A McGraw-Hill Weekly *75 Cents* *July 5, 1963*

electronics®

NEXT FOR MICROWELDS: LASERS OR ELECTRONS?

Lasers have a chance to get to work, also competition, p 23

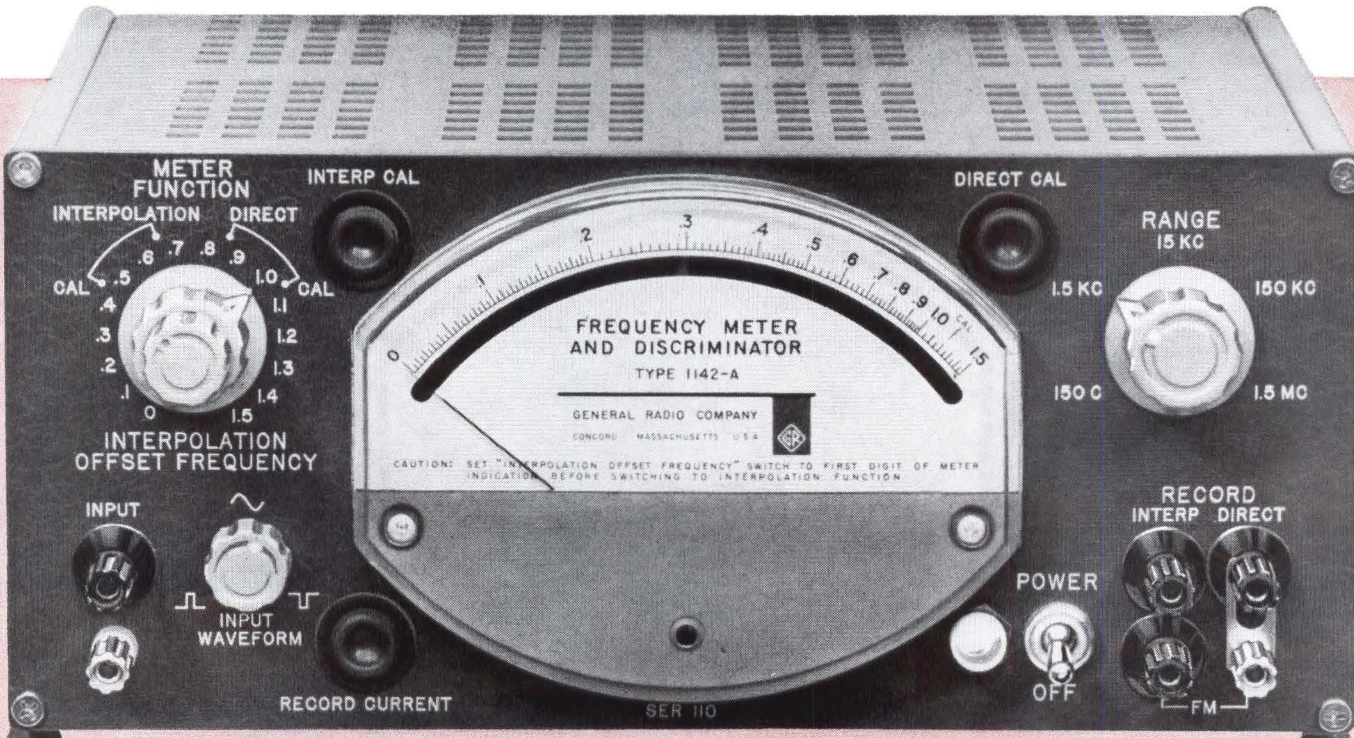
FLYING THE HYDROFOIL

Special controls make high-speed craft practical, p 14

THESE TINY NEEDLES *now orbit the earth as Millstone Hill transmitter bounces signals across the continent*

0.2% Accuracy in an Instrument with a Meter?

Sounds impossible but it's true. Of course there's a little trickery involved . . . but it's honest. We've moved the first one or two digits off the meter and put them on a switch, and thereby let the meter do the fine work — the interpolating. The switch (marked Interpolation Offset Frequency) controls a precise 0.05% voltage divider connected across a highly linear frequency discriminator. The meter (accuracy, 1% of reading) simply reads what's left over. This technique lets you read up to three significant figures without eye strain. Pencil and paper will soon show you that this procedure gives you an accuracy of better than 0.2% of full scale.



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July 5, 1963

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Contents Continued

electronics

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CONTENTS continued

DEPARTMENTS

Needles No More

FEW SCIENTIFIC experiments have caused the ferment in high places generated by Project West Ford.

The launching of an orbiting belt of resonant dipoles to test the feasibility of orbital scatter communications so agitated astronomers—prior to the fact—that it finally took a White House decision to go ahead (p 7, Aug. 25, 1961).

West Ford has been the subject of debate in the British House of Commons. And the Russians have topped off their crusade against it with a complaint to the United Nations.

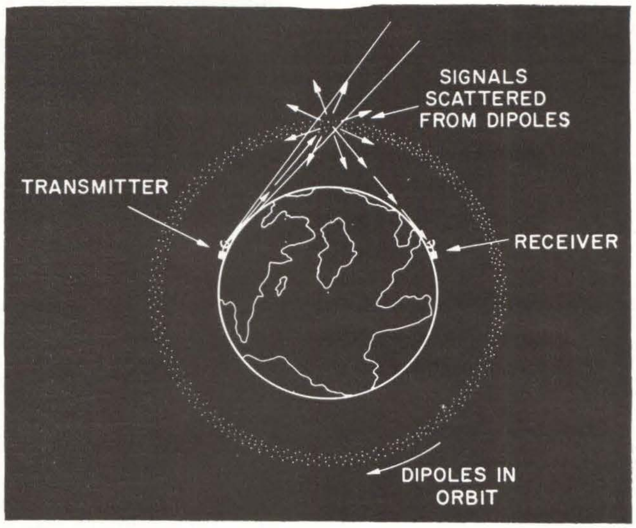
In the House of Commons last May, an MP suggested that the Prime Minister ought to seek to prevent "a cold war in space involving the distribution of haberdashery all over the place."

The "haberdashery" is an allusion to the name Needles with which, unfortunately, the project was originally tagged. The copper dipoles are more like strands of red hair, almost diaphanous, and in no way suggesting the metallic rigidity and sharp-pointedness of needles.

The historical derivation of this name, however, is in itself an interesting commentary on the technological advances achieved since the "Needles" Project was conceived. And, indeed, the technological advances were force-fed by this X-band communications project.

Five years ago, few envisaged klystron tubes that could put out 40 Kw at 8 Gc, but today such tubes are operating at the West Ford terminal in Pleasanton, Calif. Since the length of reflecting dipoles must be one-half the wavelength of the transmitted radiation to which they are tuned, researchers thought five years ago in terms of reflectors close to two inches long. And since the ideal dipole at that time was straight and stiff, naturally the first prototypes resembled needles. Work on X-band technology and on materials since then, however, have permitted the use of fine-texture, pliant, hair-like dipoles 1.77 cm long which in no way resemble needles. West Ford, now the official Air Force name, is simply a two-word version of Westford, the Massachusetts town in which the eastern terminal of the transceiver system is located. The other is at Camp Parks in northern California.

Project West Ford is considered by some command-and-control experts as the one type of invulnerable, unjammable, indestructible communications vital for post-attack military needs. Pointing out that anyone can use the orbiting



belt, political economist Oskar Morgenstern suggests that probably we should even cooperate with the Russians "and build the Needles system together, so each of us could have a secure system and in addition always be able to communicate one with the other."

Some of the most persistent attacks on the idea have come from astronomers, optical and radio. This type of objection has persuaded the U. S. to restrict the project to an experimental belt of predictable lifetime until the effects on astronomy and space activities can be determined. Meanwhile, the clamor, particularly from British scientists, induced Nobel laureate Edward M. Purcell of Harvard to defend the project's usefulness. Purcell pointed out that the U. S. has conducted the experiment in a thoroughly responsible manner, announcing the proposal at least a year ahead of time for examination by the world scientific community.

Many inaccuracies have been reported about the project, some generated by a lack of knowledge of the technology involved, and some by a mistaken notion that it is wrapped in secrecy.

Actually, it is perhaps the most highly publicized activity ever engaged in by Lincoln Laboratory. And, as Adlai Stevenson told the U. N. in answer to a Soviet protest on West Ford: ". . . it has been discussed more thoroughly in advance than any other space experiment."

We have been covering West Ford developments, with an eye to both news and technical accuracy, since it was declassified nearly three years ago. For the latest, see p 12.

COMMENT

Satellite-Transmitted Cover

[Regarding your May 24] cover transmitted via the Relay satellite . . . I am impressed with the fidelity of the transmission and the article (p 51) on this experiment.

R. P. DUNPHY
Manager, Project Relay
Radio Corporation of America
Princeton, New Jersey

By Degrees

Good grief! As neither an MD nor a PhD in microbiology, your rating the latter as somehow inferior to the former (editorial, p 3, May 17) is like comparing apples and oranges. The same holds true for your inapt comparison of the two education degrees.

A PhD in microbiology indicates that its holder is interested, trained and creative in that field, as opposed to an MD degree, which recognizes the same qualities in another field.

But enough talk of degrees and awards and titles; if an engineer recognizes his shortcomings in one or more fields, the extension or late-afternoon courses, or company sponsored programs, can fill many of the gaps. They don't dish out fancy titles, but they do teach.

R. G. GOULD
Menlo Park, California

We do not mean to imply that any of the doctorates are inferior or superior to any of the others.

The distinction was that some of these degrees require a thesis based on original research, while others do not, and that the requirement of performing original research often presents an insurmountable obstacle to engineers employed in industry.

Negative Resistance IV

The letter from Mr. Wayne T. Sproull which appeared in your April 26 *Comment* (p 4) demands a few additional words. I feel that he has a very limited idea as to what is meant by the term "resistance."

As I understand Mr. Sproull, he would violently disagree with such terms as plate or collector resistance, since by definition they are dV_p/dI_p and dV_c/dI_c, respectively. There are many other conditions in which the resistance is, in truth, defined by dV/dI and not just V/I.

Since Mr. Sproull does admit that dV/dI can be negative, then we must concur that the resistance may also be negative.

We cannot limit the term resistance to those cases of pure linearity, but must be sure of what *type* of resistance concerns us. A given component might have an entirely different d-c resistance than its small signal resistance.

Proper use of negative resistance elements allows us to parallel equal magnitudes of positive and negative resistance to yield net infinite value.

I trust Mr. Sproull was not additionally irritated upon reading the new product story on our recently announced Negative Resistance Elements as it appears on page 94 of the same issue that contained his letter.

CARL DAVID TODD
Hughes Aircraft Company
Newport Beach, California

The first of several articles by Mr. Todd on the negative resistance element was in our May 31 issue (p 21); a second one will appear next week.

Motional Feedback

In part I of your interesting series on consumer electronics, the Matsushita motional feedback system is discussed (p 54, May 3). The last paragraph says that "the phase shift of the feedback voltage increases in the high-frequency range, and unless acceleration feedback is reduced, an unstable feedback system may result."

It should be added that the design of the Matsushita MFB speaker-amplifier system takes this into consideration, and insures constant gain by taking advantage of the negative feedback voltage available from the audio output transformer through an RC network.

SOL FIELDS
Matsushita Electric Corporation of America
New York, New York

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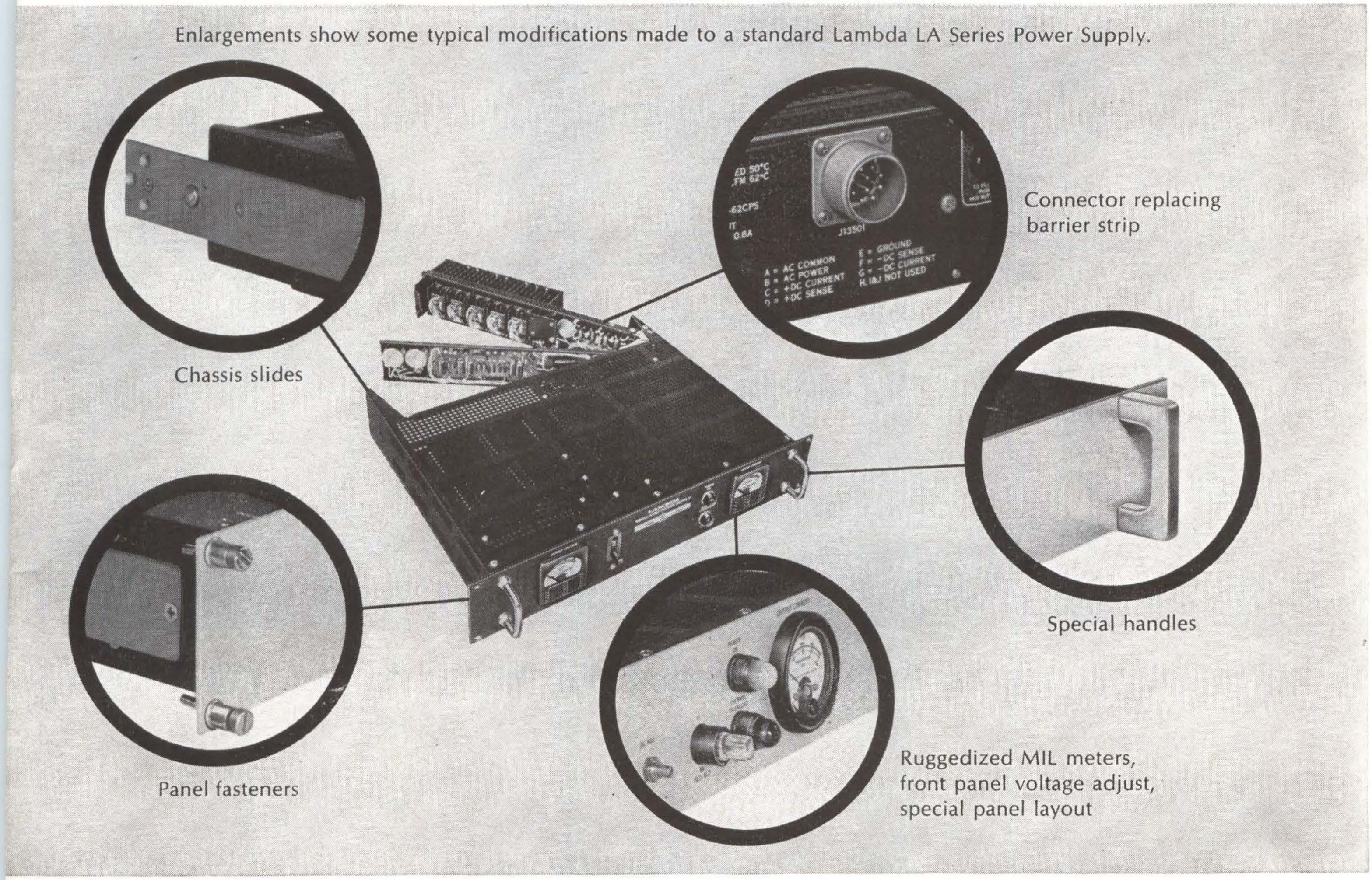

Now you can have Lambda power supply quality and reliability even if you must have a unit tailored to your needs. In most cases, Lambda can meet your special requirements by making simple, fast, low-cost electrical and mechanical modifications to any of its transistorized and tube regulated power supplies. Illustrated are just a few of the many modifications that Lambda makes to a standard LA Series transistorized power supply.

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Sensitivity:	High level, < 0.35 mw produces 100 mv output Low level, 0.4 mv dc/μw cw
Output impedance:	< 15 K shunted by 10 pf
Maximum input:	100 mw
Noise:	200 μv p-p, with cw power applied to produce 100 mv output
Output polarity:	Negative; positive available
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How to Rid Pesticides of Pestiness

SAN FRANCISCO — An improved system for precise and simultaneous analysis of pesticide residues is helping the Federal Drug Administration put an end to silent springs. Developed by Dohrmann Instruments Co., San Carlos, Calif., the system utilizes electrochemical devices to measure residues as small as ten billionths of a gram. A Dohrmann spokesman said it does the job "faster and better" than two previous models, the first of which appeared three years ago.

The system, the FDA says, is one of its main devices for tracking down possibly harmful pesticide residues on many foods. Intense controversy has surrounded the subject since Rachel Carson, biologist and writer, said in her book, "Silent Spring," that such residues are killing off insect and bird life and endangering the health of humans.

The Dohrmann device includes a gas chromatograph, into which dissolved pesticide extracts are fed, and a microcoulometric titration cell, where, as gases, the pesticides are electrochemically titrated for qualitative analysis. The system, which costs $10,000 including recorder, differs from previous models in that the temperature controller and programmer allow separation and regulation of the rate of pesticide flow. The temp controller uses silicon control rectifiers in conjunction with an open-loop servo amplifier.

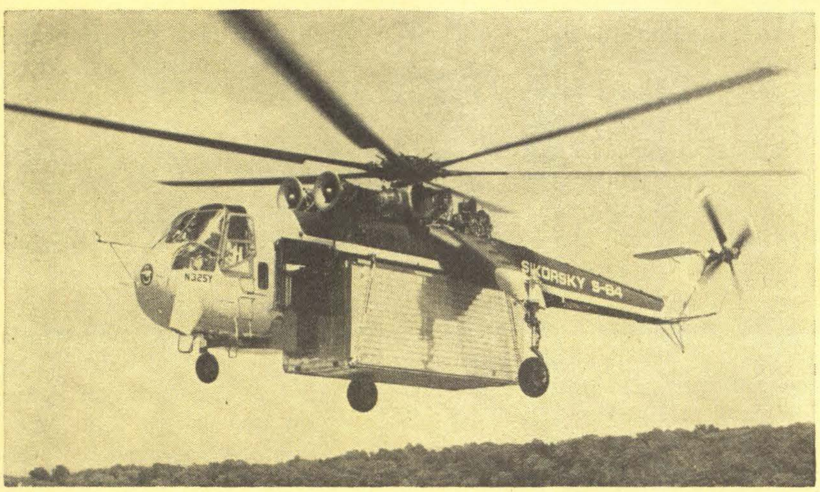
Gemini Gear Design Nears Completion

ANN ARBOR, MICH. — Instrumentation for the Gemini spacecraft is expected to be frozen shortly, according to R. T. Hayes of McDonnell Aircraft. A team of astronauts met with McDonnell June 19 to iron out final instrumentation plans, Hayes said. He spoke at the annual meeting of the Institute of Navigation here.

On-board rendezvous equipment will include a six-pound radar completely transistorized except for two tubes. The capsule is to be capable of docking with an orbiting Agena stage either visually or with instruments comparable to an "ILS under zero, zero conditions." For rendezvous, Gemini radar will have range and rate-of-closure scales.

Gemini will also have an attitude ball "like an ILS," with 360-degree and three-degree-of-freedom capability. With three gyros and four gimbals, the system has reference as a horizon scanner, to a fixed point in space or to the on-board computer.

Help for a Whirlybird



SOLID-STATE, *semiconductor load cells allow pilots of Sikorsky S-64 Skycrane helicopters to control engine torque more accurately during lifting and in-flight operations. The cells, developed by Fairchild Camera & Instrument, include a convoluted-cylinder load-sensitive element coupled to a silicon semiconductor strain gage*

Question and Answer

KEYBOARD *(lower right) transmits inquiries over commercial telephone lines to a modified Honeywell computer, which processes them and responds with a voice answer. The system can handle as many as 28 different inquiry routines*

Dielectric Film May Cut Weight of Power Systems

PITTSBURGH—Dielectric films may make possible lighter weight space power systems, B. H. Beam of NASA said here last week at the "Dielectrics in Space" symposium, cosponsored by NASA and Westinghouse.

A new method of solar-energy conversion would use a high-dielectric-strength capacitor layer covering the satellite skin. As the satellite rotated with respect to the sun, solar radiation would charge successive portions of the dielectric. The energy would then be commutated and stored or used as needed.

The system, now in experimental stages at NASA's Moffett Field, Calif., uses a ¼-mil film of polyethylene terephthalate, covering 200 square feet of satellite skin. It will produce 60 w continuously. Total power supply weight is 7 pounds.

Cape Canaveral Getting New Impact Predictor

CAPE CANAVERAL — Control Data Corp. has received a contract for two CDC 3600 computers which will replace the existing impact predictor system here. The two computers, which will be operational in mid-1964, make up a duplex system, with full back-up capability. The IBM 7094 now in use is one-sided and could cause a halt in a missile test if it malfunctioned.

With the CDC 3600s, if the main system malfunctions, the second system will automatically take over the impact prediction job, no matter what else it was assigned to at the time. The switch would be so fast that only one impact location point would be lost. The Air Force will rent the $7-million system with a two-year option to buy. If it buys, about 70 percent of the rental fee will go toward the purchase price. Rent for the first six months of operation will be $3,521,363.

Tape Plays Back Tv Programs

LONDON — Nottingham Electronic Valve Co., Ltd. has developed a system that will tape record tv audio and video for playback on the tv receiver at will. The unit operates like a domestic sound tape recorder with standard reusable quarter-inch tape. At tape speed of 120 inches a second, the 10.5 inch spool (9,000 feet) will cover half an hour's program using both tracks.

The equipment will be available in two forms: as a separate unit (to cost $177) for use with existing tv sets and as an insert built into sets by manufacturers.

Integrated Circuits Set For Commercial Computer

BONN—Siemens expects to use integrated circuits in the model 3003 commercial computer which it is now building. Company spokesman said that laboratory work on development and application of thin-film circuits with chip transistors is well advanced although not yet ready for the market. Semiconductor integrated circuits for commercial computer applications are also in the R&D stage but the extent of development was not revealed.

Huge Market Seen For Motor Controls

EVERY INDUSTRY where control of motor speed is a critical factor in production is a potential customer for a static inverter system, says Westinghouse Electric which last week introduced the AccurCon/200 Inverter. The unit will provide accurate and adjustable speed control for single a-c motors or groups of motors used in manufacturing. Its switching circuits use silicon rectifiers.

FCC Proposes Bands For Intruder Alarms

FCC WANTS comments by Aug. 1 on its proposal to provide frequencies for intruder alarms. Such devices emit a continuous r-f carrier. Any intrusion into the r-f field causes distburbances, which are electronically detected, triggering an alarm.

FCC suggests the following bands be provided: 910-920, 2-435-2,465 and 22,025-22,225 mc. It proposes limiting radiated energy to 500 μv/m at 100 feet. Electronic Detection Products, Inc. and Electro-Security Corp. petitioned for intruder-alarm bands in 1958 and 1959. EIA and at least one manufacturer have already expressed concern about possible interference to mobile radio service.

In Brief . . .

GENERAL SARNOFF, chairman of RCA, last week answered a criticism by Harold S. Geneen, president of ITT (p 8, June 28). Sarnoff said Congress should hold public hearings to help determine a national communications policy for the space age.

RCA has received a $50-million contract for work on the Lunar Excursion Module, NASA says, confirming earlier unofficial reports (p 8, May 17 and p 8, May 24).

JAPAN imported 207 digital computers worth $22,268,450 in 1962; it exported one digital computer worth $5,000. It imported two analog computers worth $5,500 and exported 84 worth $44,458.

DEW LINE communications stations will be refitted with f-m tropospheric scatter radio equipment by Radio Engineering Laboratories, Inc. under a $2.2 million Air Force contract.

EXPORTS of British electronic tubes and semiconductor devices totaled $8.4 million in the first quarter of 1963, a 30-percent increase over last year.

MOTOROLA will study a random-orbit medium-altitude communications satellite under a $250,000 subcontract from GE.

DALMO VICTOR has received a $3.3 million contract to develop radar homing and warning systems for the TFX airplane.

SIMMONDS Precision Products will build the electronic measurement and display system for gaging the propellants in the three-man Apollo spacecraft.

ITT has developed a tv system that will allow ground observers to study the functioning of elements within the Saturn I rocket.

EARL D. HILBURN has been named a deputy associate adminstrator for NASA. He was formerly vice-president and general manager of the Curtiss-Wright Electronics Division.

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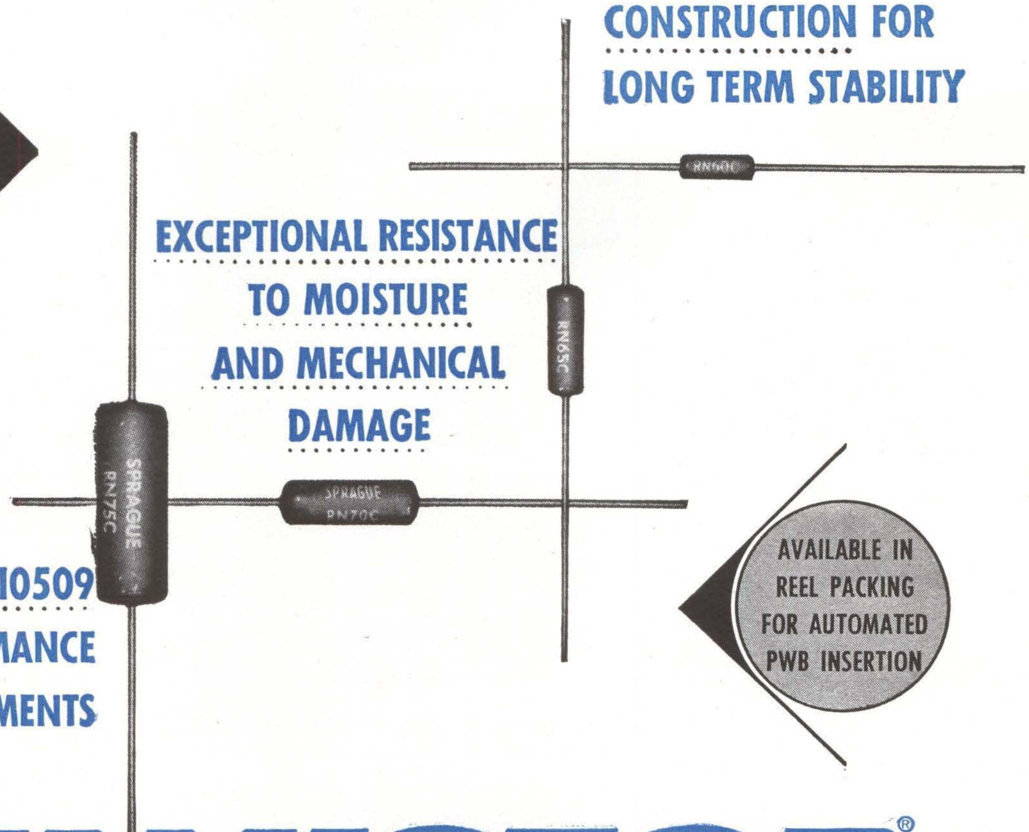

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SILICON RECTIFIER GATE CONTROLS
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THE MARK OF RELIABILITY

CIRCLE 9 ON READER SERVICE CARD

WASHINGTON THIS WEEK

WILL CONGRESS PUT SKIDS ON SPACE PROGRAM?

FEBRUARY 1 has become the key date, and the Boston electronics center the key project, for measuring the sincerity of Congress in putting the economy blocks to the $5.7 billion space budget. Cuts that are beng made in the budget—10 percent in manned space flight programs, more in space medicine, advanced engines and other programs—come out of a flurry of space effort criticism tied to a Congressional economy drive.

The electronics center has been under double attack: political critics have charged that the money is being spent just to redeem a campaign pledge by the President's brother, Sen. Edward M. Kennedy, that he can "do more for Massachusetts." Others charge that other government installations already have the potential NASA seeks to establish in Boston.

House budget watchers have sent NASA back to its books to prepare, by the February deadline, a new justification for the center. Both houses will get a chance to review the proposal then.

HOUSE BACKS DOWN ON RS-70 DEMANDS

THE HOUSE FAILED to appropriate RS-70 forced-feeding funds after having authorized their expenditure. The plane has already cost $1.7 billion and McNamara has refused to spend more. McNamara also is rejecting Congressional recommendations that he use some RS-70 funds for the coming civil supersonic transport plane.

NEW COMMITTEE TO COORDINATE INFORMATION COORDINATORS

THE WHITE HOUSE has decided on a new top-level committee to coordinate far-flung scientific and technical information handling systems. It will be an off-shoot of a study group in the Federal Council for Science and Technology and will take on permanent information policy and coordinating roles in the council. Information specialists from other government agencies will be members.

The new plan bears the earmark of presidential science advisor Jerome Wiesner, whose preference for information coordination is shaping the character of management of federal science and technology in an increasing number of areas.

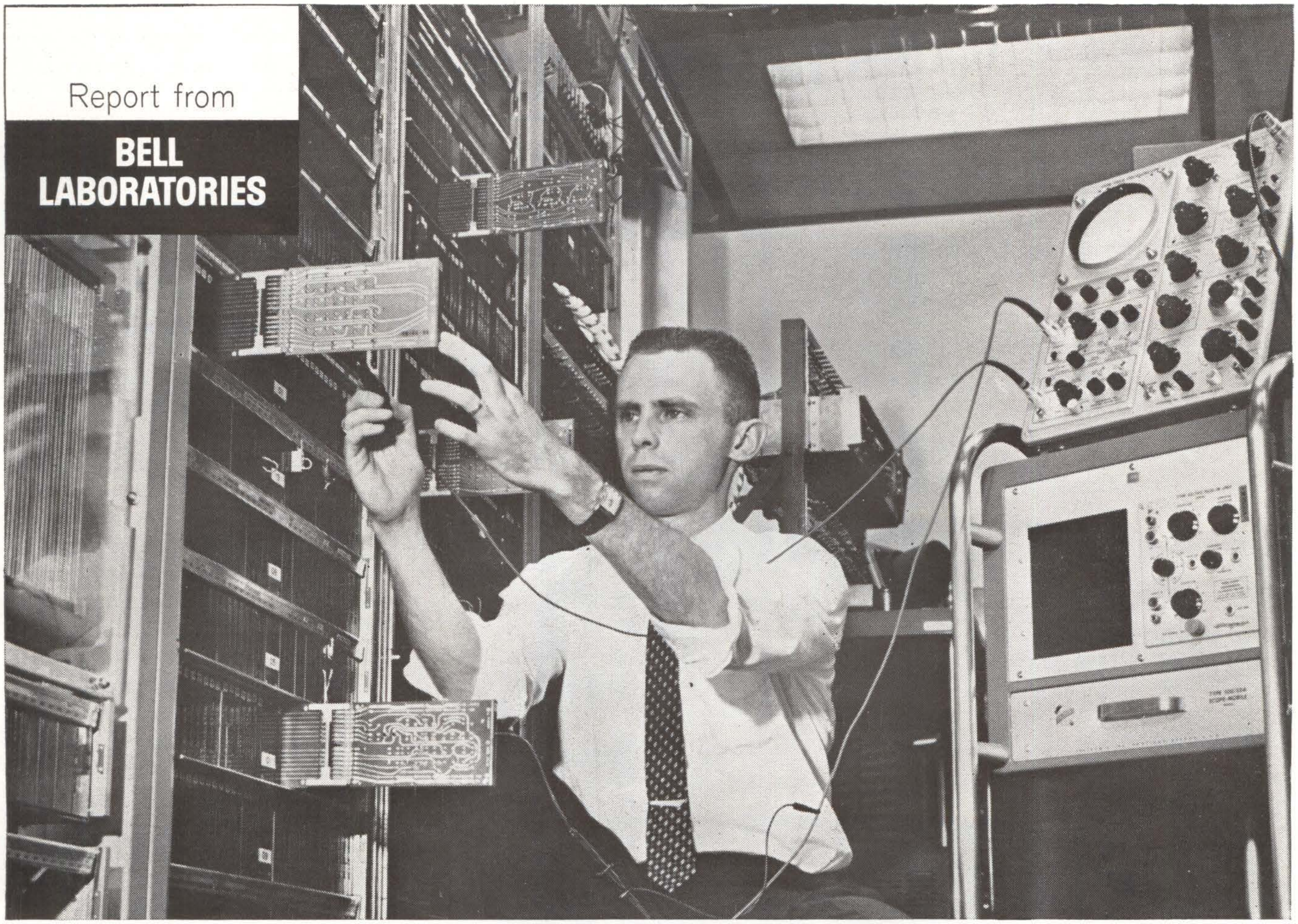
The new move is the culmination of a year's effort in upgrading the Armed Services Technical Information Agency, the Office of Technical Services in the Commerce Department, and information arms of other science-sponsoring agencies. High-level information administrators are being named in the agencies, responsible for the coordination of information sources with which they deal outside of government. The new group in turn will coordinate the coordinators.

CONGRESS ASKS FOR TECHNICAL ADVISERS

AN UNPRECEDENTED — for Congress — recommendation made by freshman Connecticut Republican Rep. Abner W. Sibal that Congress hire expert advisers as the Administration does is being considered. Because it came from a minority freshman and because it is novel, little success for HR 6866 is foreseen this year. But more and more use is expected to be made of some expert panels convened by the science and space committees in valuating complex budget items. When debate on Congressional modernization and reorganization is finally scheduled before the Senate Rules Committee, some such base for informed confrontation with administration technicians is sure to be included.

Report from

BELL LABORATORIES



Bell Laboratories' E. G. Hughes tests printed circuit boards in experimental central office control equipment for 101-Electronic Switching System. The system automatically detects trouble, switching out a defective unit and switching in a duplicate unit so service is not interrupted.

High-Speed Switching System Provides New Telephone Services for Business

A new electronic switching system designed to meet the special needs of business customers has been developed at Bell Telephone Laboratories. This system provides many new telephone services such as a way for reaching a seven- or ten-digit number by dialing only three digits, setting up conference calls by dialing other customers into the conversation, and automatically transferring incoming calls from your phone to another by predialing special codes.

A notable feature of the new system is a high-speed control unit. Operating from a telephone switching center, the unit scans—thousands of times per second—all the telephone connections in dozens of business offices that may be located many miles apart. It spends only two-thousandths of a second in each office, but in that time it determines what has to be done and arranges for the necessary actions.

Another feature of the new system is the high-capacity memory. From this, the control unit can draw, in eight-millionths of a second, such specific instructions as how to handle a certain call.

The new switching system operates compatibly with existing electromechanical switching systems in the Bell System. Such Bell Laboratories inventions as the transistor are indispensable to its compactness and the high reliability of its operation. The system was developed for use by businesses as a private branch exchange, and a model has been installed by Western Electric for trial by two New Brunswick, New Jersey, companies.

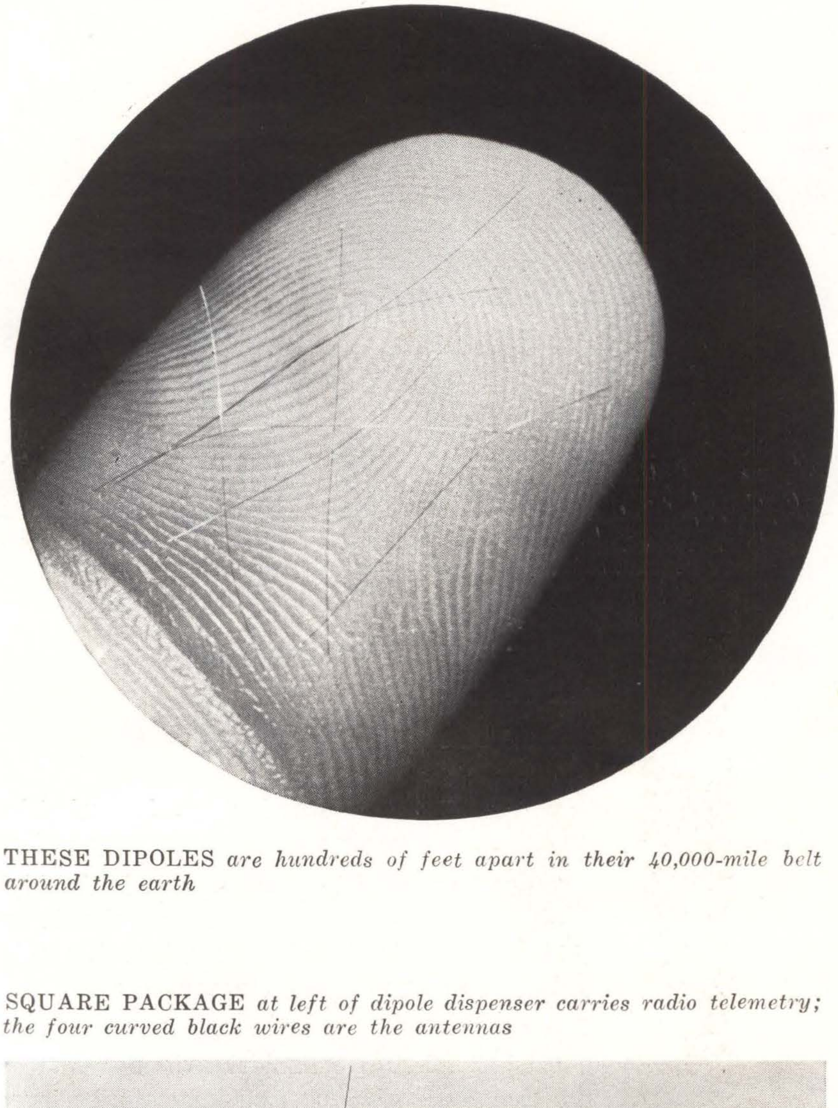
BELL TELEPHONE LABORATORIES

World center of communications research and development

WEST FORD DIPOLE BELT

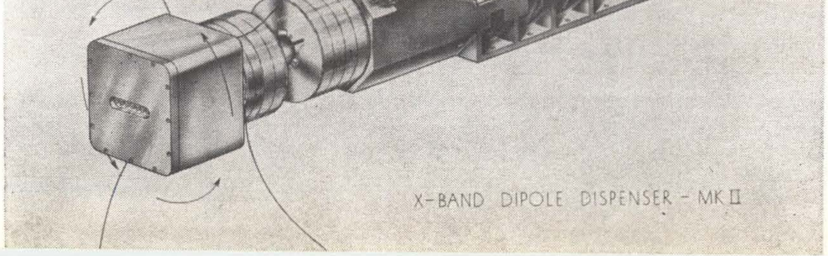
Three-year life is indicated. No side effects reported by astronomers

By THOMAS MAGUIRE, New England Editor



THESE DIPOLES *are hundreds of feet apart in their 40,000-mile belt around the earth*

SQUARE PACKAGE *at left of dipole dispenser carries radio telemetry; the four curved black wires are the antennas*



BOSTON—Four hundred million tiny copper wires launched May 9 were closing ranks this week to complete a belt around the earth, and MIT Lincoln Laboratory scientists were on watch for the first observable effects of solar radiation pressure on the orbit of the Project West Ford dipoles.

Magnitude of this pressure will be an important determinant of lifetime—a crucial factor in the U. S. decision to launch this experimental test of the feasibility of orbital scatter communications.

The most recent calculations indicate that lifetime of the belt will probably be less than three years, considerably less than the seven years predicted for the first dipoles —which never did disperse after launch in 1961—and also lower than the five years predicted shortly after the successful launch of the second package on May 9.

Sponsored by the Air Force and conducted by Lincoln Laboratory, West Ford is an attempt to test the technical feasibility of using tuned dipoles in orbit as passive reflectors for long-range satellite-relay radio communications for the military. In its conception as a communications technique for command and control, it satisfies admirably the prime military requisite of survivability (ELECTRONICS, p 28, March 22). It is immune to natural disturbances as well as hostile action.

A second purpose of the experimental belt is to provide an opportunity for objective assessment by the world scientific community of possible side effects harmful to space activities, astronomy or any other branch of science.

MORE BELTS—In the first six weeks of the belt formation, no public complaints were registered by optical or radio astronomers about interference with their observations. Unless serious objections are raised, based on measured interference effects, it is a safe bet that the Air Force will be planning an operational belt or belts. President Kennedy has pledged that

GIRDLES EARTH

there will be no additional launches until the results of the first experiment have been thoroughly analyzed.

When and if, a two-belt, higher-altitude operational system would provide worldwide coverage on a two-hop transmission basis. Operational belts would probably be launched into an altitude two to three times higher than the 2,300-statute-mile altitude of the experimental belt—chosen specifically for limited lifetime.

In the first days of the belt formation, data rates of 50,000 bits per second in teletypewriter transmission and 20,000 bps in voice were achieved—bouncing signals off the dense, compact cloud of metallic fibers. It is not expected that these rates will be obtained with the diffused ring now orbiting the earth.

Data rate is directly proportional to signal strength, and signal strength to the density of the belt or the power and sensitivity of the ground equipment. If West Ford belts become operational, it is likely that tradeoffs will be made to provide more or less permanent belts —perhaps one in polar and one in equatorial orbit — with densities great enough to give reasonable data rates for crucial military communications and yet not generate any harmful side effects. An operational system would also have to include hardened, mobile or highly redundant ground terminals for post-attack communications.

SHORTER LIFE—Lincoln Laboratory researchers cite two principal factors in lowering their predictions for the expected lifetime of the experimental ring: the diameter of the copper wires used in the second launch package was reduced to 0.0018 cm, one-third the thickness of the human hair; and the orbit achieved in the May 9 launch appears more and more to be one which makes the belt ideally responsive to perturbations which will bring it down into the atmosphere.

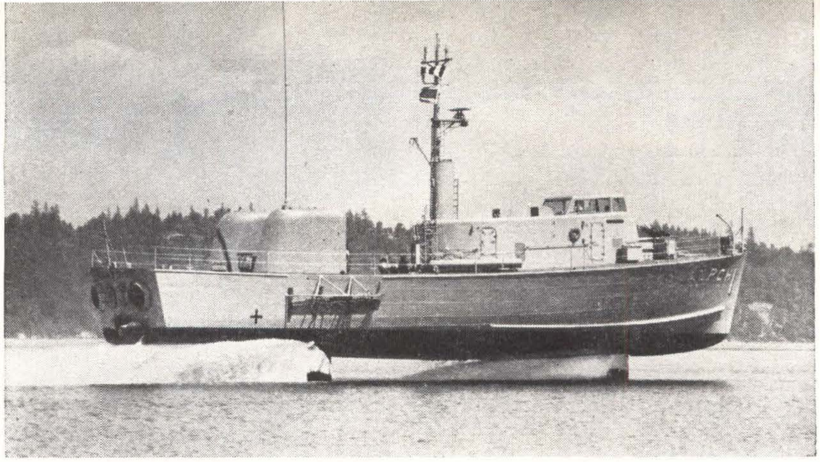
In addition to solar radiation pressure, physical perturbations which affect dipole lifetime are the earth's gravitational field, lunar and solar gravitational fields, earth-reflected sunlight pressure and atmospheric drag.

EXPERIMENTS — Measurements of the physical dynamics of the belt itself comprise an important phase of the experiment. And radar, radio propagation and communications experiments have been underway since May 12 and are continuing at the West Ford ground stations at Westford, Mass. and Pleasanton, Calif. Even fuller exploration of orbital scatter will be possible with the Haystack antenna facility (ELECTRONICS, p 49, Nov. 9, 1962), which probably will not be ready until the first part of 1964.

Radar techniques help determine details of the belt's density and distribution, and also provide measurements of orbit altitudes, particularly deviations from the initial altitude since this affects lifetime. Radar also tracks the cloud of fibers, a job which was crucial in the first stages but gets easier as the belt becomes complete and uniform. In propagation and communications experiments, the narrow transmitter and receiver beams, each about 0.15 deg wide, must intersect, and the point of intersection must lie on the narrow and swiftly moving cloud of dipoles.

Radio propagation experiments are providing quantitative details of predicted signal distortion. The signals scattered from tens of thousands of the orbiting dipoles are smeared in time delay and frequency. For communication purposes, special signal processing is required to overcome this distortion.

The ring of dipoles is in a nearly polar orbit at an altitude of about 2,000 nautical miles, forming a belt 40,000 miles in circumference and a few tenths of a degree wide. Any given section of the belt circles the earth every 166 minutes, moving at a rate of 4 miles per second.



UNDERWATER WINGS *lift hull of experimental hydrofoil subchaser. Navy boat flies over 50 mph. Boeing built the PCH-1; Hamilton Standard, the fully automatic stabilization*

How Navy Flies ASW Boats

Submerged foil craft is stabilized with electronics

By LEON DULBERGER
Associate Editor

A NEW CLASS of antisubmarine boat that requires electronic stabilization to "fly" on submerged foils is entering Navy service. The hydrofoil craft will ultimately fly at speeds over 100 mph with designs capable of ocean-going as well as coastal service. In ASW they will hunt, track and destroy high-speed submarines.

Military hydrofoils are expected to rival aircraft in the complexity and amount of electronics carried: stabilization and autopilot systems, electromagnetic speed measuring instruments, sophisticated navigation systems, height sensors, advanced radar designs, directional sonars and other systems.

Hydrofoil-borne vessels achieve greater speed and better fuel efficiency than conventional boats do. They fly on wing-like structures that lift the hull above the water's surface to eliminate hull drag.

The foils used are of two generic types: completely submerged, which require electronic stabilization to fly, and partly submerged foils, called surface-piercing types, which achieve a measure of self stabilization. Surface-piercing foils usually form a V configuration with the tips above water. When the boat rolls, increased lift on the foil being submerged and decreased lift on the foil exposed to air tends to right the craft. Military surface-piercing hydrofoil boats, nevertheless, are electronically stabilized to provide a smoother ride.

SPEED SENSING — Electromag-craft construction techniques and lightweight engines are used in military hydrofoils. The stabilization systems are similar in design and packaging to aircraft autopilot equipment. As hydrofoils get faster, experts predict even more aircraft techniques will have to be used, such as remote control of the engine, aircraft-like cockpits, safety-belts for crews.

Navy's hydrofoil subchaser, the PCH-1, developed by Boeing, uses submerged foils. Designed for coastal service, its foils are retractable to permit shallow-water operation. The boat's automatic stabilization system developed by Hamilton Standard Div. of United Aircraft Corp. provides control of altitude while flying, as well as pitch and roll attitude, and heading. It also has a pseudo-coordinated turn system to sense the yaw rate and apply foil control to bank the craft. This aids in making tight turns at high speed. It also minimizes side slip.

AIRCRAFT TECHNIQUES — Airnetic speed sensing instruments will probably be used for hydrofoils rather than a Pitot log. The latter has a poor response at speeds roughly above thirty knots, due to nonlinearity. Electromagnetic speed sensors provide linear output. They must be designed, however, to avoid inaccuracies due to cavitation. EM speed sensor technology is well established in submarine and surface craft use.

The extremely fast PCH-1 will out run and out maneuver submarines. The Navy plans to use a leap-frogging ASW tactical operation requiring two hydrofoil boats. One vessel with its sonar in contact with the water will move at slow hull-borne speeds and listen for enemy subs. On detecting a sub the hydrofoil will direct its companion ship toward the sub at high foil-borne speeds. The second hydrofoil boat will return to the hull-borne mode, listen with its sonar and direct the first boat to a new position. The pattern will be repeated until the sub is pinpointed. During patrols, hydrofoils can remain hull-borne for long periods at low fuel consumption.

OCEAN SERVICE — A hydrofoil boat designed for ocean service by Grumman Aircraft Engineering Corp., uses surface-piercing foils and a stability augmentation system provided by Hamilton Standard. Navy has shown interest in this boat which was developed for the Maritime Administration.

In the foil-borne mode, a vertical gyroscope provides information for pitch-rate control, which is applied to the aft wing. This affords ride smoothing to correct for an unstable condition when the wave period approaches the natural frequency of the boat. The condition is usually caused by a following sea, where waves travel in the same direction as the boat. A vertical accelerometer is used for heave-rate control to correct for up-and-down motion caused by a following sea. Sensor output is electronically integrated and applied to both forward wing-control flaps. A roll channel to correctly maintain the boat's angle with relation to the horizon is provided. This prevents the boat from riding rolled to one side which occurs in a quartering sea when waves approach the boat broadside. Signal information is obtained from the vertical gyro and applied to the forward flaps. Pseudo-coordinated turn control using a yaw-rate gyro is provided to bank turns. The boat is flying right now at over 60 knots.

LANDING CRAFT — Hydrofoil amphibian designs are undergoing tests now in two different formats intended for Marine Corps service. The craft would fly toward the beach, retract its foils, land, and finally operate on wheels. The LVHX-2 design employs combined submerged foils aft and surface-piercing foils forward. The LVHX-1 amphibian uses submerged foils. Both operate at thirty knots foilborne.

Other applications of hydrofoil boats include operation as a high-speed Navy command center ship. Additionally the stable platform provided in the foilborne mode allows highly accurate fire-control in bad seas.

Hydrofoil boats require accurate altitude sensing for ride stabilization systems. Among techniques employed are: sonic altimeters, radar altimeters, shorting electrodes on struts, and capacitance type sensors. Right now ultrasonic techniques seem most promising, but efforts to design radar altimeters, which overcome problems of ultrasonic systems operating in high-noise, water-fouling environments, are advancing propitiously.

Because military hydrofoil boats employ aircraft type electronics, 400 cps power is required. At this time, converters to produce 400 cps from 60 cycles using solid state techniques are used. Inverters to change dc to 400 cps are on some foilcraft. Eventually 400 cps primary power sources will be standard on military hydrofoils as they are smaller and lighter than lower frequency generators.

Is USSR Ahead in Space

Vostok V and VI flight reports indicate more instrumentation

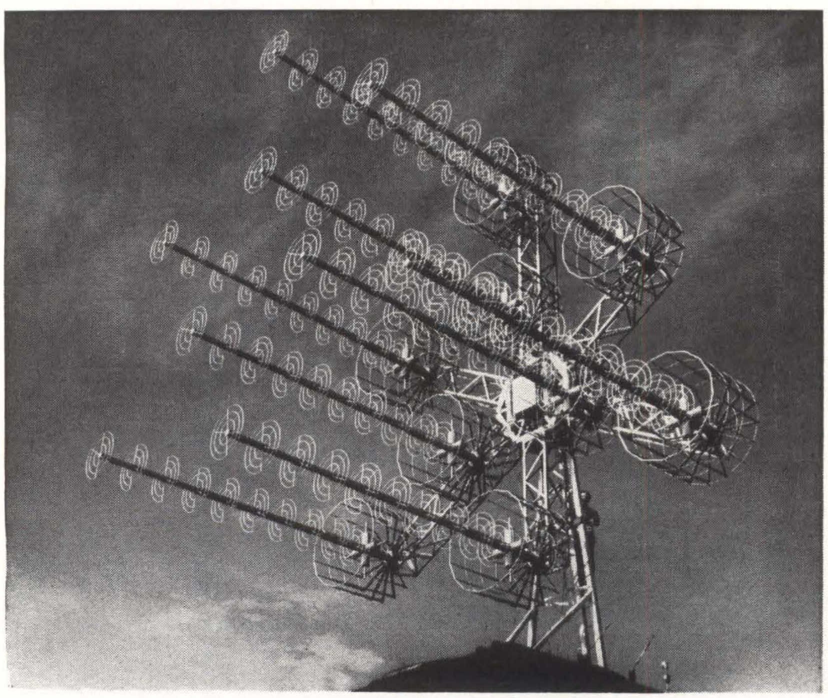
By STEWART RAMSEY
McGraw-Hill World News

MOSCOW — Soviet cosmonauts Valery Bykovsky and Valentina Tereshkova were especially wired for sight and sound, according to information given at a televised press conference here. Mstislav Keldysh, president of the USSR Academy of Sciences, described a flight program that provided for a number of new scientific observations to be carried out besides the extensive medical-biological studies of the astronauts themselves. Vladimir Yazdovsky, Soviet specialist in space medicine, indicated that a new system of sensors for registering respiration and cardiac activity had been necessary for Miss Tereshkova, Cosmonaut 6. Improvements were made in radio and tv systems for both Bykovsky and Tereshkova.

BIOTELEMETRY — Purpose of the complex observations made upon the two space travelers was to discover the effectiveness of life support and safety systems. Measurements included electrocardiography, seismocardiography, pneumography, electroencephalography, electrooculography and skin galvanic recording. Yazdovsky said that physiological information was telemetered to earth. In addition pulse count was obtained through a continuously operating radio transmitter. Although details are lacking, a so-called cosmovision circuit was worked out in conjunction with radiotelephone communication to bridge the previous gap between space traveler and the doctor on earth. Heart activity was thus checked by pulse frequency, by ekg structure and seismocardiography. Breathing was checked by changes in chest perimeter both in conditions of calm and during articulation.

EYE MOVEMENTS — Psychomotor activity was checked by a vast group of indices including analysis of oral speaking, dynamics of the movement of the face, changes in eye-movement rhythms, by desynchronization as measured by electroencephalograph and by spontaneous changes of electrical resistance to galvanic currents of the skin. Radiation checks were carried out by both physical and biological dosimeters. Bykovsky's summary dose was given as 35 to 40 millirads; Tereshkova's as 25.

STUDIO TECHNIQUES—According to Anatoly Blagonravov, head of technical sciences at the USSR Academy, uniform illumination of the space cabin was needed to insure good television pictures when the astronaut left his seat to float about. Special lenses and an automatic brightness adjustment were



New Antenna For NASA's Scientific Satellites

FIRST OF FOUR *of these antennas has been delivered to NASA by Radiation Systems, Inc. for high-power transmission of command signals to the Eccentric Orbiting Geophysical Observatory (EOGO) and other highly eccentric scientific payloads. The four will operate in Alaska, North Carolina, Ecuador, and South Africa*

Space Budget

WASHINGTON—Sharp cutbacks in the United States space program seemed imminent last week as the House Science and Astronautics Committee dealt a severe blow to NASA's $5.7 billion budget. While the committee will meet again July 9 to put the finishing touches on its recommendations, the Administration is expected to pressure the Senate to restore some of this money in the face of mounting Soviet advances.

In many cases, the committee found plans for projects too vague or premature, and decided that some projects, particularly in the bio-sciences, would duplicate work done by the military. They also uncovered duplication—requests for funds previously allocated for the same purpose.

The committee cut $259,122,000 in funds (about 7.4 percent) from the manned space budget and postponed until later a proposal to build a $50,000,000 electronic research

Instruments?

incorporated. Pictures were slowed down and signals incoming to the Moscow television center from several receiving points were regenerated to reduce distortion on transmission lines. As a result, pictures were good on Intervision and by cable and radio relay to the Eurovision system.

INTERSHIP DUPLEX—For the first time, simultaneous transmission and reception were possible both at shortwave and ultra-shortwave, enabling the astronauts to talk to each other and the earth while listening. Intership communication was possible over distances of several thousand kilometers. Radio relay via earth was also successful.

No details were given about navigation devices. Although Tereshkova said her mission included manual control of the space ship, Bykovsky stated that his reentry was accomplished automatically at a signal from earth.

Gets the Axe

center in the Boston area. Project Apollo, which takes nearly 75 percent of the total NASA budget, was trimmed by slightly less than 10 percent.

A cut of 12.1 percent in funds for space sciences research and development resulted in approval of $648,700,000 plus $17,777,700 for construction and facilities. The committee cut 5.2 percent in advanced research and technology R&D leaving $314,700,000 approved, with $57,432,700 set for construction and facilities.

Scrapped were plans for $28,200,000 Surveyor Orbitor to circle the moon. A Mariner request for another Venus fly-by mission was reduced by $15,000,000. The advanced Fire program, designed to study reentry problems of a manned vehicle returning from the moon was deferred to a later date.

Application satellites and tracking and data acquisition requests will go on the chopping block July 9.

ELECTRONICS INDUSTRY
Nudges Fourth Place Nationally

Defense Department still holds first place as world's largest customer

Total Electronic Industries	Factory Sales (in billions) 1963 (Estimated)*	1962*
Consumer Products	$2.500	$2.407
Industrial Products	2.700	2.450
Government Products	9.200	8.348
Replacement Components	.675	.620
Total	$15.075	$13.825

* Calendar years

FACTORY SALES for the electronics industry will hit $15 billion in 1963, according to Electronic Industries Association estimates. This represents a nine percent increase over 1962's volume of $13.8 billion, EIA's reelected president Charles F. Horne said. According to Horne's breakdown of sales for 1962 and those estimated for 1963 (see table) the nine percent increase could move the electronics industry into fourth place nationally.

In spite of the general economic health of the electronics industry, Horne warns of pitfalls for firms not keeping pace with its changing character. He says, "Rapid technical changes such as the industry has experienced constantly for more than a decade always bring hazards to companies which fail to keep abreast of progress. As a consequence," he said "financial failures and reverses have increased, according to the EIA Credit Committee, and many companies have found costs cutting down profits."

The U. S. government is expected to spend over $10 billion of an estimated $98.8 billion budget for fiscal 1964 for goods and services provided by the electronics industry.

LARGEST CUSTOMER—The Department of Defense is the world's largest consumer of electronics, according to EIA. It will spend $8.3 billion for electronics in fiscal year 1964. This is 16.4 percent of its budget. In fiscal year 1963, DOD spent $7.7 billion which was 15.9 percent of appropriated funds.

DOD expenditures in electronics research, development, test and evaluation contains the steepest increase. The fiscal year 1964 request for electronics RDT&E amounts to $2.1 billion, 30 percent of total RDT&E funds. This is up from fiscal year 1963 which was $1.7 billion.

The major budget categories and their electronics content for fiscal year 1964 requested are: aircraft, $1.4 billion; missiles, $1.5 billion; ships, $570 million; vehicle and ordnance, $100 million; electronics and communications, $1.072 billion; operations and maintenance, $1.4 billion; and construction, $59 million.

NASA's fiscal year 1963 estimated expenditures in electronics total $1.6 billion, about a quarter of the agency's total request. FAA will spend $160 million in the electronics industry.

INDUSTRIAL—According to EIA the industrial electronics segment of the industry reached factory sales of $2.45 billion in 1962 from $2.2 billion the previous year. Ranking second in value of sales behind government products, EIA expects total sales will reach an estimated $4 billion in 1966. Factory sales in 1962 for industrial electronics in major categories were: computing, data processing and industrial control and processing, $1.19 billion; testing and measuring, $315 million; communications, navigational aids and broadcast and commercial sound, $650 million; and nuclear, medical and miscellaneous, $295 million.

CONSUMER—Sales of home entertainment electronic products reached $2.4 billion in 1962, up roughly 3 million from the previous year. An increase to $2.5 billion in 1963 is predicted.

Newer products are looked upon to lead consumer electronics above the leveling off point it has assumed in recent years. Factory sales of monochrome tv receivers reached 6.6 million sets with a value of $833 million in 1962, are expected to achieve 6.5 million worth $810 million in 1963. Radio sales, counting automobile sets, are expected to approximate last year's level of 19.1 million units valued at $385 million. Phonograph sales will move to 5.2 million valued at $408 million in 1963, up from 5 million worth $385 million in 1962.

SEMICONDUCTOR — Sales of semiconductor units increased in 1962, but a $1.4 million drop in factory sales value to $563.1 million is noted. EIA pointed out that the rapidly growing semiconductor industry is not completely stable due to rapid technological developments, high rate of new company formation and other factories, but points out that historical analysis of industry growth patterns points to this pattern where an industry gains maturity.

The microelectronics market, which EIA terms Integral Circuit Package, has received nearly $30 million in DOD research and development funds in the last five years. Up to $110 million has been invested by private interests. A $3-to-$4 billion defense market for electronic equipment in which integral circuit packages might be used is foreseen by 1970. A significant share would go to electronic parts manufacturers.

MEETINGS AHEAD

ADVANCED CONTROL THEORY AND APPLICATIONS, Massachusetts Institute of Technology; at MIT, Cambridge, Mass., **July 8-19.**

ANTENNAS & PROPAGATION INTERNATIONAL SYMPOSIUM, IEEE-PTGAR; National Bureau of Standards, Boulder, Colo., **July 9-11.**

MEDICAL ELECTRONICS INTERNATIONAL CONFERENCE, IFME, University of Liege, Liege, Belgium, **July 22-26.**

ELECTROMAGNETIC MEASUREMENTS & STANDARDS SEMINAR, National Bureau of Standards; NBS Laboratory, Boulder, Colo., **July 22-Aug. 9.**

AEROSPACE SUPPORT INTERNATIONAL CONFERENCE & EXHIBIT, IEEE, ASME; Sheraton-Park Hotel, Washington, D. C., **Aug. 4-9.**

INTERNATIONAL ELECTRONICS CIRCUIT PACKING SYMPOSIUM, University of Colorado, et al; at the University, Boulder, Colo., **Aug. 14-16.**

WESTERN ELECTRONICS SHOW AND CONFERENCE, WEMA, IEEE; Cow Palace, San Francisco, Calif., **August 20-23.**

HYBRID COMPUTATION SEMINAR, Electronic Associates, Inc.; at EA's Princeton Computation Center, Princeton, N. J., **Aug. 26-30.**

DATA PROCESSING NATIONAL CONFERENCE & EXHIBITION, Association for Computing Machinery; Denver Hilton Hotel, Denver, Colo., **Aug. 27-30.**

AUTOMATIC CONTROL INTERNATIONAL CONGRESS, International Federation of Automatic Control; Basle, Switzerland, **Aug. 27-Sept. 4.**

MILITARY ELECTRONICS NATIONAL CONFERENCE, IEEE-PTGMIL; Shoreham Hotel, Washington, D. C., **Sept. 9-11.**

ELECTRICAL INSULATION CONFERENCE, IEEE, NEMA; Conrad-Hilton Hotel, Chicago, **Sept. 10-14.**

INTERNATIONAL ASSOCIATION FOR ANALOG COMPUTING, AICA; Brighton College of Technology, Lewes Rd., Brighton, England, **Sept. 14-18.**

PHYSICS OF FAILURE IN ELECTRONICS SYMPOSIUM, Armour Research Foundation and Rome Air Development Center, Illinois Institute of Technology, Chicago, **Sept. 25-26.**

ADVANCE REPORT

INFORMATION DISPLAY EAST COAST SYMPOSIUM, *Society for Information Display; New York City, Oct. 3-4.* **July 15** *is the deadline for submitting 5 copies of a 500-word abstract and summary and author's biography to: Harold Rapaport, ITT U. S. Defense-Space Group, 500 Washington Avenue, Nutley 10, N. J. Symposium is directed toward the latest advances in the following information display areas: systems; technology; equipment; software.*

Far from being gained at the expense of each other...

High Profits and High Wages Are Industrial Siamese Twins

What advantage do higher profits offer to the wage worker? And what do they mean to the consumer?

Contrary to much popular misconception, they mean higher wages and better jobs for the workingman. For consumers they contribute decisively to more and better products. In the process they make a key contribution to more general prosperity. These propositions are demonstrated in this editorial – one of a continuing series on the role of business profits in the U.S. economy.

Profits and Prosperity

Profits lead the economy. When profits begin to climb, employment and income generally climb as well. And when they fall, employment and income follow close behind.

There is no novelty in this observation. The fact is widely recognized. The venerable National Bureau of Economic Research, for instance, long has classified corporate profits among its "leading indicators" – a clear suggestion, from an unimpeachable objective source, that rising profits presage expanding prosperity, declining profits, business slumps.

Nor is this an accident. It follows as day from night – from the simple fact that profits propel free enterprise. Whenever profit possibilities exist, firms are eager to hire the men, buy the machines, and go to work producing the things people want and need. Without profit possibilities, on the other hand, business will retrench, producing a smaller output and providing fewer jobs for workers. In short, good profits are accompanied by prosperity; poor profits by rising unemployment.

Higher Wages

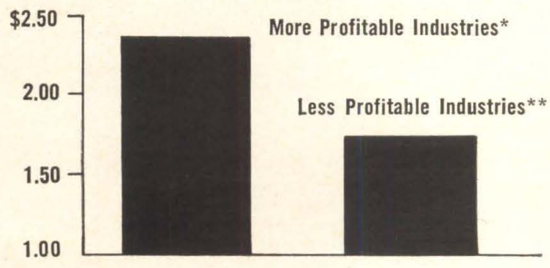
Yet the notion that profits are made at the expense of workers and consumers lingers on. Particularly suspect are industries reporting above-average earnings, which, it is frequently contended, must spring from a gouging of customers or from the strong-arming of employees.

But these allegations are largely based on myth (as was discussed by an earlier editorial in this series) which, if widely enough believed, could wreck our economic system. **The most profitable U.S. industries are the ones that give workers the greatest benefits.**

The chart in the box below points up this fact. It compares the six most profitable U.S. manufacturing

MORE PROFITABLE INDUSTRIES PAY HIGHER WAGES

Average Hourly Earnings, Production Workers, 1958-1962



*Aircraft, Autos, Chemicals, Electrical Eqpt., Instruments, Tobacco
**Apparel, Food, Furniture, Leather, Lumber, Textiles.
Source: U.S. Bureau of Labor Statistics.

industries with the six least profitable. It shows that the more profitable industries pay much higher wages than their less profitable counterparts, — about 35% more on the average.

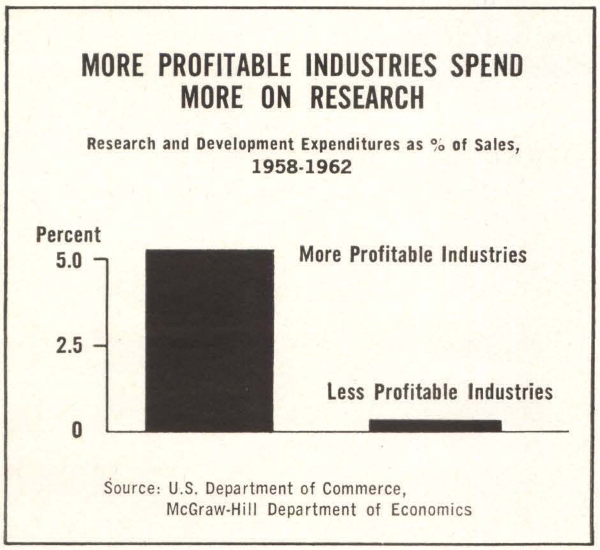
More Research and Development

Of equal importance, and even more dramatic, are differences in the sums spent on research and development.

Between 1958 and 1962, the five most profitable industries in the U.S. spent a far larger percentage of their sales dollar on research and development than did the five least profitable — about 40 times more to be exact. The contrast would be even more dramatic if the research and development expenditures of the aircraft industry, one of the six most profitable, were included. But these have been excluded because they go so heavily for defense. The chart below illustrates the companionship between higher profits and higher outlays for research and development.

In the U. S. economy, this research effort has a two-pronged effect. It improves productive processes, thereby increasing efficiency.

And it makes available new products, which help provide consumers with a fuller life and greater variety. Attesting to this fact is the latest McGraw-Hill Survey of Business' Plans for New Plants and Equipment, conducted by our Department of Economics. It shows that in 1962, over 43% of the sales of the most profitable manufacturing industries, those doing the most research, came from products that did not exist ten years earlier. For the least profitable manufacturing industries, only 14% of 1962 sales came from new products.



More Modern Tools

One reason why high profit industries can pay better wages and do more research is that their workers are more productive. This is largely because each worker has more modern tools to help him do his job.

The most profitable industries have been pushing their investment programs along at a rapid pace. Between 1958 and 1962 the high profit group boosted the value of its property, plant and equipment at a rate more than twice as fast as the low profit group boosted the value of its property.

That this program has enabled them to keep better abreast of our rapidly advancing technological know-how is shown by the latest **McGraw-Hill Survey.** It reports that in December 1962 the most profitable manufacturing industries considered only 12% of their plant and equipment technologically outmoded. The figure for the least profitable was 22%, almost twice as high.

Summing Up

So what do higher profits mean to workingmen and consumers?

Here, in summary, are three key points:

(1) Higher profits, earned under fair competitive conditions, mean greater prosperity and more jobs.

(2) Workers in high profit industries receive better pay.

(3) Through research and modern tools, high profit industries provide consumers with more products, better products, and provide them in greater variety.

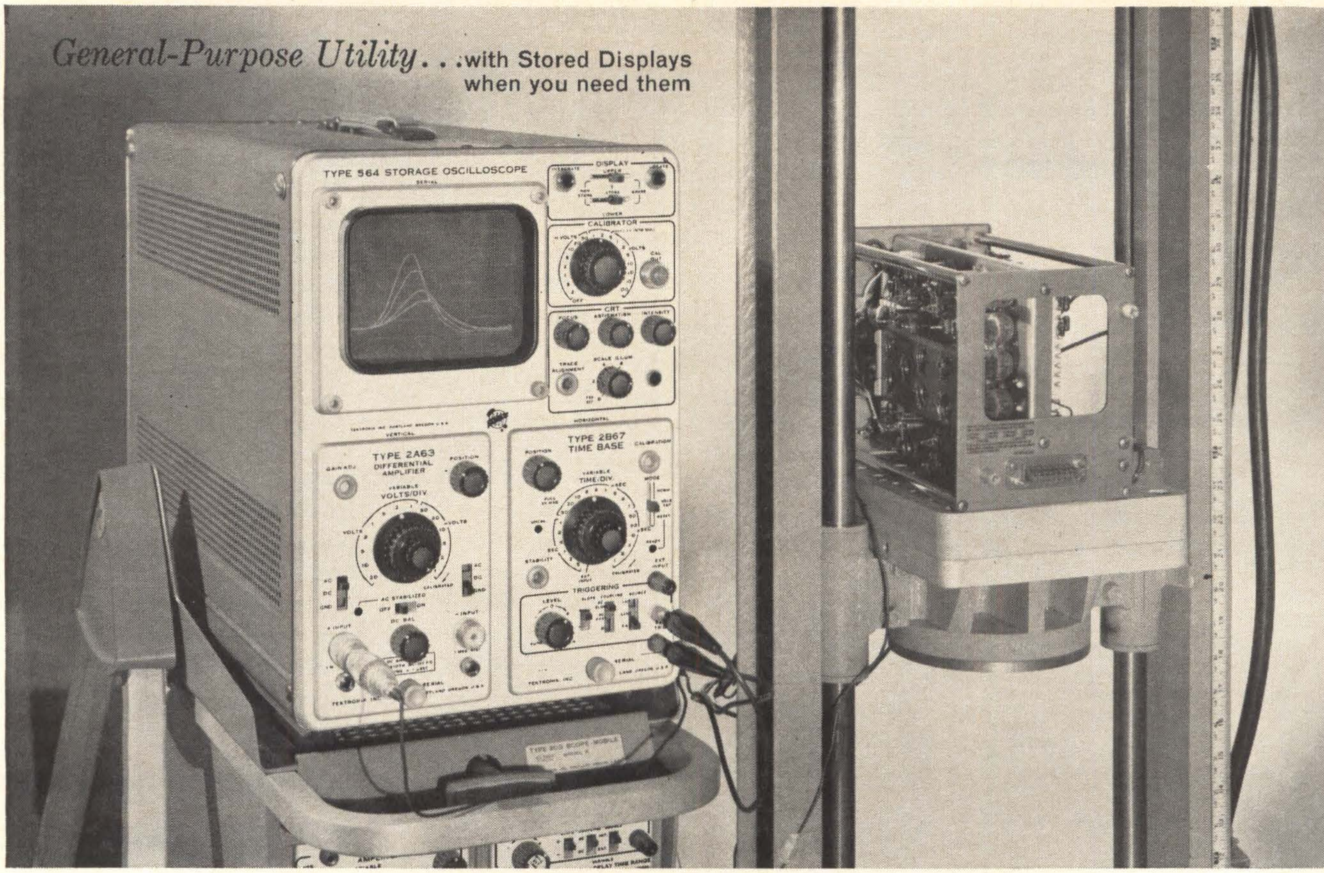
All of which leads to this conclusion: whatever hamstrings profits — whether oppressive taxes, excessive wage demands, punitive government moves against high profit makers, or poor business management — hurts consumers, workers and the economy generally, including the omnipresent tax collector.

This message was prepared by my staff associates as part of our company-wide effort to report on major new developments in American business and industry. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or part of the text.

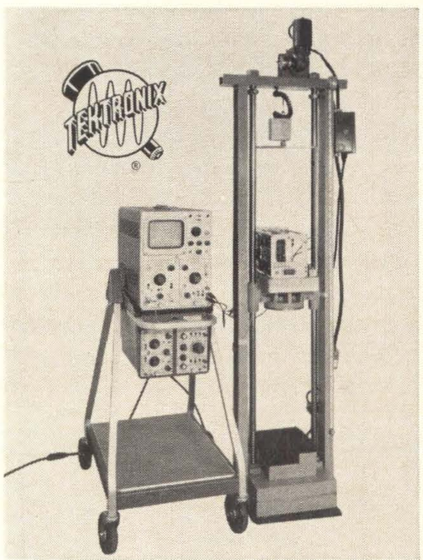
Donald C McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY



THE NEW TEKTRONIX TYPE 564



The Type 564 in a typical mechanical measurement. Waveforms on screen represent shock imparted on the device under test when dropped from successively increasing heights. Trace is calibrated vertically at 8.6 g/cm and horizontally at 2 msec/cm. Storage facility permits easy analysis of shock data without need for multiple exposure photography.

. . . *As a General-Purpose Oscilloscope*

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Vertical Plug-In Units Offer:

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DC to 4 Mc at 50 mv/cm—Type 3A75	$ 175
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DC to 300 kc at 1 mv/cm—differential input—Type 2A63	$ 130
Dual-Trace, DC to 650 kc at 10 mv/cm—Type 3A72	$ 250
Dual-Trace, DC to 10 Mc at 10 mv/cm—Type 3A1	$ 410
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Same as Type 3B3 except delay not continuously calibrated and no single sweep—Type 3B1	$ 475
0.2-nsec/cm to 10 μsec/cm equivalent, for sampling—Type 3T77	$ 650

. . . *As a Storage Oscilloscope*

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Type 564 (without plug-in units) $950

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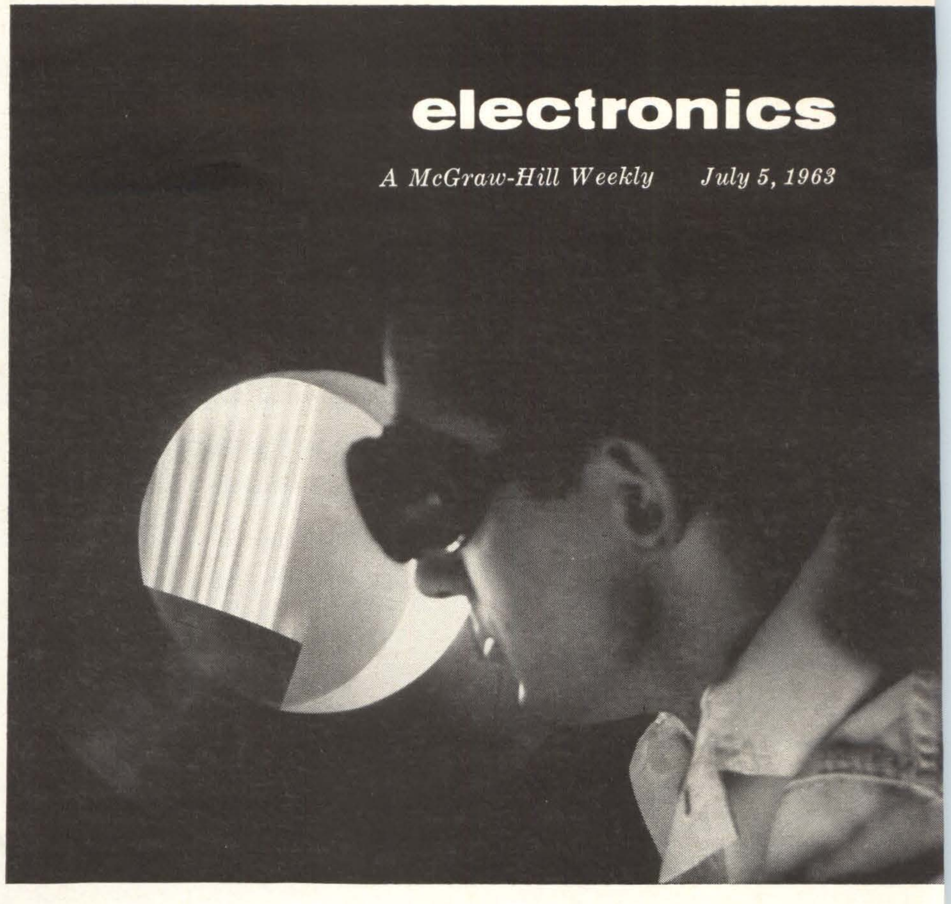

PLASMA *in a hollow-cathode electron-beam device furnishes electrons used in metal-strip annealing process*

One promising application for pulsed ruby lasers is in welding special alloys and microcircuits. However, advances in electron-beam techniques provide strong competition. These include air or controlled atmosphere welding and use of a plasma cathode

MICROWELDING

LASER OR ELECTRON BEAM?

By THOMAS MAGUIRE, New England Editor, ELECTRONICS

A LASER-BEAM fusion system developed for line welding of refractory metals and super alloys will undergo extensive industrial performance tests this summer.

The ruby laser welding system is being built by TRG Inc. for the Aeronautical Systems Div. of the Air Force. When completed, it will be turned over to Grumman Aircraft Co. for extensive tests.

At the Fifth Electron Beam Symposium, it was pointed out that one of the unknowns in this new field is the strength of laser welds—this is one of the parameters which will be probed.[1]

A fast quench is believed to give a strong weld.

One of the major features of laser welding is that it provides a high-intensity weld in a brief time period. Unlike most electron-beam-welding setups, it can produce a weld in a work area that does not have to be enclosed in a vacuum.

In microelectronic and integrated-circuit welding, pinpoint heating by the laser beam aids reliability. There is no space-charge problem with a laser beam, no vacuum to contend with, the momentum associated with the beam is

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WORK FOR THE LASER?

At least one eminent scientist has called the laser the playboy of the electronics industry. One of the most promising practical applications for lasers available today is in microwelding applications. But there is an active and growing competitor: the electron beam

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negligible, and the speed of the thermal cycle minimizes any inert gas shielding problem. A laser welding device can readily be automated.

Principal limitations are in efficiency and total power. The low pumping efficiency of the lamps and of the ruby rod limit the average power. The pump lamps cannot take a high pulse repetition rate. Also, the crystals tend to heat up. Thus, the pulse repetition rate and power are limited by the capacity of the system to remove heat from the laser rod.

In the TRG system, a ruby laser was chosen for its mechanical and thermal durability, availability, low cost, power output possibilities, and thermal characteristics. Neodymium-doped calcium tungstate or fluoride will also prove useful for welding applications.

The system consists of a milling table with the laser head and associated optics mounted above it (Fig. 1A). The work sample moves under the head, and the beam is pulsed on and off when welding a continuous line.

A pulse-forming network stores energy over a relatively long period and transfers it in a short burst of controlled shape to the pump lamps in the laser head. This network produces 0.45 to 18 msec pulses. Its energy storage can be varied from 2,000 to 60,000 joules at a maximum of 8,000 volts.

Minimum requirement for laser output power is 10 watts average. Peak pulse power will be 5,000 watts. Initially, the system will be worked at one pulse per second, with 10 joules output energy per pulse.

The output beam will be in the form of a spot or a line. Spot diameter or line width can be varied from 0.005 in. to 0.040 in. Line length will be variable from 0.060 in. to 0.64 in.

Lamps and ruby will be water-cooled for increased reliability. Divergence of the beam can be varied by varying the positions of the prisms at the totally reflecting end of the ruby rod. This is one means of controlling the spot size with a given lens system.

The system also can be used to drill and cut.

ELECTRON-BEAM — This kind of welding in air—or in a controlled gas atmosphere immediately surrounding the beam—avoids the use of large vacuum chambers.

A lab system (Fig. 1B and 1C) has been built to verify the feasibility of generating an electron beam in vacuum and then bringing the beam out into the atmosphere to do its work.[2] Goal is to achieve welds that exhibit the general characteristics of the electron-beam vacuum process: high depth-to-width ratio, minimum heat-affected or recrystallized zone, and a minimum of deleterious impurity contamination.

Principal problems include electron scatter, beam transfer through the pressure differential from vacuum to atmosphere and attaining maximum power density by controlling the atmosphere immediately surrounding the emergent beam.

The beam is degraded by scatter as it traverses regions at near-atmospheric pressures. Methods to counteract this include increasing the voltage and using gases of low molecular weight.

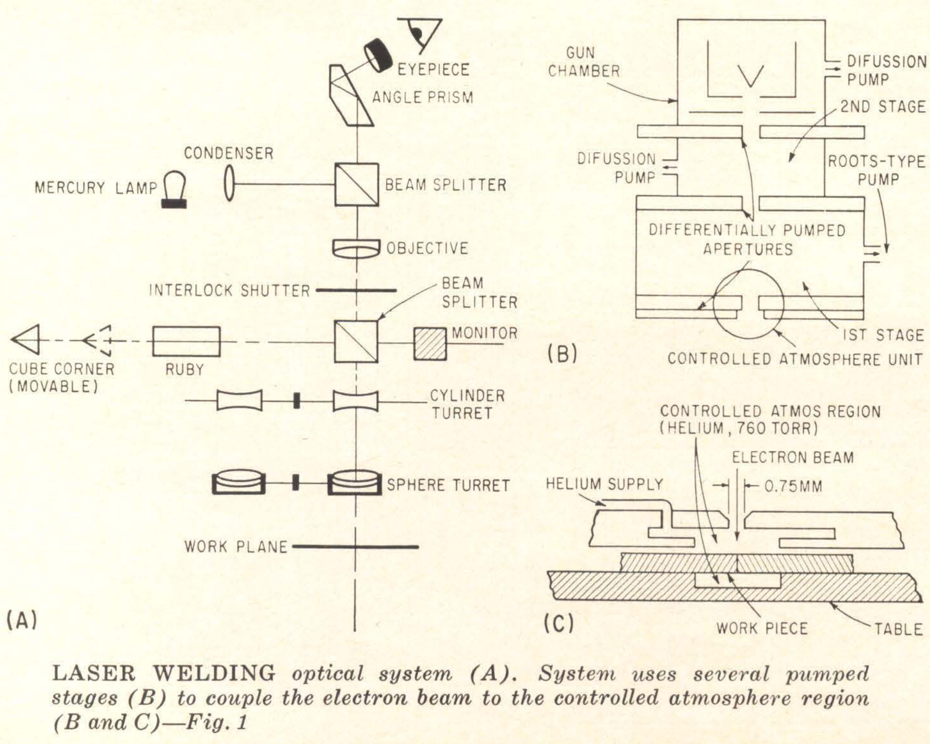
Differentially pumped apertures are used along the beam path (Fig. 1B and C). This system limits the flow of gas into the high vacuum region by small orifices that restrict gaseous effusion and by use of a secondary vacuum pumping system. Note that if the beam path is too long, there is excessive energy loss and scatter.

Dispersion can be reduced by lowering the gas density along the path length of the beam. The chamber closest to atmosphere should be operated at the lowest pressure consistent with the vacuum system.

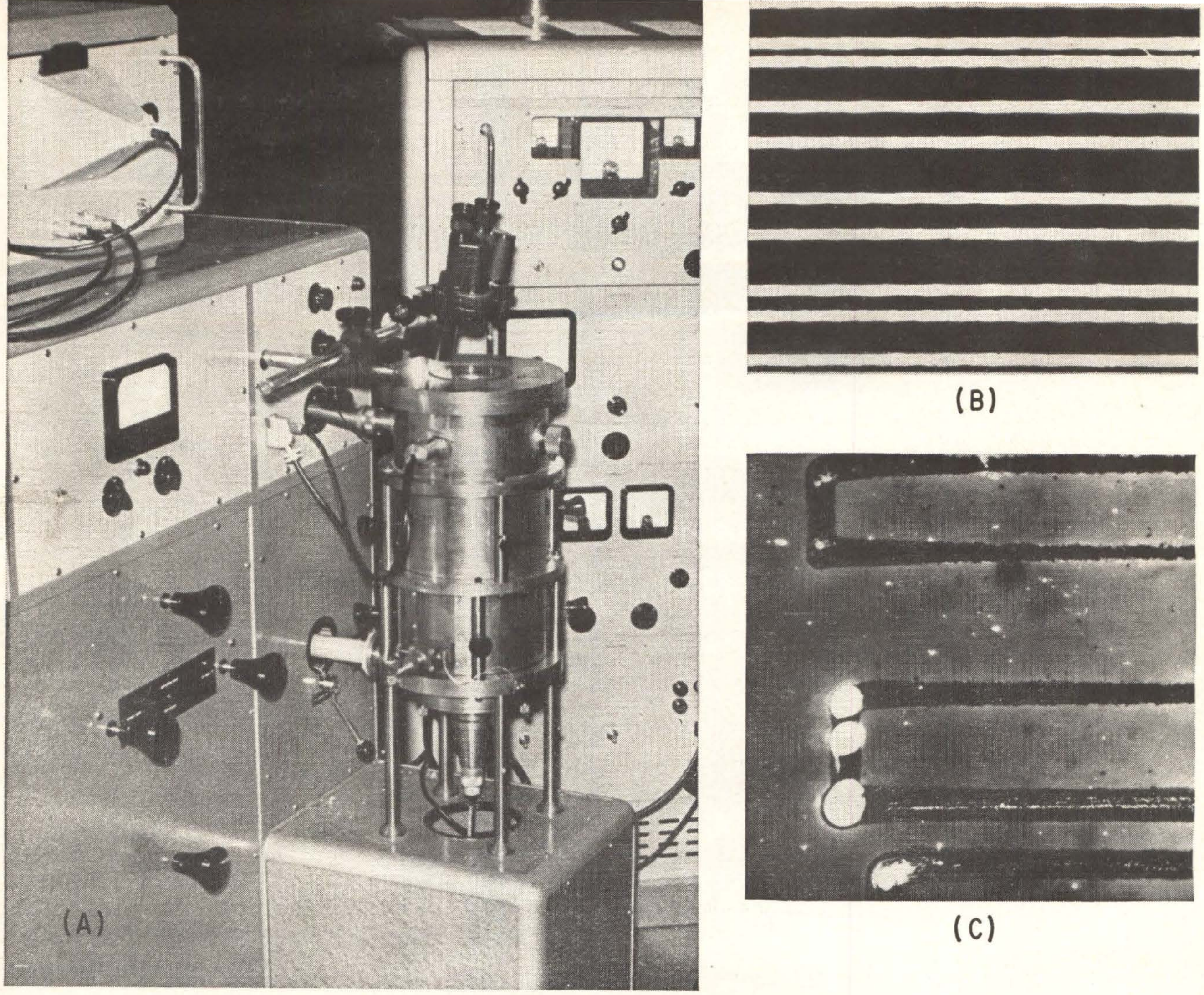
A controlled-atmosphere unit, external to the differential pumping system, is required for the weld if the maximum attainable power density is to be achieved. Electron scatter by gas molecules is the governing factor and this can be minimized if the gas through which the beam passes is helium. The controlled-atmosphere chamber (Fig. 1C) is maintained at a slight positive pressure with respect to the surrounding atmosphere.

MODULAR DESIGN—A British-built electron-beam system of modular design permits various configurations within two major fields of application. The Intercol (Interchangeable Electron Beam Column) can be used for point source devices or for image magnifying instruments where a primary image is enlarged and recorded.[3]

Intercol consists of an electron-optical column (Fig. 2A) with the gun at the bottom and any combination of electron lenses, working



LASER WELDING *optical system (A). System uses several pumped stages (B) to couple the electron beam to the controlled atmosphere region (B and C)—Fig. 1*



ELECTRON GUN *is at the bottom of electron optical column (A). Interchangeable lenses, working chambers and intermediate stages are mounted vertically above gun. Etching photos show lines 20 microns thick (B) and a partial etch in transmitted light (C)—Fig. 2*

chambers and intermediate stages mounted vertically above the gun.

Microcircuit etching is one of the point-source applications and requires the addition of scanning generators, beam modulation, and control systems for following a planned diagram and observing the result. When used for this purpose, Intercol operates at 5 Kv to 30 Kv and up to 2.5 ma. The scanned area may be 2 cm by 2 cm, with the focal plane 4 cm above the top of the lens. Spot size depends on the speed of scan needed and the material, but may be below 10 microns. By maintaining high current density at 10 Kv and below, it is possible to remove extremely thin layers of material, as shown in Fig. 2B and C. Electron penetration into the material is much less than at high kilovoltages.

PLASMA SOURCE—The hollow cathode discharge, a heat source based on the extraction and acceleration of electrons from a plasma cathode, provides a low-voltage, high-current, high-power electron beam device for melting, annealing, welding and other applications in vacuum metallurgy.

The hollow cathode discharge uses a plasma cathode as the source of electrons. The device developed at Alloyd[4] can deliver up to 1,000 amp. Acceleration of the electrons to the workpiece is carried out somewhere between 30 and 50 volts; the electron beam has a total power of about 40 Kw.

Technique used for generation of the plasma is r-f excitation of argon. When r-f is coupled into the gas, ionization occurs, producing a low-pressure plasma within the hollow cathode. Electrons are removed from the plasma by the applied voltage gradient and are accelerated to the anode or workpiece. An axial magnetic field of 200 to 300 gauss prevents spreading of the beam by space charge forces.

Removal of electrons leaves an excess of positive ions in the plasma. These ions are accelerated back to the cathode and raise its temperature so that thermionic emission occurs and the electrons emitted from the hot cathode supplement those from the plasma. By operating the cathode at about 2,400 K, a reasonable cathode life is obtained and power transfer is made 70 to 80 percent efficient. Many different shapes and sizes of cathodes can be used.

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TUNNEL DIODES PART IV—Logic and

Tunnel-diode switching speeds push an order of magnitude higher than transistor's. Logic circuits can be made radiation-resistant and operated at rates above 100 Mc

IN THE INFANCY of tunnel-diode development there was much enthusiasm over the potential of the tunnel diode in digital and other switching circuits. This was due to the tunnel diode's high switching speed, and to the simple circuits that were envisioned. Subsequently, it was discovered that many of the simple circuits were not too practical owing to the limited voltage swing available from the tunnel diode and because of the tight component tolerances this required.

The tunnel diode could not compete in performance or cost with other active devices in many applications such as lower speed logic and large memories. On the other hand, the tunnel diode's advantages outweigh its limitations in recently developed switching techniques. In such circuits the tunnel diode not only competes, but surpasses some existing devices in performance.

Stability criteria of the series circuit dictates that the negative resistance portion of the tunnel-diode characteristic is an unstable region if the total circuit resistance is larger than the negative resistance of the tunnel diode. Consequently the tunnel diode can only switch through the negative resistance region to its two stable regions. This can be seen in Fig. 1A and 1B, where the conductance load-line is superimposed on the tunnel-diode characteristic. The load line intersects the tunnel diode characteristic at points *A* and *B*, which are both stable since they occur in the positive region of the characteristic. If the stable point is initially at point *A*, the tunnel diode will switch to point *B* if the current through the tunnel diode is increased to a value greater than the peak current. This can be accomplished by increasing the supply voltage (which moves the load line horizontally) or by injecting a current at the input (which moves the load line vertically). Conversely, the tunnel diode can be switched from point *B* to point *A* by decreasing the current through the device below the valley current, I_v.

If the total circuit resistance is less than the negative resistance of the tunnel diode, the series circuit becomes a monostable or astable oscillator, depending upon the magnitude of the supply voltage. (An inductance is required—this can be the circuit inductance or one that is added in series with the load.) If the supply voltage is such that the load line intersects the tunnel diode in the negative-resistance region (point *H* in Fig. 1C) the circuit will oscillate as an astable multivibrator; if it intersects in the positive-resistance region (points *G* and *I*), the circuit functions as a monostable multivibrator.

The switching speed of the tunnel diode between its two stable states is determined primarily by the junction capacitance. If a trigger of minimum amplitude is used in conjunction with a constant current bias source, the rise time of the tunnel diode voltage between the 10 and 90 percent points is approximately $t_r = (V_{fp} - V_p)\, C/(I_p - I_v)$ where C is the tunnel diode capacitance, V_{fp} and V_p are the forward and peak voltages respectively, and I_p and I_v are the peak and valley currents. The switching speed is independent of peak current, and can be reduced only by decreasing the C/I_p ratio. Ultra-high-speed tunnel diodes are now commercially available. However, the speed of most high-speed circuits is not limited by the tunnel diode's switching speed, but instead by the package-circuit inductance and by the diode's capacitance. The shortest rise time is 27 picoseconds (27×10^{-12} sec.)—thus a TD101 tunnel diode switches in the time it takes light to travel 0.3 inch.

In addition to tunnel diodes, another important device in many of the switching circuits is the back diode or tunnel rectifier. These devices are nothing more than low peak current tunnel diodes; however, their use is different. The normal characteristic in the first quadrant of Fig. 1B, given by *O-C-D-E*, blocks the flow of current, while the characteristic *O-F* in the third quadrant is the conductive direction of current flow. One of the most important parameters of a back diode for high-speed switching applications is its capacitance, and germanium back diodes are available today with capacitances that are a fraction of a picofarad.

PURPOSEFUL CIRCUITS

New circuits have been developed which ease the component tolerance problem in high-speed tunnel-diode logic configurations. Tunnel diodes also give well defined advantages in other circuits. Thus, tunnel-diode level detectors respond to charge of less than 0.015 picocoulomb (a flow of fewer than 100,000 electrons), counting circuits run on 200 microwatts per stage, and tunnel diodes can switch in the time it takes light to travel 0.3 inch

THE LOCKED PAIR—The locked, or balanced pair was first described in 1960 and has been called the Goto pair and the twin.[1] It is a one-port threshold gate synchronously driven by an a-c clock. While it is a majority gate, it can also function as a conventional AND or OR gate. Only tunnel diodes are used in the circuit; unilateral propagation of information is ensured by a three-phase clock system.

The operation of the locked pair can be seen from Fig. 1D. Supply

Switching Circuits

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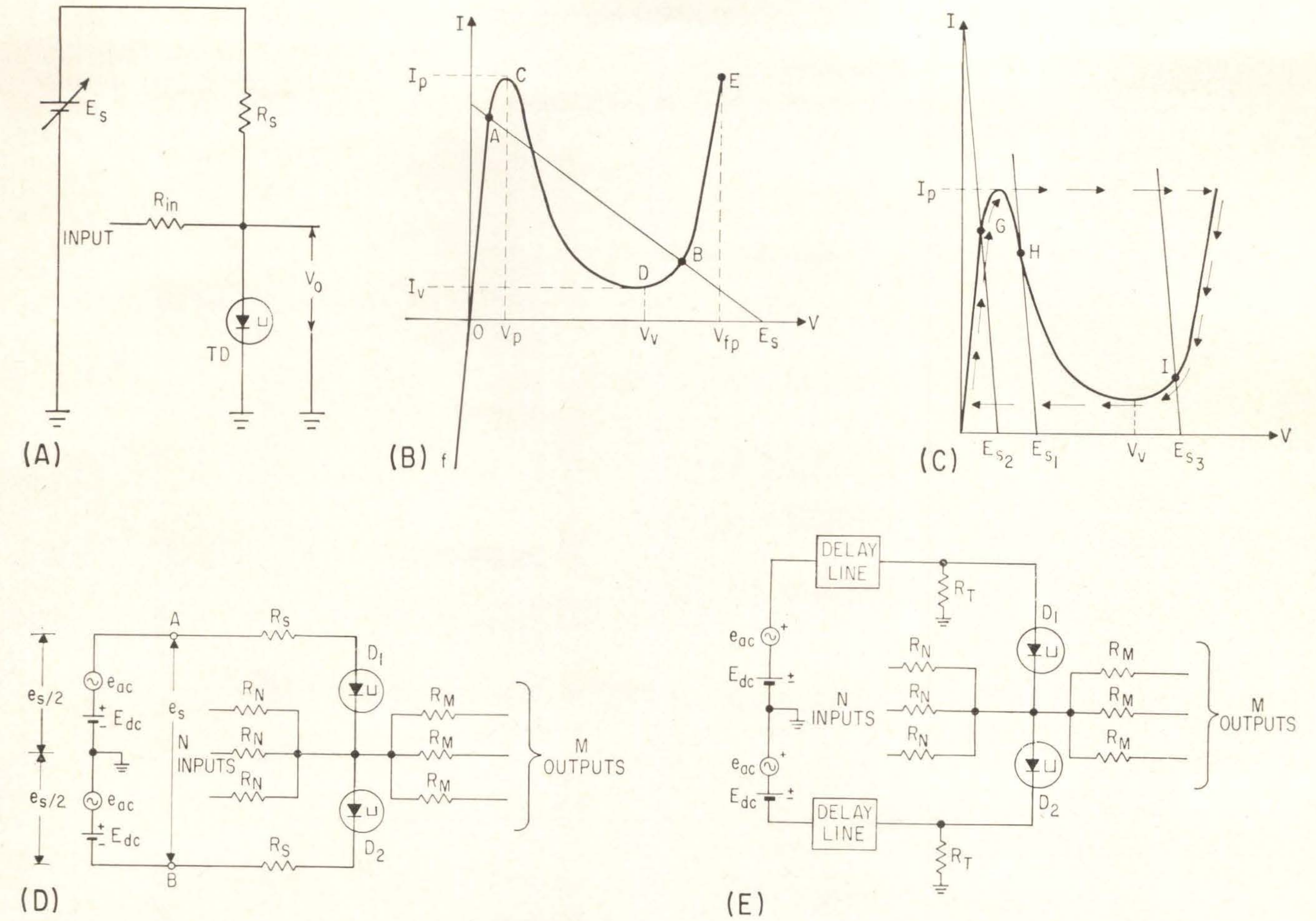


BASIC *tunnel diode circuit (A), with load-line intersecting the tunnel-diode characteristic for bistable operation (B), and monostable operation (C). Locked-pair logic element (D) and balanced-line logic element (E)—Fig. 1*

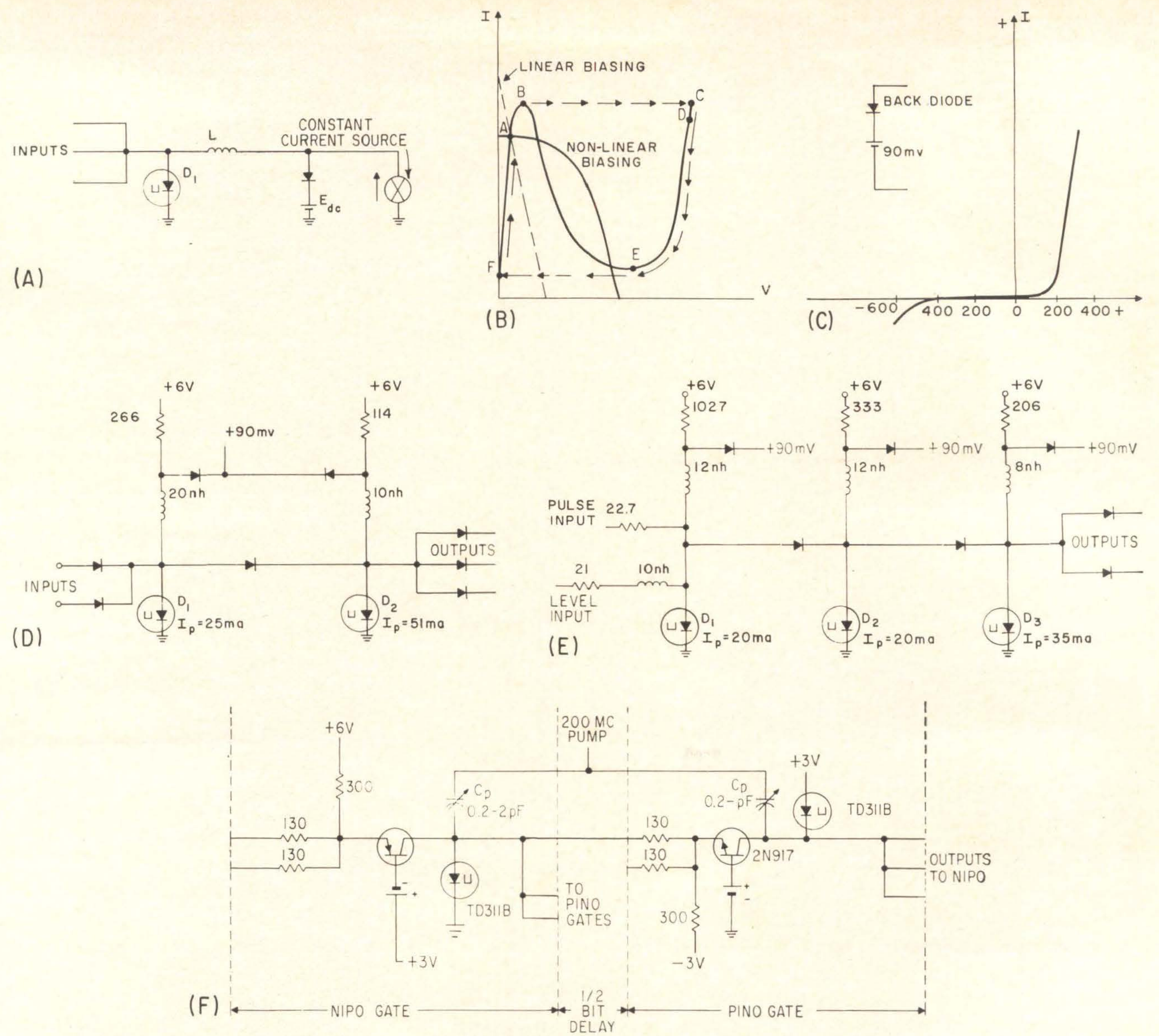
voltages and tunnel diodes are arranged in a bridge and the input and output voltages are taken with respect to the junction of tunnel diodes and supply voltages. The supply or clock voltage is an a-c signal superimposed on a d-c bias. During the negative half-cycle of the supply voltage, when point *A* is negative with respect to point *B*, the tunnel diodes are reverse biased and node *C* is at ground potential because of the symmetrical configuration. When the supply voltage becomes positive (point *A* is positive with respect to point *B*) both diodes conduct in their forward direction. Node *C* remains at ground potential until the current through one of the two diodes exceeds its peak current.

Which tunnel diode reaches its peak current first is dependent upon whether the majority of input signals is positive or negative with respect to ground. If the analog sum of the input voltages is positive, signal current will flow into point *C*, causing D_2 to reach its peak current first since the current adds to the current in D_2 and subtracts from that in D_1. Diode D_2 switches to its high-voltage state; D_1 is then forced to remain in its low-voltage state if the supply-voltage amplitude is limited to a value less than the forward voltage of the tunnel diode. The output voltage at *C* is then positive if the majority of the input signals are positive. If the majority of the input signals had been negative, D_1 would reach its peak current first, and the voltage output at *C* would be negative. To perform conventional AND or OR functions, one of the inputs is returned to a plus or minus potential. Thus if a positive voltage is considered a ONE, the circuit, Fig. 1D, will be a two input AND gate providing one of the inputs is returned to a negative supply. If one of the inputs is returned to a positive supply, the circuit becomes a two input OR gate since only one of the two remaining inputs need be positive to obtain a positive output.

The high-speed switching performance of the locked pair has been analyzed in detail.[2,3]. The maximum reliable repetition rate of the circuit with a sinusoidal supply and with a fan power of four is 250 Mc. This upper limit is set by the lead-case inductance and diode capacitance.

Others[4] have evaluated the system problems using the locked pair. This includes the distribution of power supply voltages, packaging, subsystem fabrication, and system tolerances.

BALANCED-LINE LOGIC — The balanced-line logic element[5] (BLLE)



MONOSTABLE *circuit with nonlinear biasing (A), biasing characteristics (B), nonlinear-source characteristics (C). Two cascaded monostables form an* OR *Gate (D), three cascaded monostables are necessary in* AND *gate to provide adequate gain (E). Basic pumped tunnel-diode transistor logic gates are interconnected (F)—Fig. 2*

is a logic circuit similar to the locked pair in that it contains a pair of matched tunnel diodes, performs majority logic, and uses a multiphase a-c clock to direct the flow of information. This circuit produces an output pulse with a flatter top than does the locked pair, thus improving the timing tolerance, and reducing cross-coupling effects of circuits on the same a-c phase.

The BLLE element is shown in Fig. 1E. Its push-pull power supply consists of a d-c bias and a superimposed sinusoidal a-c voltage applied to the two delay lines. The d-c load-line intersects the negative-resistance region of the composite characteristic of the two diodes in series. Thus, without any a-c present the BLLE element will free run. For example, if diode D_2 switches to the high-voltage state, a negative voltage step is impressed on its delay line, while an attenuated positive step is impressed on the other delay line. The voltage steps propagate to the low impedance power supply, where they are inverted and reflected. These reflected waves propagate back through the delay lines, and when they reach the tunnel diodes they switch D_2 back to its low voltage state. The transients that caused D_2 to switch to its low voltage state cause the voltage across the diodes to increase toward the d-c power supply. When the tunnel diodes reach their negative resistance region, another cycle begins. A similar explanation can be given for D_1 switching to the high-voltage state, producing a negative output pulse. Diode switching is determined by the polarity of the input at the time of switching; amplitude of input need only be sufficient to overcome any unbalance in the circuit caused by mismatch in the diodes and resistors, or unbalance in the power supply. The sinusoidal power-supply component synchronizes the logic element, and its amplitude can be small with a loose tolerance.

ASYNCHRONOUS LOGIC—A set of complete logic circuits has been developed to operate from d-c supplies, running at 200 Mc with only

1 nanosecond logic delays[6] and using no a-c clock. Directionality is obtained by using back diodes, and gain through the use of regenerative pulse amplifiers.

The basic amplifier for the logic circuits is the monostable multivibrator with nonlinear biasing, Fig. 2A. The bias comprises a constant-current source, a back diode, and the small d-c voltage, E_{d-c}. Regardless of linear or nonlinear bias, the basic operation of the circuit is the same. The tunnel diode is biased at the stable point *A* in Fig. 2B. If a current-pulse of sufficient amplitude occurs at one of the inputs so as to raise the tunnel diode over the peak point, the tuunel diode switches along the trajectory *B-C-D-E-F-A* of Fig. 2B. The voltage across the tunnel diode will be a pulse of width determined by the time it takes the current in the inductance to decay from the value at point *D* to the valley current. The maximum triggering-rate is limited by the time it takes the current in the inductance to go from the valley-current to the bias value at point *A*. Thus to operate at high speeds, the inductance must be in the nanohenry region. For this low value of inductance with a linear bias, the impedance presented by the inductance is small, requiring a large input-current to trigger the tunnel diode.

The voltage-current characteristic of the back-diode combination is shown in Fig. 2C. For a positive voltage, the combination is nonconductive to about 200 mv, and has low impedance above 200 mv. Use of this nonlinear biasing characteristic is shown in Fig. 2B. The constant current biases the tunnel diode at point *A*. The impedance presented by the back diode and constant current source is high; therefore all of the input current will flow into the tunnel diode. Only after the tunnel diode switches to the high voltage state does the impedance of the back diode become small, allowing the circuit to function in the monostable mode.

Fig. 2D shows an OR gate: it consists of two monostables cascaded to provide current gain. If either of the inputs has an input current of 8 ma or higher, an output is obtained.

The AND gate is shown in Fig. 2E. Three monostable stages are necessary for the required gain. The bias to the first monostable is reduced so that both inputs must be present to trigger it. Because of the timing problem at high speeds, one of the inputs is obtained from an OR or AND gate and the other comes from a bistable circuit (not shown). The circuits described, in addition to the bistable unit, have been built to perform storage, shifting, counting, parity-checking, and other applications.

PUMPED TD-T LOGIC—Pumped tunnel diode transistor logic (PTDTL)[7] is a high-speed, hybrid-logic circuit where the tunnel diode performs the functions of thresholding, gain, and pulse reshaping, while the transistor provides isolation and directionality. Each gate has a minimum number of components since it consists only of one transistor, one tunnel diode, three resistors, and one capacitor. The transistor is operated in the linear mode and in the grounded base configuration. Since it is not required to provide any power gain, the transistor can be operated near its alpha cutoff frequency. The clock frequency of the PTDTL to be described is 200 Mc; however, data reduction can be performed at 400 Mc or higher because the delay through each gate is only 1.5 nanoseconds.

Basic PTDTL gates and the method of interconnection are shown in Fig. 2F; the gates are NOR circuits, but they reverse the input polarity. This requires two gates, one that accepts positive inputs and provides negative outputs (PINO), and another accepting negative inputs and providing positive outputs (NIPO). Additionally, a 1:1 transmission-line inverting-transformer of sufficient bandwidth is available for inverting any variable to produce the correct polarity.

The tunnel diodes, Fig. 2F, are biased near their peak point by the d-c transistor current, with the transistor operated in its linear mode. The 200-Mc pump or clock is coupled to the tunnel diode by capacitor, C_p. If there are no inputs, the clock has sufficient amplitude to fire the tunnel diode from the low voltage to the high voltage state: it fires the NIPO stages on the positive half-cycle and PINO stages on the negative half-cycle. If an input signal is present, the current through the transistor is decreased and the pump or clock current has insufficient amplitude to fire the tunnel diode. Thus a basic NOR gate results, generating an output pulse only when there is no input. The tunnel diode is reset to the low voltage state during the alternate half cycle of the pump.

Because the transistor operates in the grounded base configuration, the input impedance is very low, providing isolation between the two inputs. Also, the output admittance is low, isolating the inputs from the tunnel diode. The PINO and NIPO gates are interconnected by direct-coupled and terminated transmission lines that provide signal delay for timing. Termination of the transmission line reduces reflections, and the d-c coupling avoids the adverse effects of coupling capacitors. The d-c potentials on both ends of the transmission lines are balanced by adjusting the d-c voltages in the base of each transistor. PTDTL, arithmetic units, shift registers, counters, psuedo random noise generators, parallel-series converters, and analog to digital converters have been built and tested.

ENHANCED TD CIRCUIT — A new high-speed, hybrid logic circuit using a charge-storage diode and a tunnel diode is shown in Fig. 3A.[6, 7] The tunnel-diode bias is supplied by the voltage source E_b and resistor R_b. Diode, D_3, and the clock-reset are used to set the tunnel diode in the low voltage state at the beginning of each operation, while the set-clock, combined with the charge-storage-diode, set the tunnel diode in the high-voltage state if no input is present. Thus the circuit is a NOR. The output is taken across the tunnel diode, with a ONE represented by the high-voltage stage, and a ZERO by the low-voltage state.

At the beginning of each logic operation, the tunnel diode is set to the low-voltage state by the reset clock (the tunnel diode is biased below its peak current by the bias current, E_b/R_b). Resistor R_1 adjusts the voltage at node *A*. If all the inputs are in their zero state, the input diodes are nonconducting. A current I_F flows through charge-storage-diode D_S and resistor R_F to the voltage sink E_f. The charge stored in the diode is $I_F t_f$. When the clock pulse appears, it reverse biases the diode D_s and a reverse-current I_R flows through the diode from node B to node A. Reverse-current $I_R = V_c/R$ where R is the total loop impedance and V_c is the clock voltage. The recovered charge is given by $Q_R = I_R t_r$, and since $t_R << t_f$, I_R is much larger than I_f. Thus a considerable current gain is achieved. The current I_R triggers the tunnel diode to the high voltage state. Reverse characteristics are shown in Fig. 3B.

If a ONE was present at any input, the voltage at B would be higher than at A (the input diode is conducting) so that no charge is stored in D_s. When the set clock pulse occurs, there is no reverse current I_R and the tunnel-diode remains in the low-voltage state.

Worst-case calculations indicate the circuit can operate with tolerance figures of ±20 percent for clock voltage, ±5 percent each for the constant current and peak current, and ±30 percent for the peak voltage.[7] A fan-in of 5 and a fan out of 3-to-5 is realizable in high speed (nano second) circuits. Several logic configurations have been built to test the circuit and these operated at a speed of 2 to 4 nanoseconds per logic level. One of the configurations built and tested was a 32-bit register recirculating at a 125-Mc clock rate.

STORAGE—At the present time, application of tunnel diodes as a storage element seems to be most useful in small, high-speed buffer memories.

An example of such a storage element is shown in Fig. 3C.[9] This storage element uses two tunnel diodes in series and the power-supply voltage is constrained so that only one of the two tunnel diodes can be in the high-voltage state at any time. At the start of the write cycle, a negative write control pulse is applied to each word, and the lower tunnel diode D_2 is set to the low-voltage state. Consequently the upper tunnel diode is forced to the high-voltage state. If a ONE is to be written, a positive write pulse is applied to the given bit by the digit write line. The lower tunnel diode D_2 is set tothe high voltage state, and D_1 is forced tothe low voltage state. To read the information, a positive read control pulse is applied to the read control line. If D_2 is in the high-voltage state (a ONE stored), the read control pulse appearing at node A is attenuated. However, if a ZERO is stored, D_2 is in the low-voltage state and the read control pulse appears at node A with little attenuation.

This element was used in the construction of a 20 word, 50 bit each, nondestructively read random access memory which had read and write cycle times of twenty nanoseconds.

A second example of a tunnel-diode memory cell, in which the reading and writing are accomplished by voltage selection through a diode, is shown in Fig. 3D[10]. The diode is a germanium gold-bonded type with a forward voltage drop of 250 mv at peak-current. The voltage drop of the tunnel diode in the high-voltage state at the peak current is 500 mv.

Information is written into the tunnel diode by first reducing the bias current I_0 to zero, thus setting the tunnel diode in the low voltage state. A negative pulse whose amplitude is between 300 and 750 mv is applied to the word line and the digit line is held at ground potential if the diode is to switch to the high voltage state. The digit line is set to a negative voltage if the tunnel diode is to remain in the low-voltage state.

The state of the tunnel diode is read by setting the digit line to ground and applying a negative pulse (300 to 750 mv) to the word line. If the tunnel diode is in the low voltage state, the germanium diode will conduct and a current will flow in the digit line. If the tunnel diode is in the high voltage state no current will flow in the digit line. This circuit has been used in the development of a 32 word computer index store.[11]

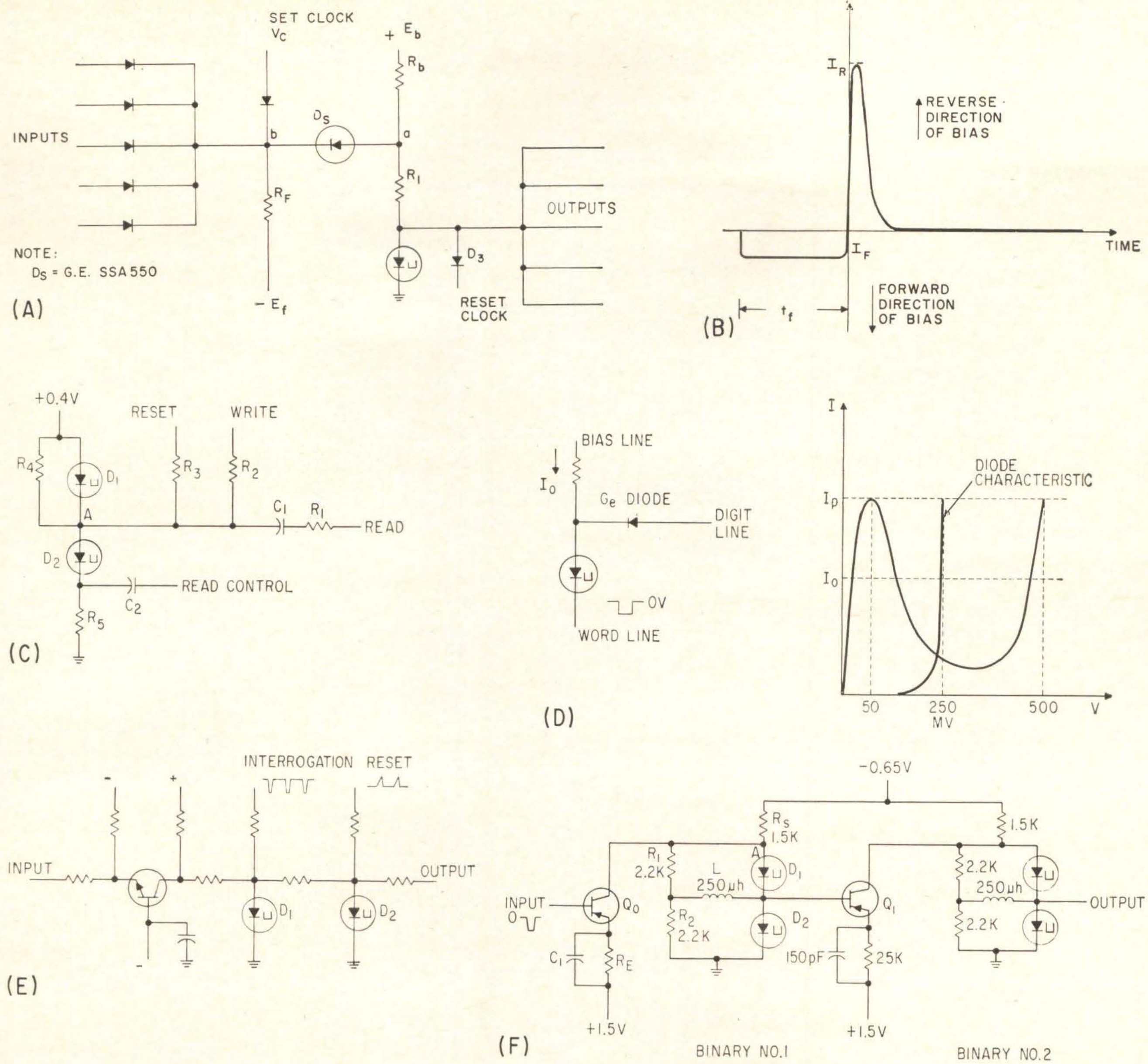
OTHER APPLICATIONS — One important application of tunnel diodes is as a threshold device, Fig. 3E, which forms an important part of a high speed analog-to-digital converter.[12]

The transistor acts as a termination for the input transmission line and isolates the threshold circuit from the input. Diode D_1 is the threshold diode and is fed both by the signal current and an interrogation one nanosecond wide and has a 50-Mc repetition rate. In the absence of the interrogation pulse, D_1 can never be switched to the high-voltage state by the signal current. At the instant of interrogation the tunnel diode switches to the high-voltage state if the signal is below the threshold level. The second tunnel diode D_2 is biased below its peak point and will switch to the high voltage state if D_1 fires. It is reset to the low voltage state by the reset line.

The threshold tunnel diode is able to resolve current level differences of less than 50 μa in 300 picoseconds—this corresponds to a charge less than 0.015 picocoulomb or 100,000 electrons.[12]

LOW LEVEL COUNTER—Besides its high speed, the tunnel diode (or backdiode) consumes little power. Both of these properties are used to full advantage in the high speed, low level counter shown in Fig. 3F. This circuit was developed by Bush for satellite applications.[13]

The supply voltage and resistances R_s, R_1 and R_2 are selected such that only one of the two diodes can be in the high-voltage state. If D_1, for example, is in the high-voltage state, then a negative pulse into the base of the coupling transistor, Q, will short node A to ground (Q_1 emitter is bypassed). Current through the tunnel diodes is reduced below the valley current, and therefore both tunnel diodes are returned to the low voltage state. However, a current had previously been flowing through R_1, L and D_2, and since current through L cannot change instantaneously, the voltage across the inductor reverses, switching D_1 to the high voltage state. Upon application of the next negative pulse to the base of Q_1, the same series of events is repeated; D_2 is switched to the high voltage state and D_1 is returned to the low voltage state. Thus, for every two negative input pulses to the transistor base, one negative pulse is generated across D_2 (when it switches to the high voltage state). A silicon transistor used in coupling the binary stages is biased in the linear mode to eliminate any emitter-base offset-voltage problem. The transistor operates as an emitter follower when no transient is present; however, when a negative transient appears at the base,



HYBRID *circuit uses charge-storage diode for* NOR *logic A), reverse characteristic of p-m junction (B), tunnel-diode storage element (C), and memory cell for diode selection, with diode characteristics (D). Threshold detector responds to 50 microamp in 0.3 nsec (E), low-level counter (F)—Fig. 3*

the base current increases appreciably since the capacitor holds the emitter voltage to its original value. The transistor saturates and effectively short circuits the binary. Either *pnp* or *npn* silicon transistors can be used in this circuit.

A counter constructed with 1N2939 germanium tunnel diodes had a power consumption of only 525 microwatts per stage (transistor and binary). This counter was operated reliably up to 5-Mc. Another counter was constructed using G. E. XF1A533, backdiodes, having a peak current of 0.25 ma.

This counter consumed only 200 microwatts per stage and operated reliably from −55 to 100 C with input rates up to 2.5 Mc. The minimum supply-voltage tolerance for a four-stage counter over this temperature range was +10 percent and −20 percent.

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Parasitics In Integrated Circuits:

Design of fully integrated circuits is going to be more complex than circuit design using conventional components. Isolation problems can be solved by adding extra p-n junctions, but at the expense of introducing extraneous diodes, capacitors and transistors

By H. K. DICKEN

Motorola Semiconductor Products, Inc., Phoenix, Arizona

IN A FULLY integrated circuit, both active and passive circuit elements are formed by diffusions into a single-crystal silicon substrate. Circuit elements, however, must still be isolated from each other, and this is now typically accomplished with diffused *p-n* junctions that form back-to-back diodes. Although adequate isolation is obtained, the structures have several inherent detrimental parasitic effects. These include substrate transistor action from diffused resistors, parasitic capacitance at each junction and higher series resistance in some conducting paths. These effects can completely degrade circuit performance.

Isolation by *p-n* back-to-back diodes is the basic technique of integrated circuit construction. In a typical structure, as shown in Fig. 1A, a 20-micron layer of 0.5 ohm-cm *n*-type silicon is grown epitaxially on a wafer of 5 ohm-cm *p*-type silicon. Channels are then selectively etched through the SiO_2 coating on the surface of the wafer for the *p*-type isolation diffusion. This diffusion forms the electrically isolated areas for each section of the circuit. Each *n*-type area then provides the basis for the remaining diffusions to form transistors, diodes, resistors, and capacitors—all isolated by the equivalent of the reverse characteristics of a diode. Normal leakage current of the reverse biased diodes is less than 1 microamp.

PARASITIC ELEMENTS — Each *p-n* junction of the resulting four-

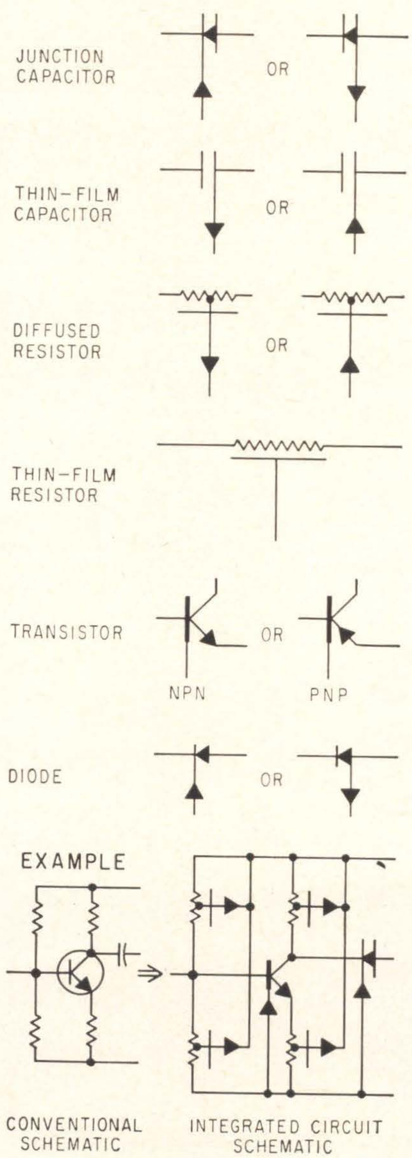
SPECIAL SYMBOLS FOR INTEGRATED CIRCUITS

One of the troubles with fully integrated circuits is that they are more complicated than circuits using discrete elements. A resistor no longer is a simple passive device—not even at d-c.

Accordingly, some engineers feel conventional circuit symbols do not lend themselves to integrated circuits because of the parasitic effects and the method of circuit construction. The symbols here are used at Motorola to show component function, construction, and parasitics.

Basic to the symbols is a third terminal on the passive devices and a fourth on the active devices that indicates each component has some parasitic action to a common substrate. The arrow indicates the direction of the diode action between the component and the substrate material in immediate contact, such as a **p**-type diffused resistor in an **n**-type isolated area. Here it is assumed the resistor has been designed such that there is no parasitic transistor action. It is also assumed that associated with each arrow is the parasitic capacitance inherent with every **p-n** junction.

The circuit example illustrates two possible advantages. First, the requirements for a fully integrated layout are apparent from the connections of the substrate terminals. Second, the effects of the parasitic capacitances on the circuit performance are apparent and an accurate picture of the final circuit is produced



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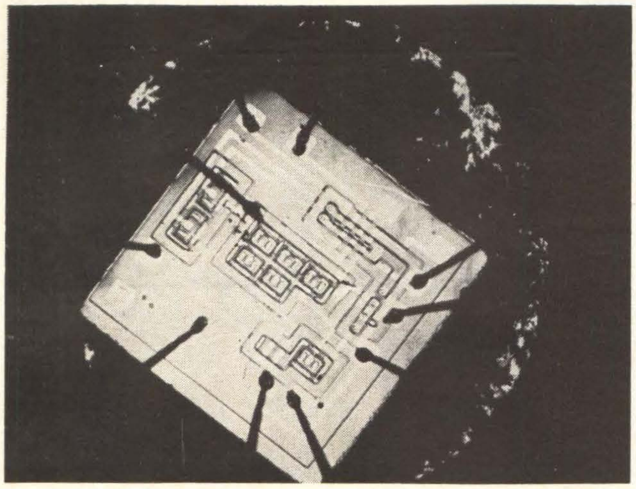
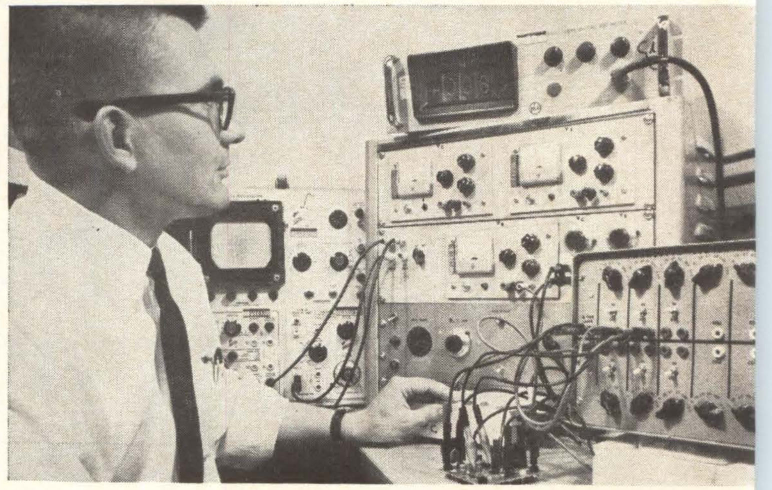
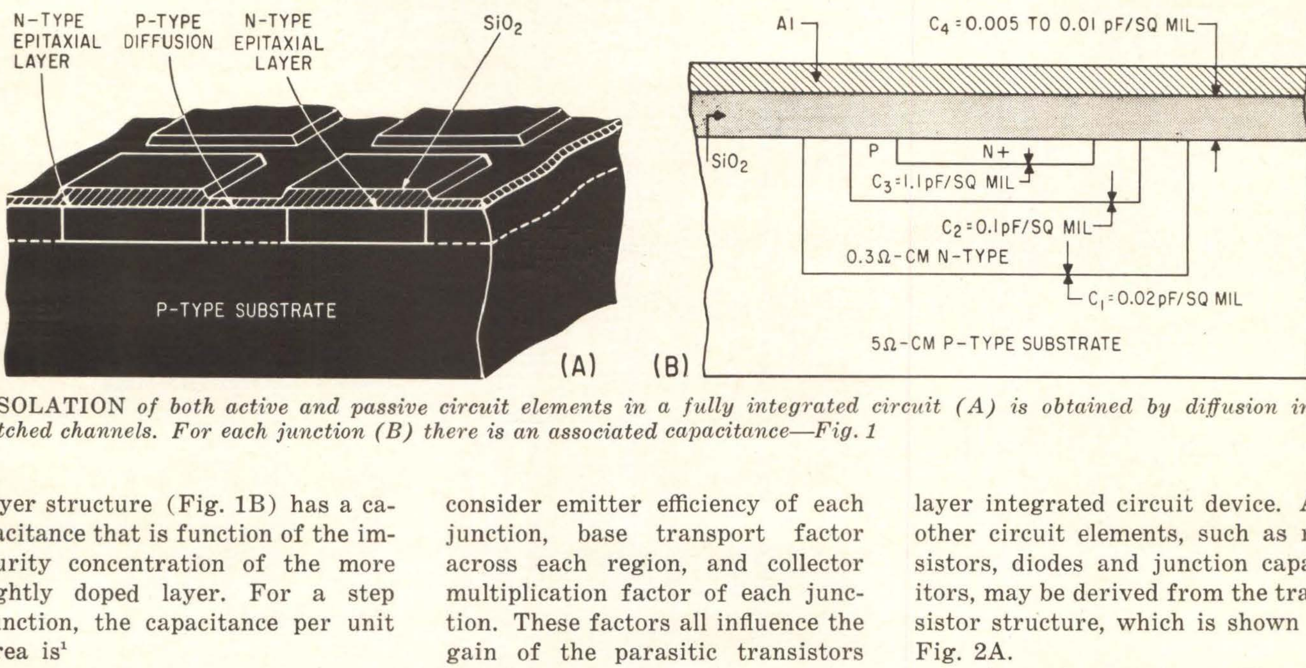


FULLY INTEGRATED *logic circuit has high reliability and small size*



BEFORE *the integrated circuit is built, its design is checked out with circuit simulator for parasitics*



ISOLATION *of both active and passive circuit elements in a fully integrated circuit (A) is obtained by diffusion into etched channels. For each junction (B) there is an associated capacitance—Fig. 1*

layer structure (Fig. 1B) has a capacitance that is function of the impurity concentration of the more lightly doped layer. For a step junction, the capacitance per unit area is[1]

$$C = \sqrt{\frac{qK\epsilon_0 N}{2V}}$$

where q = electron charge (1.6×10^{-19} coulomb), k = dielectric constant of silicon (12), ϵ_o = permittivity of free space (8.85×10^{-14} farad/cm), N = impurity concentration of more lightly doped layer, and V = total junction potential.

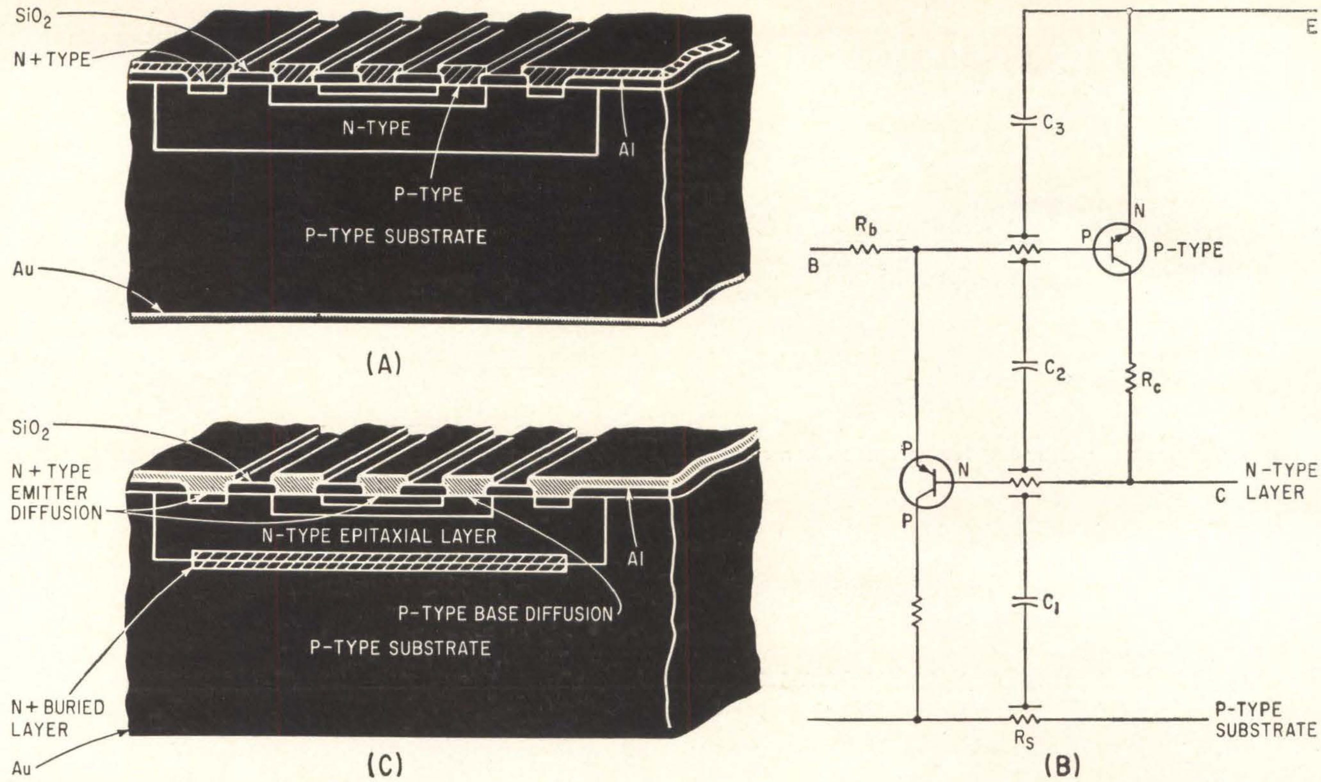
Average valves for C_1, C_2 and C_3 are indicated in Fig. 1B at zero volts bias; C_4 is not affected by bias. Actual capacitance will depend on the impurity concentration.

In addition, the designer must consider emitter efficiency of each junction, base transport factor across each region, and collector multiplication factor of each junction. These factors all influence the gain of the parasitic transistors and thus determine if interaction between circuit elements will occur.

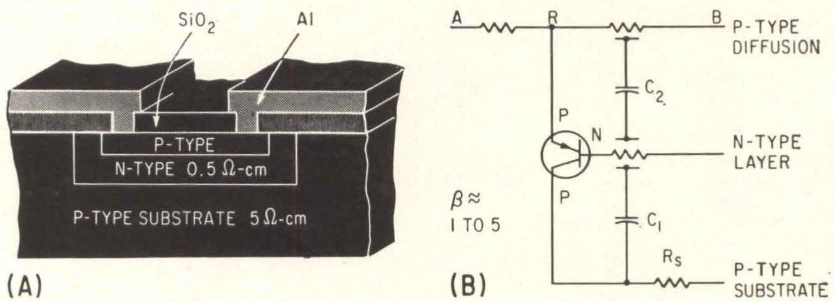
Resistors, capacitors, diodes and transistors have greatly changed equivalent circuits in fully integrated structures. The elements are now tied to a common *p*-type silicon substrate. The equivalent circuits following have been simplified to show only the critical elements. Actual equivalent circuits would be based on a model similar to a distributed four-layer active structure.

TRANSISTORS — The transistor structure is the fundamental four-layer integrated circuit device. All other circuit elements, such as resistors, diodes and junction capacitors, may be derived from the transistor structure, which is shown in Fig. 2A.

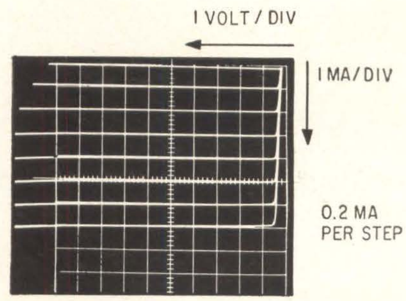
In the equivalent circuit, Fig. 2B, an integrated circuit transistor is shown as a four-layer device. However, under normal bias conditions, parasitic action to the substrate is limited to a diode and distributed capacitance C_1, with C_1 approximately 0.02 pf per sq mil of collector area. For normal transistor geometries, this would give a total collector to ground capacitance of less than 10 pf. However, other detrimental effects are inherent in this structure. One of the primary disadvantages is the increase in the collector saturation resistance, R_c,



CROSS SECTION *of an npn integrated-circuit transistor (A) and its simplified equivalent circuit (B). Collector saturation resistance can be reduced by adding n-type buried layer (C)—Fig. 2*



DIFFUSED *resistor (A) has an associated, built-in, distributed transistor, as indicated at (B)—Fig. 3*



CHARACTERISTIC *of a substrate-type npn transistor—Fig. 4*

due to the collector being brought out to the surface of the wafer through a relatively high resistance material. The product of this resistance and collector capacitance limits high-frequency response.

The alpha-cutoff frequency f_{hfb} (gain is down 3 db) of any transistor is a function mainly of four terms: ω_e the emitter delay-time constant; ω_b the base-transit time; ω_d the collector depletion-layer transit time; and ω_c the collector delay time constant. This collector delay time constant is $\omega_c \approx R_c C_2$, where R_c is the series resistance of the collector region and C_2 is the collector capacitance. For an integrated circuit transistor, ω_c is the dominante time factor. For typical geometries, R_c is of the order of 50 to 100 ohms and C_2 is approximately 5 pf, thus resulting in f_{hfb} from 300 to 500 Mc. The high saturation resistance also causes large power losses in such applications as audio amplifiers.

The effects can be minimized by several methods. One technique is to sacrifice the breakdown voltage and lower the resistance of the collector material, thus decreasing r_c but increasing C_c. A second more promising method involves an epitaxial growth over a buried $n+$ layer under the transistor, as illustrated in Fig. 2C.

RESISTORS—The integrated resistor differs more than the other circuit elements from its conventional counterpart and illustrates most of the parasitic *pnp* transistor effects. The elements are normally formed during the base diffusion cycle. Figure 3A is a cross-sectional view of an integrated circuit resistor. The *n*-type silicon layer is used for isolation while the *p*-type layer, approximately three microns deep, determines the resistance.

As shown in Fig. 3B, the final element has both a distributed capacitance and a distributed transistor effect. Thus the *n*-type layer, which is used for isolation, becomes the base of a low beta (h_{fe}) *pnp* transistor. The distributed transistor, which has a beta from 0.5 to 5, is a result of the relatively narrow (approximately 17 microns) *n*-type epitaxial layer between the *p*-type substrate and the *p*-type resistor diffusion.

The alpha (h_{fb}) of this *pnp* transistor is determined by the emitter efficiency of the normal base-collector junction, the base transport factor across the collector material, and the collector multiplication ratio of the collector-substrate junction. The overall alpha may be written as the product of these mechanisms.

$$\alpha = \gamma \beta^* \alpha^*$$

where γ = emitter efficiency, β^* = base transport factor, and α^* = collector multiplication ratio.

Emitter efficiency γ is defined as the ratio of the injected hole current to the total emitter current. The value of γ is a direct function of the ratio of emitter resistivity to base resistivity, or for this structure, the ratio of the base diffusion resistivity to the epitaxial layer resistivity, which is on the order of 1 to 5. This ratio gives a value for γ of 0.8 to 0.9.

For this structure, the base-transport factor β^* is defined as the probability that the hole carrier will cross the *n*-type epitaxial layer and reach the substrate. This is given by

$$\beta^* = \text{Sech } W/L_{pb}$$

where, in this structure, W is approximately 17 microns and L_{pb} is the hole diffusion length in the epitaxial layer. This gives a value for β^* of 0.6 to 0.8.

The collector multiplication ratio α^*, is related to the ratio of the minority carrier concentration to the majority carrier concentration in the substrate region. For integrated circuits, where the substrate resistance is from 5 to 10 ohm-cm, α^* may be equal to or greater than 1.

These factors result in an approximate over-all alpha of (0.85) (0.7) (1) or 0.6, thus giving a typical beta for the substrate *pnp* transistor of about 1.5. Figure 4 shows the *V-I* characteristics of a *pnp* transistor of this type.

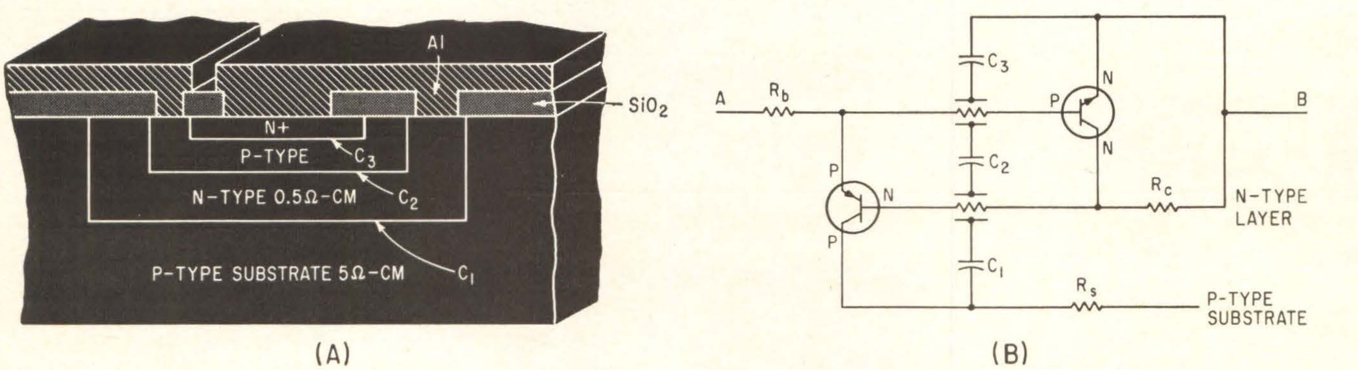
Because the substrate is normally connected to the lowest potential of the circuit, conduction will occur when the *p-n* junction of the resistor and the epitaxial layer is forward biased due to junction leakage or other defect. As Fig. 3B shows, current leakage between the substrate and the *n*-type layer could be multiplied by the beta of the transistor and act as a shunt leakage between the resistor and the substrate. To prevent such effects, the *n*-type layer is connected to the highest circuit potential.

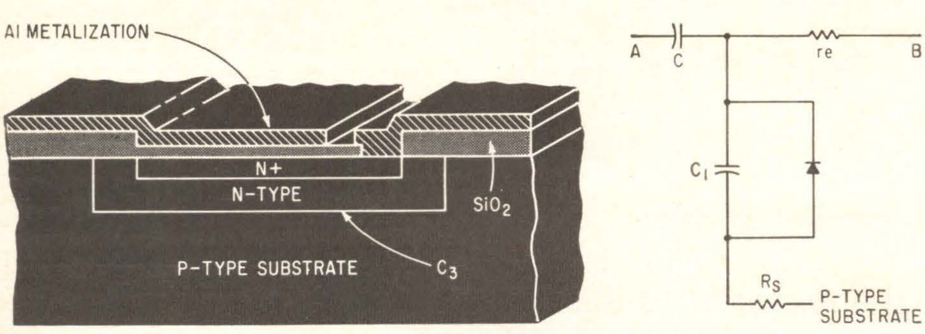
Other parasitic effects associated with diffused resistors are the distributed junction capacitances. Their values are a function of junction area and are as given in Fig. 1B for C_1 and C_2. The effects of these capacitances become significant at high frequencies. The h_{21} transfer characteristic (i_2/i_1) decreases from unity in the range from 10 to 100 Mc because of the shunting effect of the distributed capacitance.

CAPACITORS—Integrated circuit capacitors are formed by two techniques: first, through the utilization of the capacitance inherent in a large area *p-n* junction; second, through the use of the thin film of silicon dioxide (SiO_2) between an *n*-type silicon layer and the aluminum metalization. For both types of capacitors there is a finite ratio of total to shunt capacitance. This ratio, which is on the order of 20 to 1, limits the usefulness of either type, particularly at high frequencies.

With the junction capacitor, a sandwich of two junctions can produce a higher ratio of total capacitance to shunt capacitance. As shown in Fig. 5A, a transistor structure is used with one contact to the *p*-type layer and the other shorting the two *n*-type layers. This structure has a relatively large capacitance per unit area — approximately 1.1 pf per sq mil.

Several factors should be considered when utilizing the junction capacitor, as the simplified equivalent circuit of Fig. 5B indicates. First, the total capacitance is a function of the applied voltage, decreasing





JUNCTION-*type capacitor (A) has a relatively large R_b (B) and thus a relatively low Q. It is most useful for bypass applications. Oxide capacitor (C) has about 0.25 pf per sq mil of metalized area (D) —Fig. 5* with an increase in reverse bias. Thus in some circuits an unwanted voltage modulation would be present. Second, because it is a diode, the unit must be reverse biased. Third, series contact resistance R_b is relatively large, thus reducing the Q of the unit. R_b may be minimized by the same techniques used to reduce the r_b' of a transistor. Because of these factors, the junction capacitor is normally used for bypass.

The oxide-type capacitor, Fig. 5C, eliminates some of these effects. The structure is simply a dielectric (SiO_2) between the $n+$ silicon and the aluminum metalization on the surface. Again, the n-type layer is used for isolation from the substrate. As shown in the equivalent circuit, Fig. 5D, the parasitic effects consist of a small series resistance r_e, a diode and shunt capacitance C_1 to the substrate.

CIRCUIT SIMULATOR—The substrate *pnp* transistor action typically associated with a diffused resistor can completely change circuit performance. However, an integrated circuit simulator, shown schematically in Fig. 6, can be used with standard components to produce the same parasitic effects that occur with the diffused resistors of a fully integrated circuit. The simulator, Fig. 6, consists of low beta (h_{fe}) *pnp* transistors and capacitors to simulate the isolating junctions associated with integrated resistors.

The resistor terminals are connected across each resistor of the circuit breadboard. The substrate terminal is connected to the most negative potential of the circuit while the n-layer terminal is connected to the most positive. The switch associated with each grouping determines if the resistor is separately isolated. Switching characteristics of a standard component circuit with the simulator attached are shown in Fig. 6A and 6B. These characteristics reveal an improperly designed integrated layout. The corrected switching characteristics shown in Fig. 6C and 6D are obtained when the n-type layer for each resistor of the simulator is connected to the highest circuit potential, thus preventing transistor action.

Circuit design can eliminate some of the parasitic effects. The effect of a high series collector resistance can be reduced by a buried $n+$ layer. To eliminate the collector to substrate capacitance C_1, a resistive bar of silicon provides isolation between transistors, thus eliminating the capacitance associated with diode type isolation.[2]

Much of the work reported here was done under Air Force Contract #AF33(616)8276 on Compatible Techniques for Integrated Circuits.

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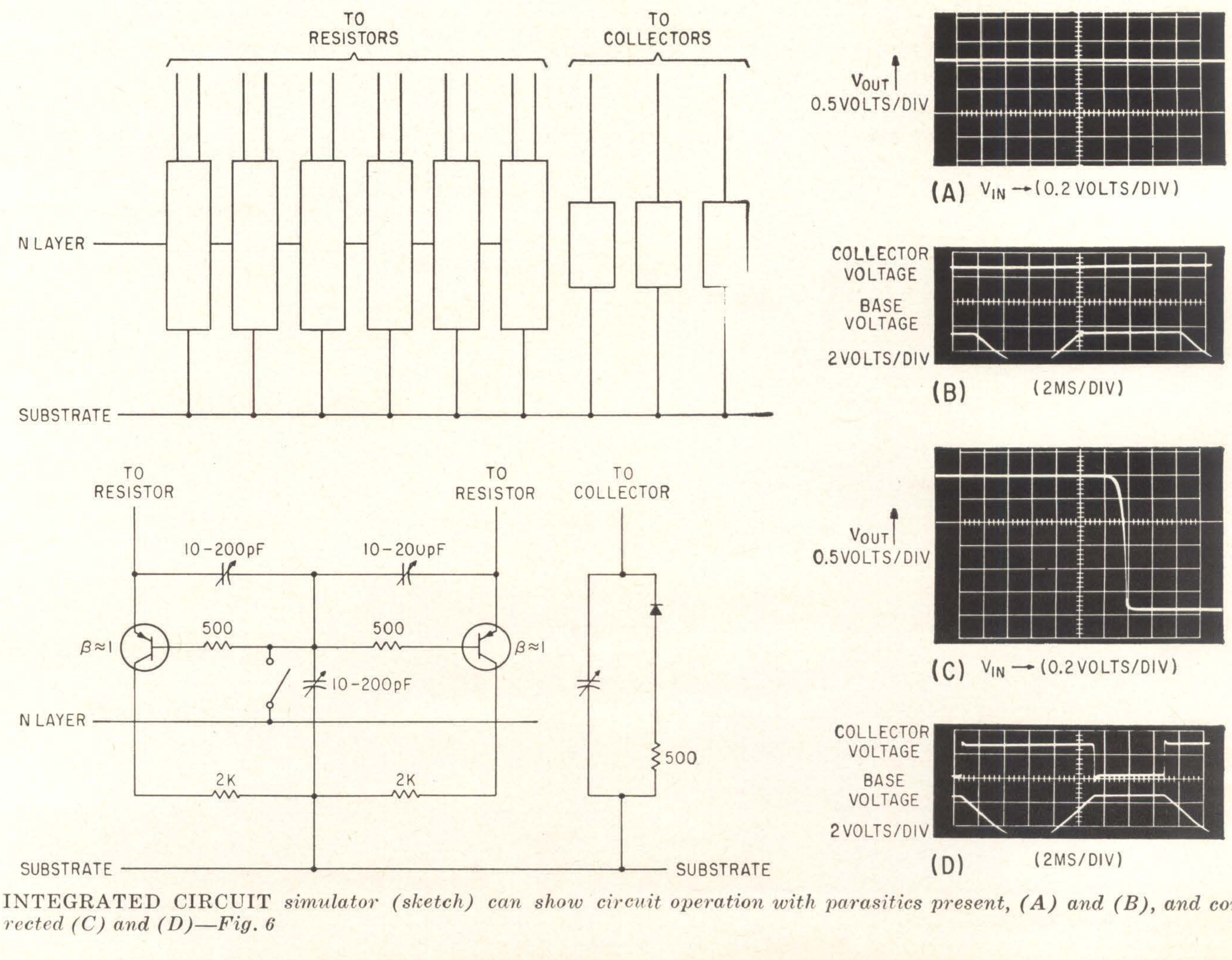

INTEGRATED CIRCUIT *simulator (sketch) can show circuit operation with parasitics present, (A) and (B), and corrected (C) and (D)—Fig. 6*

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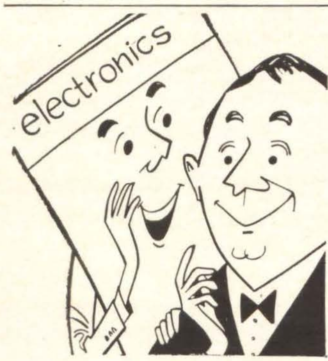

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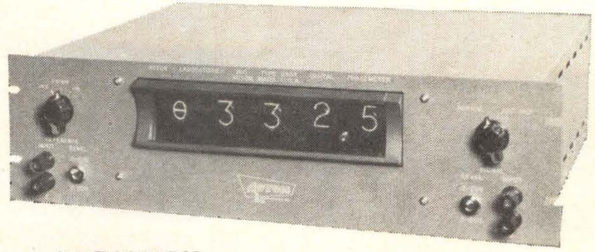

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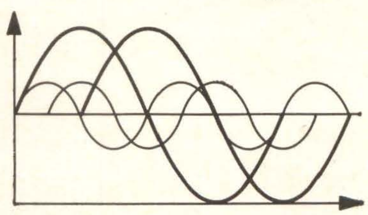

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Nomograph Speeds Amplifier Design

By ROGER T. STEVENS
Video and Display Section,
Sanders Associates, Inc.,
Nashua, New Hampshire

SUCCESSIVE detection i-f amplifiers provide an output signal that is approximately equal to the logarithm of the incoming signal. They are used where it is necessary to reduce the dynamic range of incoming signal data to a more limited range, that can be handled by succeeding circuits, without loss of signal intelligence. The basic successive detection technique requires that the amplifier be adjusted so that a minimum-level input brings the final amplifying stage just to limit level. The output signal is that from the last detector only, the contributions of the other detectors being negligible. If the given gain of each stage is n, and the units of measurement of the input signal are defined so that the minimum input is n units, the output for this minimum signal will be m. If the input signal is increased n times to n^2, the next to last stage will reach the limit level and its detector will produce an output, m. Meanwhile, the last stage is limiting, so its output is the same as for a minimum signal and its detector is supplying the same signal m. Thus, for a signal n^2, the summed video output is $2m$. Similarly, an input n^3 yields a $3m$ output, an input n^4, a $4m$ output and so forth. The output signal, therefore, is the logarithm of the input.

Two common methods of producing successive detection logarithmic i-f amplifiers use a diode detector at the output of each amplifying stage. The video outputs are summed through a delay line having the same delay characteristics as the i-f amplifying stages so that video outputs from the different stages will precisely add in time. In some circuits, a diode detector used only in the last stage. The other stages make use of the fact that as each pentode begins to limit, it acts as an infinite impedance detector, producing a video signal at its cathode. The cathodes are bypassed for i-f only; video signals from the cathodes are combined in a resistive adder.

DYNAMIC RANGE—It is not generally realized that the dynamic range of input and output signals alone is sufficient to determine the overall small-signal gain of a logarithmic i-f amplifier. For example, it is not possible to have a logarithmic i-f amplifier that will accept a 60-db range of input signals, compress them into a 12-db range of output signals and have an overall small signal gain of 60 db, since the first two requirements indicate that the small signal gain will be 80 db.

For a given dynamic range of input signals, move up the curve of Fig. 2 until the desired range of inputs produces the desired range of outputs. Each line segment of the curve represents a stage of gain, and since the small-signal gain of the amplifier is linear, it is the cascaded gain of all the stages required to make up the number of line segments necessary to reach the portion of the curve with the desired output dynamic range. Mathematically, if e_1 is an input signal that causes the final stage of the amplifier to saturate, reaching a particular desired portion of the logarithmic curve might require that the first usable input signal saturate m stages and would thus be $g^{m-1}\, e_1$, where g is the gain-per-stage. If the amplifier contains n unsaturated stages, the maximum usable input signal at this point is $g^{m+n-1}\, e_1$. Range and gain calculations are shown in the panel.

NOMOGRAPH — The nomograph provides a mechanical means of

DYNAMIC RANGE AND SMALL-SIGNAL GAIN

Usable dynamic range of input signals is the ratio of maximum to minimum signal or

$$\text{Dynamic Range (Input)} = D_1 = \frac{g^{m+n-1} e_1}{g^{m-1} e_1} = g^n \qquad (1)$$

The minimum and maximum output signals are respectively (m) $g^N e_1$ and (m + n) $g^N e_1$, where N is the total number if stages in the amplifier

$$N = m + n \qquad (2)$$

The dynamic range of output signals is the ratio of maximum to minimum signal

$$D_o = \frac{(m+n)\, g^N e_1}{m\, g^N e_1} = \frac{m+n}{m} \qquad (3)$$

Combining Eq. 2 and 3

$$D_o = \frac{N}{N-n} \qquad (4)$$

Taking the log of Eq. 1 and combining with Eq. 4 to solve for N

$$D_o = \frac{N}{N - \log D_I / \log g} \qquad (5)$$

$$N = \frac{D_o \log D_I}{(D_o - 1)(\log g)} \qquad (6)$$

$$N = \frac{D_o\, D_I\, db}{(D_o - 1)\, g\, db}, \qquad (7)$$

where the db subscript indicates that these terms are in db. The overall gain of the amplifier for small signals is

$$G = N g\,\text{db} = \frac{D_o\, D_I\,\text{db}}{D_o - 1} \qquad (8)$$

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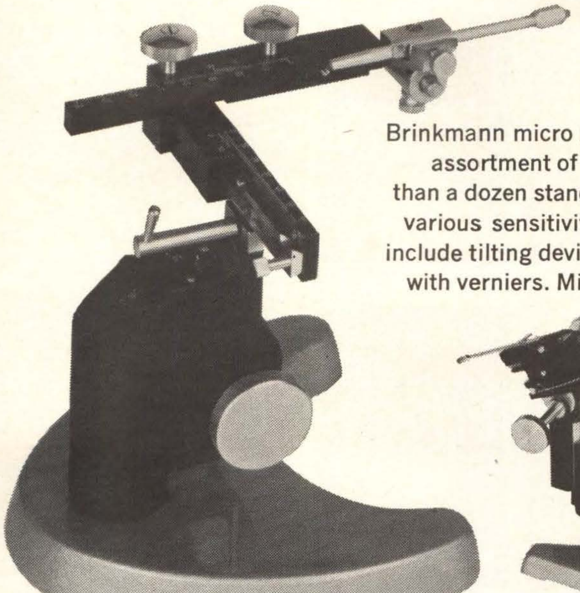

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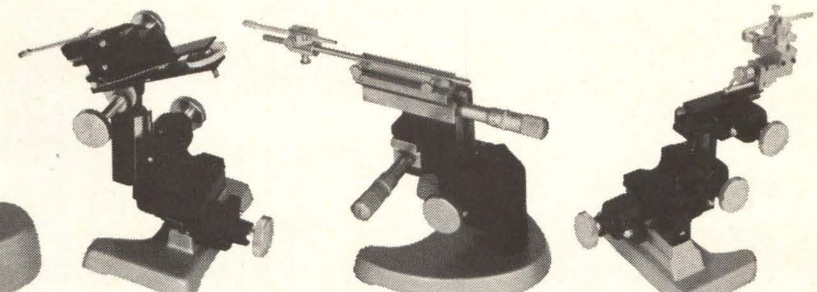

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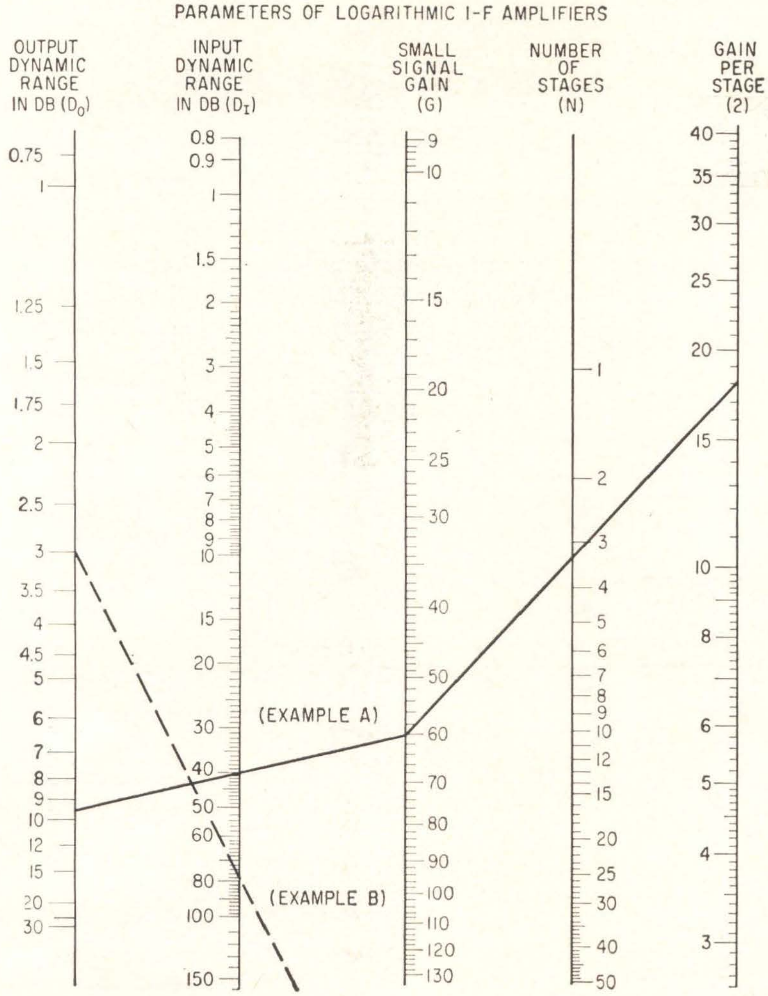
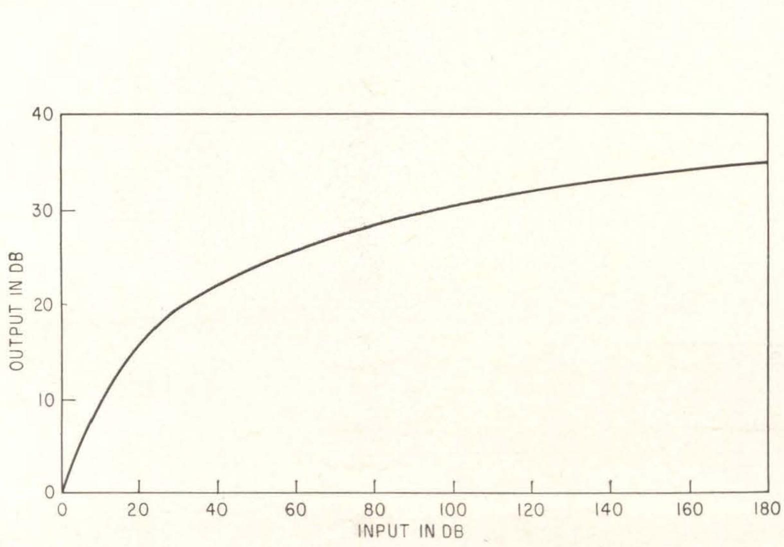


NOMOGRAPH *supplies parameters of logarithmic i-f amplifiers. The two lines represent examples discussed in text—Fig. 1*



OUTPUT CURVE *for typical successive-detection i-f amplifier—Fig. 2*

solving these equations. Once the desired input and output dynamic ranges are determined, a straight line drawn through these points on the nomograph will intersect the gain scale to show the necessary small-signal gain of the amplifier. A line drawn from this point to the proper gain-per-stage on the last scale will intersect to show the required number of stages. The logarithmic amplifier is an approximation to the logarithmic curve by a series of straight line segments, hence, the closest approximation to a true logarithmic curve is by a large number of stages having small gain-per-stage.

EXAMPLES—The use of the nomograph shown in Fig. 1 can be illustrated with examples of two different amplifiers. Example *A* is represented by the solid line and example *B* by the dashed line on the nomograph.

For example *A*, a logarithmic amplifier is required to compress a 40-db dynamic range of input signals into a 9.5-db range of output signals with a small-signal gain of 85 db. Each stage will have a gain of 18 db. How many stages are required? A line connecting the 9.5-db output dynamic range and 40-db input dynamic range shows that small-signal gain of the i-f strip will be 60 db. Connecting this point to the 18 db gain-per-stage point shows that 4 stages will be required. The additional 25 db of small-signal gain required can be supplied by a preamplifier preceding the log i-f amplifier.

In example *B*, a log i-f amplifier is required to compress an 80-db range of input signals into a 3-db output range. Each stage will have 20 db of gain. What is the small-signal gain and number of stages required? A line connecting the 3-db output dynamic range and the 80-db input goes right off the bottom of the nomograph but would correspond to a small-signal gain of about 280 db. This would correspond to 14 stages. However, this amplifier is clearly a practical impossibility to build and stabilize.

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Automatic System Probes B-70 Stresses

Valuable research tool conducts aeronautical vibration stress analysis

By MAX A. LOWY
Gulton Industries, Inc.,
Metuchen, N. J.

AUTOMATIC STRESS ANALYSIS

A unique case of automatic testing/design systems, the equipment described here saves hundreds of man-hours in analysis and development of airframes. Using over a hundred accelerometers, it can monitor the effects of vibration testing on a prototype airplane frame, is currently being put into use to determine bending modes on the B-70 bomber

A NEW LOW-FREQUENCY vibration analysis system has gone into operation at North American Aviation, Los Angeles, to determine bending modes for the B-70. The system, engineered and built by Gulton Industries' Systems Integration Group, automatically monitors structural response to very low frequency vibrations—as low as one cps—at very low g levels—down to 0.005 g—at 100 points on the airframe.

The system uses servo accelerometers, peak and phase detectors and scale measuring devices to generate data for presentation on x-y plotters and recording oscillographs, with an accuracy of about 0.1 percent. Internal control assures maximum operating speed regardless of number of channels or frequency of excitation, and requires acknowledgment of successful operation of each step before proceeding to the next one.

AUTHOR *examines a servo accelerometer, one of a hundred incorporated in the automatic testing system*

A control unit coordinates the entire data acquisition system. Logic accepts digital information from the scanner, voltmeter, phase detector and front panel controls, and presents the digital information to an IBM punch card in the proper sequence.

BASIC TECHNIQUE—Groups of inputs are gated sequentially, with each group representing one column on the punched card. A group consists of one to nine inputs, each corresponding to one row on the punched card. Since only one row in any column can be punched, only one input of each group can be at −12 volts. There are 11 such groups, representing the 11 columns in each data word to be punched on the card. A command unit generates 11 sequential pulses, each of which opens all the gates in an input group. The −12 volt input in the column group selected then causes a specific row to be punched.

Five 13-column data blocks and one 15-column reference channel data block are punched on each card. Since each block contains only 11 columns of information, the vacant columns are skipped. The card punch yields an electrical signal after completion of punch.

VOLTMETER INPUTS — Digital voltmeter inputs must first be converted from the 2-4-2-1 BCD code to a 10-line decimal, and then are gated to the output relays. A ONE is represented by +12 volts, so it is necessary to invert in order to be compatible with the PNP logic, which requires −12 volts. To decode the BCD code to decimal with NOR circuits, it is necessary to have both the BCD number and its complement. The complementary BCD number is obtained from a conventional inverter, before conversion in the NOR gates. When the voltmeter has completed its conversion function it transmits a signal to the command unit.

CLOCK—The timing signal is derived from 60-cps line frequency. A Schmitt trigger converts the 60 cps to a square wave; the signal is then divided by two flip-flop dividers to yield the basic 15-cps timing signal.

COMMAND UNIT—The command unit consists of a four-bit binary counter and a NOR gate decoder, to provide 11 sequential outputs from the 15-cps timing signal. The NOR gate decoder outputs are strobed with delayed single-shot pulse and shunt gates to eliminate spurious outputs when the counters are changing state. Inverter circuits invert the negative-going pulses from the NOR gates to provide a positive-going command pulse, and emitter follower circuits are employed as buffer amplifiers. The command cycle is initiated only after the gate between the 15-cps clock and the binary counter is opened by a signal from the start detector logic.

START DETECTOR—Several cycles of the input voltage are required to complete the phase measurement. This operation requires more time for completion after the scanner advances to a new input channel than any of the other operations. Therefore, the readout procedure is not initiated until five input cycles occur.

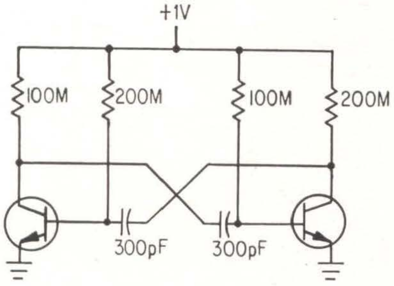
In order to detect when the required number of cycles has transpired, a Schmitt trigger is operated by a signal from the input amplifier in order to present a sharp rise time to a binary counter each time the input waveform passes through zero volts in the negative direction. A NOR gate detects the fifth state of the counter and provides a negative pulse which (1) starts the digital voltage through a relay driver and relay and (2) sets a flip-flop which holds open the command unit counter input gate until the operation is completed. A twelfth position on the command-unit output causes the command-unit binary counter, the start detector binary counter and the gate flip-flop to be reset to zero by a single-shot, emitter follower buffer and three inverters in preparation for the cycle of operation. The completion signals from each unit are incorporated into the AND gates to preclude premature operation.

LEVEL DETECTOR—There are three gain positions for each input channel. To know what multiplier should be used with each channel's digitized voltage level, a second voltage is fed to the Schmitt trigger circuits from the scanner. This second voltage can have one of three levels, depending upon the setting of the gain switch for the channel which is currently being scanned. The Schmitt trigger circuits detect which of the three levels this voltage is and causes the indicative row to be punched in the gain setting column of each data block on the card. The inverter circuits at the output of the Schmitt trigger circuits are used to short all lower-level outputs to ground so that only one row is punched in this column.

REFERENCE CHANNEL — The last (sixth) data block on each card must contain information for a selected input channel known as the reference channel. On the command unit cycle preceding the sixth data word, the scanner is not advanced, but instead a reference channel relay connects the selected channel to the digital voltmeters.

Micropower Goes International

NATO talks hardware, suggests candidates for future equipment



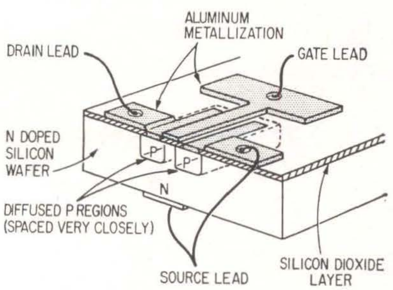
STILL *in design stage at CBS, 19-nanowatt free-running vibrator, is yet to be built—Fig. 1*

PARIS—NATO's Micropower road Show (ELECTRONICS, p 38, June 28) has continued on to engineering audiences in Malvern England, Stuttgart and Rome. Talks analyzed basic requirements for micropower devices and also stressed practical hardware—existing and imminent.

A. W. Lo of Princeton and IBM looked beyond the polar transistor, and listed the following candidates for succeeding generations of micropower equipment:

- Thin-film cryrotrons. They consume no power except when switching, and switching power can be held very low for a cryrotron on a superconducting substrate; however, refrigeration presents a problem.
- Square loop magnetics. Although they require circuit artifices to obtain directivity of signal flow, they have distinct advantage of storage.
- Parametric phase-locked oscillators. They operate in majority logic and therefore reasonable variations in circuit parameters are not disturbing as long as the variations are uniform among individual components. Also, the system is immune to noise.

Thin-film magnetics or low-loss variable-capicitance diodes point to practical micropower in the very near future.



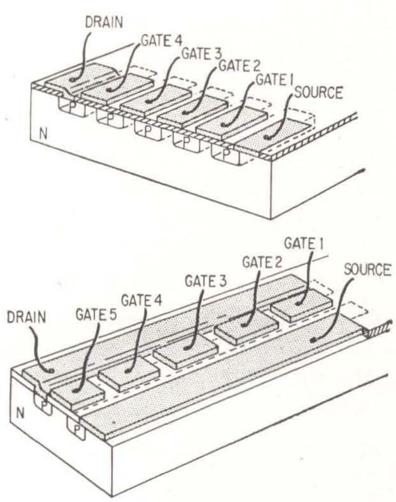
AROUND THE CORNER *device—the insulated gate field effect semiconductor—can be produced with n-type as well as p-type structures —Fig. 2*

TECHNIQUES — European engineers also learned about CBS techniques for depositing thin-film passive elements right on wafer, company's nanowatt linear vibrators and a free-running multivibrator (Fig. 1) recently designed by CBS.

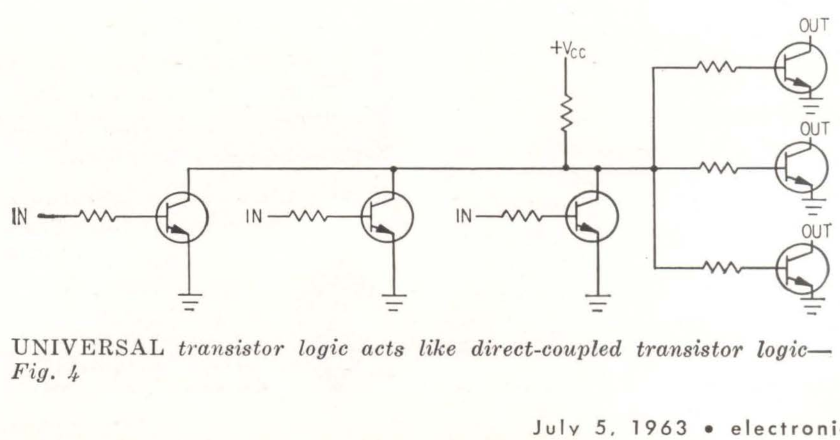
Fairchild's G. E. Moore told European designers that technology of the insulated gate field effect semiconductor (Fig. 2) has been advanced enough to produce n-type as well as p-type structures. Moore presented diagrams of arrays that have as many as 2,500 elements packed on a wafer 1-inch on a side (Fig. 3).

A. W. Lo of Princeton University and IBM showed a universal transistor logic circuit, Fig. 4, that uses base resistors to even out distribution of base current to the driven transistors.

At first glance, this circuit seems an unlikely candidate for optimum low-power operation. But Lo explained the base resistances were so low, compared to the collector resistance, that the circuit acts more like direct-coupled transistor logic than transistor-resistor logic.



ARRAYS *of insulated-gate field effect semiconductors point to nanowatt memories with 2,500 elements packed in one-inch square wafers—Fig. 3*



UNIVERSAL *transistor logic acts like direct-coupled transistor logic—Fig. 4*

Standards Urged for Hall Effect Devices

A UNITED STATES proposal for color codes and standards for Hall effect generators will be presented this Fall to the International Electrotechnical Commission.

The code proposal will be in competition with a German proposal which U. S. technical people find confusing.

Whether or not the Soviet Union will come in with a third proposal has net yet been determined.

A need exists for some standardization for domestic industry use, NATO standards and a broader international base.

The German proposal of a code was made to IEC last July. Members of the U. S. electronics community were unable to find in it any relation either to the variety of systems in use in this country or to the systems which have traditionally been employed by German industry itself.

COMPROMISE — To avoid the possibility that the IEC at its October meeting in Europe this year would have nothing against which to measure the German proposal, a small group in this country decided to seek another standard for presentation. They hope some compromise acceptable to both U. S. and German industry can be reached.

The U. S. group is considering a set worked up by Sherwin Rubin, National Bureau of Standards scientist working under a Navy Bureau of Weapons contract. Rubin's proposed Mil-Std 681 A will be taken up by a group later this Spring for possible presentation with U. S. backing at the October meeting.

The group will also consider the formal organization of a standardization group for Hall generators like those that exist in transistors and other areas.

Rubin's color proposal, already being employed by some U. S. manufacturers, are essentially on the control current end, red for the positive and black for the negative; on the Hall voltage end, blue for positive and black for negative.

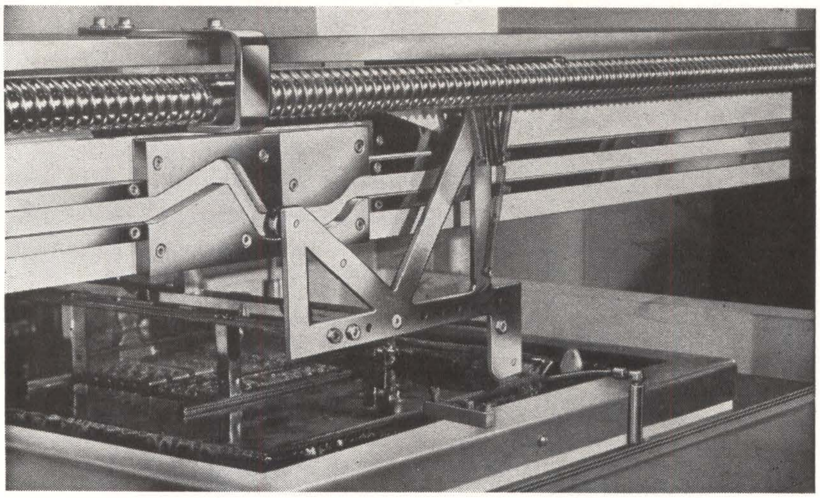
Rubin's proposal employs the same color for a pair of purposes.

Dips and Waves Improve Soldering

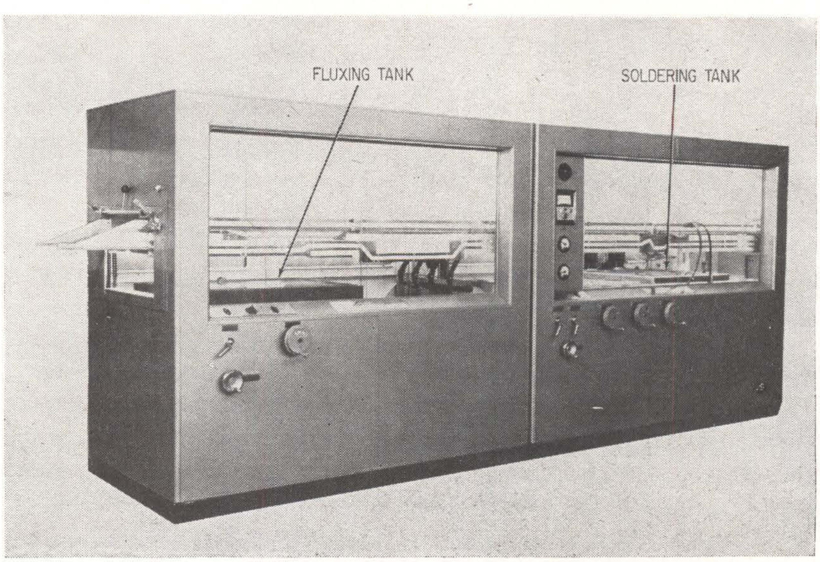
Overflowing technique used for both soldering and fluxing

By ALAN R. McMILLEN
Product Improvement, Corp.
Fullerton, Calif.

INCREASE in soldering-process reliability and accompanying decrease in rework on printed-circuit-board solder joints justified the combining of automated dip and wave soldering techniques. Until recently, this two-technique approach had been considered impractical because it was thought that required positioning mechanisms for circuit-board carriers would be too complicated. However, a lead screw and cam track configuration was developed to provide a practical, simple positioning method for both techniques. Further simplification was attained by designing mechanical capabilities into the carrier's swivel arm for oscillating the boards during dipping.



COMBINED *dip-and-wave soldering technique was made possible by circuit-board-positioning mechanism using a simple lead screw and cam track configuration. Swivel arm on board carrier includes a mechanism for oscillating boards during dipping. Solder in tank overflows and recirculates to maintain dross-free application of solder*



WINDOWED *cabinet encloses process entirely to provide controlled ambient conditions respecting both temperature and contamination. Fluxing is performed at front end and soldering at after end*

DROSS FREE—Main feature of process, however, is a continuously overflowing solder tank (pot) used for both techniques. Overflow solder is kept recirculating at rates adjustable up to 10 gallons per minute to assure that the solder applied to circuit-board joints is dross free, clean solder being transferred to the top at all times; circulation is maintained by an impeller-type pump driven by an air motor. In this way, a more reliable solder joint is produced than that resulting from use of a static pot.

Circuit board is first dipped using oscillating motion before passing it over soldering wave to assure thorough peneration of joints by liquid solder. Amplitude of oscillating motion is adjustable from 0 to ½ inch, while frequency can be set at 0 to 400 cycles per minute over a period of 0 to 10 seconds.

PROCESS PARAMETERS—During development phases of process, pertinent parameters of dip, wave and their combination were evaluated in terms of their effect on various types of printed circuit boards. It was discovered that:

- Best solder joints resulted when boards traveled through the two-technique process at constant speeds of 2-6 feet per minute. At this rate, four 10 × 18-inch boards could be processed each minute; smaller boards could race through at speeds of up to 12 per minute
- During fluxing (also an integral part of process—see below), interface conditions between board and flux solution must be constant with board's bottom surface being approximately 0.020 inches below flux surface
- Constant interface condition needed during soldering requires

that board bottom remain approximately 0.050 inches below solder surface

- Temperature and duration of board preheat should be adjusted so that board temperature does not exceed 250 degrees F and the flux on board's bottom surface dries to a slightly tacky condition with no excess fluid flux remaining
- Optimum dwell period in solder dip ranges from 2-4 seconds
- Oscillation period, amplitude and frequency needed varies appreciably for various types of circuits and has to be determined by trial. For example, high-density boards might require: oscillation periods of 2 seconds, amplitude of $\frac{1}{4}$ inch, $1\frac{1}{2}$ cpm frequency
- Solder wave height (adjustable) of 1 inch and a width of 21 inches are most efficient in handling large boards.

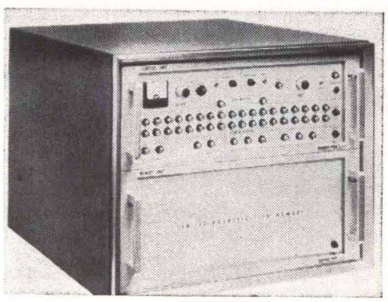
PRECISE CONTROL — Above parameters are governed by accurate control adjustments that assure solder-process reproducibility:

- Lead screw and cam track conveyor system is adjustable to provide board speeds of 1 to 9 feet per minute. It also assures proper interface relationships during fluxing and soldering to prevent gaseous entrapments
- Six radiant heaters impart board preheat temperatures of 250 degrees F—a calibrating thermistor assures that preheat temperature is within desired range
- Dip dwell time is interlocked with oscillation period to assure oscillation is completed prior to starting of conveyor system
- Oscillations are adjustable through an amplitude of 0 to $\frac{1}{2}$-inch at 0 to 400 cycles per minute over a period of 0 to 10 seconds
- Solder temperature is normally held to a temperature of 475 degrees F $\pm 1\frac{1}{2}$ degrees, but can be adjusted over a range from 300 to 500 degrees F
- Pre-skimmer mechanism attached to board carrier furthers dross-free condition attained with overflow system
- Overflowing flux technique similar to overflowing solder technique is used within process. Vibrator mechanism connected to inner pan of flux system creates a dancing action on flux surface to provide optimum fluxing action.

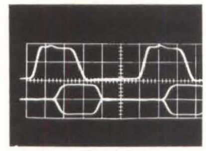
Thin-Film Memory Cycles In 300 Nsec

Destructive readout memory system tolerates wide variations in parameters

MARKETED by Fabri-Tek, Inc., Minneapolis, Minnesota, the FFM-202 is the first self-contained magnetic film memory system commercially available with 300 nanosecond total cycle time. Unit has four operating modes including read only, write only, read-restore and read-modify-write. Access time is 150 nsec and read or write only time is 200 nsec. The system has a capacity of 512, 36-bit words and uses either random or sequential address selection. Word select current is unipolar and has a nominal value of 400 ma, while digit current is nominally 160 ma as shown in the oscillogram. Information written into the memory is determined by the polarity of the digit current, while magnetic shielding of the memory stack assures wide margins in the presence of large external magnetic fields.

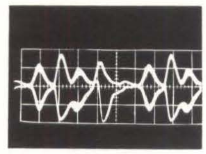


Memory elements in the FFM-202 use magnetic film with a thickness of 1,000 angstroms packaged in multilayer laminated overlays that contain all drive and sense lines; a typical 8 × 10 memory plane contains 128, 36-bit words. Several planes may be interconnected to obtain a variety of memory sizes and word lengths.



WORD CURRENT: 400 MA
DIGIT CURRENT: ±160 MA

50 N SEC/DIV



OUTPUT WAVEFORMS AFTER AMPLIFICATION:
128 "ZEROS"
128 "ONES"
70 MV/DIV

50 N SEC/DIV

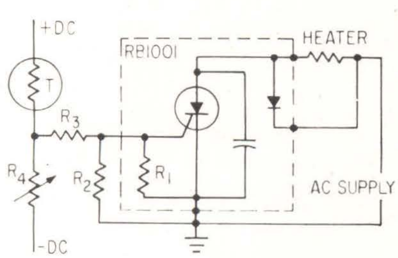
According to the manufacturer, this type of memory provides more high-speed registers than would be economically feasible using flip-flop storage. Moreover, they point out that the FFM-202 can reduce hardware requirements in real time data processing applications such as radar-data processors, where bit rates as high as 20 Mc are encountered.

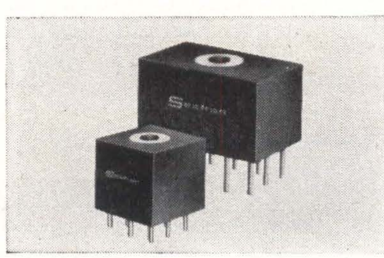
CIRCLE **301**, READER SERVICE CARD

Solid-State Modules Have Gain Of 10^7

MANUFACTURED by Sectron, Inc., 1 Pinegree Street, Salem, Mass., packaged SCR assemblies called Output Drivers are ideal for sensing transducer outputs such as thermistors, photocells and tachometers, and driving relays, solenoids, lamps, audible alarms and heaters. Compact epoxy-encapsulated modules will operate in extreme environments of shock vibration and corrosive atmospheres between −55 C and +85 C, and will detect at levels between 50 μa and 50 ma at 0.6 to 400 volts. Moreover, they will switch 100 watts ON in 0.1 μsec and OFF in 20 μsec.

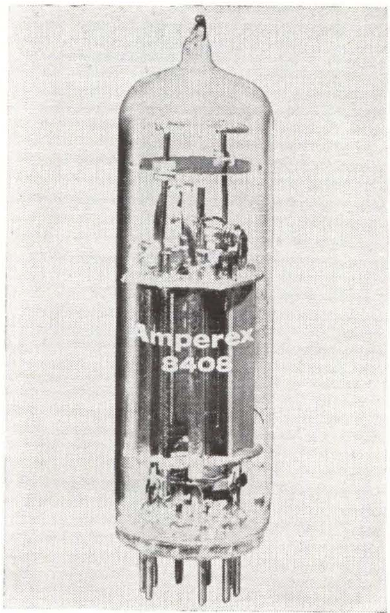
Schematic shows a typical application where the Output Driver controls the temperature of a small oven by detecting the change of resistance in a thermistor sensor. Bias resistor R1 sets the detection level at 50 μa and 0.6 volt. Higher currents can be detected by decreasing R_2 from infinity; increasing R_3 from zero will permit detection of higher voltages. In the application shown, variable resistor R_4 is used to set oven temperature. Degree of system accuracy depends somewhat upon thermistor accuracy and oven time constant. However, accuracies in the order of $\frac{1}{3}$ a degree C may be maintained from 30 C to 100 C. Units are priced between $17 and $35. **(302)**





Frame-Grid Tube Heats In 0.5 Sec

DESIGNED for use in continuous and intermittent vehicular communication equipment, the 8408 is a push-pull tetrode intended as an r-f amplifier or frequency multiplier in transistor vehicular transmitters. Tube is internally neutralized for frequencies up to 500 Mc. The new frame-grid tube operates on a



heater voltage of 1.1 volts.

According to the manufacturer, Amperex Electronic Corp., 230 Duffy Ave., Hicksville, N. Y., the 8408 can deliver 6 watts of useful power to a load when driven by 1.5 watts with a plate voltage of 175 and plate current of 2 × 40 ma at 500 Mc in a typical CCS push-pull configuration. The tube has an amplification factor of 26, transconductance of 7,000 μmhos and can achieve an overall plate and tank efficiency of 57%. When used as a push-pull frequency tripler, the 8408 delivers 2 watts of power with an overall efficiency of 33%. **(303)**

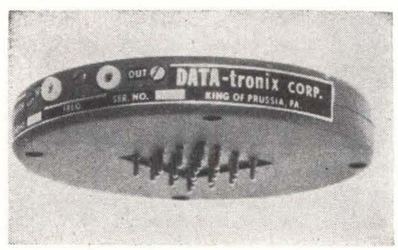
Maser Amplifier Operates at 4.2 K

FIELD OPERATIONAL S-band (2,300 Mc) traveling-wave maser amplifier uses closed-cycle refrigeration and features minimum gain of 25 db. Designed to function continuously on a moving antenna with no necessity for adding liquid helium, the model 7010 operates at 4.2 K. Unit has also been successfully operated in an open dewar with no degradation in performance. It features an instantaneous bandwidth of 17 Mc (typical) at the 3 db power points, a gain stability of ±0.1 db/10 hr, and a noise temperature of 10 K max. Microwave Electronics Corp., 3165 Porter Drive, Palo Alto, Calif.

CIRCLE 304, READER SERVICE CARD

Transistorized VCO For Aerospace Use

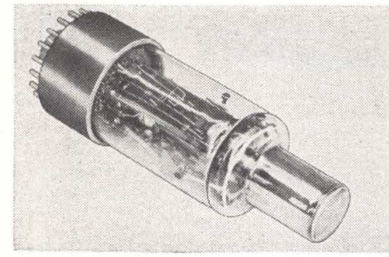
MODEL 7003A transistorized voltage controlled oscillator is designed for use in aerospace telemetry applications where a cylindrical form factor is desirable for efficient utiliza-



tion of volume. It is available in all IRIG bands from 1 through 18 and A through E and incorporates a high reliability 24-pin connector in the center of the unit. A configuration of the 7003A allows the stacking of one upon the other, thus forming a system without the use of an additional mount for forming the inter-connecting of the various units. Unit measures 2.6 in. diameter by $\frac{7}{16}$ in. thick. DATA-tronix Corp., Penn & Arch Sts., Norristown, Pa. **(305)**

Multiplier Phototubes Have Low Noise

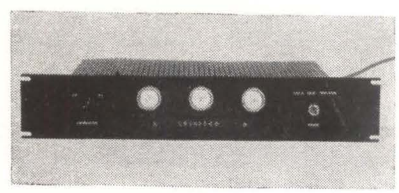
THREE ultra-low-noise multiplier phototubes are announced. All are 16-stage units. FW-118 features an S-1 response; FW-129 an S-11, and FW-130 an S-20. Principal applications are for star tracking, guidance, field uses in laser receivers, and unambiguous photon counting. The tubes have extremely low equivalent noise inputs, typically 10^{-12}



lumens max; high sensitivities, typically from 20 to 100 μa per lumen for the photocathodes; and anode dark currents of 20, 3 and 0.01 μa respectively. ITT Industrial Laboratories, division of International Telephone and Telegraph Corp., 3700 E. Pontiac St., Fort Wayne, Ind. **(306)**

Indicator Shows Liquid Level

LIQUID LEVEL indication of all cryogenic fluids (liquid fluorine excepted) is achieved accurately and dependably by this device. Sensing probes are small carbon resistors that will be fabricated to



customer specification and furnished with the device. Available in any number of points of indication, the unit operates satisfactorily under a wide pressure range. Factory precalibration for two or more liquids is available on request. Unit is completely transistorized and utilizes solid state circuitry. Optional automatic control circuit between any two points of indication available in the same package. Cryogenic Research Co., Inc., 2965 Peak Ave., Boulder, Colo. **(307)**

Literature of the Week

CUSTOMIZED OVENS Gruenberg Electric Co., Inc., 9 Commercial Ave., Garden City, N. Y. Bulletin 230 describes a line of ovens for vacuum bakeout to 600 C and higher. **(308)**

PLUGS AND RECEPTACLES The Pyle-National Co., 1334 North Kostner Ave., Chicago 51, Ill. Bulletin 666 describes Triploc electrical connectors for portable cable requirements. **(309)**

PRECISION MANUFACTURING Emerson Electric Mfg. Co., 8100 Florissant Ave., St. Louis 36, Mo. Brochure entitled "Precision . . . The Story of Manufacturing Capability at Emerson Electric" is offered by the company's Electronics and Space division. **(310)**

DIGITAL FREQUENCY SYNTHESIZER Bendix Radio Division, Baltimore 4, Md. Bulletin describes the digital frequency synthesizer, an electronically tuned precision frequency source that provides high speed selection of ultra-stable frequencies in the 2-32 Mc range. **(311)**

POWER SUPPLIES Electro Products Laboratories, Inc., 6120 W. Howard, Chicago 48, Ill. Six-page folder covers the specifications, performances and applications of new low cost d-c power supplies. **(312)**

COOLING DEVICES Deltron Inc., Fourth and Cambria Sts., Philadelphia 33, Pa. Catalog C-363 describes all electronic cooling devices manufactured by the company. **(313)**

DIGITAL INSTRUMENTS Houston Instrument Corp., 4950 Terminal Ave., Bellaire 101, Texas. Precision digital instruments for laboratory and industrial use are described in a 16-page, 2-color catalog. **(314)**

DIGITAL SIGNAL SYNCHRONIZER Telemetrics, Inc., 12927 S. Budlong Ave., Gardena, Calif. Data sheet 15 covers the model 6103B digital signal synchronizer. **(315)**

TRANSIENT TIMER Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J. Bulletin R3c describes a transient timer that provides substantial savings in telemetry bandwidth requirements. **(316)**

PRECISION POTENTIOMETERS International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa. A 23 in. by 34 in. wall chart summarizes requirements of all Military Specifications for precision potentiometers. Address requests on company letterhead.

RETENTION/COOLING DEVICES The Birtcher Corp./Industrial Division, P.O. Box D, Monterey Park, Calif., offers a 12-page illustrated catalog on retention/cooling devices for tubes, transistors and components. **(317)**

Mincom Division Erecting New Plant

MINCOM division of the 3M Company has begun construction of a one-story 218,000-square foot plant in Camarillo, Calif. The structure, which will be adjacent to the 3M magnetic products plant now being built, is expected to be finished early in 1964.

The new building will provide administrative, sales, research, engineering and production facilities for Mincom which manufactures precision magnetic tape instrumentation record/reproduce systems for military and industrial applications.

"Since Mincom became a part of 3M in 1956," F. C. Healey, general manager, said, "employment has increased from 25 to almost 600. Our move to Camarillo will allow us to consolidate all Mincom activities now being carried on at nine different locations in Los Angeles."

Mincom magnetic tape equipment is used for data acquisition from missile and related testing operations, for predetection recording of missile telemetry data and for launch and trajectory data acquisition and storage. Its record/reproduce systems are used in several NASA and Department of Defense programs such as Titan II, Minuteman, Polaris and Mariner. In addition to the recording equipment, the division launched into the commercial broadcast field early this year with its Dropout Compensator, an accessory for video tape playback.

Giannini Controls Names Leonhardt

APPOINTMENT of Charles G. Leonhardt as general manager of Powertron, Giannini Controls' Long Island, N. Y., subsidiary, which specializes in ultrasonic components and systems for the industrial and military markets, has been announced.

Leonhardt was one of the four founders of Powertron, which became a part of Giannini Controls in the fall of 1962.

Bloch Moves Up At Honeywell EDP

RICHARD M. BLOCH has been named a vice president of Honeywell Electronic Data Processing, Wellesley Hills, Mass. In his new position, he will continue to specialize in marketing development activities for the division.

Anderson Laboratories Hires Milliken

ARCHIE S. MILLIKEN has been named general manager of Andersen Laboratories, Inc. Wiresonic division, Farmingdale, N. Y., manufacturer of magnetostrictive delay lines.

Prior to joining Andersen, Milliken was with The Gerber Scientific Instrument Co., Hartford, Conn., as production manager.

EOS Elects Richter Vice President

HENRY L. RICHTER, JR., has been elected a vice president of Electro-Optical Systems, Inc., Pasadena, Calif. He also continues in his present position as manager of EOS advanced systems development operations, according to A. M. Zarem, president.

Bendix Corporation Names O'Neal

R. D. O'NEAL has been appointed to the new position of vice president-aerospace systems of The Bendix Corporation. He will make his headquarters at the systems division of Bendix in Ann Arbor, Mich. He had been headquartered at the company's central office in Detroit as vice president in charge of engineering.

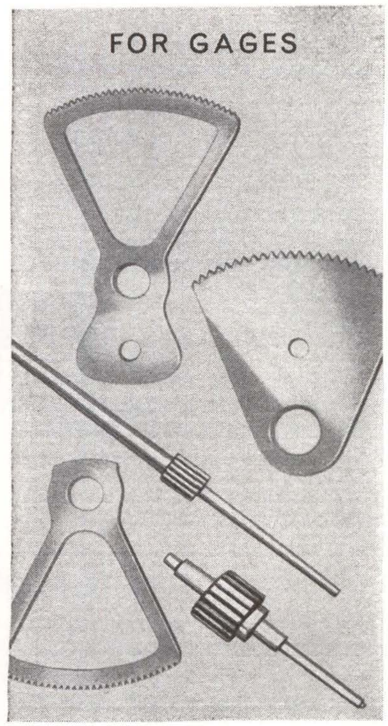
W. E. Kock, research vice president of Bendix, assumes the engineering staff responsibilities of O'Neal. L. B. Young, formerly general manager of the Systems division, joins the staff of R. H. Isaacs, vice president for military relations, as director of government systems sales.

Martin Company Appoints Voorhies

NICHOLAS M. VOORHIES, a veteran of 20 years with Martin Company, has been appointed general manager of Martin activities in Washington, D. C. He was formerly director of sales and requirements at the Company's Denver division.

Granger Associates Hires Evans

FORMATION of a Data Systems department at Granger Associates, Palo Alto, Calif., with William E. Evans, Jr. as its head, is announced. The new activity, which reports to E. W. Pappenfus, vice president for engineering, will deal broadly in the electronic signal processing and display field.



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electronics

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This Qualification Form is designed to help you advance in the electronics industry. It is unique and compact. Designed with the assistance of professional personnel management, it isolates specific experience in electronics and deals only in essential background information.

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3. Notice the key numbers.
4. Circle the corresponding key number below the Qualification Form.
5. Fill out the form completely. *Please print clearly.*
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AMERICAN MACHINE & FOUNDRY CO. Alexandria Div. Alexandria, Va.	120*	2
ATOMIC PERSONNEL INC. Philadelphia, Penna.	121*	3
BELL AEROSYSTEMS CO. Div. of Bell Aerospace Corporation A Textron Company Buffalo, N. Y.	121*	4
COLLINS RADIO COMPANY Dallas, Texas	98*	5
GENERAL DYNAMICS/ELECTRONICS A Div. of General Dynamics Corp. Rochester, New York	57	6
LOCKHEED MISSILES & SPACE CO Div. of Lockheed Aircraft Corp. Sunnyvale, California	109*	7
SPACE AND INFORMATION SYSTEMS Div. of North American Aviation, Inc. 12214 Lakewood Blvd. Downey, Calif.	53	8

• These advertisements appeared in the June 28th issue.

(cut here) **electronics WEEKLY QUALIFICATION FORM FOR POSITIONS AVAILABLE** (cut here)

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Personal Background

NAME ....

HOME ADDRESS ....

CITY ....................ZONE.......STATE............

HOME TELEPHONE ....

Education

PROFESSIONAL DEGREE(S) ....

MAJOR(S) ....

UNIVERSITY ....

DATE(S) ....

FIELDS OF EXPERIENCE (Please Check)

7563

☐ Aerospace	☐ Fire Control	☐ Radar
☐ Antennas	☐ Human Factors	☐ Radio—TV
☐ ASW	☐ Infrared	☐ Simulators
☐ Circuits	☐ Instrumentation	☐ Solid State
☐ Communications	☐ Medicine	☐ Telemetry
☐ Components	☐ Microwave	☐ Transformers
☐ Computers	☐ Navigation	☐ Other ....
☐ ECM	☐ Operations Research	☐ ....
☐ Electron Tubes	☐ Optics	☐ ....
☐ Engineering Writing	☐ Packaging	☐ ....

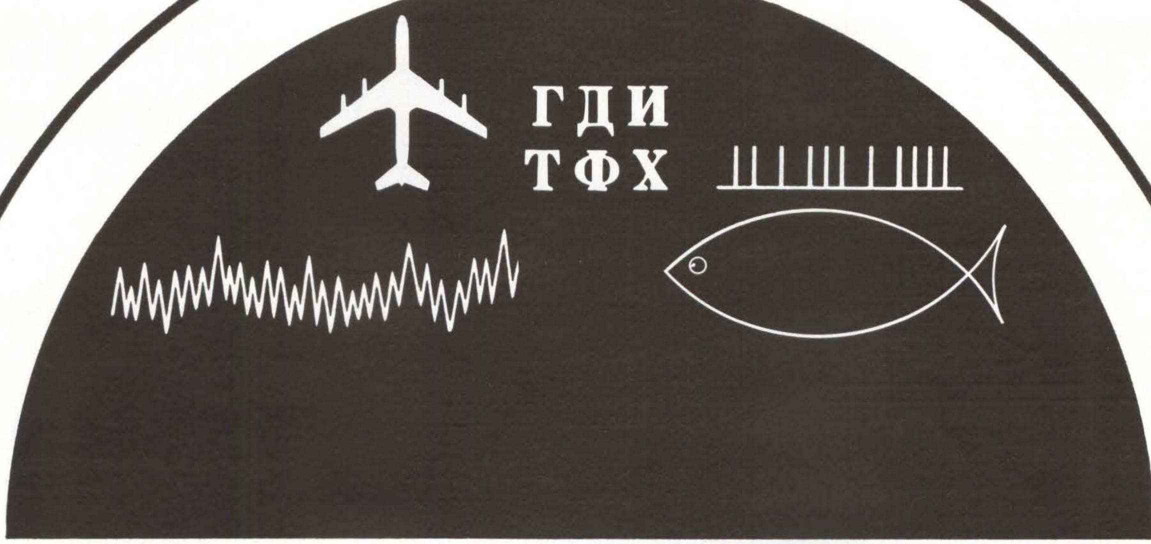
CATEGORY OF SPECIALIZATION

Please indicate number of months experience on proper lines.

	Technical Experience (Months)	Supervisory Experience (Months)
RESEARCH (pure, fundamental, basic)	......	......
RESEARCH (Applied)	......	......
SYSTEMS (New Concepts)	......	......
DEVELOPMENT (Model)	......	......
DESIGN (Product)	......	......
MANUFACTURING (Product)	......	......
FIELD (Service)	......	......
SALES (Proposals & Products)	......	......

CIRCLE KEY NUMBERS OF ABOVE COMPANIES' POSITIONS THAT INTEREST YOU

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



A PATTERN IS A PATTERN IS A PATTERN

Contrary to the obliqueness of a Gertrude Stein, General Dynamics/Electronics is quite direct in its conception of pattern recognition.

Our scientists and engineers, for example, have developed a machine that does a no-nonsense job of multiple font type recognition. Now a group drawn from many disciplines are teaching this machine to spot various speech patterns. Progress has gone as far as recognition, with 100% accuracy, of 10 basic phonetic vowel sounds produced by 175 different male and female voices.

Pattern systems of the future – enabling machines to diagnose X-ray pictures or predict weather from cloud formations – are also under consideration by these teams.

Interdisciplinary effort itself is a recognized pattern at General Dynamics/Electronics. Fun for our engineers and fine for us, it makes for both progressive careers and systems of top capability in a wide range of categories. Our past successes and follow-on contracts include important Doppler tracking systems, speech analysis, bandwidth compression, single sideband communications, underwater detection systems and digital communications.

A NEW PROGRAM

Our electronic design engineers have recently taken on a new responsibility: to design and build the equipment to test the most sophisticated electronic equipment imaginable for the most advanced tactical aircraft on the drawing boards today. The men who work on this project will learn all about a complete equipment – its operation, capability, circuitry – that will be designed by world leaders in their respective fields. Then the engineers at General Dynamics/Electronics will determine how to measure the characteristics of the various circuits, and design equipment to test these parameters.

PRESENT OPENINGS

are for graduate Electrical Engineers with design experience in the following areas:

SPACE COMMUNICATIONS • RF CIRCUITRY • TRACKING EQUIPMENT • ADVANCED PULSE CIRCUITRY • DOPPLER SYSTEMS • MOBILE COMMUNICATION SETS • NAVIGATION AIDS • RECONNAISSANCE/ COUNTERMEASURES • USW/ASW EQUIPMENT • AEROSPACE GROUND EQUIPMENT • IFF EQUIPMENT • TELEMETRY RECEIVERS & TRANSMITTERS.

EXCELLENT LOCATION

Rochester, N. Y., home of General Dynamics/Electronics, is noted for its cultural advantages, educational institutions, recreational facilities, and nearby picturesque vacation areas. Today, Rochester boasts the largest percentage of professional people in the nation for a city in the 500,000 population class.

For immediate consideration, send your resume to **R. W. Holmes, Registered Engineer,** Dept. 22.

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The advertising rate is $27.25 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request. AN ADVERTISING INCH is measured 7/8 inch vertically on one column, 3 columns—30 inches—to a page. EQUIPMENT WANTED or FOR SALE ADVERTISEMENTS acceptable only in Displayed Style.

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TO SEARCHLIGHT ADVERTISERS

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. . . not only for the advertiser, or the publisher, but **FOR YOU!** When you mention this publication in inquiries to advertisers, you enable them to value the evidence of your readership . . . This advertisers 'satisfaction' means we have an easier time securing more SEARCHLIGHT advertisements — meaning MORE information, MORE choice of products, MORE value—**FOR YOU!**

INDEX TO ADVERTISERS

■

• See advertisement in the July 25, 1962 issue of Electronics Buyers' Guide for complete line of products or services.

This Index and our Reader Service Numbers are published as a service. Every precaution is taken to make them accurate, but electronics assumes no responsibilities for errors or omissions.

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Riverside 7-9721 (area code 214)

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Alpine 5-2981 (area code 303)

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TOKYO:
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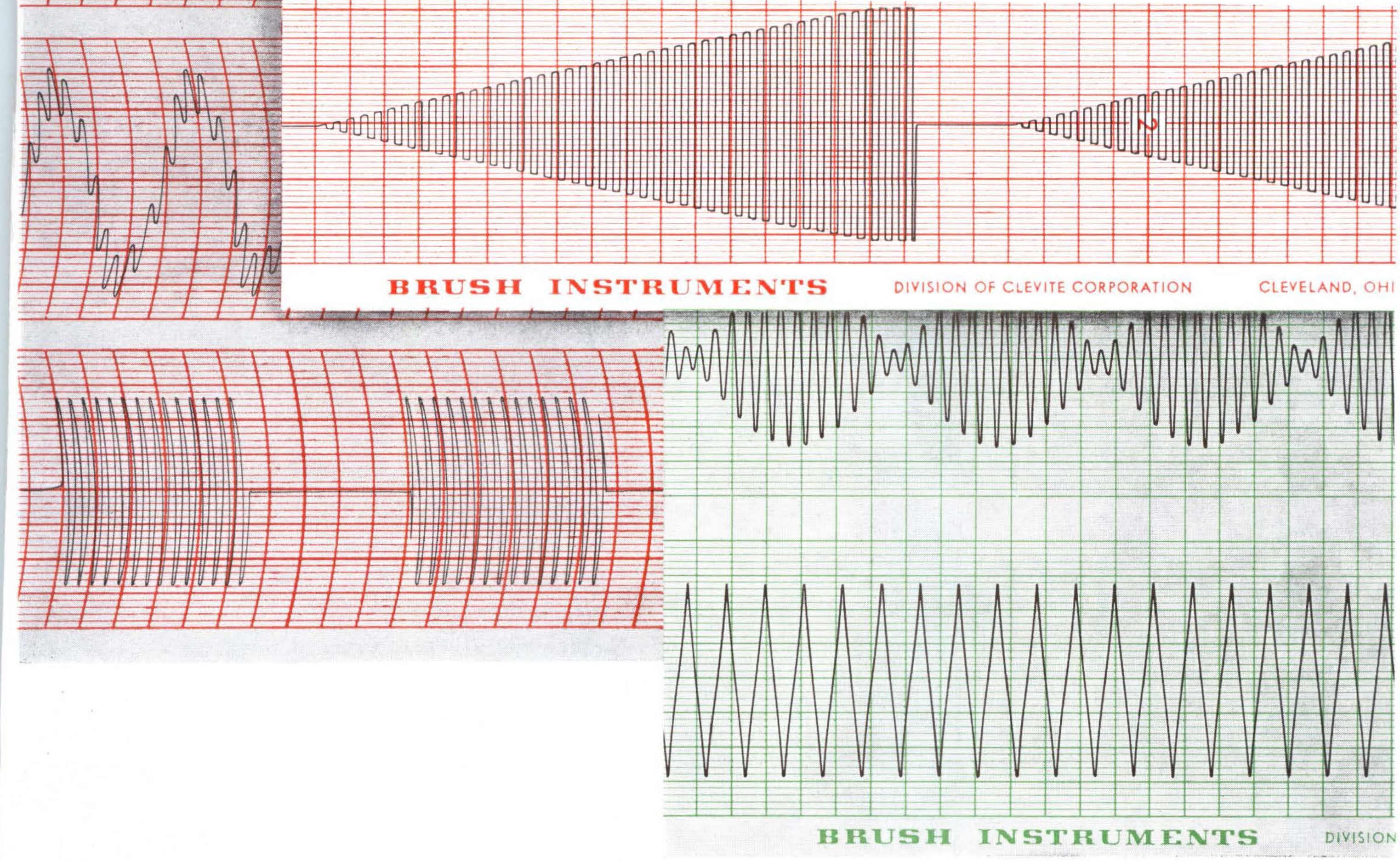
1, Kotohiracho, Shiba, Minato-ku



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CIRCLE 901 ON READER SERVICE CARD

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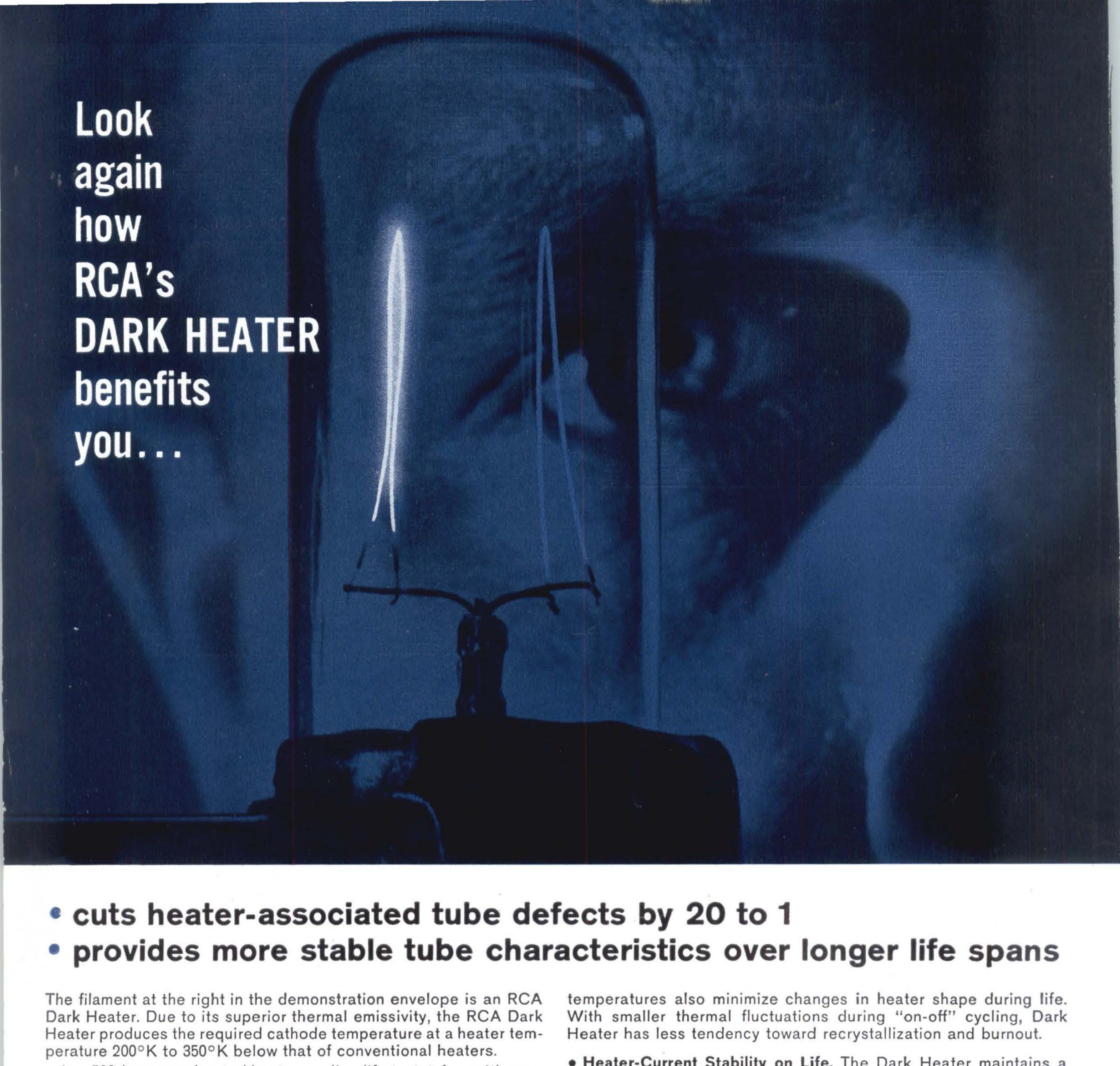
DIVISION OF CLEVITE 37TH AND PERKINS, CLEVELAND 14, OHIO



• cuts heater-associated tube defects by 20 to 1
• provides more stable tube characteristics over longer life spans

The filament at the right in the demonstration envelope is an RCA Dark Heater. Due to its superior thermal emissivity, the RCA Dark Heater produces the required cathode temperature at a heater temperature 200°K to 350°K below that of conventional heaters.

In a 500-hour accelerated heater-cycling life test, tubes with conventional heaters had 20 heater-associated defects per 100 tubes, while tubes with the RCA Dark Heater had only one! The tests were conducted at 143% of rated heater voltage (9 volts for a 6.3-volt type) and a heater-cathode voltage of 180 volts. The operating cycle was one minute on and two minutes off. These life tests are the equivalent of operation of a heater for 14,500 hours at normal heater voltage and they represent more than 250,000 tube-hours.

Features of the RCA Dark Heater which contribute to superior long-life performance include:

- **Exceptional Mechanical and Chemical Stability.** RCA's Dark Heater wire has an approximately 50% higher ultimate tensile strength when it operates at a temperature 350°K below the operating temperature of conventional heaters. Cooler operating temperatures also minimize changes in heater shape during life. With smaller thermal fluctuations during "on-off" cycling, Dark Heater has less tendency toward recrystallization and burnout.
- **Heater-Current Stability on Life.** The Dark Heater maintains a remarkably stable current characteristic throughout life.
- **Reduced AC Heater-Cathode Leakage and Hum.** The Dark Heater reduces AC leakage and hum, particularly "spike" or pulse leakage currents. In addition, lower heater temperature reduces both AC and DC leakage from heater to cathode and heater emission to other tube electrodes.
- **Greater Safety Margin in H-K Voltage Ratings.** Cooler operation means greater safety margins in present H-K voltage ratings.

Dark Heater, now available in 231 popular O.E.M. types of RCA Receiving Tubes, is another RCA innovation to give you better performance and longer tube life. For full information on the Dark Heater, call your RCA Field Representative.

RCA ELECTRONIC COMPONENTS AND DEVICES, HARRISON, N. J.

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