes.

Available for $1 from Precision Arc Co., 785 Woodend Rd., Stratford, Conn.
TO PROVIDE a microcircuit systems approach adaptable to breadboarding, small quantity and production runs

- all-new, highly competitive prices
- built-in drivers, inverters and buffers eliminate most interconnecting wiring
- up to 18 microcircuits per card enable high density and lower costs
- boards designed to meet MIL- and NASA standards
- boards keyed to assure proper mounting
- dual in-line packages easily replaced for ease of maintenance
- off-the-shelf delivery

The Vitro microcircuit systems approach is directly adaptable to a broad range of requirements. Whether the application be for breadboarding, one-of-a-kind units or total production runs, Vitro Micromodules are designed to provide the systems engineer with a low-cost, flexible, building-block approach to designing an integrated-circuit system.

The logic implementation on all Vitro boards has been standardized for positive NAND logical functions at a voltage swing from 0 to +3 volts. The diode-transistor logic devices employed have individual circuit speeds up to 10 MHz, and equipment speeds above 5 MHz. These circuit boards can be provided as directly off-the-shelf logic, with standardized performance to simplify a logic design application, or can be custom-built according to customer specifications. High density packaging is utilized providing up to 18 removable microcircuits on a single card. Ease of maintenance is assured since all dual in-line circuit packages can be easily removed and replaced in the field. To further simplify maintenance, Vitro-supplied chassis configurations are constructed of standard components assembled on a building block principle.

For further information on the complete line of Vitro microcircuits, mounting hardware, card files, wiring accessories, and power supplies, contact the Micromodule Sales Department, VITRO ELECTRONICS, 919 Jesup-Blair Drive, Silver Spring, Maryland 20910, Phone No. (301) 585-1000.
Bypass your EMI/RFI packaging problems by selecting from ten standard front panel sizes, each quickly available in six enclosure depths, from 12" to 27". These sixty standard EIA shielded and vented enclosures are provided with removable top and bottom covers, front and rear panels. Every shielded enclosure features standard EMI/RFI-tight vents. All cover and panel seams are EMI/RFI gasketed. Captive fasteners and screws are included, properly spaced to insure effective shielding. The standard enclosures readily accommodate slides for drawer installation. Call or write today for data sheets, parts information and EMI/RFI shielding effectiveness reports... save valuable time in your design and procurement activities.

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City ____________________________ State ____________________________

ON READER-SERVICE CARD CIRCLE 885

Application Notes

Piezoelectric Accelerometer

Want to know all about piezoelectric accelerometers, how they work and their applications?

"The Piezoelectric Accelerometer Users Handbook" a 24-page publication put out by the Consolidated Electrodynamics Corp., Pasadena, Calif., is said to be one of the most comprehensive in the field.

A piezoelectric accelerometer, according to the company, is essentially a transducer that converts mechanical forces, such as vibration, pressure and acceleration, into electrical energy.

The device consists basically of a crystalline material—quartz, lead zirconate or lead titanate—that generates a charge when force is applied. The incorporation of a mass in direct contact with the crystal produces an acceleration transducer. When a varying acceleration is applied to the mass-crystal assembly, the crystal is subjected to a varying force (F-Ma) that causes a changing electrical charge across the crystal, or

\[ q = dF - dMa, \]

where \( d \) is the piezoelectric constant. Thus the electrical charge (\( q \)) is directly proportional to the acceleration of the transducer.

According to the company, piezoelectric transducers are superior to other types of vibration-measuring devices in key areas. They are described as:

- Self-generating.
- Of wider frequency response.
- Without phase shift in the frequency range of interest.
- Of small size.
- Providing an electrical output directly proportional to acceleration.

The handbook presents an evaluation of current design, materials, theory and the applications of low-impedance piezoelectric accelerometers. The amplifier requirements of conventional high-impedance piezoelectrics are also covered. Included are associated diagrams, curves, useful formulae, and definitions of terminology.

CIRCLE NO. 277
No one has a larger line of disc memories.

See the largest line of disc memories available at the Spring Joint Computer Conference, Booth 913-916

Whether your information storage requirements are small or require data stored in millions of bits, Librascope Group of General Precision, Inc., has a disc memory system for every application. These systems have a proven history of reliable performance in computing systems designed for military, business, engineering, and educational applications.

LIBRAFILE mass memories: Large-capacity, high-speed, random-access information storage systems. Two disc sizes available. 48" discs capable of storing up to 400 million bits. 38" discs with a capacity of 200 million bits. LIBRAFILE mass memory information retrieval is either fixed-address search or search-by-record content. Access time less than 20 ms. Data transfer rates in the megacycles.

Militarized disc-memory systems: High-speed, random-access, information-storage systems. Consists of disc memory for data storage and an electronic subsystem that provides complete interface, control, and read/write electronics. These systems can be used as a data base for shelter, van, or shipboard applications. Storage capacity of 25 million bits on 24" discs. Customized capacity up to 80 million bits.

L-400 magnetic-disc memory systems: Provide data storage and transfer in computer systems, peripheral equipment, and other systems where rapid-access memory is a requirement. 24" disc storage capacity up to 36 million bits.

Airborne disc file: Small, compact file designed for airborne (MIL-E-5400 class 2) applications, as well as for shipboard and mobile field operations. 61/4" disc with capacity of 1 million bits. Customized airborne memories available with capacity up to 50 million bits.

L-300 disc memory: For use in computer systems and peripheral equipment as main storage, buffer storage, or as a supplemental memory. 10" disc with a capacity of 275,000 bits. For complete details, write for our technical bulletins.

Engineers: For career openings, call or send resume in confidence to B. Larson, General Precision, Inc., Librascope Group, 808 Western Avenue, Glendale, California 91201. An equal opportunity employer.

A Plans-for-Progress Company.
Radio electronics catalog
Lafayette's 1966 Christmas gift catalog covers the latest in electronics and stereo hi-fi equipment. A complete selection of stereo hi-fi components, citizen band 2-way radio, tape recorders, ham gear, test equipment, radios, TVs and accessories are included. Lafayette Radio Electronics.

CIRCLE NO. 278

Plastic semiconductor lines
A broad line of plastic-encapsulated economy semiconductors is described in this 12-page booklet. The data covers product characteristics, applications, advantages and typical uses for commercial, military and industrial purposes. Among the devices described are silicon and germanium bipolar and field-effect transistors, unijunction and power transistors, silicon rectifiers and monolithic ICs. Texas Instruments Inc.

CIRCLE NO. 279

Ceramic disc capacitors
Full specifications and selection tables describing ceramic disc capacitors are offered. The types include temperature compensating 500-Vdc, general-purpose high-capacitance 12 and 30 Vdc, by-pass coupling 50 Vdc and by-pass coupling 500 Vdc. Nucleonic Products Co.

CIRCLE NO. 282

IC digital assemblies
This portfolio of data sheets details a line of DTL IC logic assemblies. Included in the folder are basic NAND gates and J-K flip-flops, binary-to-octal, binary-to-hexadecimal, and BCD-to-decimal decoders, BCD and binary up-down counters and shift registers and arithmetic/logic circuits. Cambridge Thermonuclear Corp.

CIRCLE NO. 283

Semiconductor procurement
The 1966-67 semiconductor procurement directory is a 12-page booklet covering more than 6000 of the popular types and brands. Prices listed are, in most cases, below prevailing factory prices. MIL-type diodes and transistors are also included. Corvair Electronics, Inc.

CIRCLE NO. 284

Electron tube catalog
Containing descriptions and basic specs of the full line of Amperex tubes, this catalog serves as a quick reference guide for OEM designers as well as for replacement tube buyers. The full line consists of power tubes, thytratrons, subminiature tubes, entertainment and audio tubes, tuning indicator tubes, uhf special purpose tubes, rectifiers, diodes, counting, selecting and indicating tubes, CRTs, ignitrons, voltage reference and regulator tubes, vidicon tubes and cold cathode indicator diodes. An insert covers pulse magneto- trons, continuous wave magnetrons, BWOs, klystrons, disc-seal triodes and TWTs. Amperex Electronic Corp.

CIRCLE NO. 285

Scientific equipment
New, surplus, hard-to-find and desirable items for optical, mechanical and electrical use are covered in this catalog. New and interesting among the 4500 items in the 1967 catalog are plastic fiber optics light guides, holograms, and a solid-state thermoelectric cooling system. Edmund Scientific Co.

CIRCLE NO. 286

RF terminations
This 4-page short form catalog covers RF coax load resistors. The brochure lists a line of dry and oil-cooled terminations ranging from 5 to 600 W. Bird Electronic Corp.

CIRCLE NO. 287

Electronic kits catalog

CIRCLE NO. 288
Get immediate delivery of P&B Precision Switches from authorized P&B distributors*
Factory Prices too

Your authorized P&B switch distributor has a wide variety of P&B precision snap-action switches on his shelves. You can get immediate delivery at factory prices. Included are general purpose, miniature and subminiature switches in a wide choice of actuators, contact arrangements and terminations. Most are directly interchangeable with competitive types. All meet U/L and CSA requirements. Mounting dimensions and materials meet military specifications.

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time / delay / relay

All these proofs (meeting MIL specs) mean miniature AGASTAT pneumatic time/delay/relays remain accurate under the most rugged operating conditions. Environmental hazards can't foul these AGASTAT timers, because they're hermetically sealed.

Tight squeezes don't cramp AGASTAT timers—they measure only 1 1/2" square by about 5" long, weigh only 16 ozs.
Voltage changes, temperature changes or transients can't fool them—their timing action is pneumatically controlled. (Pneumatic timing also means you get instant recycling, with full delay periods regardless of how often the cycle is interrupted before relay "times out." And because timing is pneumatic, it can even time without electric power!)

Another advantage is an exclusive dial head that lets you make simple, but accurate, linear adjustments over the full timing range of each unit with just a single revolution of the adjustment screw. (Nine timing ranges cover a total span from 0.03 second to 3 minutes.)

AGASTAT timers are available with delay on pull-in or drop-out or both in one unit. You can also choose from a wide selection of mounting and terminal styles. They operate on all popular ac or dc voltages.

Send for our catalog.

Semiconductor specifications

Over 1500 pages of up-to-date information, including 16 edge-referenced sections containing complete data sheets for more than 2800 devices from diodes to ICs, are contained in this hard-bound volume. In addition, the general information section boasts short-form specs for more than 10,500 EIA-registered 1N, 2N and 3N devices. The index identifies the semiconductors by major application and gives the type numbers of recommended replacements. The data sheets are arranged in 12 sections, each prefaced with application-oriented quick selection guides. Application notes in the last section are outlines of general design procedures, rather than specific circuits.

Available for $3.95 from Technical Information Center, Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix.

Solid-state sidelights

The latest issue of the "Tip-Off," the second in a series entitled "The Semiconductor Story," contains a background of the development of the "Solid State Age." The 8-page note details early innovations and presents glimpses into the lives of early experimenters such as Armstrong, deForest and Pikard. The issue includes charts, diagrams and photographs of early equipment and the men responsible. Schweber Electronics.

CIRCLE NO. 289

Electronic Design 25, November 8, 1966
Light source reference guide

A new 6-page color product reference guide covers a line of lamps, power supplies and related equipment. The publication gives general and technical information on short arc, capillary and flash lamps, power supplies, pulse generators and lamp housings. The brochure also provides applications information. Pek Labs Inc.

Basic timer principles

“Magnetic Timer Principles” is a 12-page booklet discussing magnetic materials and timer components. A companion 8-page booklet discusses the manufacturer’s magnetic core counter timer. The bulletin analyzes diamagnetic, paramagnetic and ferromagnetic materials and associated magnetic field effects. It illustrates and describes the basic components required for a magnetic time delay relay and compares magnetic and RC units. Finally, it discusses various applications, both simple and complex, for magnetic timers. ESNA, Agastat Div.

Tape data charts

Typical properties of 41 different tapes are listed in this electrical tape data and sample chart. The chart includes sample strips of each tape and includes such information as thickness, tensile strength, elongation adhesion, electric strength, temperature class, insulation resistance, electrolytic corrosion factor, MIL-spec and cost. 3M Co.

hp 465A, 467A Amplifiers

465A Solid-State General-Purpose Amplifier:
- High power gain (5x10^4); voltage gain selectable (10 or 100)
- Bandwidth 5 Hz to 1 MHz (<2 db down)
- Gain accuracy ±0.1 db (1%) at 1 kHz
- 10 megohm input impedance, true 50-ohm output impedance
- Low noise <25 µv rms referred to input (1 meg across input)
- Output 10 v rms open circuit, 5 v into 50 ohms
- 3-terminal device isolated from chassis, float up to 500 v dc above chassis ground

467A Power Amplifier:
- Gain X1, X2, X5, X10 plus variable control
- Accuracy ±0.3 %, dc-10 kHz with load of 40 ohms or greater
- Distortion <0.01 % at 1 kHz
- Frequency response ±1%, dc-100 kHz ±10% dc-1 MHz
- Output: ±20 v peak at 0.5 amp peak (10 w)
- Also use as -20 to +20 v variable, regulated dc power supply

Here are two high-performance amplifiers for a multitude of applications. Use the 465A as a general-purpose lab instrument, an oscilloscope preamp, an in-system amplifier component, power amplifier for solid-state oscillators, impedance converter, ideal for cascading, compact, light weight, hp 465A, $190.

Use the 467A to drive magnetic cores, ultrasonic transducers, recording galvanometers, servo motors, or to amplify oscillator inputs, as a dc power supply. Protected from short circuits or input overloads to 200 v p-p. hp 467A, $575.

Call your Hewlett-Packard field engineer for complete specifications, or write Hewlett-Packard, Palo Alto, Calif. 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

Data subject to change without notice. Prices f.o.b. factory.
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1. Inexpensive
2. Small
3. Adaptable
4/5. In Stock

Five words will tell you quite a bit about Min-Econ Amplifiers . . . but not the whole story. For instance, "In stock". That actually means 17 models sitting on the shelf. When you call in your order . . . it goes out the same day. "Small" . . . these are all 1 1/4" high x 2 1/4" wide x 3 1/4" long. That's small! "Inexpensive" . . . prices range from $65 to $195. "Adaptable" . . . there are 17 basic models with many standard modifications. These are not "flea power" devices, as are so many so-called "amplifier modules". These are silicon, solid-state amplifiers, built to do a job. Check EEM for our Short Form Catalog. If you don't see what you need, call us or your nearest C-COR representative, for the whole story and detailed data sheets . . . and place your order. Min-Econ is the perfect solution for laboratory, breadboarding or systems amplification.

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NEW LITERATURE

Thumbwheel switch catalog
This 54-page thumbwheel switch catalog has complete technical data on a line of switches. Codes and electrical output configurations, dimensional sketches, standard performance specifications, prices and typical applications are included. Digitran Co.

CIRCLE NO. 293

Gas discharge noise sources
History, fundamentals, characteristics and applications information on gas discharge noise sources are summarized in this 16-page brochure. Included in the brochure are definitions of noise sources and noise generators, as well as a brief history of noise source measurements. Discussions on noise power, excess noise ratio calibration, methods of operation and microwave characteristics are accompanied by applications photos, circuit diagrams, noise vs noise source graphs and tube drop vs tube current graphs. Signalite Inc.

CIRCLE NO. 294

Radio/TV equipment
The need for consumer education in TV/radio and other home entertainment equipment has mounted. This booklet, in clear and uncomplicated terms, states that there is more to TV/radio than just buying it and putting a plug into a wall socket. The 12-page brochure goes on to answer many of today's common questions. NATESA.

CIRCLE NO. 295
Magnetic components folder

"Magnetic Components for Commercial and Aerospace Applications" is a 6-page folder covering components such as power transformers, inductors, saturable reactors, audio transformers, pulse transformers and coils. Transonic Inc.

CIRCLE NO. 296

Radar test equipment

Typical radar test and simulation equipment is described in this 2-color folder. The equipment is designed for military tactical use, aerospace operations support, radar system design evaluation and operator training. Canoga Electronics Corp.

CIRCLE NO. 297

Custom power supplies

Custom-designed power supplies are described in this 24-page brochure. The bulletin includes examples of design, prices, specs, photographs and products. In addition, the brochure contains a glossary of electronic terms. Sola Basic Industries.

CIRCLE NO. 298

Rotating servo components

A 100-page catalog gives specifications, performance and application data, schematics and dimensions of a comprehensive line of rotating servo components. Included are servo, stepper, and synchronous motors, motor/generators, gear trains, synchros, and resolvers. Most components are listed in sizes from 5 to 23. Harowe Servo Controls, Inc.

CIRCLE NO. 299

TV/FM distribution gear

A full line of all-channel, all-solid-state distribution equipment is covered in this catalog. The booklet includes amplifiers and preamps, vhf, uhf and FM, mixing networks, tap-offs, splitters, filters, cable equalizers, terminating units, attenuators, matching transformers and low-loss cable. Jerrold Electronics Corp.

CIRCLE NO. 300
Here is a realistic approach to a problem that has long plagued the communications engineer: electrical interference. This practical guide to minimizing and controlling electrical interference shows the entire field as a unified discipline. After demonstrating how interference control is introduced in the design of equipment, the author goes on to develop the best practices necessary to contain interference. But the most important new advance in this book is that it takes the system viewpoint, the approach that the electronics industry feels is best. Now the reader can have at his fingertips all the basic information necessary for the solution of problems encountered in designs ranging from a small radio receiver to a large missile system.


256 pages Clothbound, $8.75

NEW LITERATURE

Capacitor catalog

Marshall's major capacitor series and styles are summarized in this catalog. These include metalized mylar, metallized polycarbonate, mylar and foil, polystyrene and foil, metallized paper and ceramic capacitors. Standard styles include wrap-and-fill, epoxy case radial and axial lead, and hermetic seal round and rectangular. General specs, performance curves and environmental data are given along with parametric trend curves and acceptance criteria. Marshall Industries.

CIRCLE NO. 301

"How-To" electronic library

The first 12 volumes in a library of "How-To" electronics books includes titles such as "Diodes," "The Volt-Ohm-Milliammeter," "Basic Alternating Current," "How To Read Circuit Diagrams," "Basic Electronics Math," "Handbook of Transistor Circuits," "Learn Electronics In 5 Minutes, 37 seconds," "The Oscilloscope," "The Vacuum-Tube Voltmeter," "Elements of Electronics," "How To Use and Enjoy Your Tape Recorder" and "Practical Radio." The library will consist of 103 books when it is completed.

Available for $1.25 each from IRC Inc., 414 N. 13th St., Philadelphia.

Indicator lights

Data, drawings and catalog numbers for the company's subminiature and miniature indicator lights are included in this catalog. Also given are lamp selection charts for the lamps employed by these indicators. Also included is a discussion of the safety factors provided by the assemblies and the mechanical shutter dimming available with various units. Dialight Corp.

CIRCLE NO. 302
Relay catalogs

Mercury-wetted contact relays are covered in a 22-page catalog. Dimensional diagrams and photos accompany descriptions of epoxy and encapsulated types, polarized and sensitive or bistable types. The second catalog covers mercury displacement relays. Information includes applications, selection factors, construction features, dimensional drawings, and performance characteristics of time delay and load units. Adams & Westlake Co.

Technical information service

This brochure describes its publisher's information services, available in cumulative or journal form. Technical information from journals, books, magazines, research reports, conference proceedings, patents and theses are continually scanned and abstracted for the solid-state, electronics and computer fields. Subject areas are divided into categories and sections, all of which are described along with their subscription charges. Cambridge Communications Corp.

Ge transistor applications

A comprehensive "Germanium Transistor Application Guide" lists over 130 transistor types. The guide keys individual transistor types to product family, performance range and specific circuit application. General Instrument Corp.

Printed circuit products

Over 20 product families are described in this 60-page guide. Detailed specs, plus application and dimensional data, are included for two-piece connectors, card-edge connectors and single-lead connectors. Complete packaging concepts such as modular interconnection systems, cellular packaging techniques and reusable component receptacles are explained. Hand tools for maintenance and production of interconnection systems, as well as automatic and semiautomatic production machinery are also described. Amp Inc.

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- Full-Range Variable Supplies
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SUBSIDIARIES: ERA Electric Co. • ERA Acoustics Corp. • ERA Dynamics Corp. • ERA Pacific, Inc.

ON READER-SERVICE CARD CIRCLE 892

Electronic Design 25, November 8, 1966
Diode reliability

Gallium arsenide hot carrier diode reliability is discussed in a 4-page report. The results of GaAs hot carrier diodes tested for 2000 hours at 150°C are given. International Semiconductor, Inc.

CIRCLE NO. 104

Reprints Available

The following reprints are available free and in limited quantities.

To obtain single copies, circle the number of the article you want on the Reader-Service Card.

Hall Effect Multiplier Simplifies Poplar Display (No. 307)
Keeping a CRT's Spot on Focus (No. 308)
Designers Challenge (No. 309)

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Universal continuous process systems can combine almost any functions—with a big advantage in labor savings. This new 20-page bulletin illustrates how to feed raw materials...assemble...coat...test...sort...code and package finished axial lead components automatically. By combining processing steps into complete systems, Universal enables you to maintain physical control from one function to the next. Standard modules can be combined with customized units for systems designed to meet special requirements. Send for this valuable engineering reference.

Universal Instruments Corporation
E. Frederick St., Binghamton, N.Y.
(607) 772-1710

Piezotron® Quartz Accelerometer

Four-page illustrated Bulletin 321466 on Model 818 quartz accelerometer describes Piezotron principle which eliminates need for costly amplifiers and permits use of just one single-wire shielded cable for both power and signal. Bulletin also describes how base strain sensitivity problem is prevented. Diagrams of the basic circuit and a typical system show operation. Performance data is graphically displayed. Complete specs and ordering information are included.

Kistler Instrument Corporation
8969 Sheridan Drive
Clarence, N.Y. 14031

Free Semiconductor Data Book

Free only from Schweber Electronics with each 250 dollar purchase of semiconductors, a valuable data book that will enable you to SELECT the one unique device for your design, rather than SETTLE for a stereotyped compromise. A durable, cloth bound book of 1526 pages. Thoroughly indexed for easy reference, from zener diodes to integrated circuits, plus more than 100 pages of application notes. Every engineer has been waiting and hoping for such a book to come along. Don't miss it.

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