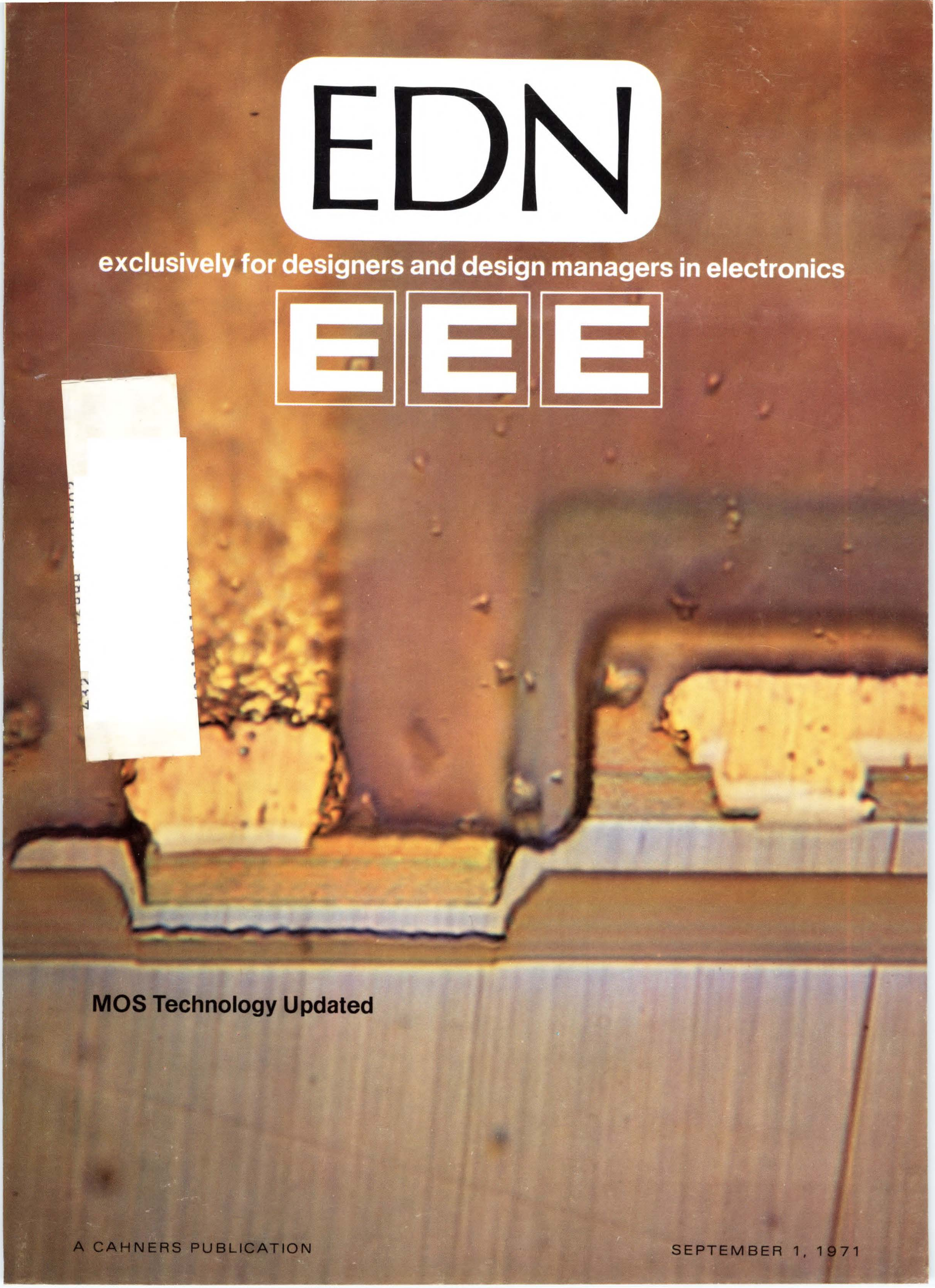

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MOS Technology Updated

A CAHNERS PUBLICATION

SEPTEMBER 1, 1971

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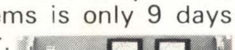

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CIRCLE NO. 1

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	PART NUMBER	DESCRIPTION	LEADS/PKG.	FREQUENCY RANGE	NUMBER OF BITS	TYPICAL POWER DISSIPATION	CLOCK LEVELS	GATE THRESHOLD
DYNAMIC SHIFT REGISTER	RD55G	Dual 50	10 TO5	10KHz - 1MHz	100	240mw	-27V	HVT
	S1708	Quad 40	12 TO8	10KHz - 1MHz	160	200mw	+5, -12V	LVT
	RD63G	Triple 66	10 TO5	10KHz - 1MHz	198	125mw	-27V	HVT
	S1724	Variable 256	14 DIP	10KHz - 1MHz	2-257	200mw	+5, -12V	LVT
	S1606	Quad 84	16 DIP	10KHz - 2MHz	336	200mw	+5, -12V	LVT
	RD65G	Single 426	10 TO5	1KHz - 5MHz	426	280mw	+5, -12V	LVT
	S1723	Dual 256	10 TO5	10KHz - 2MHz	512	150mw	+5, -12V	LVT
	S1705	Dual 256	10 TO5	10KHz - 1MHz	512	300mw	+5, 0V	LVT
	S1685	Dual 480	12 TO8	10KHz - 2MHz	960	200mw	+5, -12V	LVT
	S1687	1000/1024	12 TO8	10KHz - 2MHz	1000/1024	150mw	+5, -12V	LVT
	S1701	Dual 512	14 DIP	10KHz - 2MHz	1024	250mw	+5, -12V	LVT
	S1709	FIFO 8 x 13	24 DIP	10KHz - 100KHz	104	500mw	+5, -12V	LVT
STATIC SHIFT REGISTERS	SP51L	12 bit Serial/Parallel	24 DIP	DC - 2MHz	1-12	250mw	-27V	HVT
	RS53G	Dual 40	10 TO5	DC - 1MHz	80	150mw	-27V	HVT
	S1463	Dual 64	12 TO5	DC - 3MHz	128	180mw	+5, -12V	LVT
	S1670	Dual 100	14 DIP	DC - 3MHz	200	250mw	+5, -12V	LVT
RANDOM ACCESS MEMORIES	S1509	128 x 1, 64 x 2, 32 x 4	28 DIP	1.5 MHz	128	300mw	+5, -12V	LVT
	S4006	1024 x 1, Static	16 DIP	1.5 MHz	1024	600mw	None	I2 *
	S2103	1024 x 1, Dynamic	18 DIP	1.5 MHz	1024	320mw	-15V	SIGATE
READ ONLY MEMORIES	S8452	256 x 4	28 DIP	DC - 200KHz	1024	500mw	None	HVT
	S8457	128 x 12 Hollerith to ASC II	24 DIP	DC - 300KHz	1536	500mw	None	I2 *
	S8539	128 x 12 ASC II to Hollerith	24 DIP	DC - 300KHz	1536	500mw	None	I2 *
	S8538	2048 x 1	24 DIP	20KHz - 1MHz	2048	400mw	+5, -12V	LVT
	S8453	512 x 4	28 DIP	DC - 200KHz	2048	500mw	None	HVT
	S8502	256 x 8	28 DIP	DC - 1MHz	2048	650mw	+5, 0V	LVT
	ME51L	2240 - 5 output	28 DIP	DC - 1MHz	2240	300mw	None	LVT
	S8327	2240 - 5 output	24 DIP	DC - 2MHz	2240	400mw	+5, -12V	LVT
	S8499	2240 - 7 output	28 DIP	DC - 300KHz	2240	300mw	None	HVT
	S8501	256 x 10	40 DIP	DC - 1MHz	2560	650mw	+5, 0V	LVT
MULTIPLEXERS	MX52D	6 Channel	14 FP			NA	NA	HVT
	MX53C	10 Channel	22 FP			NA	NA	HVT
	MX54C	4 Channel, 50Ω	22 FP			NA	NA	HVT
	MX55C	4 Channel, 50Ω	22 FP			NA	NA	LVT
STANDARD LOGIC ARRAYS	UL51L	Dual FF, Dual Excl OR	24 DIP	1 - 100KHz		60mw	-27V	HVT
	UL52L	Quad 2 NAND Expandable	24 DIP			40mw	-27V	HVT
	UL53L	Quad 2 NOR Expandable	24 DIP			120mw	-27V	HVT
	MX53L	10 Input Expander	24 DIP					HVT
	SP51L	12 bit Serial/ Parallel	24 DIP	DC - 2MHz	12	250mw	-27V	HVT
	S1694	8 bit Counter/ Shift Register	40 DIP	DC - 1MHz	8	15mw		LVT

	PART NUMBER	DESCRIPTION	LEADS/PKG.	RON @ -15V	PROTECTION	TYPICAL V_{GST}
DISCRETES	DM01B	Dual Matched 50mw	6 TO5	1250	No	-4V
	DM02B	Dual Matched 100mw	6 TO5	1250	No	-4V
	DM03B	Dual Matched 150mw	6 TO5	1250	No	-4V
	DM05A	Dual	8 TO77	250	Yes.	-4V
	DM06A	Dual	8 TO77	250	No	-4V
	DD07K	Single	4 TO72	125	Yes	-4V
	DD08K	Single	4 TO72	125	No	-4V
	DD09K	Single	4 TO72	250	Yes	-4V
	DD10K	Single	4 TO72	125	Yes	-2V
	DD11K	Single	4 TO72	700	Yes	-4V
	DD12J	Single	3 TO5	32	Yes	-4V
	DD13K	Single	4 TO33	32	Yes	-4V
	DD15K	Single	4 TO33	18	Yes	-2V
	T1368	Quad	14 FP	125	Yes	-2V
	T1337	Quad	14 DIP	125	Yes	-2V

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CIRCLE NO. 3

SEPTEMBER 1, 1971
VOLUME 16, NUMBER 17

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photomicrograph, a metallographic angled cross section view of an MOS device, shows polysilicon over the gate with a three-metal (primarily gold) beam-lead interconnect. RCA Solid State Div., Somerville, N. J., which provided the photo, is applying beam-lead technology to MOS chips. See MOS article on p. 23.

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ibpa International Business Press Associates
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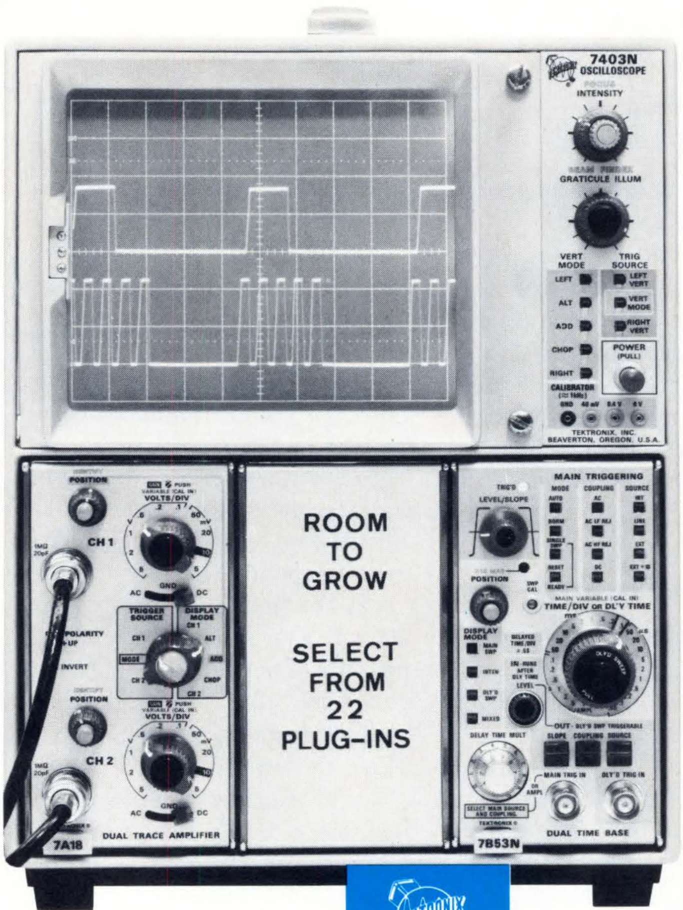

If you wish, select a plug-in for the second vertical compartment to give you 10 μV/div at 1 MHz *or* 1 mV/div at 55 MHz *or* 1 mA/div at 55 MHz *or* another dual-trace unit for 4-trace capability, etc., etc. Plug-in prices start at a low $270. Call your nearby Tektronix field engineer today for a demonstration.

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CIRCLE NO. 7

Why Pussyfoot?

Obviously the U.S. will soon be going metric, if for no other reason than to remain competitive in world trade. Most of us agree that the change should be made. We may even feel that it is overdue when we look at the accomplished fact in such countries as Japan.

Our Commerce Secretary, Maurice H. Stans, has recently proposed that we make the changeover under a "10-year plan". I, for one, feel that this is far too slow. It is about like wetting one toe at a time before taking the plunge in the pool. Things move fast today—so fast that 10 years is virtually an eternity. It's also far too long to be in the vulnerable condition of "part metric, part 'U.S. Customary' (our present standard)".

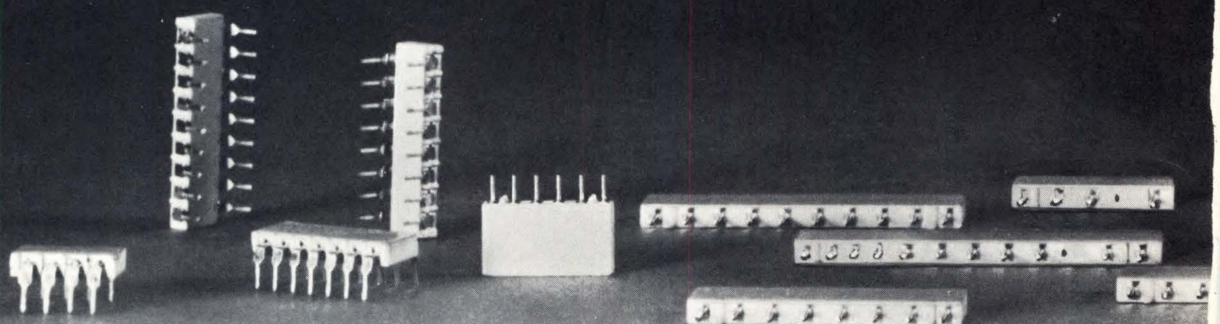
Let's get with it forthwith. A speedy changeover undoubtedly can cause more disruption than a drawn-out one. Also there is greater risk in a quick changeover, but the expected rewards can more than compensate. What we don't need is to have this move studied to death. When Japan made the changeover 10 years ago most of the anticipated difficulties proved to be either nonexistent or much less disruptive than predicted.

Soon we will be specifying length in meters, mass in kilograms, time in seconds, electric current in amperes, temperature in kelvins and luminous intensity in candelas. Let's put some enthusiasm and push into this changeover so that we can start reaping its benefits.

Earle Dilatush

MANAGING EDITOR

CTS *has the answer in*



You name it—we have the exact cermet resistor network size and characteristics you need. Here's the choice you get right now: our *750 line* includes: .100″ centers with 4, 6 & 8 pins; .125″ centers with 2, 4, 6 & 8 pins; and .150″ centers with 4 through 13 pins. And we're working on new designs right now!

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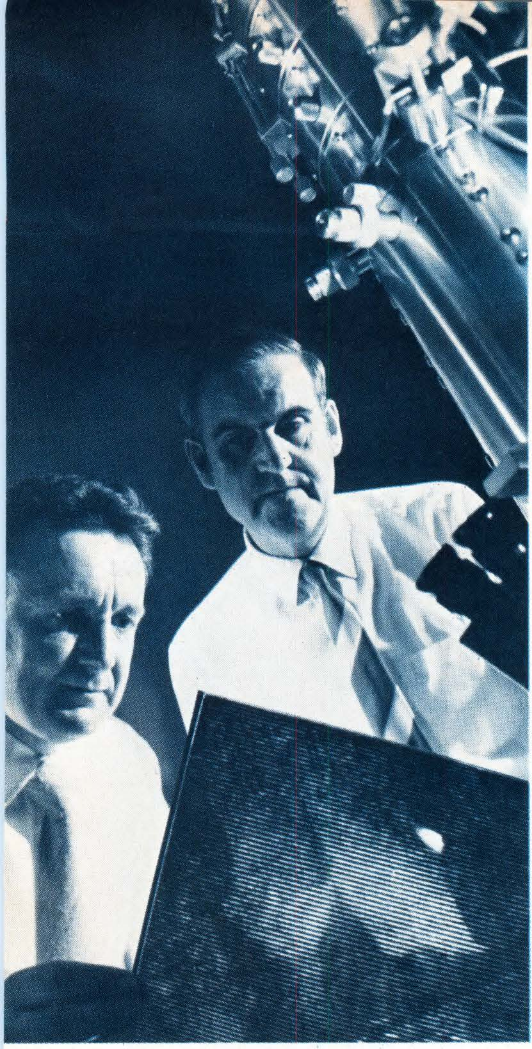


One Million Times Direct Magnification Achieved

Direct visual access to the planes of atoms in most metals and alloys is now possible with a specially modified electron microscope at the General Electric Research and Development Center, Schenectady, N.Y.

Details as small as 8 billionths of an inch wide have been observed on the viewing screen of the modified Philips EM 300 transmission electron microscope. Photographic enlargement of the screen image provides overall magnification of 27 million times—enough to clearly observe the planes of atoms and detect imperfections in the spacing between rows.

To achieve this milestone GE researchers doubled the magnification of the instrument's final magnetic lens and improved the illumination of the sample by maximizing the intensity and concentrating the electron beam onto a very small sample area. They also optimized resolution by making careful adjustments and minimizing vibration.

This achievement offers significant improvement over conventional electron microscopes that magnify from 300,000 to 600,000 times, and will allow more detailed observation of the atomic structure of metals and alloys.

Dr. Victor Phillips (right) and John Hugo examine streaks showing the location of planes of atoms in an aluminum-copper alloy. Total magnification including photo enlargement equals 27 million times.

Super Power Tetrodes Aid in Pollution Battle

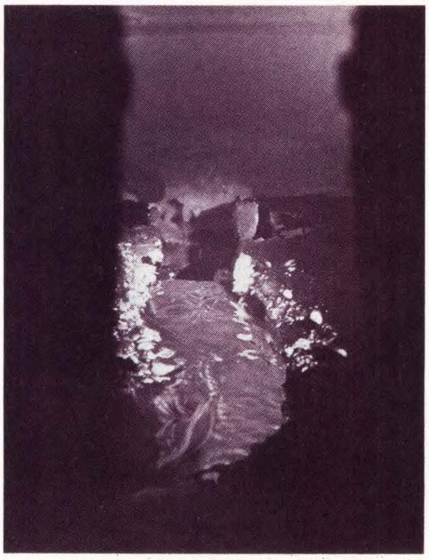
No smoke, no fumes, no ash and no industrial wastes to pollute San Francisco Bay are claimed by Airco Vacuum Metals' new steel-making plant at Berkeley, Calif.

Producing 30,000 tons of stainless steel per year, the plant operates profitably without coal or fossil fuels. Instead, it uses a new process incorporating a battery of Varian/Eimac super power tetrodes to regulate the power that fires its giant electron-beam furnace.

Each of the 22 electron-beam guns utilizes a 200-kW tetrode as a high-speed switch in the high-voltage lead. They act as isolators to prevent RF flow back into the power supply system and also to stop current flow into the vacuum furnace whenever there is an incipient arc.

High switching speeds provided by the super power tetrodes allow higher efficiency than that afforded by inductance limited power supplies and reduce the necessary kVA rating of the supply.

Another advantage of their system, which utilizes electron superheat and high vacuum, is the elimination of nickel in the manufacture of stainless steel.



Acoustic Microscope Magnifies Onion Skin

Using high frequency sound waves rather than light to probe a biological specimen, Zenith researchers have produced what is believed to be the first acoustic microscope photograph of actual biological cell structure ever taken.

Although the concept of an acoustic microscope is not new, Zenith's development of novel acoustic holography techniques using their new acousto-optic laser deflector made this working instrument possible.

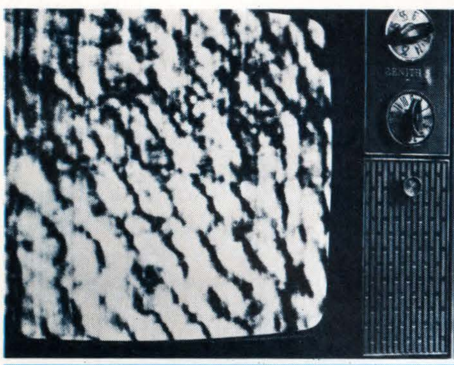
A specimen to be investigated by the microscope is immersed in water in the path of a high-frequency (100-MHz) sound wave. This wave, carrying spatial information about the specimen, strikes a plastic mirror mounted at 45 degrees to the direction of the ultrasonic wave and causes a minute ripple pattern on the mirrored surface. At the same time, a focused laser beam scans a selected area of the mirror and receives periodic angular deflections caused by the ripples. A photodiode converts the beam deflections to electrical signals which produce an acoustic hologram or a magnified picture of the sound field on a television monitor.

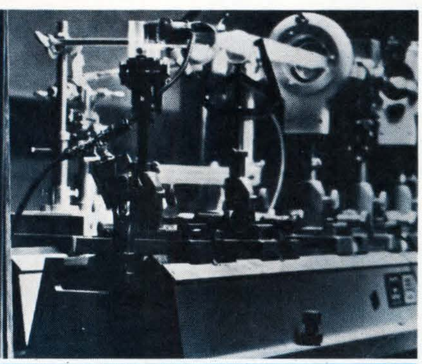
Using a frequency of 100 MHz, the smallest detail visible measures approximately 0.001 inch. In later versions, frequencies 10 to 50 times greater will be used to provide resolving power approaching that of an optical microscope.

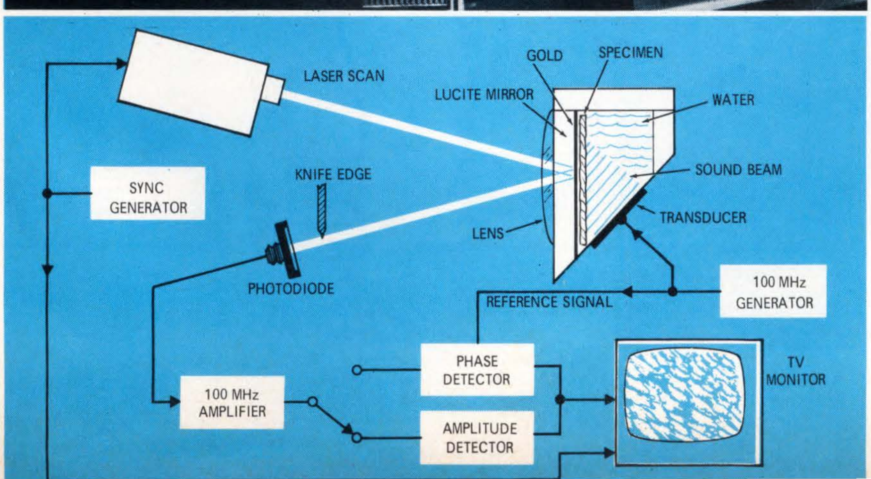
However, resolution is not the most important feature of the acoustic microscope. The fact that sound is a mechanical wave motion, while light is not, makes it possible for an acoustic microscope to show features of a specimen which may go undetected by an optical microscope. This could prove important in such applications as the study of cell tissues. One additional advantage of great potential value in the biological sciences is that the acoustic microscope could make possible the study of live specimens. With the optical microscope, specimens most often must be killed and chemically stained before study.

Thus, the acoustic microscope is not a replacement for either the optical or electron microscopes, but a new third type of microscope with its own unique capabilities.

Individual cells of an onion skin magnified 400 times. (*Zenith*)







Set Your Watch By TV

Unknown to most viewers, accurate time and frequency information has been riding "piggyback" on some commercial television broadcasting signals for several years.

Developed at the National Bureau of Standards, the experimental television-time-code system is ultimately intended to provide inexpensive time signals and precise frequency signals to a great number of users.

Special equipment at the broadcasting studio puts a time code from an atomic clock on line one in the vertical interval. This code carries information designating the hour, minute and second (HMS). At the receiver, a special decoder recognizes the time code and causes it to be displayed in numerals 20 lines high at the bottom of the screen. The numbers change in exact step with the master clock at the broadcast station or network origin.

For those users requiring a precise time code with resolution better than one microsecond, a second code is transmitted alternately with the HMS code on line one. With suitable circuitry, the HMS decoder also recognizes the precise time code, and measures the difference between a local clock at the receiver and the master clock in the studio. The difference is displayed on the screen in nanoseconds. Thus with known transmission time delays the two clocks can be synchronized.

In addition to time information, the system transmits a precise 1-MHz frequency that makes it possible to calibrate a local frequency source to one part in 10^{11} in half an hour, according to scientists at NBS Boulder Laboratories.

The system has been field tested in Denver, Cheyenne, Los Angeles and Washington D. C. areas. For more information, NBS provides a free, 12-page brochure, "NBS TV Time and Frequency System". **220**

Watch for **EDN/EEE's** fifth annual Caravan tour, October-November 1971. A traveling exposition of products and ideas visiting leading computer and peripheral equipment manufacturers throughout the U.S.A.

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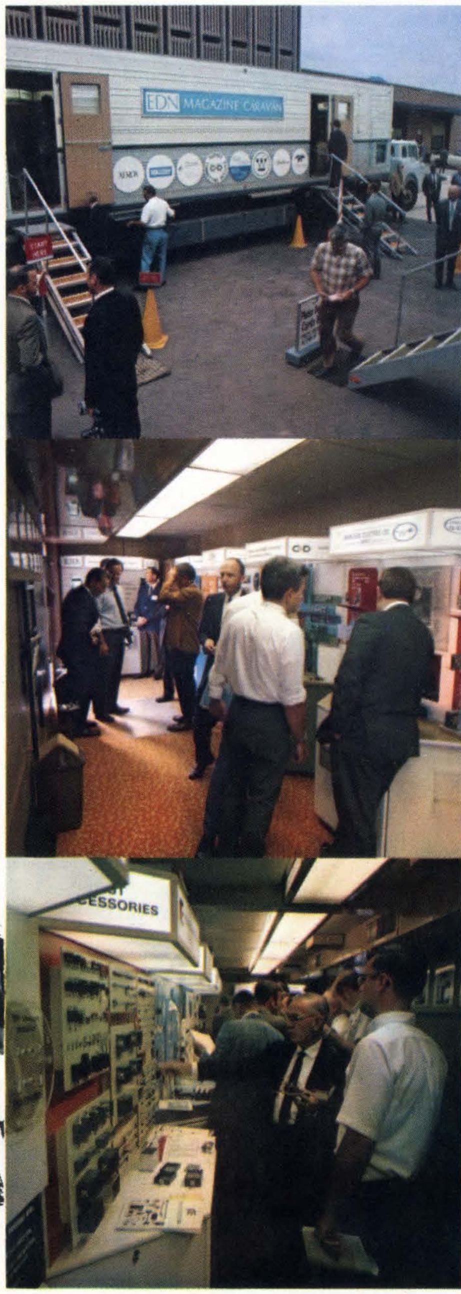

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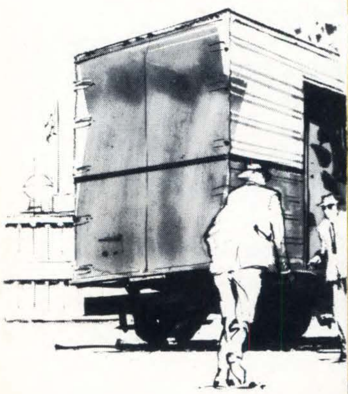
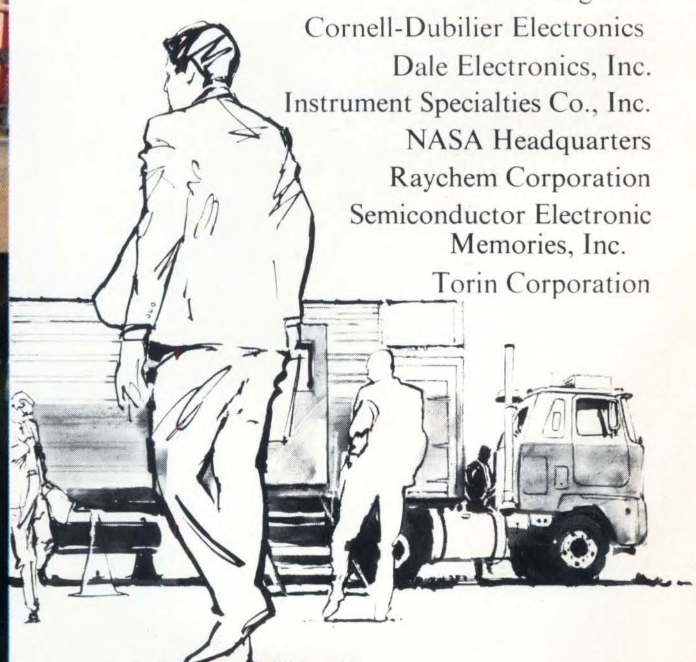




World's Largest Lightning Rod?

That's the question scientists from the Air Force Systems Command's Cambridge Research Laboratory hoped to answer in the initial phases of the recent Apollo 15 flight.

Since the flight of lightning-struck Apollo 12 in 1969, AFCRL scientists have been involved in a joint effort with NASA in the "Lightning Strikes to In-Flight Missiles" program. Instruments rugged enough to record data while bathed in the exhaust from rocket motors were developed to make conductivity and electrical field breakdown strength tests on Minuteman and Atlas missiles at Vandenberg AFB. Air Force tests showed that the rocket plume acts as a good conductor of electricity—like a wire stretched from the rocket to the ground. And, should the rocket enter a thunder cloud, it would act like a lightning rod.

Efforts during the Apollo 15 launch were primarily directed toward determining the effective length of the conducting plume. "The rocket is 363 feet long, and the visible portion of the plume, which contains incandescent carbon particles and other burning matter, is perhaps another 500 feet of good conductor," said John L. Heckscher, AFCRL project scientist. "The invisible trailing portion may also be electrically conductive and that's what we want to find out."

Hologram Admits Employees to Laboratory

Employees of Laboratories RCA, Ltd., Zurich, Switzerland, carry unique "keys" to gain entrance to the laboratories' new technical center.

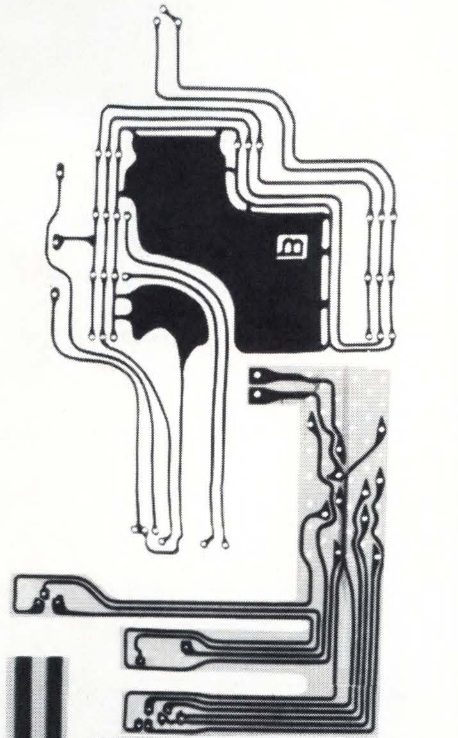
The new system, called Hololock, is the world's first lock-and-key system based on a laser-made hologram. Employees of the lab carry cards with holograms that contain a coded number and other information about the employee. When inserted into a slot in a special box at the center's main entrance, the card's number is read out by illumination with a standard light bulb. The number is then compared with the number punched into a keyboard by the employee. If the two match, the door unlocks. Since highly-specialized equipment is needed to produce the hologram and it cannot be altered, the system affords a high degree of security.

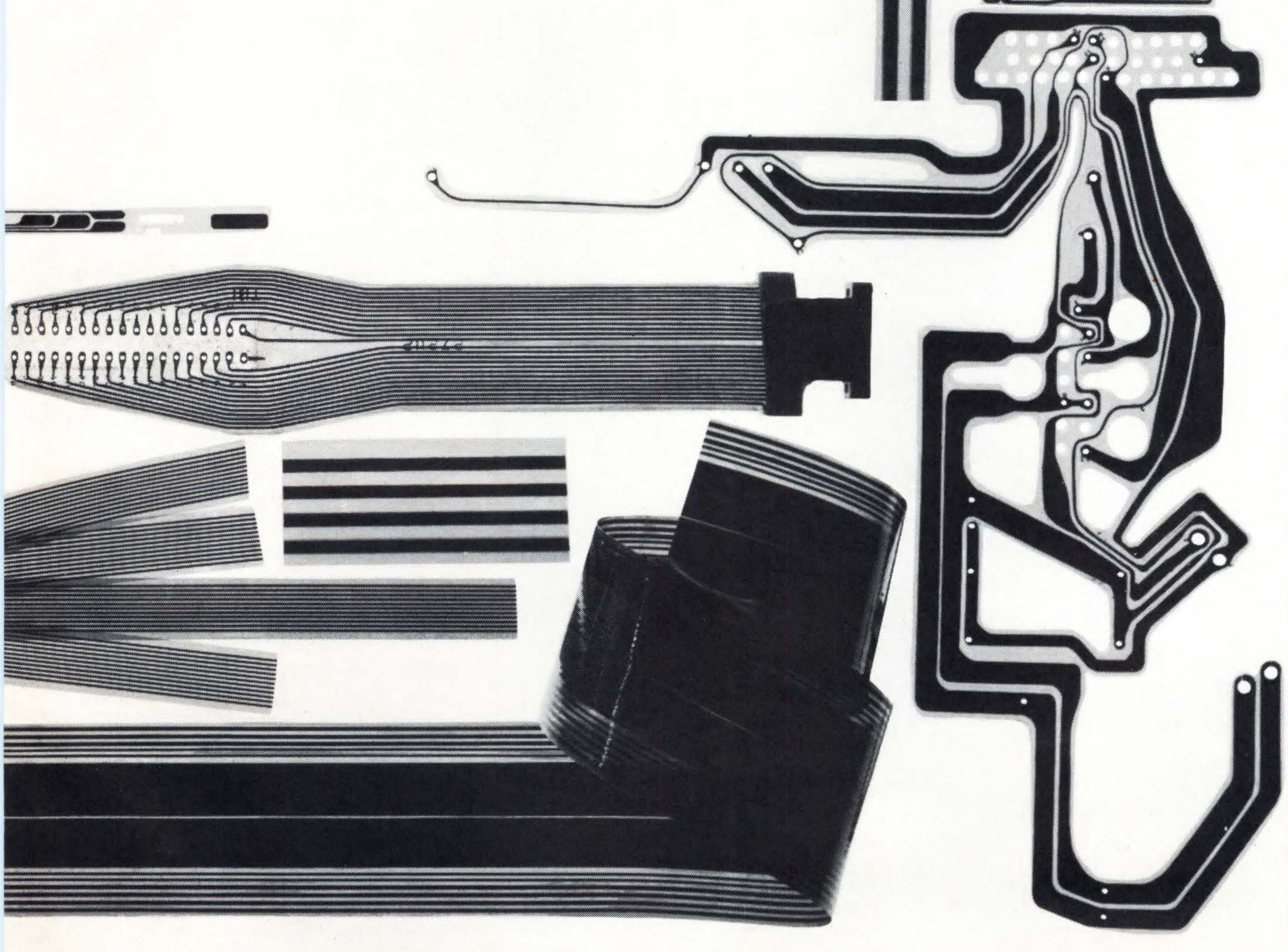
Huge Job Boom Predicted for Scientists, Engineers

At least one prominent member of the engineering community is optimistic about the future job market for engineers and scientists.

Dr. Simon Ramo, delivering the main commencement address at the Polytechnic Institute of Brooklyn, where he received an honorary Doctor of Engineering degree, predicted an era of unprecedented job opportunity in science and engineering as the industrial complex regears to alleviate the massive social crises of the final third of this century. Dr. Ramo told more than 900 graduate and undergraduate degree recipients that the United States is headed toward a radically new "social-industrial complex". He predicted that the influence of this social-technological cooperation—involving such areas as urban development and renewal, health care, education, race relations, environment control, rapid transit and housing—will be far more pervasive than the present military-industrial alliance and will involve more jobs, more private industry-invested funds and more of the nation's resources. "Its influence for good—and for bad—will be proportionately greater," according to Dr. Ramo.

In training the new "socio-technologists," the science and engineering professions "must accept that you cannot apply science to society unless you understand society as well as science. The whole of engineering has got to be understood to concern something bigger and broader than has been true in the past."





RAHAM to Detect RF And Microwave Radiation Hazards

Several models of a new type of environmental pollution detector called RAHAM – Radiation Hazards Meter – are being developed for the Air Force Systems Command, Rome, New York, by General Microwave Corporation, Farmingdale, New York.

The instrument is designed to detect and measure electromagnetic radiation at power density levels potentially hazardous to human life processes. RAHAM will detect and automatically warn of dangerous radiation from a variety of high-power radio energy sources used in military, industrial, medical and consumer installations, such as communications transmitters, industrial microwave processing equipment and home microwave ovens. Existing instrumentation is deemed inadequate because of limited bandwidth and power range.

General Microwave's president, Sherman A. Rinkel commented, "As the number of high power radio and microwave installations continues to grow, we can no longer ignore the potential danger from electromagnetic radiation to which people in all walks of life may be exposed.

As with ionizing radiation from atomic sources, awareness of exposure comes only after damage – sometimes irreversible – has been done. By adapting techniques pioneered by General Microwave almost a decade ago for the broadband measurement of low levels of microwave power, a totally new approach to the measurement of radiated fields has evolved which will eliminate the many shortcomings in existing power density meters. It is believed that RAHAM will become as valuable and essential for human safety in electronics and related fields as the radiation dosimeter already is in the atomic-energy field."

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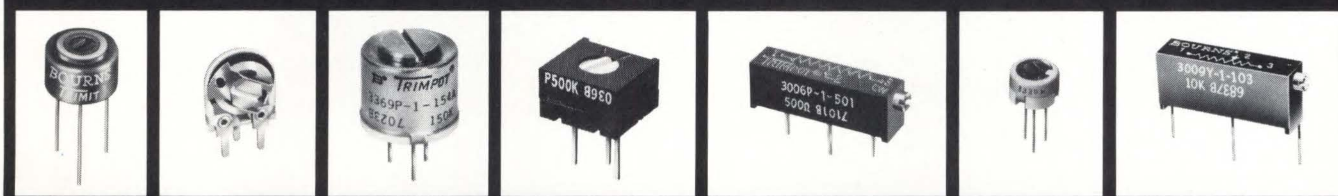

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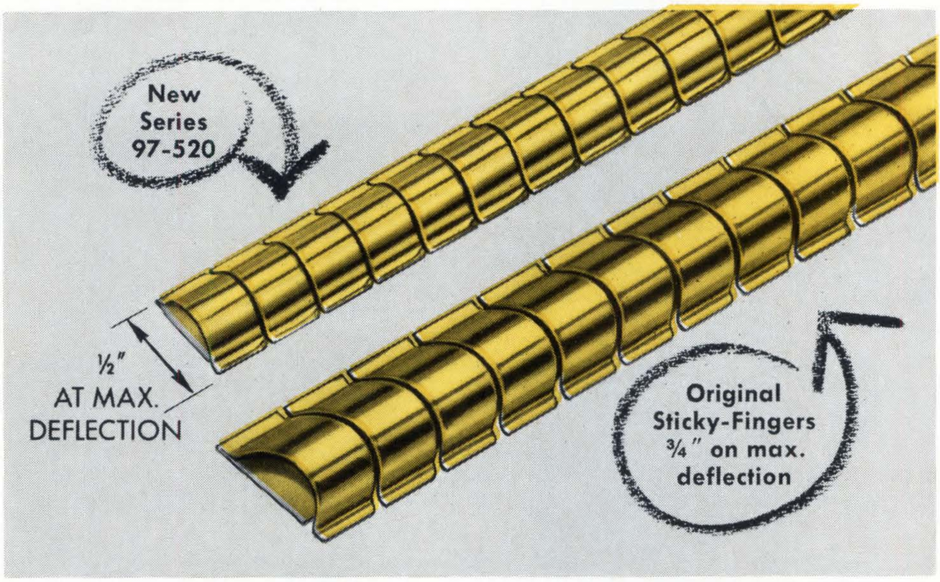

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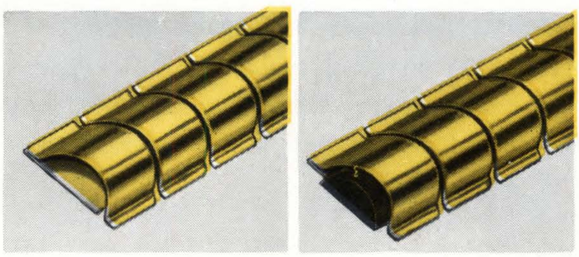

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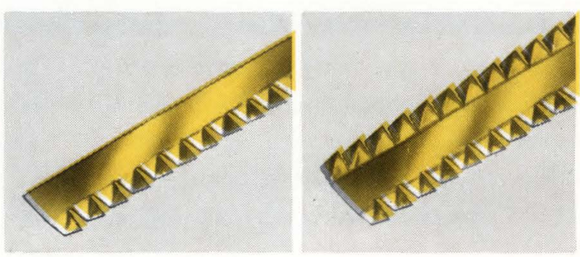

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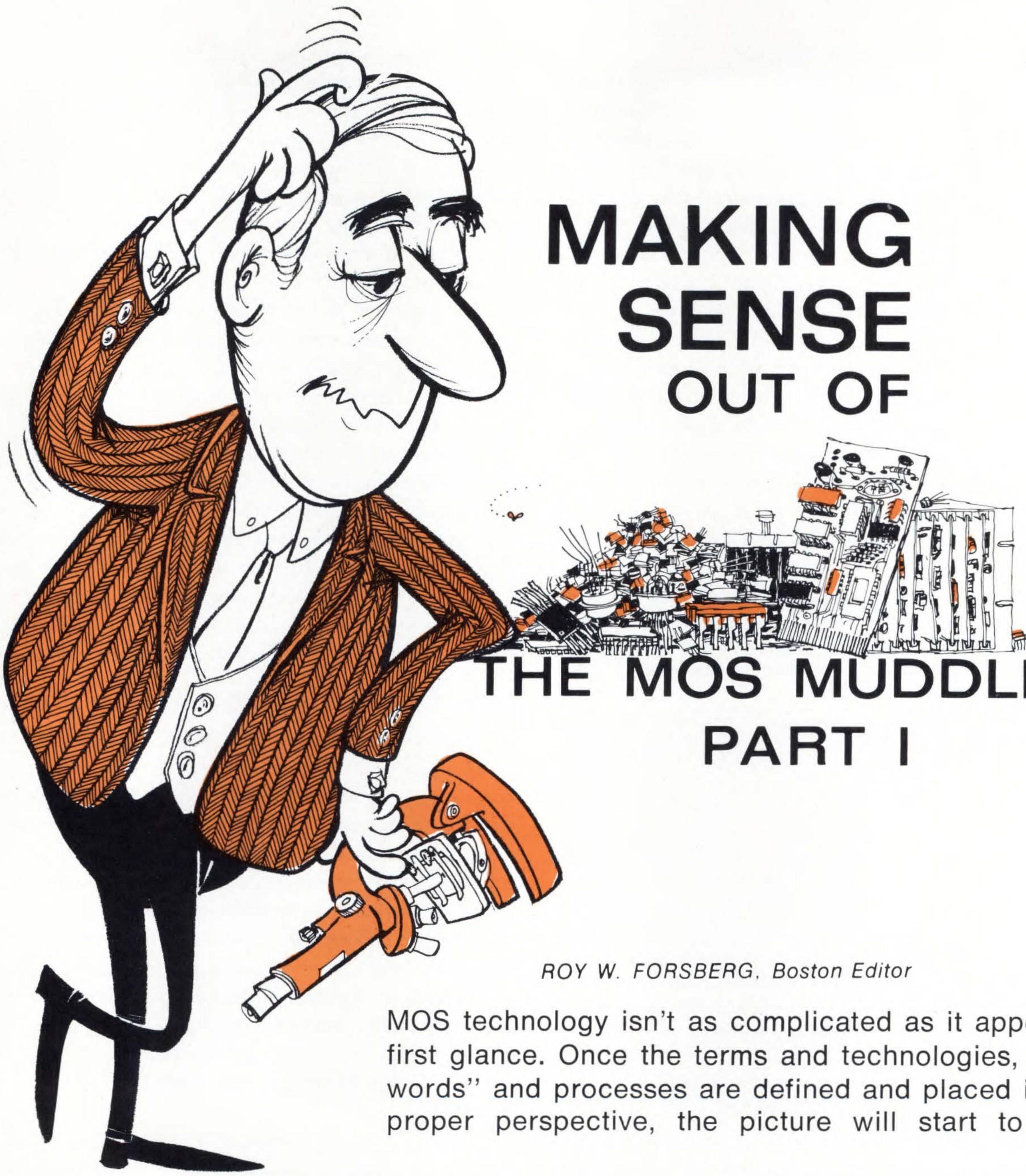


MAKING SENSE OUT OF THE MOS MUDDLE— PART I

ROY W. FORSBERG, Boston Editor

MOS technology isn't as complicated as it appears at first glance. Once the terms and technologies, "buzz-words" and processes are defined and placed in their proper perspective, the picture will start to clear.

A technology with a rocky road of acceptance behind it, MOS still has a long way to go before it is generally accepted by many designers as a useful design tool. Many potential applications for MOS devices haven't even been considered by designers because of the mystery and confusion generated by those who deal in and write about MOS. This includes those vendors who sell technologies vs performance, and engineers who present nonobjective papers at various conferences while plugging a certain technology. It also includes the trade press, which does the same thing when single technology articles are presented without their content being weighted against the rest of the MOS world.

In the past, MOS fought problems such as limited availability, early device failure, low yields that kept costs higher than expected, and difficulty in interfacing with bipolar. Today these problems have largely been solved. Now a new set of roadblocks has popped up. Technologies have been promoted in place of performance and cost, and buzz words have been used with no explanation of their meaning—causing confusion

(Continued)

and making communication difficult.

MOS really isn't too difficult to follow once things are defined and put in good order. It is a relatively simple manufacturing process that employs simplified masks as compared to bipolar. It has higher functional density – thus lower cost per function. It also has high impedances, giving low current densities and simplified interconnections. On the other hand, it is not the answer to all the world's problems. It doesn't fit all potential applications and shouldn't be forced to.

There is really no overwhelming reason for a designer to concern himself with which technology or combination thereof, he makes his circuits. Any technology should be acceptable if the devices meet his performance and cost requirements and can be delivered in quantities needed. There are, however, two pervasive reasons why a designer must be able to make sense out of the MOS muddle and know which technology he is using. One, he must be able to evaluate the mass of available information so that he can make some rational and objective judgements. Two, he should use these judgments to select a continuing mainline technology, so that projected high volume costs can be realized and devices can be second-sourced. Many applications can be solved very well by a number of processes, so this latter consideration becomes a big factor.

Factors Affecting MOS Parameters. V_T and gain are functions of the equations shown, while packing density is a function of device geometry, masking tolerances and interconnect flexibility; and capacitance is a function of overlap C, junction C and interconnect C.

THESE FACTORS		AFFECT THESE
CRYSTAL ORIENTATION	<100> <111>	Threshold Voltage
GATE INSULATOR	SiO_2 Si_3N_4 Al_2O_3	Capacitance Threshold Voltage Gain
GATE MATERIAL	Silicon Aluminum Refractory Metal	Threshold Voltage Packing Density Capacitance
DOPING PROCESS	Diffusion Ion Implantation	Packing Density Threshold Voltage
SUBSTRATE MATERIAL	N-Silicon P-Silicon Insulator	Capacitance Threshold Voltage Packing Density Gain

GAIN

$$g_m = \frac{Z}{L}\,\mu C_O\, V_D$$

where $C_o = \frac{K_{eo}}{T_{ox}}$

Z = channel width

L = channel length

μ = carrier mobility

THRESHOLD VOLTAGE

$$V_T = \frac{T_{ox}}{K_{eo}}\left[Q_{SS} - Q_B\right] + \Phi_{MS}$$

T_{ox} = Thickness of gate oxide

K_{eo} = Dielectric constant of gate insulator

Q_{ss} = Fixed surface-state charge density per unit area

Q_B = Charge per unit area (channel)

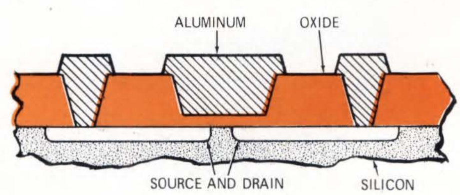
Φ_{MS} = Gate material/silicon work function difference

With these needs in mind, we traveled across the country and surveyed most major manufacturers of MOS. In the first part of this two-part article, we will look at each technology and combination of processes from the designer's point of view. We will see what they can and can't do, and note their advantages and disadvantages. We will also present a glossary of terms to clear up the common buzz words. Finally, we will take this information and put it into proper perspective so that you can see how it all fits together.

In Part Two, we will discuss which processes are likely to survive, and what to look for in the near future. Last, we'll give a chart of "who makes what".

MOS TECHNOLOGIES AND PROCESSES

When considering different MOS processes, the two most important characteristics are availability and cost. Also very important (though in different degrees depending on need) are packing density, power, ease of design, reliability, TTL-compatibility and speed. No one technology or combination of processes meets all these requirements simultaneously. Therefore, the process you choose will depend on your individual application needs. The various process steps and materials shown in **Table 1** affect each of the above parameters differently. How they relate to each other is illustrated in **Fig. 1**. If you keep these factors in mind as we discuss each technology, the pieces will begin to fit together.



P-CHANNEL HIGH V_T <111>

P-Channel, High V_T <111>, the first production process for MOS, has been around since 1964. It has been, and still is, the "workhorse" of the industry. It is a high-voltage process but does have an advantage over the same process using <100> crystal orientation, in that hole mobility is about 25% faster. This coupled with the higher power makes the circuits fast-

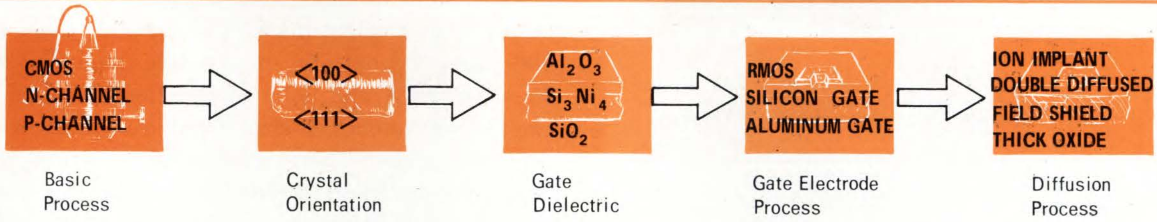


Fig. 1—**MOS terms** broken down by steps in the production process. To make an MOS device at least one choice must be made from each block.

er. Most manufacturers use five masks including the final glassivation. North American Rockwell, however, offers a sixth mask to control gate oxide thickness and to get better threshold control.

Its advantages include a long production history and good reliability data. It is highly controllable, has good yields, very low costs and high noise immunity. Aside from its long history, its biggest advantage is that it is common to the industry and is easily second-sourced using the same set of masks.

It has several disadvantages. Among these are: 1) high threshold voltages (V_T) because of a high aluminum gate work function, thick gate oxide and low K_{eo} for silicon oxide; 2) slow speed because of high capacitances from gate to source and drain overlaps, and relatively large gate areas; 3) incompatibility with TTL because of high V_T; 4) gate sensitivity to contamination, which makes devices generally unsuitable for low-cost plastic packaging; 5) high odd-ball voltage supplies needed; and 6) it's more difficult to design with.

Best applications for it are those that do not require low power, high speed or high densities, such as ones that operate in real-time and interface with people. Typical uses are in nonportable calculators; in timers for washing machines, dryers and dishwashers; and in industrial controls. Circuit functions this technology serves best are random logic, shift registers and ROMs where cost is more of a consideration than performance, as well as those applications not requiring TTL compatibility. Operating voltages are most commonly −12 and −28V.

P-Channel, Low Voltage <100> was the second process of importance to come along, and has been in wide use since 1967. It looks the same as the high voltage process, physically, and uses the same number of masks, but differs from it by using a <100> crystal orientation to gain low V_T and therefore TTL compatibility. The Q_{ss} term, surface state density, is lowered by using <100> material, and is the major reason for the low V_T. This process requires minimal steps to attain low V_T, is in wide use, and has a long production and reliability history.

Among its advantages in addition to low V_T are tighter V_T control, about one half the operating power of <111> process, TTL-compatibility and low cost.

Unfortunately the lowering of V_T by this process also causes a lower field inversion threshold (to about 20V). Thus voltages in this range cannot be distributed on metal conducting paths over the field. National Semiconductor overcomes this by using a special processing technique to raise field thresholds to the 30-35V range, while others use channel stoppers. However, the latter approach requires additional space and reduces density. Gate overlap capacitance is still present, causing low speeds, and power supply noise immunity is low.

Best applications for this technology include those requiring TTL compatibility, low cost, and relatively low power—but where high densities and high speeds are not a factor. It is well suited for ROMs, random logic, custom circuits and some shift registers.

Operating voltages commonly used are +5 and −12V, although Hughes claims to be able to run at +5 and −5V without going to a nitride process.

P-Channel, Low-Voltage, Thin-Oxide <100> is virtually the same as the previous process, except that the field oxide is thinner. Its field inversion voltage is lower, so guard rings or channel stoppers must be used. Hughes has two versions, one with field inversion voltages at 25V and another at 40-45V to replace high-threshold products.

The disadvantages are larger chip size, an additional mask and few suppliers (most have switched to thick oxides).

P-Channel, Silicon Nitride. There are various versions of this process that use the nitride for differing reasons. Two are identical to the p-channel <111> and <100> processes, except that a thin passivating layer of silicon nitride is added over all oxide surfaces. This gives added protection and prevents sodium ion migration, permitting plastic packaging. Another version uses the nitride to form a self-aligning gate structure. Here the nitride is laid down to define the gate areas before diffusing the source and drain beds. It acts as a mask, and prevents boron dopants from penetrating

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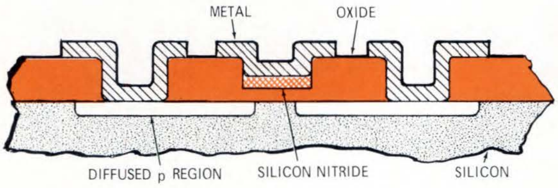
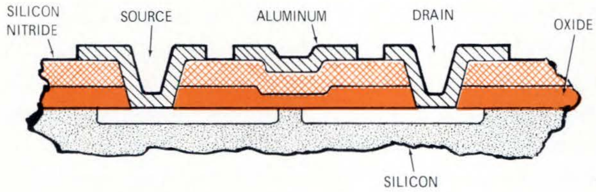
into the gate area during the latter step. Very few suppliers are making devices by these processes.



P-CHANNEL SILICON NITRIDE

The version most common to the industry deposits nitride in the gate region over a layer of oxide (General Instrument's MTNS process differs in that nitride pas-



P-CHANNEL SILICON NITRIDE

sivates the entire chip). A <111> substrate is used to maintain high field inversion thresholds, while the high dielectric constant of silicon nitride provides a low V_T device. The high dielectric constant also increases the gain factor and drain current, enhancing bipolar output compatibility.

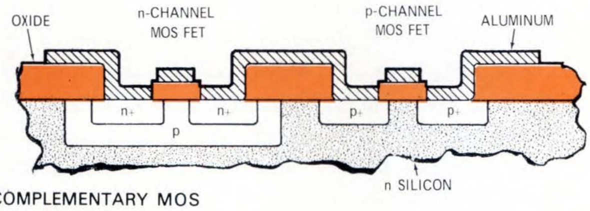
Among its advantages are low cost; the achievement of low V_T and TTL compatibility without the layout difficulties of silicon gate or the low field inversion of PMOS <100>; about half the power consumption of PMOS <111>; high drain currents; use of the same masks as for PMOS <111>; higher speed than with either PMOS version; and gate protection against contaminants which makes plastic packaging feasible.

Among the disadvantages of this process to designers are densities less than silicon gate, and possible V_T shifts from trapped charges built up in the oxide-nitride layer because of the differences in conductivity.

From an application standpoint, MNOS or MTNS are suitable for use in RAMs, ROMs, shift registers, and random logic where medium speeds and relatively low costs and power are necessary.

Voltages most commonly used are +5 and −12V, although some companies like North American Rockwell and MOS Technology will customize other voltages. The latter has a single +5V version on the way.

Complementary MOS is a very interesting process that combines both p-channel and n-channel transistors on the same substrate. The n-channel transistor is normally the driver and the p-channel the load in each cell, and the circuit is arranged so that one transistor is always on. This usage gains a number of benefits, especially high speed and low standby power. It is more complex to make than other processes, for it requires seven to eight masks and normally takes about 30% more real-estate than single-channel devices. However, RCA and Solid State Scientific claim they can get equivalent cell sizes if you are willing to sacrifice some yields. There are several variations to the basic process. These include the use of silicon gates to attain ultralow V_T, lower power, improved V_T control, higher packing densities and ion implantation. Hughes uses ion implantation to get ultralow thresholds, low power and good V_T control. They implant a p-well in the n-type substrate, tailoring the n-channel V_T at the same time, and then use ion implantation to adjust the p-channel V_T.



COMPLEMENTARY MOS

Advantages of complementary MOS are numerous, and in many applications more than offset the disadvantages. It attains very high speeds (up to 20 MHz), consumes power in the microwatt range and has nanowatt standby power. Other pluses noted for CMOS include high noise immunity (about 40% of the supply voltage), complete TTL compatibility, single power supply, wide operating voltage ranges, relative insensitivity to temperature variations and ease of user design.

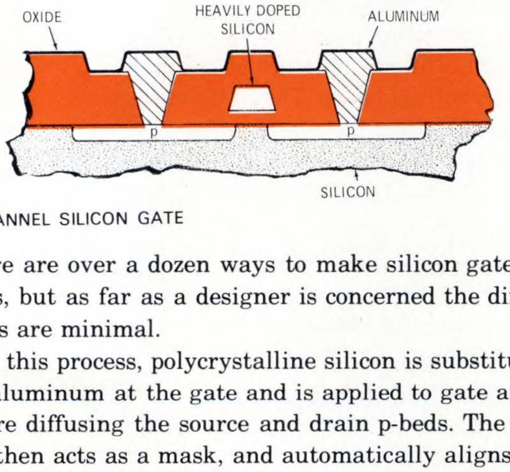
There are some formidable disadvantages, such as the high cost that results from a more complex process and larger-size chips.

A single supply is all that is needed, with required voltages that vary all over the lot. RCA has two lines, one that operates anywhere between 3 and 15V and another at 1.3V, as does Solid State Scientific with a 5 to 15V line and a 1.2V line. Ragen has 3 to 16V and 1.5 to 6V lines, and Motorola has 4.5 to 18V and 3 to 18V lines using metal gate processing, plus standard low-threshold silicon-gate devices specified down to 1.3V. Intersil has units that operate on 1.2V supplies, and Hughes' complete line will run at 1.35 to 15V. These wide supply tolerances buy speed to the tune of 0.8 MHz/V. Thus a device will be about two times faster when run at 5V than at 3V.

CMOS also opens up a wide variety of applications. The most obvious are those battery-powered ones that require ultralow power drains, such as electronic watches. Motorola has shipped, to at least one major customer, evaluation samples that are guaranteed to operate at less than 1V (at room temperature).

Most agree that CMOS is not best suited for large arrays like memories. A few, however, dispute this, pointing out that ultralow power densities virtually eliminate cooling problems. Ragen is one who backs this up with arrays containing as many as 2000 devices on a chip, AMI is building I^2 random logic chips with over 8000 devices and RCA is aiming at MSI bipolar markets. But most applications are those requiring low power or battery operation, or where power supplies are both noisy and variable. They include timing circuits for watches or clocks, home appliance timers, remote communication and monitoring systems like gas- and water-meter readers, medical instruments and other portable communications devices. Especially attractive are automotive applications (because CMOS works well from unregulated and noisy power supplies) and those applications combining linear and digital devices on the same chip (because CMOS can operate from the linear device's power supply).

P-Channel Silicon Gate. First announced commercially by Intel, silicon gate technology can be used for p-channel, n-channel, and CMOS devices, although p-channel is predominant today because it is an easier and more controllable process with a longer history.



P-CHANNEL SILICON GATE

There are over a dozen ways to make silicon gate devices, but as far as a designer is concerned the differences are minimal.

In this process, polycrystalline silicon is substituted for aluminum at the gate and is applied to gate areas before diffusing the source and drain p-beds. The silicon then acts as a mask, and automatically aligns the gate between source and drain with minimum overlap (lateral diffusion is inherent but overlap is still small compared to metal-gate devices). Low V_T results because of this low overlap capacitance, a low silicon-to-silicon work function and a low interconnect capacitance. Junction capacitance is also reduced, for the gate area can be substantially smaller because the source and drain interconnects don't have a metal gate separation to worry about. The silicon gate itself, because it is buried in oxide, affords an additional level of device interconnect, and in most cases leads to high packing densities.

Silicon gate has the same advantages as MNOS and MTNS – namely that it is a stable, reliable, reproducible process with low V_T, high field inversions and TTL compatibility. It has further merits in its higher packing densities, its 50% increase in speed over MNOS and MTNS and its added layout flexibility resulting from the extra layer of interconnect. Since chip sizes are smaller, more chips can be made from a wafer. The higher yields should offset the additional processing steps.

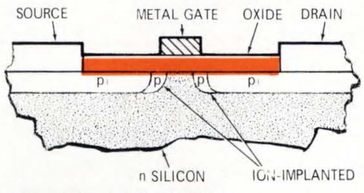
Disadvantages are few and minor. Primarily, this is a relatively new, immature process and few suppliers are in high-volume production at this time.

There is some controversy over which applications this process fits, but the main area of contention lies in the fact that the inherently small source-drain spacings are balanced by the need to make metal contact through a top layer of oxide to the polysilicon gate. The contact must be made off to the side of the source-drain region, and yet remain insulated from adjacent circuitry. Layouts will not permit a continuous bar of silicon to run through the oxide, so if the circuit application calls for many oxide cuts to connect to silicon gates, it is conceivable that this could chew up more real estate than conventional metal gates.

Just about everyone is unanimous that this process is best suited for large scale RAMs. Beyond this, opinions are mixed with regard to ROMs, shift registers and random logic. It looks as if this question is best solved by applying the design rules used by each manufacturer while considering individual system needs. General Digital, for example, feels that it can provide most circuits more efficiently with silicon gate because of a combination of their design rules and CAD techniques. On the other hand, Nortec believes that for certain applications ROMs and random logic can be made more efficiently by metal gate technologies, but at a cost in performance.

Most companies use five masks while a few add one more to attain greater packing densities. Operating voltages are nearly universal at +5 and −12V.

Ion-Implantation Self-Aligning Gate is a high V_T process similar to standard PMOS <111>, except that the gate area is initially made wider than usual. After the aluminum gate is laid down, the source and drain regions are extended to the edge of the gate metal by ion implantation, with the gate acting as a mask. This results in about the same supply voltage levels,



ION IMPLANTATION SELF-ALIGNING GATE

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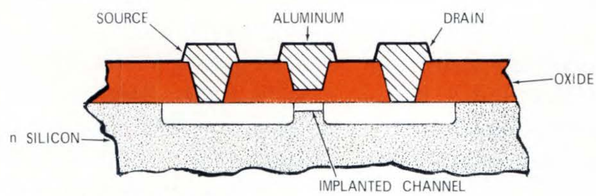
logic levels, V_T and field inversion as the standard PMOS <111> process—but with higher speeds because of the zero gate overlap (Miller capacitance), and better V_T control.

Hughes has a variation on this process—they also ion implant to adjust V_T and to implant high value resistors. This results in both low V_T and the ability to make simple analog functions on the same chip. Supply voltages are usually +5 and −5V.

Ion-Implantation—Low V_T. Ion implantation is really a processing step rather than a process itself. (I^2, sometimes used to describe this step, is a registered trademark of American Micro-systems Inc.) It can be applied to p- and n-channel devices, to silicon gates, and to CMOS in many different ways. For the most part it is used to adjust thresholds by implanting ions in the gate region after source and drain beds are diffused. The most common procedure is to start with a high V_T p-channel device and implant enough ions in the gate (or channel) region, partially depleting it, until the desired threshold is achieved.



ION IMPLANTATION LOW V_T

This reduces Q_B (charge per unit area), and makes the device TTL-compatible. The implanted doping level is controlled either by beam current or implant time, both of which are highly controllable. The nice thing about the process, especially as applied by MOSTEK, is that devices are removed from the normal high V_T PMOS process line for only one additional step (implanting) and require no additional masking. A real plus for this process is that depletion-mode loads for enhancement-mode drivers can be made on the same chip. This involves one additional mask (six vs five), and is accomplished by implanting additional dopants in the desired channels until they become depleted.

This latter combination buys you a lot of goodies. Depletion loads are about two-thirds the size of enhancement devices, and output buffers can be about half the size of those for silicon gate. In addition, these devices can run from a single 5V supply with wide voltage tolerances, and at milliwatt power levels. This can't compete with the microwatt levels of CMOS, but it can fill many applications that can tolerate low milliwatt levels but not the higher cost of CMOS.

All this doesn't come for free, though. Implanting equipment is costly and quite complex. Many also cite low throughput as a disadvantage, although MOSTEK and Hughes, who are heavily committed to and well experienced in this process, say otherwise. MOSTEK claims to run 100 slices/hr. Hughes has one machine that processes 40 wafers in 2 hrs, and another that processes 20 wafers in 1-1/2 hrs. Another disadvantage as compared to silicon gate is that you don't get that extra layer of interconnect.

Best applications are dense, high-speed, low-power dynamic RAMs, especially if both the depletion loads and the linear sense amplifiers are on the same chip. Both ROMs and circuits that combine linear and digital functions on the same chip are also likely candidates, as are certain battery-powered applications. This process is also well-suited for automotive applications because of its ability to tolerate wide voltage variations.

Without depletion loads, power supplies are generally +5 and −12V, and with depletion load they can be a single supply in the 5 to 20V range.

N-Channel, although quite attractive to many companies, is plagued by processing problems. The silicon surface is very sensitive to contaminants, which tends to make all the devices on a chip depletion devices. Also thresholds are in an undesirable range. Ultraclean processing will probably clear up the former problem, while a substrate bias will shift V_T to the desired operating levels. The latter offers somewhat of an advantage, since V_T can be adjusted independently of other circuit parameters. For example, doping and oxide thickness can be varied to attain certain performance gains. Then V_T can be adjusted separately, via the bias, to get the desired levels (vs geometries and process controls in other technologies). One way of eliminating the substrate bias is to go to ratioless circuit designs.

Some advantages are low V_T because of the low work function, TTL compatibility, high field inversion and high speed as a result of the electron mobility being about three times that of holes. NMOS has high drain current and high gain. Also, since power is dissipated only when the output is on, it wastes less output power than PMOS.

The disadvantages are not minor ones, but they can be overcome in time. They include the need for tighter process control and wide V_T control, the need for an extra power supply to bias the substrate, little available history, the requirement for large output buffers to drive TTL, few suppliers and little acceptance by designers.

The process, which uses five masks, operates at +10, +5 and −6V (for substrate). However, Cogar can go as low as +6, +4 and −4V.

Cogar, the only company with n-channel in production, seals each device with a phosphosilicate quartz to prevent contamination, and produces all devices in flip-chip form.

Applications for which this is best suited include all performance-oriented circuits except those requiring very low power.

N-Channel, Silicon-Gate is quite similar to its p-channel counterpart in terms of physical construction, and has the same problems as straight n-channel. The addition of the silicon gate does little for speed in n-channel, but it does increase packing densities. There seems to be much more active effort put on n-silicon gate than on straight n-channel, and many of the active companies are those who have developed some expertise in CMOS. Electronic Arrays is working on a version of this. They add silicon nitride as an ionic barrier to prevent contamination, and to help maintain enhancement-mode operation. Intel and Intersil expect to have n-channel silicon gate as a production item by the last quarter of 1971. Its main advantage will be in providing a low-cost approach to high-speed mainframe memories.

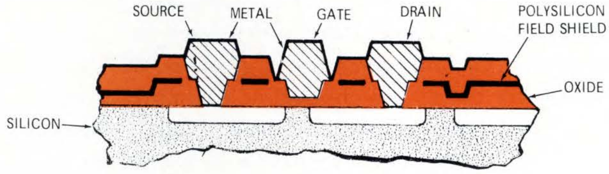
As with other approaches, the disadvantages are numerous, but can be overcome. It is a difficult process to control, is not well known, is more sensitive than some to processing parameters, has high tolerance spreads and cost and there is little experience with it.

Best applications will be in high-speed RAMs and shift registers, both aimed at mainframe memories.

Depending on who you talk to, the process uses five or six masks, and has a variety of operating voltages. These range from +12 and −12V (substrate) at Electronic Arrays to +5 and −12V or simply +5V (sacrificing speed) at Signetics, to any 15V spread at Solid State Scientific.

MOS/Bipolar, or more particularly p-channel/bipolar, uses a vertical npn transistor in an emitter-follower configuration, and requires only one extra diffusion unless isolated npns are needed. It is useful where heavy current drive of output stages is required, and could be used in a number of ways, depending on the application. There is little action in this area except at General Instrument Corp.

Field-Shield is simply an n-channel process with a silicon guard or "field shield" added that extends over the entire chip, except at gate and contact regions. The shield prevents low field inversion, which is so low with high-resistivity substrates that all devices tend to short together and be depletion devices. Use of a low-resistivity substrate partially solves this, but at the expense of speed. The combination of a thin-oxide-nitride gate dielectric with the field-shield allows the use of high resistivity substrates, yet ends up with field inversion voltages essentially at infinity, and with very high gain factors. The former is possible because the field shield isolates the silicon substrate from the metal and oxide above, and the latter results from the high dielectric constant of the oxide-nitride sandwich. The shield is normally biased to the substrate, and the substrate, as in conventional NMOS, has a small negative bias for V_T shifting.

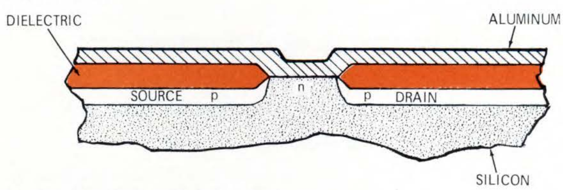


FIELD SHIELD

This process ends up with several advantages over conventional n-channel. The processing provides self-aligned gates and very small gate areas. This reduces all capacitances and results in high-speed, high-density devices. The low V_T insures TTL compatibility, and the shield provides such added benefits as reduced noise and cross-talk at high frequencies, a convenient ground bus and the possibility of making low-capacitance resistors by etching (to isolate a piece of silicon of the desired size).

Among its disadvantages are the fact that it is a more complex new process, that there is only one vendor—Varadyne (although Motorola has been licensed to use the process), that there is no history, and the requirement for a bias supply.

The process uses the same number of masks (five) as conventional n-channel, and operates at +15, +5 and −5V.



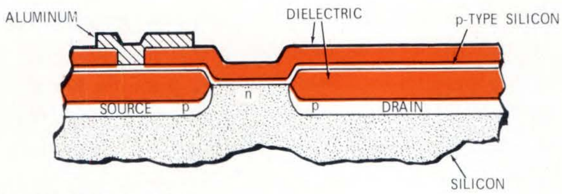
SATO WITHOUT SILICON GATE

Self-Aligned Thick Oxide (SATO) is a process used by Texas Instruments Incorporated that appears somewhat similar to the nitride self-aligned gate process. However, they use a proprietary dielectric material in place of silicon-nitride. This process allows the option of using silicon gates, not as a mask for self-alignment, but to gain the extra level of interconnect. It has a very low V_T (making it TTL-compatible thanks to <100> crystal structure), low gate overlap capacitances and high dielectric constant of the thin dielectric.

Without the silicon-gate feature this process is faster

(Continued)

MOS Muddle (Cont'd)



SATO WITH SILICON GATE

and more dense than MNOS, because of the self-aligning, and costs about the same. Its performance is supposed to be equivalent to silicon-gate processes but lower in cost. When silicon gates are added to SATO, improved packing densities, higher speeds, lower V_T, and lower power are claimed as compared to conventional p-channel silicon gates, but at equivalent costs.

SATO without silicon gates is best used for RAMs and ROMs, while SATO with silicon gates is suitable for very-high-speed RAMs and shift registers.

Operating voltages are +5 and −12V. Disadvantages are the same as for any new process—little history or long-term reliability data, and a single source of supply.

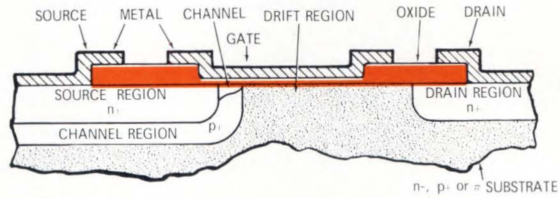
Refractory MOS (RMOS). From a process standpoint, this is virtually the same as silicon gate and can even use the same masks. It has the same advantages as silicon gate with regard to the self-aligned gate giving low V_T and high speeds, an extra layer of interconnect, less chance of gate contamination because no photoresist is used on gate oxide, and similar layout rules. But here the similarities end. Molybdenum is used in place of polycrystalline silicon, and GE claims that this deposited metal promises higher yields than diffused silicon by eliminating over/under diffusion problems. The low gate conductor sheet resistivity buys a number of benefits, including shorter delays because of the lower voltage drops across the gate electrode. Also, the moly can serve as a power conductor without excessive voltage drops, clock signals can be distributed either by aluminum metal or moly runs, and the moly can be used for long buried runs in RAMs and ROMs without long delays.

What all this says is that devices made by this process should be faster than equivalent silicon gates, and that designers may find that they can lay out circuits differently and more efficiently. However, the process is so new that it is simply too early to tell.

Once again, disadvantages crop up because it is a new, unproven, single-source process.

RMOS should fit most high-speed, dense circuitry applications quite well. It avoids part of the controversy raised by silicon gates over frequent oxide cuts needed in some circuits, and the operating voltages should be in the +5 and −12V range.

Double-Diffused MOS (DMOS) is a process recently-developed by Signetics. It departs from conventional MOS processing in that it is not mask limited to obtain very precise, narrow channels. Rather, channels are defined by two diffusions of n and p dopants through the same mask opening. The drift region is always depleted, so that when the narrow channel is turned on the device switches at very high speeds.



DOUBLE-DIFFUSED MOS

The extremely narrow channels and self-alignment features are independent of masks, etching, and photolithography, and give very high speeds because of resultant low feedback capacitances. DMOS is TTL-compatible at input and output, can also have depletion loads, has good V_T control and gives large current drives. Silicon gates or ion implantation can be used for threshold control.

As for disadvantages, DMOS requires one extra diffusion and a precise diffusion source, has nonsymmetrical drain characteristics and has not been proven in production. It also has no reliability history, has only one supplier and is costly.

As of now, operating voltages are +5 and −10V. Its best applications, once it is proven in production, should be in high-speed operations like ROMs, RAMs, shift registers and random logic—applications where speed is more of a factor than cost.

Aluminum Oxide is not really a process but a processing step, similar to the nitride process. The aluminum oxide is claimed to allow more flexibility in adjusting thresholds, even to the point of making possible depletion-mode devices on the same chip with enhancement devices without having to ion implant. Not too much is known about this process, for the bulk of the work appears to be centered in Japan.

Charge-Coupled Device is not an MOS process. Rather, it uses MOS processing to make potentially very fast (up to 100 MHz), low-power dynamic shift registers. Basically, it is the electrical equivalent to the magnetic bubble or DOT. It was developed by Bell Labs and essentially works by shifting charges along a silicon substrate through simple voltage switching on a pattern of electrodes that defines the register. It is unique as a shift register in that it is in a sense analog, for the amount of charge can be varied. This makes imaging devices another potential application.

Its disadvantage, aside from the fact that it is still a

MOS COST

LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH
PMOS (thin oxide)	MNOS	Field-Shield	N-Si Gate	MOS/Bipolar
PMOS <111>	NMOS	SATO	DMOS	
PMOS <100>	P-Si Gate	Ion Implant SAG	SATO Si Gate	
	Ion Implantation (Low V_T)	RMOS	CMOS	

Table II

MOS SPEED

LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH
PMOS (thin oxide)	MNOS	SATO	Field-Shield	N-Si Gate
PMOS <111>		P-Si Gate	SATO Si Gate	CMOS
PMOS <100>		Ion Implant SAG	NMOS	DMOS
		Ion Implant (Low V_T)	RMOS	MOS/Bipolar
		CMOS (Low V_T)		

Table III

laboratory-type device, is the very stringent oxide requirements.

It can be made by most MOS processes, and lab devices are using −5 and −10V supplies at this time.

Costs and Speed

Costs. The ranking of costs shown in **Table 2** is quite arbitrary, and is a consensus of industry opinions. Where one process or another falls on the ranking chart is purely a subjective opinion. It mainly depends on to whom you are talking. User costs are subject to a company's pricing policy; thus two companies making devices the same way can easily end up in different cost categories. Another item to consider is the overall system cost to use one process or another. One process may produce low-cost devices, but be expensive to use because of the need for extensive interfacing circuitry and for additional power supplies. Cost is also a function of how the devices are applied, and of the design rules used to make them. One last thought about cost —cost is often related to the process that can most efficiently implement a design, and if the only way to solve a design application is with a "high-cost" process, this may actually be the cheapest bet for the user.

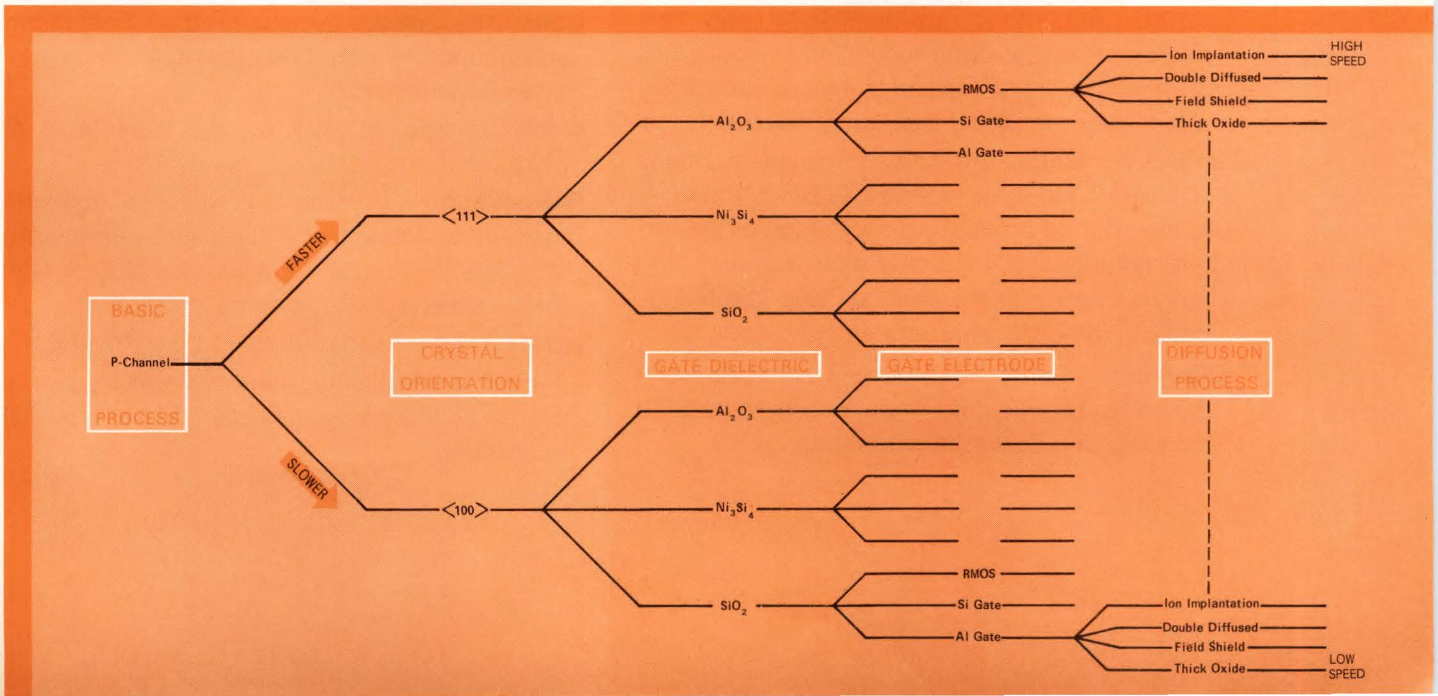
Speed is another one of those arbitrary things. Rankings shown (**Table 3**) are also somewhat subjective, but do represent a consensus within the industry. Positions are by no means agreed upon unanimously, but are more nearly so than were costs.

When discussing speed, a lot depends on speed-power tradeoffs and how circuits are used in a system. Some devices that in themselves appear fast can turn into real footdraggers when they must drive the capacitive loads of the real world.

Fig. 2 is presented to put into some sort of perspective just how the different processing steps, or combinations of these and materials, can affect speed—with all other factors ignored. It should convey the fact that an extremely large number of combinations that lie in the middle area (vs high and low ends) are able to provide equivalent speeds. Therefore, the dominant consideration should be to find combinations that can be produced reliably in high volumes, have high yields and low costs, and that consume low power. ▭

Fig. 2—**Theoretical Selection Tree.** The multitude of possible combinations is demonstrated by the branches of this tree. Obviously not all combinations are either possible or practical, but the tree shows that many different combinations will result in about the same speed.

In each process step, processes or materials are ranked (from top to bottom) as to which is potentially faster when added to the overall MOS process. Therefore if p-channel is selected and you go the <111>, Al_2O_3, RMOS, ion implant route, theoretically you would get the fastest p-channel device as opposed to going the <100>, SiO_2, Al gate, thick oxide route. On final assessment, economic criteria generally determine the best technology combination.



Glossary of Common MOS Terms

Bipolar to IGFET

Bipolar—Refers to npn and pnp type transistors in which current carriers and substrate types are at different polarities (as opposed to MOS devices which are unipolar).

Body Effect—Characteristic shift in threshold voltage resulting from bias applied to device substrate.

Carriers—Holes or electrons that are available in a semiconducting substrate for conduction of electric current.

CCD—Charge-Coupled Device. A device in which circuits made by MOS technologies allow charges to be transferred from point to point in a sequential manner.

Channel—The conducting charge layer between source and drain induced by the applied gate voltage. The charge layer is holes in a p-type device, and electrons in n-types.

Channel Stopper—In p-channel devices it is an n-type ring diffused around each transistor and connected to ground to isolate the device and prevent formation of parasitic devices in the field.

Chips—also called die, dice, bars. A tiny piece of a wafer containing an entire integrated circuit or "single" device.

CMOS—Complementary MOS. A circuit with both p- and n-channel devices on the same MOS substrate. Also COS/MOS and McMOS.

Crystal Orientation—For MOS devices, terms <100> and <111> are commonly used. This refers to the angle with respect to crystal facets at which the silicon crystal is sliced. Each has a direct effect on MOS transistor characteristics.

Depletion Mode—An MOS transistor normally ON with zero gate voltage applied (channel formed during processing). A voltage of the correct polarity applied to the gate will force majority carriers from the channel, thus "depleting" it and turning the transistor off.

Diffusion—A process of doping semiconductor materials by injecting impurities in controlled amounts at elevated temperatures.

DMOS—Double-Diffused MOS. A process where n and p atoms are diffused through the same mask opening to give precise-sized narrow channels.

Drain—Terminal which receives carriers from the MOS channel.

Dynamic—Information storage using temporary charge storage techniques. It requires a clock repetition rate high enough to prevent loss of information.

Enhancement Mode—An MOS transistor that is normally OFF with zero gate voltage applied. A gate voltage of the correct polarity attracts majority carriers to the gate area, thus "enhancing" it and forming a current-conducting channel.

FET—Field-Effect Transistor. A solid-state device in which current is controlled between source terminal and drain terminal by voltage applied to a nonconducting gate terminal.

Field—That silicon area on a chip not used or occupied by active transistors.

Field Inversion (V_{TF})—Also called "parasitic field turn-on." The creation of a channel between two nonassociated diffused beds in the field by voltages on conductors passing over.

Field-Shield—A process whereby a conducting layer covers the entire MOS chip (except at transistor terminals) between the doped substrate and interconnecting conductors to control field inversion problems.

Gain—The change in source-drain current per unit change in gate voltage. Thus higher gain gives faster devices.

Gate—Voltage-actuated control terminal of an MOS transistor.

Glassivation—A process in which a dielectric material is diffused over the entire wafer to provide mechanical and environmental protection for the circuits. Also called passivation.

IGFET—Insulated Gate Field-Effect Transistor. Though a less popular term than MOS, it more precisely defines devices made by various MOS processes.

(Continued)

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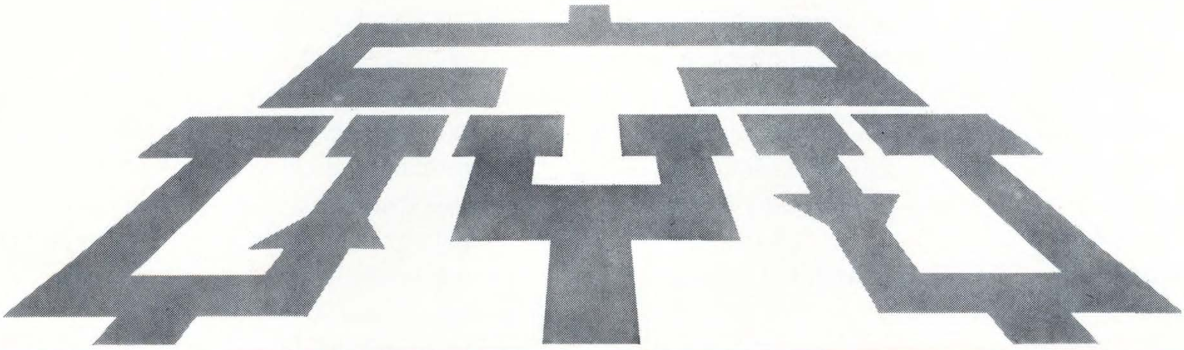
RCA Solid State



Formerly Dev. No.	Circuit Description	Commercial Type No.	Package	Price 1000-unit level
TA5385C	7 Stage Ripple Carry Binary Counter w/Buffered Reset (CD4004A Replacement)	CD4024AD CD4024AE CD4024AK CD4024AT	14 pin DIC 14 pin DIP 14 pin F.P. 12 pin TO-5	$ 7.50 3.35 8.20 7.50
TA6018W	Decade Counter/ Divider with 7 Segment Display Outputs (Display Enable Input)	CD4026AD CD4026AE CD4026AK	16 pin DIC 16 pin DIP 16 pin F.P.	12.50 5.95 13.15
TA5872W	Dual J/K F-F with Set/Reset	CD4027AD CD4027AE CD4027AK	16 pin DIC 16 pin DIP 16 pin F.P.	5.50 2.65 6.15
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Formerly Dev. No.	Circuit Description	Commercial Type No.	Package	Price 1000-unit level
TA5925W	Presettable, up/down Counter, Binary or BCD Decade	CD4029AD CD4029AE CD4029AK	16 pin DIC 16 pin DIP 16 pin F.P.	$11.95 5.75 12.60
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TA5963W	Triple Serial Adder (Positive Logic Version)	CD4032AD CD4032AE CD4032AK	16 pin DIC 16 pin DIP 16 pin F.P.	7.20 4.25 7.85
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TA5951	Triple Serial Adder (Negative Logic Version)	CD4038AD CD4038AE CD4038AK	16 pin DIC 16 pin DIP 16 pin F.P.	7.20 4.25 7.85

CIRCLE NO. 15

Glossary of Common MOS Terms

IMOS to W/L Ratio

IMOS—Ion-Implanted MOS. A method for doping substrates with a stream of ionized dopant atoms. Ions are electrically shot into the substrate instead of diffusing atoms at high temperatures.

Metal Gate—Refers to the use of aluminum as gate conductor instead of silicon or refractory metals.

Miller Capacitance—Feedback capacitance caused by gate metal overlapping source and drain regions.

MNOS—Metal-Nitride-Oxide-Semiconductor. Silicon nitride is used along with oxide as a dielectric insulator between gate metal and substrate.

MOS—Metal-Oxide Semiconductor. An FET in which silicon dioxide acts as a dielectric insulator between the gate contact metal and the substrate channel silicon.

MTNS—Metal - Thick - Nitride - Semiconductor. Same as MTOS except nitride is used with the oxide, including the area over the gate, for low V_T. A trademark of GI.

MTOS—Metal-Thick-Oxide-Semiconductor. The oxide outside the active gate area is made thicker to reduce problems with unwanted parasitic devices. A trademark of GI.

NMOS—N-Channel Device. Active carriers are electrons flowing in n-channel between n-type source and drain diffusion beds in a p-type silicon substrate.

NSOS—Same as PSOS, except it denotes n-channel devices.

Oxide Breakdown—That voltage which exceeds gate oxide dielectric breakdown, causing a gate-to-substrate short.

Pinchoff Voltage—That gate voltage needed to turn off a depletion-mode device.

PMOS—P-Channel Device. Active carriers are holes flowing in p-channel between p-type source and drain diffusion beds in an n-type silicon substrate.

PSOS—A term used by some companies to denote p-channel silicon gate devices.

Punchthrough—That voltage at which two adjacent diffused transistor beds become shorted together causing a sharp rise in current.

Q_{ss}—Fixed surface state charge density per unit area. This is a function of crystal orientation and directly affects threshold voltage.

RMOS—Refractory-Metal-Oxide Semiconductor. Refractory metals like molybdenum are used instead of aluminum or silicon as the gate metal.

SAGMOS—Self-Aligned-Gate MOS or SAG. A process in which materials like polycrystalline silicon or refractory metals are used in place of aluminum at the gate. These materials act as a mask and result in the gate being automatically aligned between source and drain regions.

SATO—Self-Aligned-Thick Oxide. A term used by Texas Instruments Incorporated to describe a proprietary low-voltage, self-aligned gate process.

SOS—Silicon on Sapphire or Spinel. A process whereby silicon is deposited on an insulating substrate to achieve certain performance gains, such as speed.

Source—Terminal which usually sources carriers. Since MOS devices are usually symmetrical, it can be interchanged with the drain terminal in a circuit.

Static—A form of information storage in shift registers and memories whereby information will be retained as long as power is applied.

Threshold Control—Used to describe the spread of threshold voltages from chip to chip. Tight V_T control means a narrow spread of V_T for all devices in a production run.

Threshold Voltage (V_T)—Minimum gate voltage needed to turn on an MOS enhancement-mode device.

TTL (or T^2L) Compatibility—A term used to describe the capabilities of an MOS device to drive, or be driven by, bipolar circuitry.

Wafer—also called "slice." The thin slice of silicon (from a silicon ingot) on which integrated circuits or other semiconducting devices are simultaneously made.

W/L or Z/L Ratio—Width-to-length ratio directly affects device gain; thus closer spacing of source-drain regions gives higher gains.

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CIRCLE NO. 17

Designing with Solid-State Filters

Inexpensive ceramic resonators can replace large, cumbersome LC filters by using good design techniques.

ROY W. FORSBERG, Boston Regional Editor

Semiconductor technology has opened the door to the miniaturization of many electronic functions, however other factors have slowed down practical implementations. Take for example the AM radio. It has been possible for quite a while to place an entire radio on a single chip except for the conventional LC resonant "selectivity" circuit. Conceivably active filter approaches could be used for this but to date this has not been a cheap way to go. An alternative is to substitute piezoelectric ceramic resonators. These can be economically batch-produced but they require special design techniques to be effective.

Applications for ring-dot ceramic resonators in IF amplifier filters are primarily of two general types:

1. Using one ring-dot resonator at the input and another at the output of an amplifying stage, with the driving and terminating impedances of the resonators being the amplifier input and output impedances.

2. Having one or more ring-dot resonators form a lumped filter at the input of an IF amplifier.

One difficulty in applying piezoelectric devices in an IF amplifier can be seen in **Fig. 1**. The deep rejection notches are advantageous in some communication receivers, but in AM radios they cause loss of AGC, overloading and oscillator pulling. The stop band rejection is only −20 dB, and implementation on a production basis would present some very formidable difficulties. Additional problems can arise if electrode parasitic capacitances are allowed to combine with high driving and terminating impedance.

However, if the resonator is driven from a low-impedance source and terminated in a low-impedance load, the parasitic capacitance effects disappear and a smooth selectivity curve results. Successful operation of ring-dot resonators in low-impedance circuits is the basis of a patent application by General Motors.

A ceramic resonator IF filter based on the preceding rationale is shown in **Fig. 2** and the selectivity curve obtained in **Fig. 3**. This selectivity curve is nearly symmetrical about its center frequency of 262 kHz, with smooth

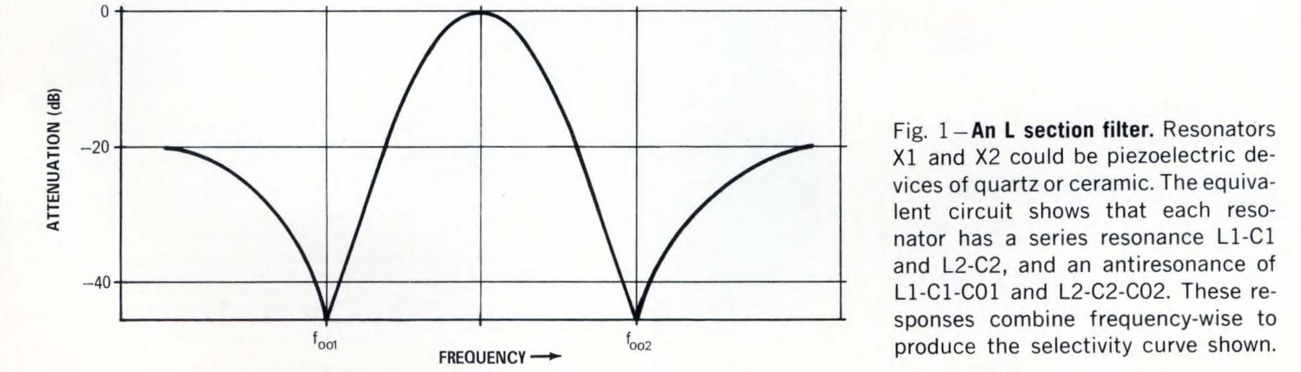

Fig. 1—**An L section filter.** Resonators X1 and X2 could be piezoelectric devices of quartz or ceramic. The equivalent circuit shows that each resonator has a series resonance L1-C1 and L2-C2, and an antiresonance of L1-C1-C01 and L2-C2-C02. These responses combine frequency-wise to produce the selectivity curve shown.

(Continued)

Solid-State Filters (Cont'd)

rising skirts and a fairly broad nose. Frequency measurements made on a large batch of resonators showed a frequency spread of ±0.75% around 262 kHz. Other center frequencies can be obtained by varying the disc diameter.

The basis for this article was a paper presented at 1971 ISSCC by Paul Wood of General Motors Corporation Research Laboratories. □

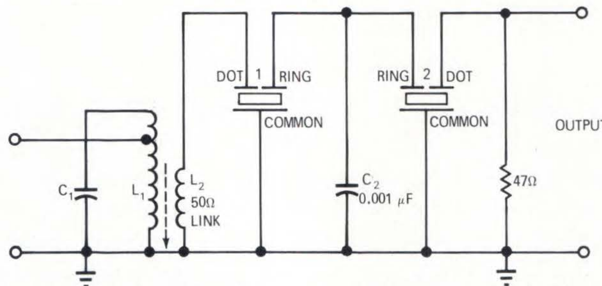

Fig. 2—**Ceramic resonator IF filter.** Two ring-dot resonators are connected back-to-back and the output is loaded with a 47Ω resistor. Resonators 1 and 2 are chosen to have series resonant frequencies equal to within a few tenths of a kHz measured when driven from their dot electrodes. Resonator 2 however is driven from its ring electrode causing its series resonance to be about 0.5 kHz higher than that of resonator 1. Therefore, a stagger tuning effect is produced with resultant broadening of the −6 dB bandwidth. The driving source is a 50Ω link, L2, coupled to the mixer resonant circuit L1-C1. An emitter follower could also be used as a low impedance driver. C2 is a mutual coupling impedance used as a bandwidth adjustment.

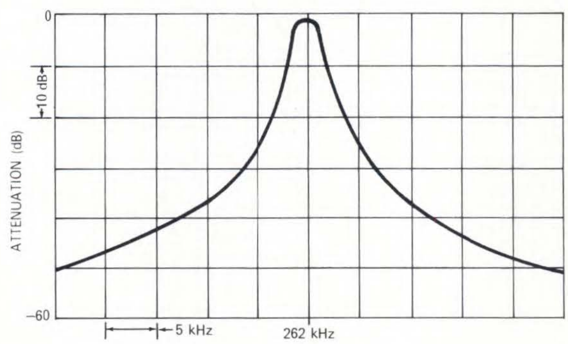

Fig. 3—**Ceramic resonator IF filter selectivity curve.** The −6 dB bandwidth is 5.6 kHz, and −50 dB bandwidth is 50 kHz. Stop band rejection is −50 dB while shape factor is 8.9:1.

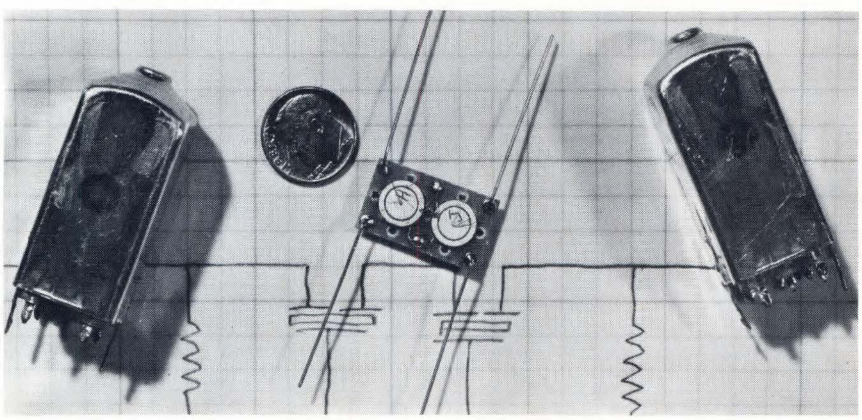

Fig. 4—**Prototype realization of IF filter.**

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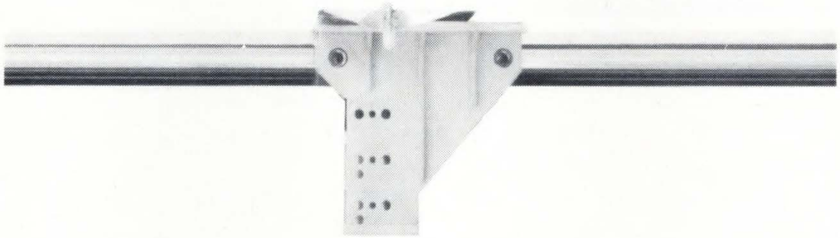
()

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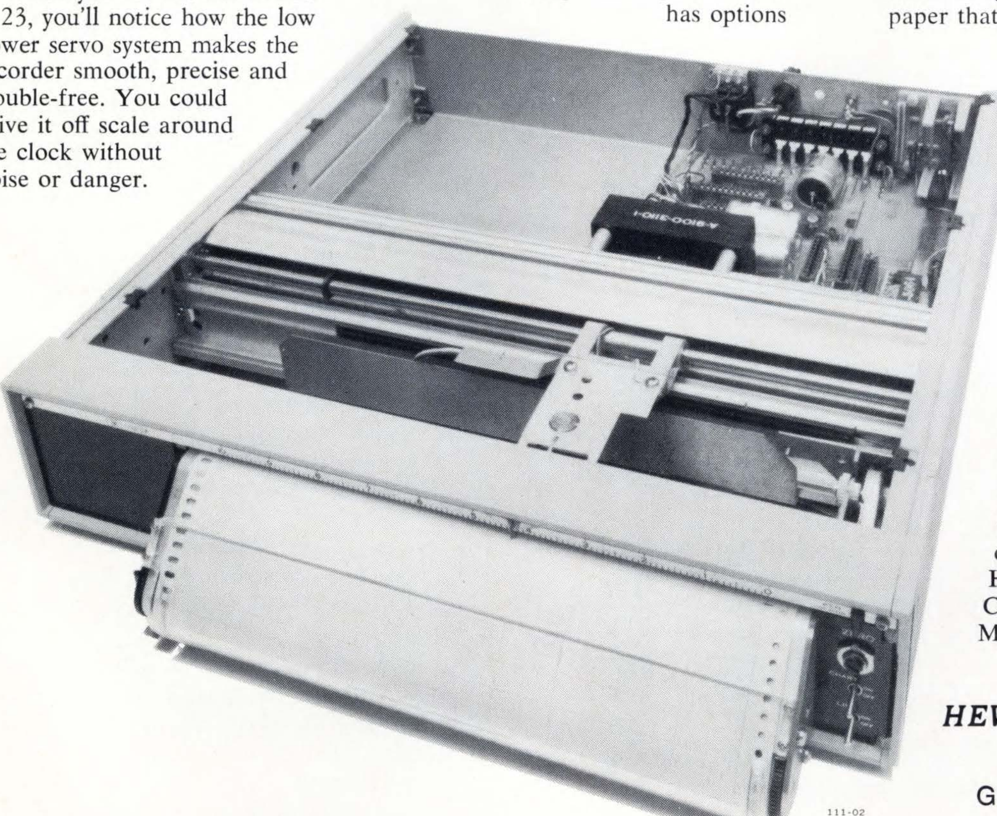

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GRAPHIC RECORDERS

111-02

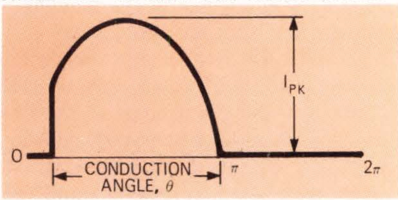
CIRCLE NO. 19

Measurements File

How to measure SCR currents

by Sidney V. Soanes

Understandably, it's easy to be confused about an SCR with a current rating of 25 A rms being permitted only 6 A of average current. We all know that the heat dissipated in a device depends on the rms current through it. But we often forget that, while rms and average values are the same for dc and not much different for full-wave-rectified ac, they can be vastly different for other waveforms.



Current waveform in an SCR used in a half-wave rectifier.

In general, consider a quantity $X(t)$ in the time interval 0 to T. The average value of X is given by

$$X_{avg} = \frac{1}{T}\int_{o}^{T} X(t)\, dt$$

The rms value is

$$X_{rms} = \sqrt{\frac{1}{T}\int_{0}^{T} X^2(t)\, dt}$$

Specifically, the current in an SCR (half-wave rectified case) looks like the waveform in the figure. Here,

$$I_{avg} = \frac{1}{2\pi}\int_{\pi-\theta}^{\pi} I_{pk} \sin t\, dt =$$

$$\frac{I_{pk}}{2\pi}(1 - \cos\theta)$$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_{\pi-\theta}^{\pi} I^2_{pk} \sin^2 t\, dt}$$

$$= I_{pk} \sqrt{\frac{1}{4\pi}(\theta - \frac{1}{2}\sin 2\theta)}$$

The quantities of interest are I_{avg}/I_{rms} and I_{pk}/I_{rms} for various conduction angles. For half-wave rectification, Table 1 shows that, as $\theta \rightarrow 0$, $I_{avg}/I_{rms} \rightarrow 0$, and $I_{pk}/I_{rms} \rightarrow \infty$.

This means, for example, that an SCR rated at 10 A rms and operating at a 30° conduction angle can safely carry only 2.5 A avg.

The situation is somewhat better in a full-wave system (e.g., SCR with a bridge rectifier, or a triac). The figures in the I_{avg} column in Table 2 are multiplied by $\sqrt{2}$, and the figures in the I_{pk} column are divided by $\sqrt{2}$.

For small conduction angles, and especially for rectangular current waveforms in low-duty-cycle operation, the junction temperature at the end of the power pulse may be considerably above the average junction temperature. This is important since the device usually has to withstand blocking voltage immediately following the end of the current pulse.

If the device junction temperature at this time is above the maximum rated value (which is the average junction temperature in the limit cases described), thermal runaway may result and produce failure for operation in a nonswitching quadrant or turn-on for operation in a switching quadrant. This calculation must be done separately using the transient thermal-impedance figures provided by the manufacturer. ■

Conduction angle, θ	I_{rms}	I_{avg}	I_{pk}
5°	1.0	0.10	167
30°	1.0	0.25	11.8
60°	1.0	0.36	4.6
90°	1.0	0.45	2.8
120°	1.0	0.53	2.2
150°	1.0	0.59	2.1
180°	1.0	0.64	2.0
dc	1.0	1.0	1.0

Table 1. Current relationships in a half-wave rectifier as a function of conduction angle.

Conduction angle, θ, in each half wave	I_{rms}	I_{avg}	I_{pk}
5°	1.0	0.14	118
30°	1.0	0.35	8.4
60°	1.0	0.51	3.2
90°	1.0	0.64	2.0
120°	1.0	0.75	1.6
150°	1.0	0.83	1.5
180°	1.0	0.90	1.4

Table 2. Current relationships in a full-wave rectifier as a function of conduction angle.

Author: Dr. Soanes is with Ferranti-Packard, Toronto, Canada.

Reference

J. S. Read and R. F. Dyer, "Power Thyristor Rating Practices," *Proc. IEEE*, Vol. 55, No. 8, pp 1288-1301, August, 1967.

CIRCUIT DESIGN AWARD PROGRAM

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Readers have voted Charles A. Herbst winner of the May 15 Savings Bond Award. The winning circuit design is "TTL Inverter Makes Stable Colpitts Oscillator".

Pulse generator offers wide range of duty cycles

To Vote For This Circuit Circle 151

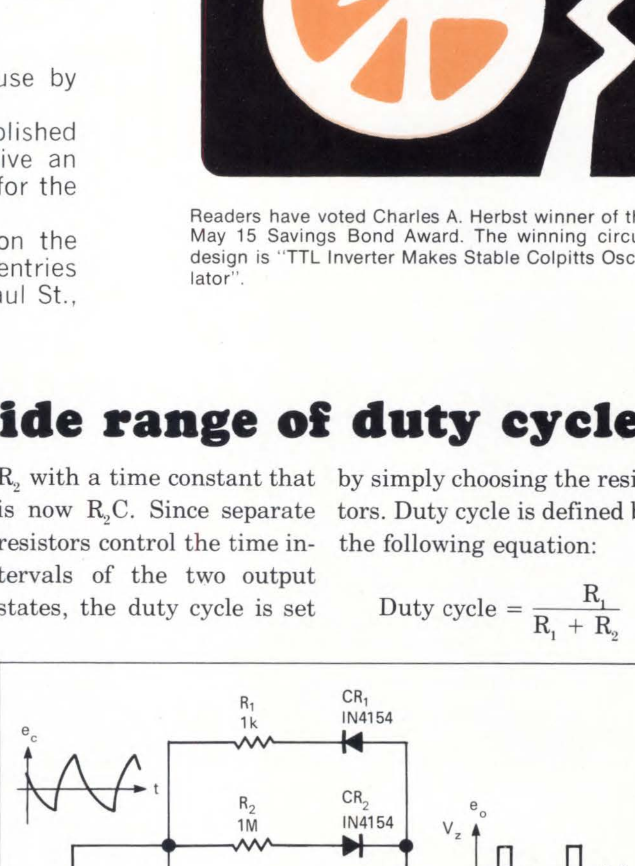
by Jerald Graeme
Burr-Brown Research Corp.
Tucson, Ariz.

Sampling time control and pulse-width modulation are commonly achieved with asymmetrical pulse trains. Unfortunately, if one needs sampling times which are small compared to the test period or if one needs large dynamic ranges of pulse width, a conventional astable multivibrator won't provide the necessary precision. However, a single op amp can readily provide precise duty cycle control over a wide dynamic range. With suitable component values, the circuit described can generate pulse trains with duty cycles from 0.1% to 99.9%.

Essentially, the op amp forms the gain element of an astable multivibrator with the two characteristic time intervals determined by feedback elements. Astable operation is insured by positive feedback via R_3 and R_4. From this feedback, the switching threshold voltage is set at the noninverting input. Switching occurs when the inverting input voltage is brought to this threshold level by the charging of capacitor C.

Capacitor charging current is supplied from e_o by one of the feedback resistors, R_1 or R_2. A positive e_o forward biases CR_1, and R_1 controls the rate of charging with a resultant time constant of R_1C. When e_o reaches e_t, the output switches, thus reversing the polarities of e_t and the charging current. The negative output then discharges C through R_2 with a time constant that is now R_2C. Since separate resistors control the time intervals of the two output states, the duty cycle is set by simply choosing the resistors. Duty cycle is defined by the following equation:

$$\text{Duty cycle} = \frac{R_1}{R_1 + R_2}$$



With a suitable choice of values for R_1 and R_2, this circuit can produce pulse trains with duty cycles from 0.1% to 99.9%.

For the resistor values shown, the duty cycle is equal to 0.001.

Period depends on the values of R_1 and R_2 and on the size of the capacitor. The complete equation is as follows:

Period =

$$(R_1 + R_2)C \ln\left[\frac{V_z - V_f + e_t}{V_z - V_f - e_t}\right]$$

where, $e_t = \dfrac{R_4\, e_o}{R_3 + R_4}$

For the component values indicated in the schematic, the period is one second.

In a practical circuit, the range of duty cycles attainable is limited by the slewing rate, output current and input bias current of the op amp. Slew rate controls the large-signal rise time, and thereby limits the minimum time interval of either state. This minimum is also limited by the slewing rate of the capacitor as set by the amplifier output current available for charging. With the minimum interval determined by the preceding two factors, maximum interval length is limited by input bias current. This input current must be small compared to the charging currents supplied by R_1 and R_2. For this reason, high input resistance must be maintained by the op amp under input overload. A good general-purpose op amp, such as Burr-Brown's Model 3500, can provide adequate performance and most FET op amps are satisfactory for this application. ▭

Track-and-hold amplifier

To Vote For This Circuit Circle 152

by Richard S. Burwen
Analog Devices, Inc.
Norwood, Mass.

The low input current and high slewing rate of the AD-503J make it a useful amplifier for track-and-hold applications. The circuit described here will track a ±10V input signal at frequencies up to 4 kHz.

When the track-hold gating signal changes from +5V to zero, the series FET, Q_3, opens and the input voltage is retained on capacitor C_1. The output amplifier A_2 provides a high input impedance so that C_1 will not discharge rapidly.

Drift rate is determined primarily by the OFF leakage current of Q_3, which tends to be greater than that of amplifier A_2. With a leakage of 100 pA, the drift rate is 10 mV/sec and the rate doubles every 10°C. Lower drift rate and higher accuracy (at the expense of a slower acquisition time) can be achieved by increasing the value of C_1. This capacitor should be a type (such as polystyrene or "Teflon") having low dielectric absorption.

Use of a low-pinchoff-voltage FET, as specified for Q_3, allows the circuit to handle ±10V input voltages with supply voltages of only ±15V.

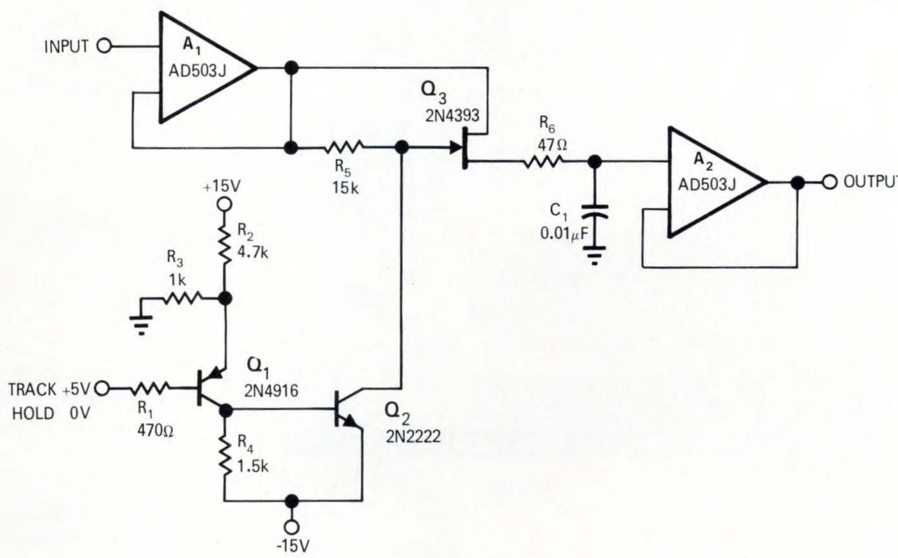
In the "track" mode, the gating signal is at +5V, Q_1 and Q_2 are cut off, and the gate of Q_3 assumes the voltage at the output of A_1. Thus the FET is zero-biased over the entire input-voltage range and has an ON resistance of less than 100Ω. Resistor R_5 adds to the ON resistance so as to better isolate C_1 from A_1 to prevent ringing.

In the "hold" mode, both Q_1 and Q_2 conduct, thus pulling the gate of Q_3 to −15V. The capacitor voltage stops tracking at the time when the gate voltage of Q_3 reaches a value 3V below the source voltage, or about 100 nsec after the track-hold gating signal changes to zero.

Because of gate-drain capacitance in Q_3, the gating-signal swing causes a small charge (proportional to the change in gate voltage, i.e. 15V plus the input voltage) to be delivered to C_1. The charge causes a small offset in the "hold" mode (relative to the "track" mode) which is typically less than 10 mV over the full ±10V input range.

There are also small settling transients in amplifiers A_1 and A_2, so it takes up to 2 msec for the output to settle to within 1 mV of the final value. The settling time for an input step of 10V in the "track" mode is less than 15 msec to within 1 mV of final value.

An added error caused by the capacitor's dielectric absorption may reach 3 mV if the input does not remain constant long enough in the "track" mode before changing to "hold." ▭



Track-hold circuit follows a ±10V input signal at rates up to 4 kHz.

Simple sinewave oscillator

To Vote For This Circuit Circle 153

by John C. Freeborn
Honeywell Inc.
West Covina, Calif.

With the component values shown, this circuit produces a low-distortion sinewave with a frequency of approximately 25 Hz. The output voltage e_0 is around 8V pk-pk. Any combination of inductor and capacitor can be used. Output frequency can be calculated from the following well-known equation:

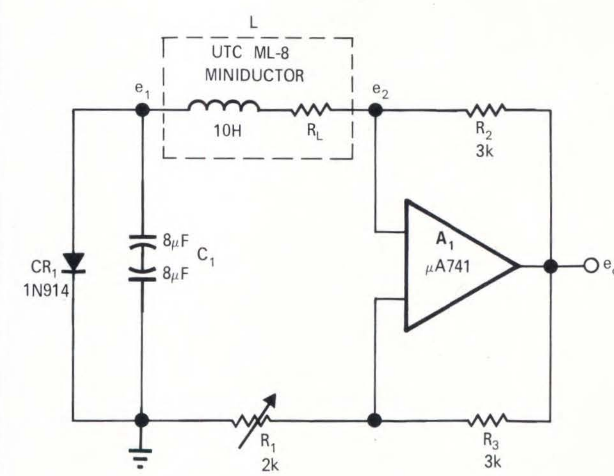
$$f_0 = \frac{1}{2\pi\sqrt{LC_1}}$$

Potentiometer R_1 allows adjustment of the amount of regeneration applied to the series-tuned circuit. To cause oscillation, the value must be roughly equal to the series resistance R_L of the choke plus a resistance value that represents core losses at the resonant frequency.

Diode CR_1 clamps the signal voltage e_1 and limits amplitude regeneration to avoid saturation of the inductor or op amp. Signal voltage e_1 will be an accurate cosine version of the output sine function. The amount of distortion can be made quite small by keeping R_1 at the minimum value needed to sustain oscillation.

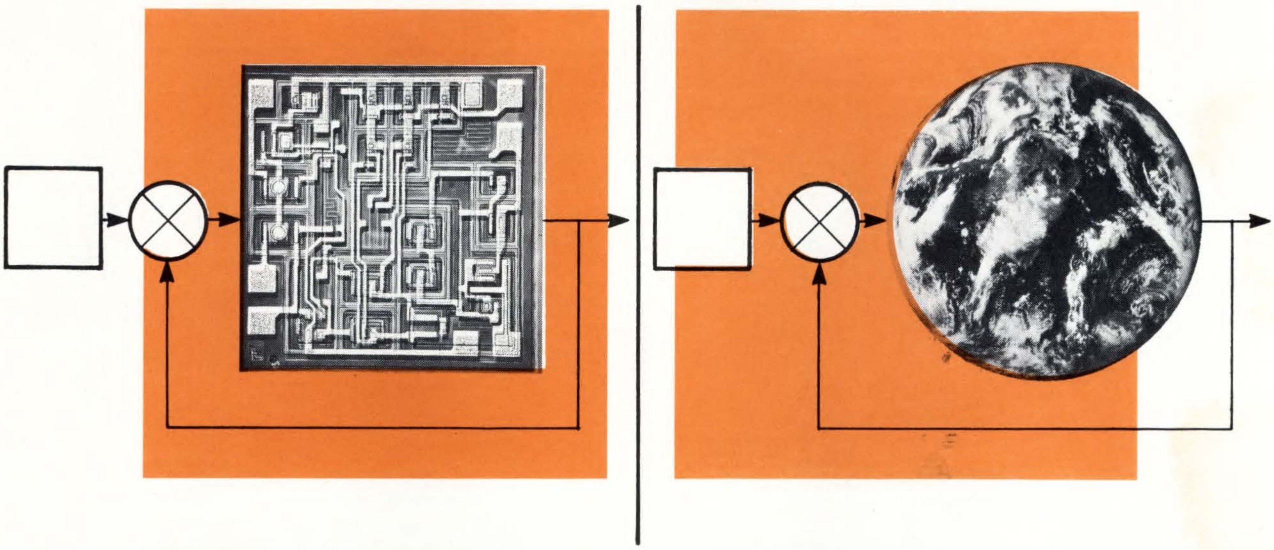
Voltage e_2 is an accurate representation of voltage loss across the inductor (core losses plus IR drop), since it is just equal to the voltage required to overcome these losses when R_1 is adjusted to the minimum value for oscillation. The output voltage e_0 is merely e_2 multiplied by the amplifier gain R_2/R_1. (Resistors R_2 and R_3 have the same value.)

Using other component values, the basic oscillator circuit has been operated at frequencies from 15 Hz to 100 kHz, with total harmonic distortion less than 0.5%. The upper frequency limit appears to be set by the response of the op amp. ▭



The upper frequency limit of this oscillator is determined by the response of the op amp. With the values shown, the frequency is around 25 Hz.

Design Interface



Can EE Systems Engineering Solve World Problems?

Engineers can create order out of chaos in the machine world, but can they do the same for the human world? We'll look at progress in applying engineering systems analysis in the larger fields of urban decay, environment pollution, etc.

ROBERT H. CUSHMAN, New York Editor

Complexity is "mother's milk" to our profession. Engineers routinely tackle mammoth computer systems that have millions of diverse elements, confidently expecting that all will play smoothly together at nanosecond speeds. But what good are machine solutions if the social world is headed for disaster? As presently used, our machines may only be hastening the end. What seems to be needed is "design for survival," or more positively put, "design for living." EEs have become adept at understanding systems in which no men are involved—the moon shot was feasible, some say, because space isn't cluttered up with bickering humans.

Putting problem and solution together, then, can the EE's ability to solve complex problems be applied to our pressing human problems? Electronics people have talked about our way of looking at things to solve all sorts of problems for at least the past 20 years. Now, it seems, one engineer, Jay Forrester of M.I.T., actually has gone ahead and tried . . . he has sat down and attempted to convert what he learned in electronics systems engineering to the analysis of major "people problems." Back in his engineering days—the 40s and 50s—Forrester invented the coincident-current addressed magnetic memory systems now so widely used for "RAMs" in computers. He became interested in systems engineering when he was one of the chief architects for U.S.A.F.'s ambitious "SAGE" system.

In the last decade he has transferred his skill at machine systems analysis over to the analysis of human systems in three logical steps:

- First he made the relatively small jump of going from military systems to commercial systems; he made models of business organizations (see Databank Ref. 1).
- Second, and much more drastic, he applied his modeling abilities to cities (Ref. 2).
- Finally, he has boldly applied his modeling to our entire world, the entire human-ecological system of the planet earth (Ref. 3).

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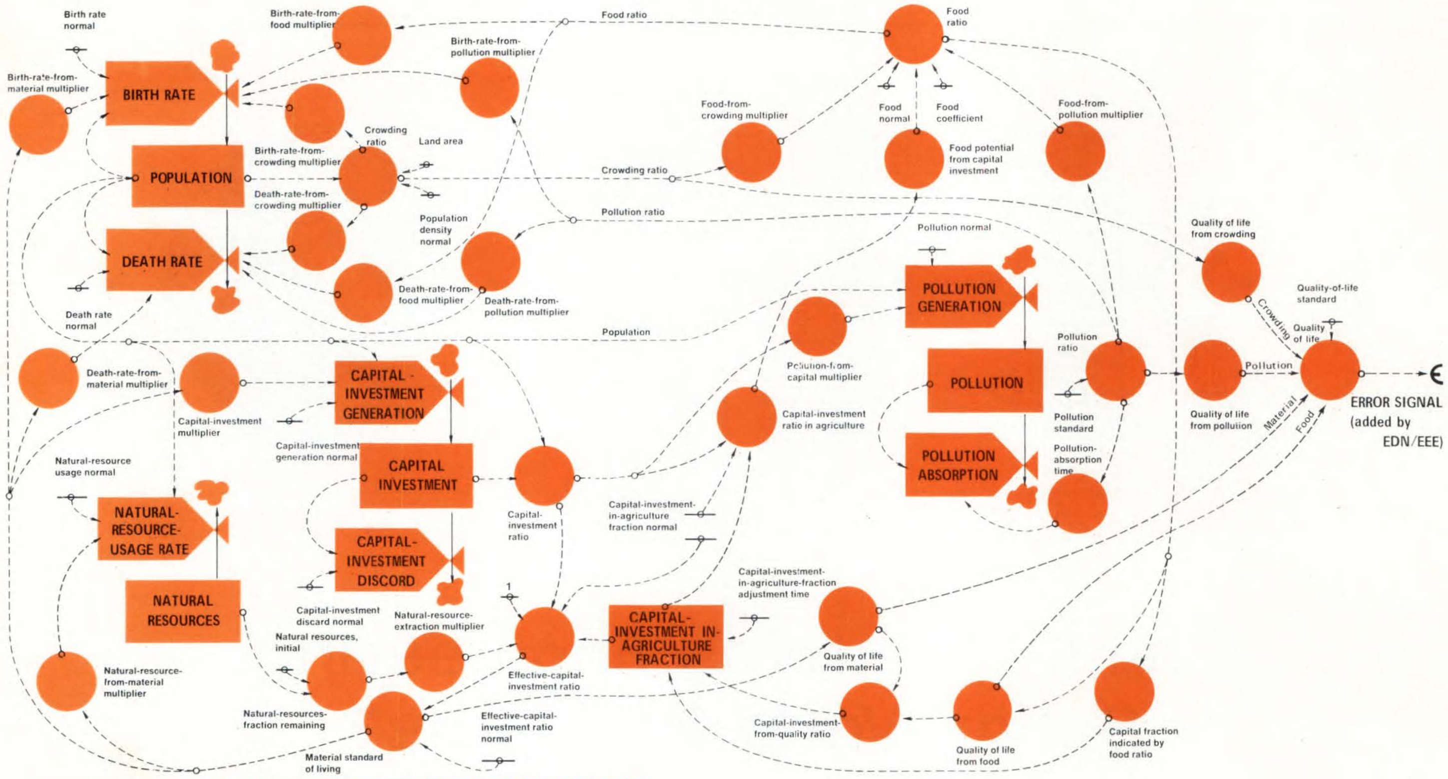


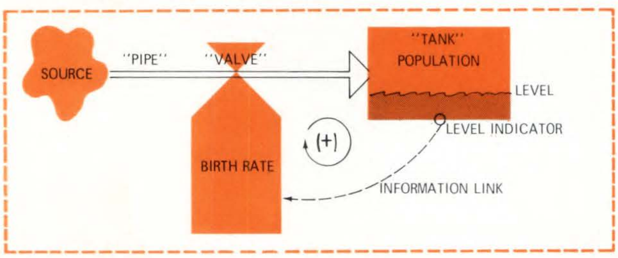


Fig. 1—**Model of life on our planet:** Forrester uses hydraulic mnemonic symbols to make the model picture easier for non-engineers to visualize. He shows major accumulations within the system as levels in hydraulic tanks. He shows pipes controlled by valves filling and draining these tanks. These valves in turn are controlled by information signals (dashed lines) from many parts of the system.

Social Model of World

Forrester's latest published analysis models the "quality-of-life" on our planet. As shown in **Fig. 1** (taken from Ref. 3), Forrester isolates the main factors that he believes affect our "quality-of-life." He interconnects them in a model structure and runs this in a numerical fashion on a digital computer to see how we can expect "quality-of-life" on this planet to change in the next 130 years. (The runs on IBM 360s compress centuries into fractions of a minute.)

It is a pretty pessimistic model. It indicates that unless we fundamentally change our way of living and industrializing, our children will be in for increasing trouble and our grandchildren will wish they hadn't been born. "Indeed," says one of Forrester's group, "they might not be born."

In constructing this model, Forrester follows the viewpoint of state-variable analysis. He classifies all the variables into two categories: level variables and rate variables. Simply put, level variables are those that remain if you "stop time," and rate variables are those that only exist when time is running. (In analog computer terms, the level variables are the charges on the integrating capacitors and the rate variables are the charges flowing through the wires.)

The five main level variables he isolates are:

1. *World Population*
2. *World Natural Resources*
3. *World Pollution*
4. *World Capital Investment (other than agriculture)*
5. *World Capital Investment in Agriculture*

These levels are shown as the five main rectangles in **Fig. 1**. Forrester likens these rectangles to hydraulic tanks containing "levels" of the five substances. Though he is by background an EE, Forrester apparently feels that a "plumbing" analogy is easier for most people to understand.

He shows pipes carrying the "fluids" of people, resources, pollution, and capital investment into and out of these five tanks. The flows come from, and go to, infinite sources and sinks represented by irregular-shaped "lakes." His system rates are then the flows in these pipes. Continuing his hydraulic analogy, he shows these flows being controlled by valve symbols inserted in the pipes.

The valve symbols are controlled in turn by information links—shown as dashed lines. He now drops his hydraulic analogy and represents the information links after the fashion of analog computer patching. The circles at the nodes of the dashed signal lines represent signal manipulations such as combination, gain control, delay, etc. This informational network interconnects the five levels into a self-contained feedback system that will come to life on its own and exhibit behavior that hopefully is analogous to the real world.

Model Structure Is Hardly Linear

"When you model social systems, you must expect 100 percent nonlinearity," Forrester says. "So, don't waste your time trying to approximate social systems with classical linear models." The nonlinearities in this model show up as the many multiplications (interlocking gain controls), the nonlinear transfer functions (not shown in detail), and the delays (also not shown but which may be as long as many years).

These systems also tend to be very high order. The five levels mean that this system is fifth order. Some of Forrester's past models have grown to over 20th order, but Forrester discourages the tendency to try to account for every imaginable thing. His reasoning is, "What is the use of completeness if it prevents the analyst from understanding his model?" As with engineering models, the simplest representation that will usefully relate the major causes and effects in the problem area is always the best.

Quantifying the Unquantifiable

From the practical standpoint, you can't have a computer do the dogwork of running a model for you until you quantify everything, even the things you are not sure of. According to Forrester, you can't make rapid progress in learning about the behavior of these complex systems until you are before a time-share terminal with the computer spewing out years of future "history" inside of a minute. For example, with this world model you can "play with the world," adjusting its parameters as if you were Mother Nature or a world leader, and within a minute have the computer draw out curves that will foretell the next hundred years.

What the Model Predicts

What does Forrester's model predict for Earth? Computer printouts of the runs of the model, shown in **Fig. 2**, forecast three of the many possibilities. In each case Forrester cranked in a different set of gain and other adjustments, and let the computer step through the simulation at one-year computation intervals. (The state-variable technique is to use the levels or states produced by the last interval to determine the rates for the next.)

The runs span two whole centuries, this 20th and the coming 21st. The model was given the initial conditions of 1900. Then the model was calibrated against the Real World by adjusting its gains and delays until its behavior tracked that of the world in the first 70 years of this century. For example, the model was given the world population of 1-1/2 billion for 1900 and it was adjusted so that it generated the correct 3-1/2-billion level for 1970.

Once calibrated, the model was allowed to continue running into the future. Various man-made policies were cranked into the model by adjusting the gains, so that each run illustrated the eventual effect of a different set of present choices.

Chart, **Fig. 2a**, shows what will happen if we continue as at present. The elements that contribute to "quality-of-life", such as abundant natural resources, will go down. The things that detract from "quality-of-life", such as population crowding and pollution, will go up.

Forrester's most repeated conviction is that computer runs of these models will always reveal things that mere mortals would not have guessed on their own. An example is shown in the run of **Fig. 2b**. Here, the model is adjusted to represent a decision made now to increase world capital investment in more efficient machines. The goal would be to conserve our natural resources, but not reduce our standard of living.

Forrester says that this is typical of the seemingly wise and logical decision that leads corporations, cities and the world into trouble. True, he points out, the computer does show the "quality-of-life" going up first "in our lifetime." This, in Real World, would probably lull everybody into a false belief that technology again has licked the problem. But then, 50 years from now, when our children's children are just getting their start in life, disaster hits. The simulation shows that the increased industrialization from the increased capital investment has so built up pollution that the "quality-of-life" takes a nosedive. This catastrophe causes population to drop, "like it has never dropped before in recorded history."

"It would hit the most industrialized nations, like the U.S., hardest," warns Forrester.

The model then shows violent oscillations. We asked John Seeger of Forrester's group, "How can this be? 'Quality-of-life' is shown suddenly recovering and

(Continued)

going way up higher than it ever was before?" Seeger explained that once such a catastrophe hits the world, our civilization would be so drastically upset that the model, as adjusted, would no longer apply.

What Does Forrester Suggest?

Forrester cautions that his model is still too new and unverified to be the unquestioned basis for designing policy for race survival. Nevertheless, he has put out some tentative conclusions. The gist of these is that Western-style industrialization must be slowed down to zero growth. He backs *zero industrial expansion* as the prime goal rather than *zero population expansion* as do many others (Ref. 4).

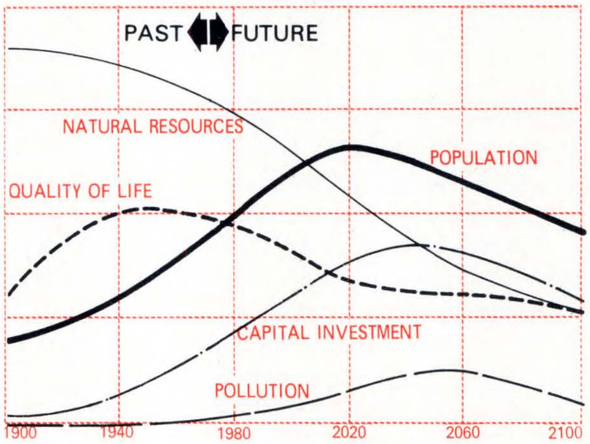
Forrester is well aware that bringing a halt to industrialization goes against our materialistic culture. Last fall he told a House of Representatives subcommittee on urban growth, "Our society has behind it a thousand years of tradition that has encouraged and rewarded growth. The folklore and success stories praise growth and expansion. But that is not the way of the future."

He urges the U.S. government and other world governments to stop thinking of industrialization as a good, humane and progressive thing, but rather to consider it as the cancer that could wipe our civilization off the face of the planet just as surely as the H-bomb.

This EE has traveled a long path, yet it is a path he probably could not have followed without his training

Possible future histories for our planet:

Fig. 2a—**If things go as at present,** the earth's natural resources will be progressively used up, and quality-of-life accordingly and progressively will continue to go down. Eventually a point will be reached—in 50 years—where population growth will be "naturally" throttled by dwindling natural resources.



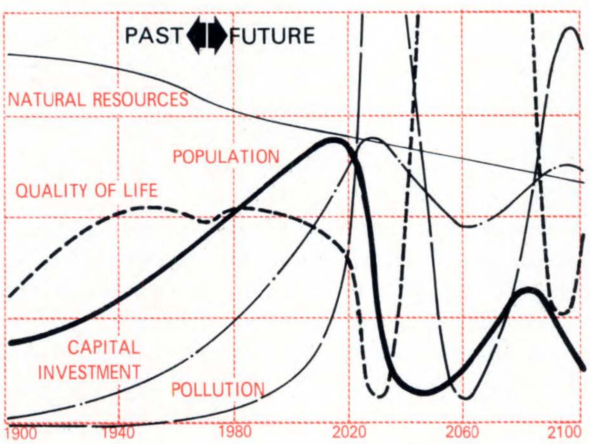


Fig. 2b—**If technology helps us** reduce the rate of natural resource consumption, while we try to increase industrialization, we'll only get into trouble faster. Under the short-sighted goal of stretching out our consumption of natural resources, capital investment is poured into more efficient plants. But the temporary rise in quality-of-life only lulls people into a false security and they multiply themselves for a quicker kill by the pollution they create.

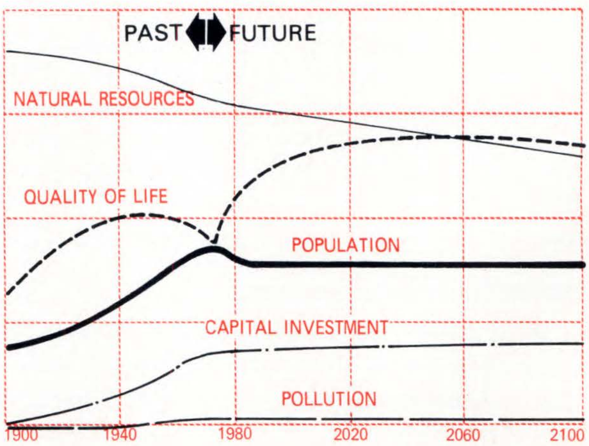


Fig. 2c—**Best choice is to establish world equilibrium immediately.** Forrester believes the answer is zero industrial growth. In this history run, the decision to drastically curtail industrial expansion dramatically improves quality-of-life within our lifetimes, and indicates that our children can look forward to a stable, pleasant planet.

in our technology. We note he includes courses in circuit theory in his curriculum for would-be modelers, whether they come from M.I.T.'s engineering or management schools.

Will the World Use These Models?

What is the likelihood that EE-type system modeling will ever prove useful in "people systems?" We questioned a scattered sample of social scientists and operations researchers. Many had never heard of Forrester, but we found at least a dozen who had. Most of their comments pertained to Forrester's earlier urban dynamics models, for the world dynamics model had not yet been widely publicized.

A Rand report written last year (Ref. 5) tells some of the fallacies social scientists believe they see in Forrester's urban models. They find his lofty, ivory-tower, universal or highly-generalized models far from the blood, guts and sewage they see in the ghettos. Also, Forrester's proposed solutions seem ridiculous to some of them. "This ex-engineer says we must make life in the cities even less attractive than it is for the poor, so they will be forced out to give industry a chance to rebuild the cities. But he does not say where the poor are to be pushed."

Apparently, one misunderstanding arises because Forrester has so thoroughly quantized his model. He had to quantize everything to be able to run fast-time-simulations spanning centuries within a minute on a digital computer. But some social scientists have mistaken his quantization as implying final-word precision on Forrester's part. Paul de Sica of Polytechnic Institute of Brooklyn's Center for Urban Studies, who has been an in-the-middle moderator in arguments on this very subject, says that Forrester's cold-blooded analytical models will probably have to be "humanized" before social scientists will accept them.

Some of the most sympathetic comments we have heard are from younger engineers and operations researchers who actually are at work on city problems. They seem to be looking ahead to the potential of the approach rather than, as some older engineers, critically tearing apart Forrester's present models.

Graduate student Alan S. Hirshberg of Caltech's Jet Propulsion Laboratory said he has been part of a project that has been using its own version of Forrester's urban model to study housing deterioration in Pasadena, California (Ref. 6). "We've been using a paper model as a conceptual discussion tool," Hirshberg explained. "We have not mathematized it yet for computer simulation, but even in its present paper form, it has helped the city manager of Pasedena see what new policies should be adopted."

Warren Walker, operations researcher with New York City's Rand group said that he has helped one of his students (Walker teaches a course at Columbia Univ.) prepare a modified Forrester-type model of the housing situation in New York. He has found Forrester's "DYNAMO" complier program quite helpful in mathematizing the model for computer simulation runs. Walker is expecting momentarily to show this simulation to Mayor Lindsay's experts on housing.

But probably the wisest comment of all came from "old timer" Professor Ithiel de Sola Pool at M.I.T. who is internationally respected for his pioneering in the use of computers for modeling people's behaviors with respect to what they hear, see and read. (He has modeled the Kaiser's temper tantrums that started World War I, and President Kennedy's and Khrushchev's mental processes during the Bay of Pigs crisis.)

Professor Pool told us that he thinks Forrester's work is very important because it permits all the diverse disciplines needed for solving present problems to have finally a precise representation of what they are talking about. Whether any particular model is 100 percent accurate or not is not really important at this time. Pool said, "What is important is that at least everybody is arguing about the same thing and has some idea of the total complexity of the problem."

It is our feeling that this type of modeling may hasten the day when our many new problems are well-enough defined that we engineers can go ahead and design the hardware systems for their monitoring, analysis and control. Spaceship Earth needs a computer-controlled, life-support system. We have only so much oxygen, so much food, so much space, and we had better start husbanding it with electronics. ▭

Databank

1. "Industrial Dynamics," Jay Forrester, M.I.T. Press, Cambridge, Mass. 1961.

2. "Urban Dynamics," Jay Forrester, M.I.T. Press, Cambridge, Mass. 1969.

3. "World Dynamics," Jay Forrester, Wright-Allen Press, 1971.

4. "Can Man Survive?" Dr. D. C. D. DeJong, University of Cincinnati Alumnus Magazine, May 1971.

5. "Two Models of the Urban Crises: An Analytical Essay on Banfield and Forrester," Harvey A. Averch and Robert A. Levine, RM-6366-RC, September 1970, Rand Corp., Santa Monica, Calif.

6. "A Conceptual Model of the Pasadena Housing System," Alan S. Hirshberger and Thomas A. Barber, Jet Propulsion Laboratory, Pasadena, Calif., AIAA Paper No. 71-500, American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N.Y. 10019.

7. "TOFT," a man-machine method for preliminary modeling of ill-defined systems, obtainable from the author at EDN/EEE.

DPMs Break $100 Price Barrier

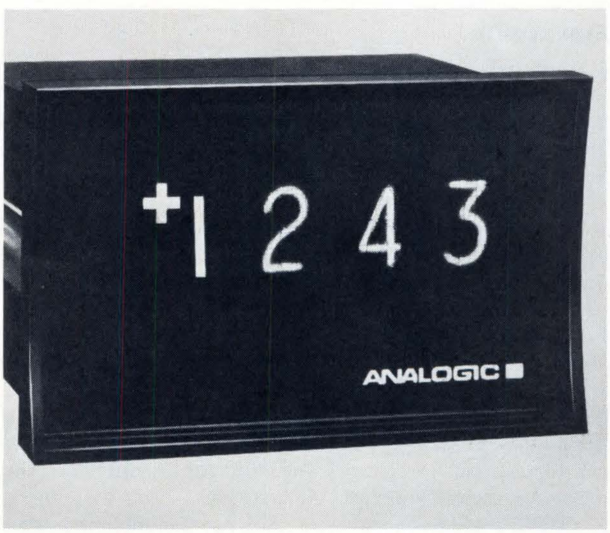
PROGRESS IN INSTRUMENTATION

Three companies have introduced new digital panel meters that sell for under $100 in quantities of 100 or more: Analogic (Model AN2532), Datascan (Model 610) and Weston Instruments (Model 1291).

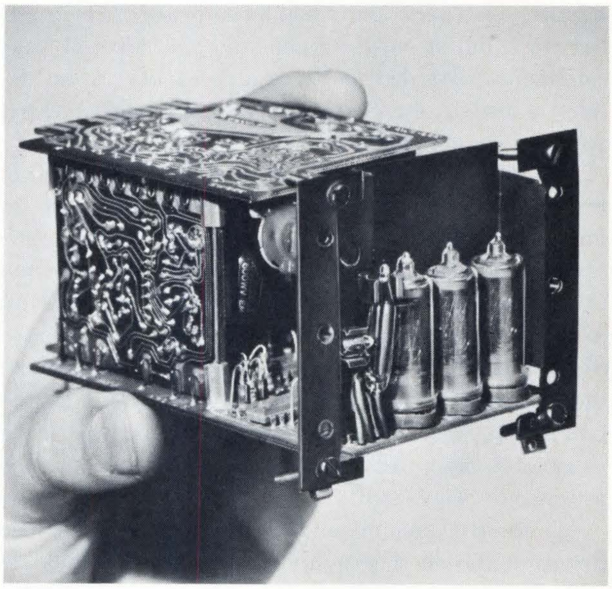
Though some low-performance or stripped-down DPMs had previously been available at under $100 in large quantities, the new DPMs cited here are all high-resolution, 3-1/2-digit units. All three units have room-temperature accuracies of ±0.1% of reading ±1 count. Thus the new instruments not only offer the convenience of digital readout, but they also offer clearcut performance advantages over even the best-quality analog meters.

Analogic's AN2532

The new Analogic DPM sells for $95 in quantities of 100, and in larger OEM quantities for as little as $85. It is a complete bipolar, 3-1/2-digit unit (not a stripped-down version), and includes such features as overrange blanking, BCD outputs and provision for linearization. Stripped-down versions (uncased or without power supply) are available for as little as $69 in moderate OEM quantities.



Analogic's AN2532 bipolar unit sells for $95 in quantities >100. Unipolar version costs slightly less.



Datascan's Model 610 is a unipolar DPM without case. It sells for $95 at the 100-quantity level. Bipolar versions cost an extra $6.

Analogic achieved the low costs as a result of production efficiencies and by use of MSI ICs, some of which were specially developed for this application. The AN2532 uses "Nixie" display tubes but is also available with the new Sperry 7-bar inline display which has 1/2-inch numerals.

Though performance of the AN2532 doesn't match that of Analogic's higher priced devices, the unit is fully competitive with other low-cost DPMs. Like the competing units, it has an accuracy (at 23°C) of ±0.1% of reading ±1 count, while the temperature coefficient is ±50 PPM of reading/°C. The zero stability is ±0.05 counts/°C. Input impedance is over 1000 MΩ, with an input offset current of 350 nA. Common-mode rejection at 60 Hz is 70 dB (with 1 kΩ imbalance).

Datascan's 610

Unlike the Analogic and Weston units, Datascan's new DPM employs single-slope rather than dual-slope integration. This allows Datascan to offer bipolar units at almost the same price as unipolar versions. The autopolar (automatic display of either input polarity) version, Model 620, costs $101 in quantities of

Progress in Products

100 (without case). The unipolar version (Model 610) without case is $95 at the same quantity level. An aluminum case and bezel cost an extra $5.

At 25°C, the 610 has the same accuracy as the Weston and Analogic units, while the temperature stability is 0.015%/°C (compared with 0.005%/°C for the Analogic unit). However, the 610 has an operating temperature range of 0 to 60°C, as opposed to the 0 to 50°C specified for Analogic's AN2532. Datascan specifies a warmup time of 5 min, whereas Analogic doesn't specify warmup and Weston suggests a longer warmup period.

The 610 has hold and trigger inputs as standard features with BCD outputs available as an option (for an additional $10). The trigger input function is especially useful in sample-and-hold applications and for use with printers. Response time of the 610 is 150 msec. Burroughs "Nixie" tubes are used for the display rather than lower-cost substitutes.

Weston's 1291

The new Weston 3-1/2-digit DPM is a single-polarity instrument, unlike the Analogic (which is bipolar) and the Datascan (which is available in a low-cost bipolar version). In quantities of 100, it sells for $99.75.

Weston's Model 1291 is a complete unipolar DPM. It costs $99.75 in quantities >100.

Similar in style to Weston's earlier DPMs introduced a couple of years ago, the 1291 has a height of only 1-3/4 inches, which is slightly less than the Analogic unit and much less than the Datascan unit. This feature allows DPMs to be stacked on a crowded panel.

Nominal accuracy at room temperature is the same as for the Analogic and Datascan instruments. But Weston does not quote a separate temperature co-efficient. The data sheet suggests that the DPM maintains its accuracy over the temperature range of 5 to 45°C, which is less than those specified for the Analogic and Datascan units. Weston does, however, specify a stability of 0.1% for 8 hours after half an hour. This implies a warm-up time of half an hour, which is much longer than the 5 min specified for the Datascan unit.

Most other specs for the 1291 are comparable with those for the other units. Common-mode rejection is greater than 60 dB with 1000Ω unbalance at 60 Hz. It should be noted that Analogic specifies 70 dB. Input impedance is 500 MΩ on the 1V range. Though half that of the Analogic unit, this is still pretty impressive. Like the other companies Weston uses Burroughs "Nixie" tubes for the display.

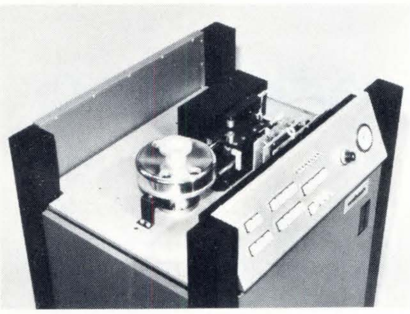
All of the units discussed here are available in a choice of voltage ranges. Weston also offers a choice of five current ranges. In all cases, the minimum voltage range is 100 mV full scale (plus 100% overrange for all units). Maximum full-scale voltage ranges are 1V for the Analogic instrument, 100V for the Datascan and 1000V for the Weston.

The Analogic and Weston DPMs are available from stock. Datascan's DPM is available from stock in prototype quantities and will be available in production quantities in October.

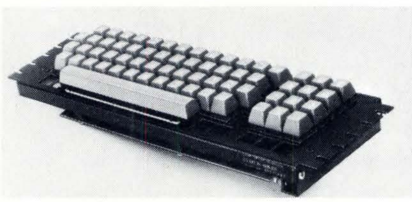
Analogic Corp., Audubon Rd., Wakefield, MA 01880. **301**

Datascan, Inc., 1111 Paulison Ave., Clifton, N J 07013. **302**

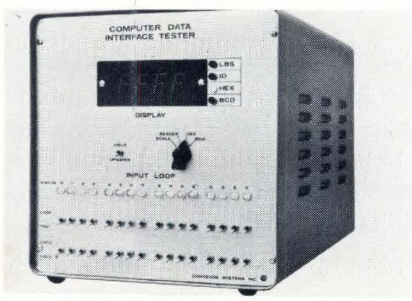
Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, N J 07114. **303**



Magnetic surface and head tester, Model 36, writes and reads data in a preselected pattern as indicated with a series of eight switches. Either a 15-MHz crystal or an external frequency source provides the basic write frequency. The tester accepts 2316- or 3336-type discs of 50- or 75-mil thickness. Spindle rotation speed is 3600 rpm, reducible to 2400 rpm. Wabash Computer Corp., Equipment Div., 10202 N. 19th Ave., Phoenix, AZ 85021. **304**

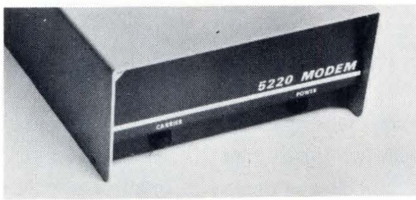


Keyboard design uses ferrite core keys to attain completely reliable contactless operation. Keyboard profile is reduced by 9/16 inch, and all IC components are contained within the assembly. Key design offers splashproof security against environmental office hazards. Available models include two-key rollover and optional fail safe N-key rollover. Licon, Div. of Illinois Tool Works, Inc., 6615 W. Irving Park Rd., Chicago, IL 60634. **305**

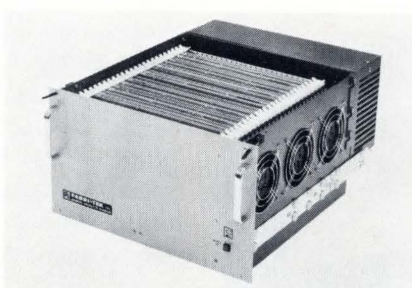


Computer-interface data tester monitors one 16-bit word of data from a field source and displays this data in digital form. The display indicates in alphanumeric characters one of four formats: 16-bit hexadecimal, 16-bit BCD, 13-bit BCD and 10-bit binary. The desired format is selected by front panel switches. Dimensions are 11 by 11 by 18 inches, and weight is approximately 14 lb. Conveyer Systems Inc., 6451 Main St., Morton Grove, IL 60053. **306**

Portable communications terminals packaged in a 7- by 16- by 21-inch carrying case weigh 25 lb. Two models are available: "COMPROPORT" 1020 (operates at 10, 15 and 20 cps) and 1030 (operates up to 30 cps). Both models print 80 characters/line spaced 10/inch with line spacing of 6/inch. The units are capable of producing up to five copies on sprocket-feed or standard letterhead paper. Compro Corp., 127 E. Dyer Rd., Santa Ana, CA 92707. **307**



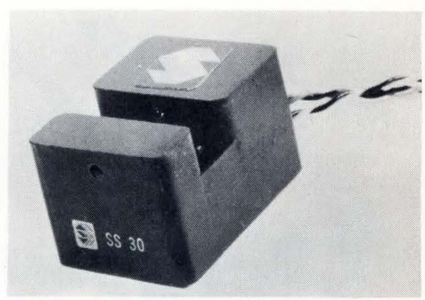
Modem, Model 5220, is an originate or answer only unit with power supply and indicating lights for power and carrier detect when supplied. The unit is compatible with the Bell 101, 102 and 113 Series, and will operate full-duplex up to 300 bps. Bandpass filters provide minimum 60 dB adjacent channel rejection. Unit prices are $180 without and $195 with carrier detect. RFL Industries, Inc., Boonton, N J 07005. **308**



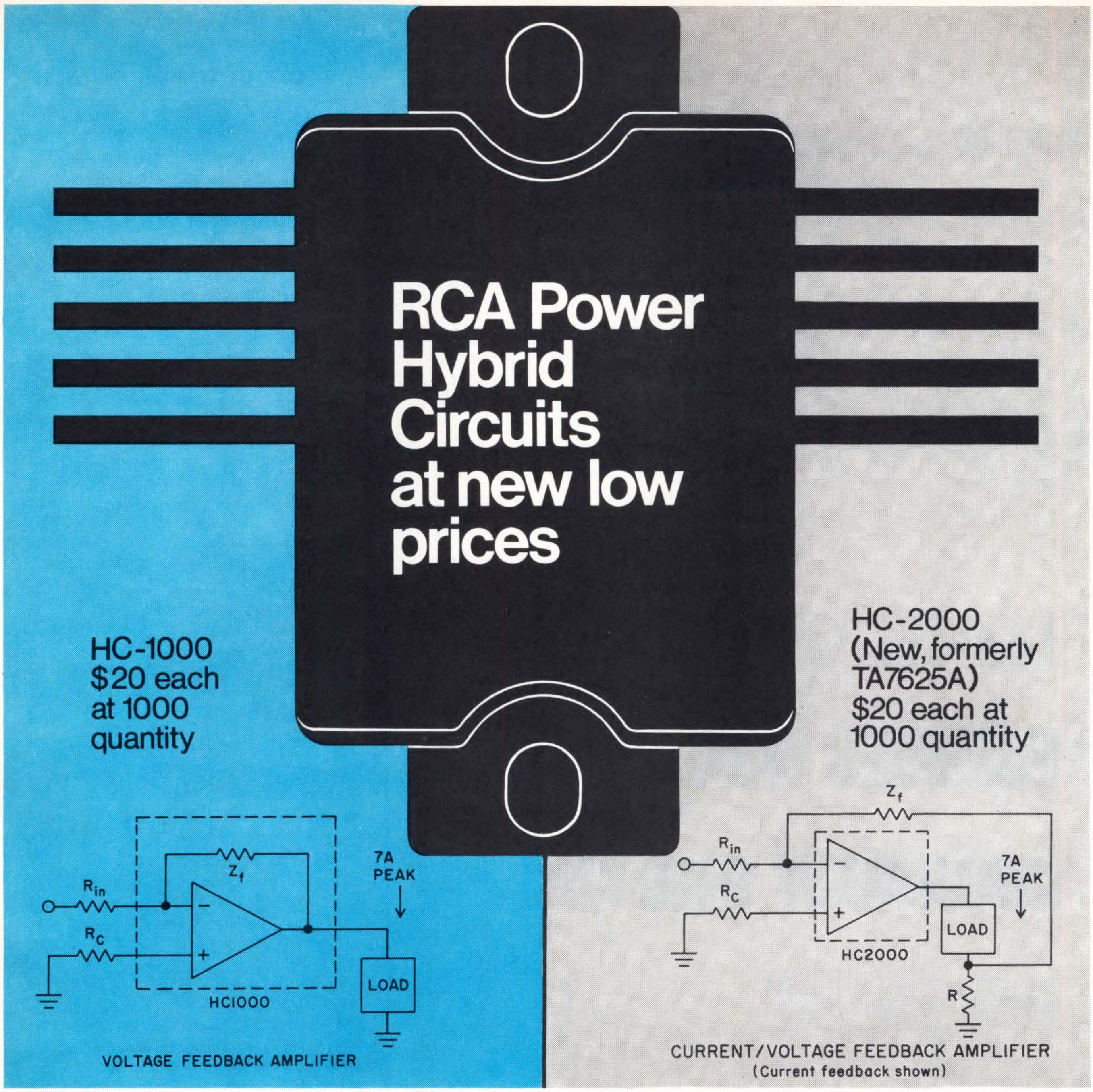
Core memories, 400 Series, are complete 9-, 18- or 36-bit systems using extended range ferrite cores, and are designed for field expansion. Capacity may range from 8k × 9 bits to 65k × 36 bits or any standard increment in that range. Full cycle time is 900 nsec with half cycle access time set at 400 nsec. Rack mount power supply is available to provide the necessary voltage requirements. Fabri-Tek, Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. **309**

Electric nonreset counters, 8Z9 Series, are designed for low-cost metering applications. These 6.5-oz units, running at 500 cpm, have a maximum count of 99,999. Dimensions for the tamper-resistant, plated steel housing are 2.735 by 1.305 inches. Power consumption is 5W. Both 115V ac and 24V dc models are available, priced at $4.50 each. Stock Drive Products, Div. of Designatronics, Inc., 55 S. Denton Ave., New Hyde Park, NY 11040. **310**

Multi-frequency audible signaling device, "Cybertone", provides programmable sounds that would be easily discerned in the presence of high-background noise. Ten different sounds are available from the same unit. The unit emits signals of up to 90 dB (max) sound power level at one meter and operates on 12V dc with a current drain of approximately 30 mA. Cybersonic Div., C. A. Briggs Co., Box 151, Glenside, PA 19038. **311**



Sector sensor SS 301 is for magnetic disc units and can double the standard packing densities while reducing jitter to <100 nsec. Using an LED and phototransistor combination, the unit includes a dc coupled amplifier and threshold detector that drives four standard TTL networks. The sensor is a replacement for the magnetic transducer that is normally used. Price is $28 (lots of 100). Spectronics, Inc., 541 Sterling Dr., Richardson, TX 75080. **312**



Price plus performance – that's what RCA's HC-1000, linear power amplifier, and HC-2000, power Op Amp, deliver in a big way! Available now at an attractive low price, these power hybrid circuits will bring new economies to your designs for industrial and commercial systems. Both the HC-1000 and HC-2000 provide these design features:

- 7 A peak current
- Bandwidth: 30 kHz at 60 W
- Power output to 100 W
- Rugged plastic package

For fixed voltage feedback systems, such as audio, you can use the HC-1000 or the HC-2000. The added feature of external feedback modification on the HC-2000 provides for both current and voltage feedback – current feedback is an important advantage for servo applications.

Using these RCA units you can simplify your designs in such areas as:

- Servos
- Tape drivers
- Stepper motors
- Linear motor controls
- Audio systems
- Magnetic deflection

These are rugged units offering uncompromised reliability. Ask your local RCA Representative or your RCA Distributor about them. For application information on these devices and the RCA growing line of power hybrid circuits, write: RCA, Commercial Engineering, Section 50I-1/UC4, Harrison, N.J. 07029. International: RCA, Sunbury-on-Thames, U.K., or P.O. Box 112, Hong Kong. RCA Limited, St. Anne de Bellevue, 810 Quebec, Canada.

RCA Solid State

CIRCLE NO. 23

Rotating-memory sector track recorder, Model PM 2120, performs all functions necessary for write timing, address and sector tracks on disc and drum memories. Up to eight plug-in cards may be ordered for any specified pattern or function. Pioneer Magnetics, Inc., 1745 Berkeley St., Santa Monica, CA 90404. **313**

Extended-core memory ECM-50 offers users of IBM 360/350 computers economical bulk core storage—an addition of 10 million bits. Cycle time is 2.4 μsec and up to eight units may be linked with a single 360 system without equipment or software modification. Ampex Corp., 9937 Jefferson Blvd., Culver City, CA **314**

Optical character reader System/70 is no larger than an office desk and is comprised of a remote automatic-feed desktop scanner, a display console and keyboard and a central processing unit. The system reads from 4- by 3.25- to 8.5- by 14-inch documents. Cognitronics Corp., ROCR Div., 41 E. 28th St., New York, NY 10016. **315**

Digital controller/processor, Model 2000, features 32 instructions (single address), 16-bit word length, MOS circuitry, a 2048 × 16-bit ROM and a 2048 × 16-bit RAM. In operation, the unit executes fixed programs stored in the ROM. Teledyne Avionics, Box 888, Charlottesville, VA 22902. **316**

Line printer is available as an option for a key-to-disc system ("KeyLogic"). The printer is IBM compatible, 132 column and fully buffered. Print speeds are 400 and 600 lines/min, with 12-channel vertical format control. Redcor Corp., 21200 Victory Blvd., Woodland Hills, CA 91364. **317**

Paper-tape reader N101 operates with standard NOVA software and responds to all paper-tape reader commands. Operating at 50 cycles/sec, it can load programs five times faster than the Model 33 Teletypewriter. Pivan Data Systems, Inc., 6955 N. Hamlin Ave., Lincolnwood, IL 60645. **318**

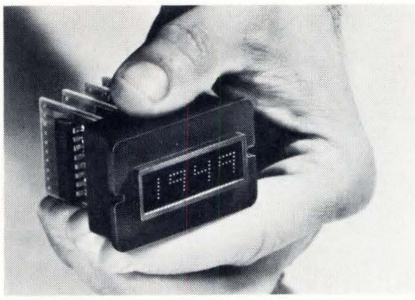
Controlled impedance cable maintains clear signal transmission with minimum crosstalk even when folded, twisted or stacked. Impedance is controlled to customer's requirements with <10% deviation in acceptable ranges. Length, lead exposure and other requirements may be specified. Woven Electronics, Box 189, Mauldin, SC 29662. **319**

A 264-bit badge reader, Model 264A, reads the first 22 columns of a standard 80-column tab card (Media I per EIA-RS-292) or a standard size CR-60 badge with Media I punching. Matrix is 12 rows × 22 columns. Instrumentation and Controls Div., The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. **320**

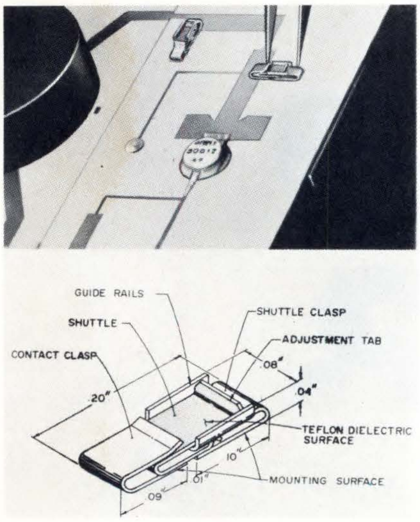
Disc memory system for IBM System/360 and 370 computers consists of a 3100 controller and up to nine 3101 disc drives, and stores 466 million bytes of information. Average access time is 29 msec. An unusual feature is a switch that permits reading of packs recorded in standard 203 cylinder 2315 format. Itel Corp., 1 Embarcadero Center, San Francisco, CA 94111. **321**

Timesharing formatted data coupler, Model 617, generates hard copy and punched paper tape from outputs of digital instruments. The unit is easily installed inside the Model 33 "Teletype" pedestal base. Datac Inc., 1773 S. Taylor Rd., Cleveland, OH 44118. **322**

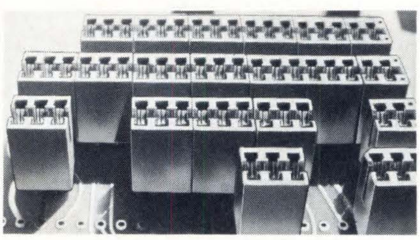
Computer-interface package, Model 67, drives programmable waveform generators and other programmable instruments. The package includes an interface card that fits into the I/O slot of a computer, cable, connectors and software (paper tape). Exact Electronics Inc., 455 S.E. 2nd Ave., Hillsboro, OR 97123. **323**



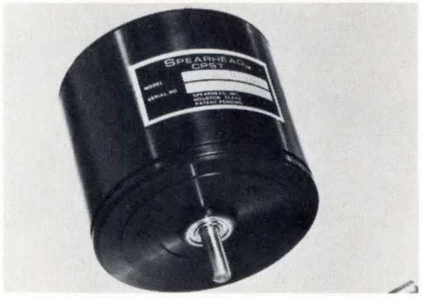
Solid-state readout, Series 749, includes decoder/drivers and a black bezel assembly for panel installation. Readout is a 6- by 8-dot matrix connected for 7-segment driving. Character heights of 0.125 or 0.205 inch are available. Price of a three-digit unit is approximately $32 each in lots of 100. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **324**



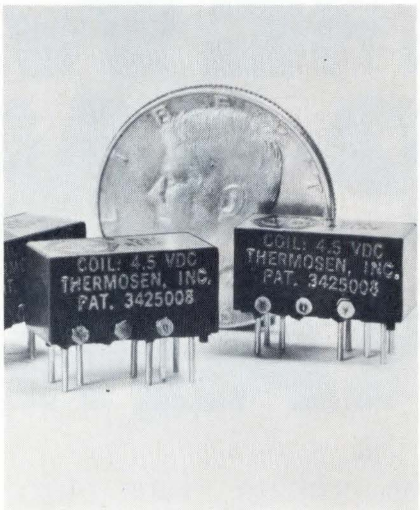
Subminiature variable capacitor tunes microelectronic circuits. Model CP2 has capacitance range of <0.1 to >2.5 pF, Q factor of over 1000 at 250 MHz and rating of 100V dc. Voltronics Corp., West Street, Hanover, N J 07936. **325**



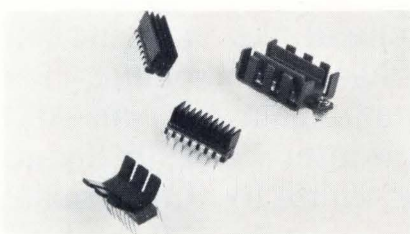
Modular card edge connector with 0.156-inch contact centers can be ganged together to custom design connectors. Series 6318 comes in modules of 4 and 6 contacts with solderless, press-fit contact tails. Elco Corp., Maryland Rd. & Computer Ave., Willow Grove, PA 19090. **326**



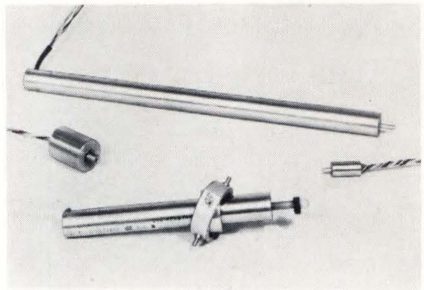
Capacitive position-sensing transducer provides 0.1% accuracy in measuring angular displacement over 160° range. The Model 3-ACP-160 CPST is basically a high-precision three-terminal 0-4 pF variable capacitor designed for applications where extremely long maintenance-free life is required. The price is $95 in lots of one to nine. Spearhead Inc., 1401A Cedar Post Lane, Houston, TX 77055. **327**



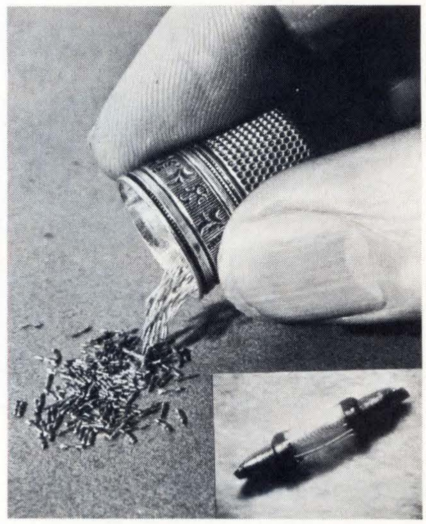
Relay is ideal for high-speed, low-level three-wire multiplexing systems. Unique magnetic and mechanical design of the D3A "Multireed" relay allows high scanning rates. Thermosen, Inc., 375 Fairfield Ave., Stamford, CT 06904. **328**



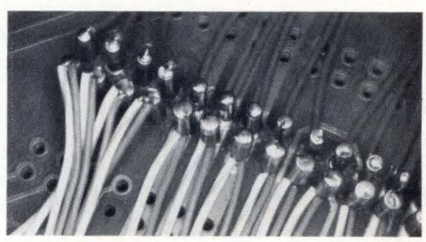
DIP heat sinks for 14- and 16-pin packages will operate with significantly reduced thermal resistance in a forced-air environment. Prices range from $0.08 to $0.60 depending on quantity and finish. Thermalloy Co., 3717 Diplomacy Row, Dallas, TX 75247. **329**



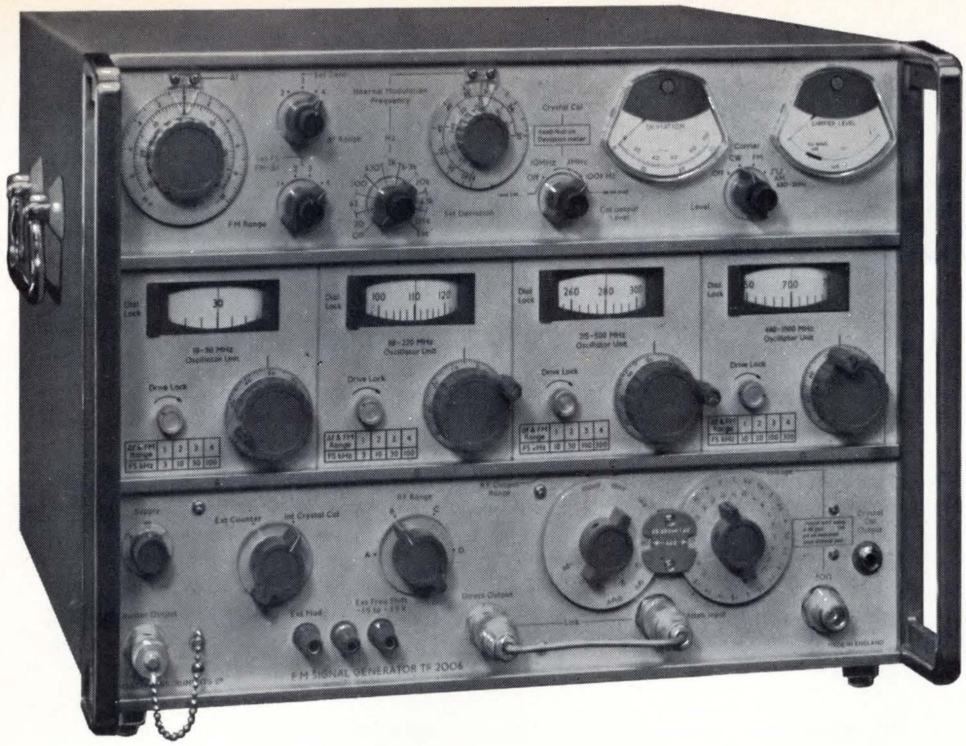
Linear variable differential transformer displacement sensors are designed for applications where voltage output directly proportional to displacement is required. Miniature, standard and high stroke series are available for a wide range of linear measurements. Prices start at $15 in quantities of 1000. Columbia Research Laboratories, Inc., MacDade Blvd & Bullens Lane, Woodlyn, PA 19094. **330**



Miniature and microminiature incandescent lamps featuring axial construction are available in a wide range of ratings and sizes from 0.200 down to 0.022 inch in diam. Starlight Corp., Mountain Home, NC 28758. **331**



Pin springs secure wires to terminal pins to facilitate soldering operation. Top or bottom entry can be used to accommodate up to five wires on a pin. Lear Siegler, Inc., Electronic Instrumentation Div., 714 N. Brookhurst St., Anaheim, CA 92803. **332**



- **Wide Range: 4-1000 MHz**
- **Stability: Better than 15 PPM/15 minutes**
- **Non-Microphonic**
- **No Range Change Drift**
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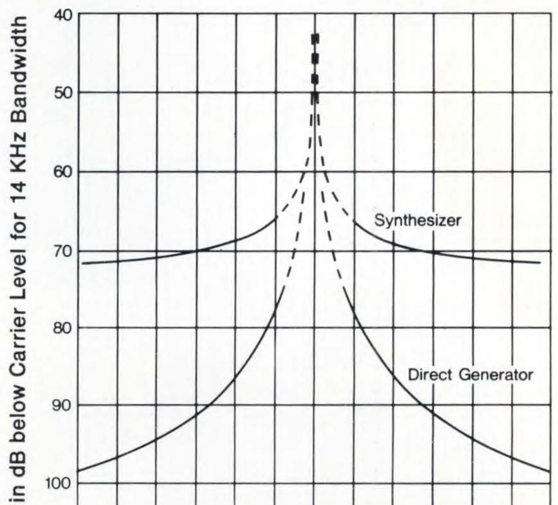
F.M. Signal Generator TF 2006 is another "first" in the field of wide-range solid-state signal generators. Based on separate high Q resonant-line transistor oscillators, this instrument provides wide deviation f.m. on highly stable carriers up to 1 GHz. Rigid mechanical construction ensures that the precision oscillators have very low drift and microphony. Automatic levelling maintains constant r.f. output over the entire carrier frequency range, which extends down to 4 MHz, and accurate step attenuators offer a dynamic range of 120 db. Electrical fine tuning and f.m. may be simultaneously applied by the drive circuitry. As a result of their electrical relationship within the instrument f.m. as well as the fine tuning may be adjusted to a higher accuracy against the comprehensive crystal calibrator. This oven-controlled calibrator indicates carrier frequencies by meter nulls at 10, 1 or 0.1 MHz intervals and therefore provides almost 10,000 check points of the carrier frequency.



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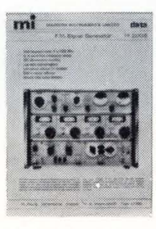


CIRCLE NO. 26

AVAILABLE UPON REQUEST...
Detailed specification brochure including operating principles, mechanical, electrical and environmental specifications.

Trimmer features tempco of 20 PPM/°C, no dc offset, no thermal noise and is noninductive. Multifingered wipers are used on the Model 1203 to eliminate catastrophic failure and wandering output. Price is $3.25 in 100-piece quantities. Vishay Resistor Products, Inc., 63 Lincoln Hwy., Malvern, PA 19355. **333**

Subminiature multipole relay with 10A rating is 50% smaller than existing electrical equivalents. Series 76 is available in two- and four-pole ac/dc types for plug-in front mounting. Sigma Instruments Inc., 170 Pearl St., Braintree, MA 02185. **334**

Sprayable dielectric insulates between semiconductors and heat sinks. Castall 343 combines low thermal resistance with high dielectric strength and can be applied with conventional spray equipment to thicknesses of 1 to 6 mils in one application. Price is approximately $15/quart. Castall, Inc., Weymouth Industrial Park, East Weymouth, MA 02189. **335**

Thermal switches feature low-profile design for applications where high reliability is required and space is at a premium. Contact rating for the 400 Series is 6A resistive at 28V dc and 115V ac, with operating temperatures as high as 300°F. Kistler Instrument Corp., Overlake Industrial Park, Redmond, WA 98052. **336**

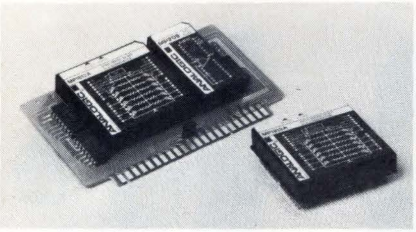
Miniature dual-tracking voltage regulator delivers up to 500 mA from each balanced plus and minus 15V dc output. The Model DVR-500 incorporates its own heat sink and requires no added external components. Integrated Circuits Inc., 13256 Northrup Way, Bellevue, WA 98004. **337**

PC boards feature high strength and ease of fabrication. "Econofab" heavy-duty circuit board is designed to replace glass polyester board. "Econofab" standard PC board has a standard laminate structure and is priced competitively with phenolic flame-retardant boards. Westinghouse Electric Corp., Westinghouse Building, Pittsburgh, PA 15222. **338**

Angle transducer operates on the principle of flux summing with output linearities of 0.1%. An isolated output proportional to angular shaft position and another proportional to rate of change of shaft position are provided in Model FA2 "Fluxpot". Permalink Corp., 327 Valley View Rd., King of Prussia, PA 19406. **339**

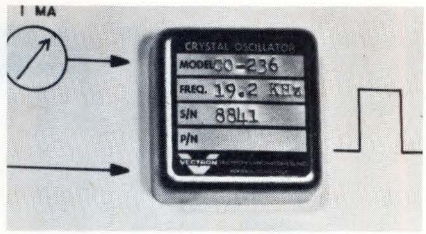
Low-cost carbon film trimming and adjusting potentiometers are available with resistance ranges from 500Ω to 1 MΩ and a variety of styles. Price is $0.10 to $0.15 in 1000-piece quantities. Waters Mfg., Inc., Boston Post Rd., Wayland, MA 01778. **340**

Taut-band meter with a 250° span and ±1% accuracy is available in a 2-1/2-inch square package to measure volts, mV, A, mA, and μA. Integrally mounted transducers may be used with the Series 1126 to read expanded scale volts, watts, frequency or power factor. Prices start at $25. Kratos Instrument Div., 403 S. Raymond Ave., Pasadena, CA 91105. **341**

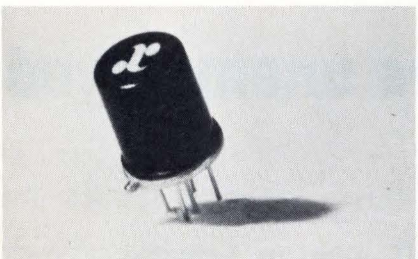


High-speed D/A converters, MP1812A and AN1812M, exhibit typical settling time to 1/2-bit accuracy of 5 μsec. Typical TC of range and offset are 10 PPM/°C and 50 μV/°C, respectively. The basic MP1812A is a 2- by 2- by 0.39-inch module with 10-mA output capability. The AN1812M consists of an MP1812A mounted on a 2-13/16- by 4-5/8-inch plug-in PC board. Analogic Corp., Audubon Rd., Wakefield, MA 01880. **342**

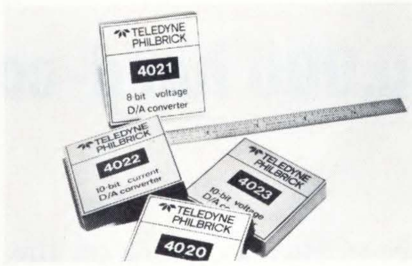
DC-DC converters that can be mounted on a PC board handle 5V with inputs of 5, 12 and 28V and outputs of 5, 12, 15, 28 and 200V—some exhibiting 75% efficiency. Input/output pins are floating with respect to each other and to the can, with 500V isolation guaranteed. Price ranges from $15 to $35 each, depending on quantity. Shane Industries, Div. of Illumination Industries, Inc., 608 Vaqueros Ave., Sunnyvale, CA 94086. **345**



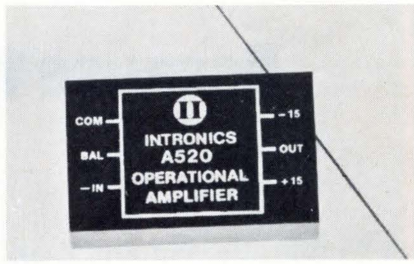
Crystal controlled clock oscillator CO-236 draws only 1 mA to generate CMOS-compatible output at frequencies up to 2 MHz. This 1.5- by 1.5- by 0.5-inch module mounts on a PC board and operates from 10V dc, providing stability of ±0.0025% over 0 to 70°C. Units with ±0.005% stability (−55 to 105°C) are available. Price for 1-4 pieces is $105 (quantity price is $40). Vectron Laboratories, Inc., 121 Water St., Norwalk, CT 06854. **348**



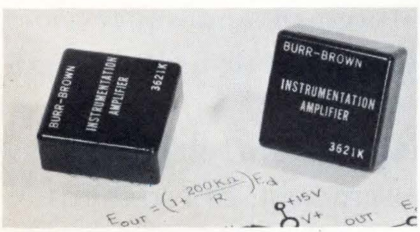
Broadband hybrid junctions in TO-5 cans offer high-density packaging with printed-circuit transmission lines. Two models, MTH-50 and MTV-50, cover the frequency ranges of 1 to 100 MHz and 40 to 400 MHz, respectively. A third unit (MTH-75) operates from 1 to 100 MHz and is available for use in 75Ω systems. All come with either pin leads or threaded-stud mounting. Small quantity price is $72. Anzac Electronics, 39 Green St., Waltham, MA 02154. **343**



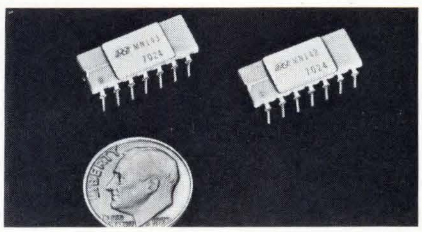
Eight- and 10-bit D/A converters are available with either current or voltage output. Nonlinearity is ± 1/2 LSB within 1% of theoretical values. Current output models, 4020 (8-bit) and 4022 (10-bit), exhibit a 200-nsec settling time at prices of $19 and $29, respectively. Settling times of the voltage output units, 4021 (8-bit) and 4023 (10-bit), are 25 μsec (±5 full-scale output) for the same prices. Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, MA 02026. **346**



Inverting operational amplifier, Model A520, has bipolar transistor input stage with <20 nA input current and uses feed-forward circuitry to achieve 100-MHz gain-bandwidth product. Other features include 300 V/μsec slew rate and settling time of 1 μsec max to 0.01% and 200 nsec max to 0.1% for a 20V step. Short circuit protected output delivers ±20 mA load current. Price for 1-9 is $49. Intronics, Inc., 57 Chapel St., Newton, MA 02158. **349**



Instrumentation amplifier modules, Model 3621 family, come in three distinct units depending on input-voltage drift. The 3621J maximum voltage drift is ±50 μV/°C, 3621K is ±15 μV/°C and 3621L is ±5 μV/°C. A FET-input stage has an input impedance of $10^{11}\Omega$ and low-input bias current of 10 pA max. Gain (1-2000) is set with external resistor. Prices range from $39 to $59, (1-9). Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **344**



Resistor networks, MN142 and MN1413, combine with Intersil's ICL 8018, 8019 and 8020 quad current switches to form a 12-bit D/A converter network. MN142 provides three sets of R, 2R and 4R resistors plus an additional 8R for the reference transistor. The MN143 includes necessary feedback, scaling and bias resistors for unipolar and bipolar outputs up to −10V. Price is $48 in quantities of 25. Micro Networks Corp., 5 Barbara Lane, Worcester, MA 01604. **347**

Miniature power modules convert 115V ac, 400 Hz to any desired dual output voltage between ±3 and ±30V dc at a full load current of 2A/output. Load regulation is ±0.1% or 20 mV (whichever is greater) from no load to full load. Ripple reduction is 0.02% or 5 mV rms (whichever is greater), 25 mV pk-pk max. Prices are $395 for one and $355 each for 2-4 pieces. Abbott Transistor Laboratories, Inc., 5200 W. Jefferson Blvd., Los Angeles, CA 90016. **350**

JOBS is

Because 15,000 American companies knew a

Because 100,000 hard-core unemployed

Last March, the National Alliance of Businessmen was formed to work with the Government on a problem of critical national importance. The Program: J O B S (Job Opportunities in the Business Sector). The Task: to hire, train and retain the nation's hard-core unemployed. To find and fill 100,000 jobs by July 1969; 500,000 by 1971.

They are being hired.

The first year's goal has been reached seven months ahead of schedule! In the nation's fifty largest cities J O B S is progressing at the rate of 20,000 placements per month—*over double the anticipated rate.* At the end of December, 100,000 hard-core workers were on the job... earning an average of $2.25/hour.

They are being trained.

Companies are bringing the hard-core into the mainstream of American business by providing the new workers with special training both educational and vocational. And by conducting imaginative "sensitivity" programs to help foremen and supervisors understand the unique problems of the hard-core.

Extra training costs are being shared by Industry and Government. In two-thirds of the cases these costs have been voluntarily absorbed by the individual employers. One-third of participating companies have signed

Dual-output power supply, Model 203, features 0.5A output, line/load regulation of 0.05% and 0.5 mV ripple. Each isolated output voltage is independently adjustable over a range from 12 to 18V dc. Price is $99 each. Viking Modules, Inc., 223 Crescent St., Waltham, MA 02154. **351**

D/A converters of 10-, 12- and 13-bit capacity feature 300-nsec settling time with a 10V output swing at 40 mA. Internal reference is standard. Prices range from $135 (10-bit) to $395 (13-bit with "deglitching" modules). Dynamic Measurements Corp., 6 Lowell Ave., Winchester, MA 01890. **352**

Potted-module dc power supply PM570 measures 3.5 by 2.5 by 1.25 inches and has an output of ±15V dc at 150 mA. Load regulation is ±0.02%, input requirement is 115 ±10V ac, 50 to 400 Hz, and TC is 0.02%/°C. Unit price is $54.95. Computer Products, Inc., 1400 N.W. 70th St., Box 2349, Fort Lauderdale, FL 33307. **353**

Tunable active filters, 730 Series, are 4-pole low-pass units with externally adjustable cutoff frequencies. The series spans the 1 Hz to 20 kHz cutoff frequency band in four overlapping versions. Unit price is $69. Analog Devices, Inc. Rte. 1 Industrial Park, Norwood, MA 02062. **354**

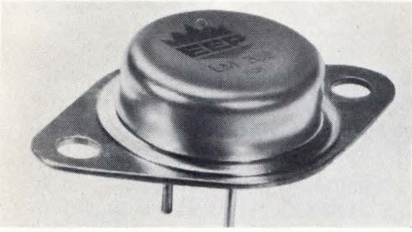
Solid-state relay, called "Clarac", switches 120V ac, 50/60 Hz (200V max peak) or 240V ac, 50/60 Hz (400V max peak) at 3, 4, 6, 7, 10 and 15A. Operation requires control voltages of 5, 12, 24 or 48V dc and 200 mW of power. Typical response time is <1 msec. C. P. Clare & Co., 3101 Pratt Ave., Chicago, IL 60645. **355**

Differential op amp, Model 3002, is a variable high-gain single-ended output dc amplifier suitable for low-level instrumentation and bridge input applications. Typical stability is 0.6 μV/°C and 5 μV/week. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **356**

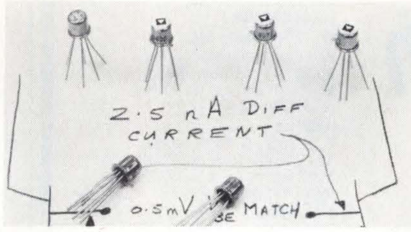
Clock oscillator, Model CO-20 is a DIP unit with an upper frequency range of 20 MHz. Height is <0.4 inch. Output is TTL compatible. Price is $12.85 each for quantities of 5-9. Paraline Products Co. Div., Kleentest Laboratories, Inc., 4835 W. Jefferson Blvd., Los Angeles, CA 90016. **357**

Signal conditioner, Model 602, provides regulated excitation for strain gage transducer and amplifies output signal from the transducer. Unit operates from unregulated 28V dc, and amplifies transducer output up to 5V dc. Unit price is only $87. Viatran Corp., 1720 Military Rd., Buffalo, NY 14217. **358**

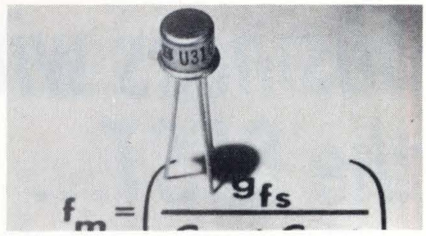
Voltage regulator provides 10A, up to 80V and comes in a hermetic TO-3 package. It offers regulation well within TTL and DTL requirements, in addition to voltage shutdown and current foldback capability in case of short circuit. Unit price is $14.50. Micropac Industries, Inc., 905 E. Walnut St., Garland, TX 75040. **359**



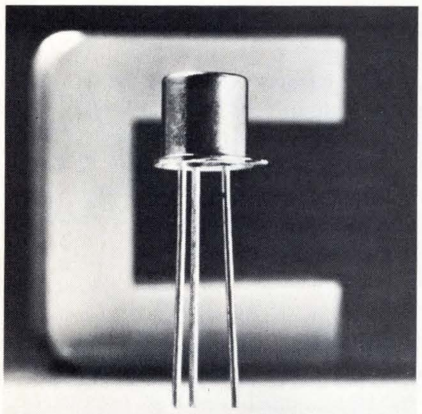
Linear IC power regulator LM336 delivers 12V output at 500 mA with line and load regulation of <1%. Ripple rejection is typically 62 dB. Overload and short circuit protection are provided. Package style is standard JEDEC TO-3 metal case, and operating temperature range is 0 to 70°C. Price for 100 pieces is $3.60. European Electronic Products Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **360**



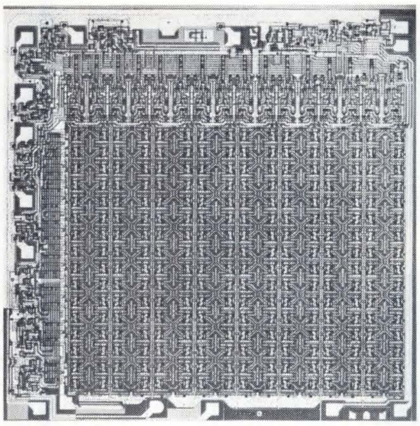
Family of monolithic dual npn transistors, AD810-813, has the following characteristics: current gain of 400 minimum for a 10 to 5000 μA emitter current range, base-emitter voltage differential as low as 0.5 mV, maximum voltage drift of 2.5 μV/°C, base current differential <2.5 nA and minimum breakdown voltage of 45V. Prices range from $2.40 (AD810) to $8.25 (AD813). Analog Devices, Inc., Box 280, Norwood, MA 02062. **363**



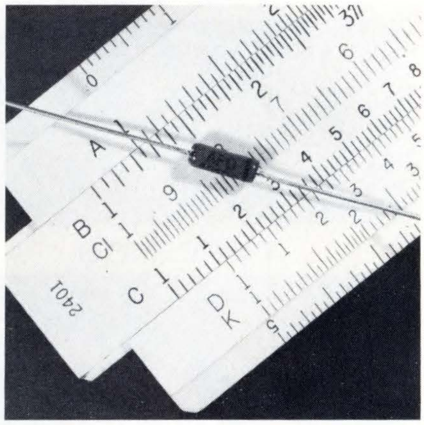
High-frequency FET U310 has a worst case input match to 75Ω of 1.25:1 VSWR and a figure of merit of 2.35×10^9 typical. Other features of this n-channel device are power gain of 16 to 20 dB at 100 MHz and 11 dB at 450 MHz, both common gate. Noise figure at 450 MHz is 3 dB typical and dynamic range >100 dB. Packaged in a TO-52, the unit price is $5.75 for quantities of 100. Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. **366**



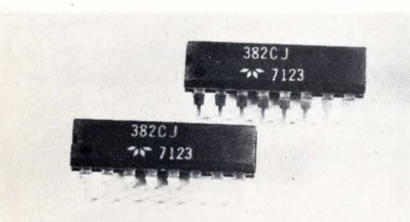
Three series of programmable unijunction transistors—2N6119-2N6120, U13T3-U13T4 (industrial) and 2N6137-2N6138 (military)—feature 150-nA maximum peak current and valley current as low as 25 μA. Prices are as low as $0.53 (U13T3) in 1000 quantities. Unitrode Corp., 37 Newbury St., Boston MA 02116. **361**



256-bit bipolar random-access memory Am2700 offers tri-state output, typical chip select speeds of 12 nsec and read access times of 60 nsec. Power dissipation is 1.5 mW/bit. Units come in a 16-pin package. Price for 100-up mix quantity is $27. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **364**

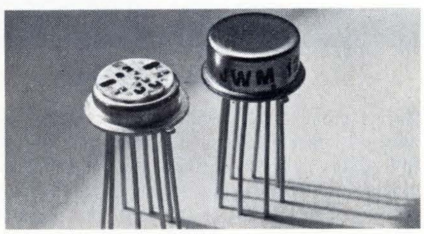


Line of 4-layer diodes includes military, commercial and JEDEC types. Existing units can be cross-referenced to any manufacturer's type numbers up to a 50V rating. In addition, special 4-layer diodes for unusual applications are available. American Power Devices, Inc., 7 Andover St., Andover, MA 01810. **367**



BCD-to-decade decoder/driver, Model 382, has >4V typical noise immunity and guaranteed 70V output characteristics. This device will drive cold cathode indicator tubes that require 7 mA or less cathode current. Available in A, B, C and M grades, the device comes in a J Silicone, an N Ceramic or an L Ceramic DIP. Price for either the A or C version is $6 each (100-999 quantity). Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **362**

SCRs, IR140 and IR141 Series, have a minimum critical dv/dt of 200V/μsec and operate up to 20 kHz. Forward dc blocking voltage is from 50 to 400V. Forward current ratings are 35A rms and 22A average. Pulse and conventional circuit commutated turn-off times are 15 μsec (IR140) and 10 μsec (IR141). Prices for 100-999 quantities range from $6.70 to $19.15 each. International Rectifier Corp., Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. **365**



Two FET analog switches, Models 1273 and 1265, feature high switching speeds. Using thick-film screening technique and stacked wafers, the 1273 comes in a 12-lead TO-8 can and the 1265 in an 8-lead TO-5. The 1273 functions as either DPST or SPDT and the 1265, a high performance unit, operates as a DPST switch. Prices range from $28.95 to $10.40 in quantity. J. W. Microelectronics Corp., 4901 Stenton Ave., Philadelphia, PA 19144. **368**

New SC's

High-voltage, high-current drivers, uAR-2001/rAR2002 Series, can be used to replace the SH2001/SH2002 or NH0011 devices. The series offers $LV_{CEO} = 40V$, $I_L = 250$ mA at 0.5V. Manufactured to MIL STD 883, Level B, price is $4 each in 100-piece lots. Integrated Electronics Inc., 16845 Hicks Rd., Los Gatos, CA 95030. **369**

Voltage regulator Am105 offers adjustable output of 4.5 to 40V and the capability of controlling output currents >10A. Other features include 0.01%/V ripple rejection, >0.1% load regulation and guaranteed line regulation of 0.03%/V. Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **370**

Read-only memory character generator EA4016 contains 64 EBCDIC encoded Japanese Katakana characters. Each character font is contained in an 8 by 10 matrix. Typical access time is 725 nsec. Electronic Arrays, Inc., 501 Ellis St., Mountain View, CA 94040. **371**

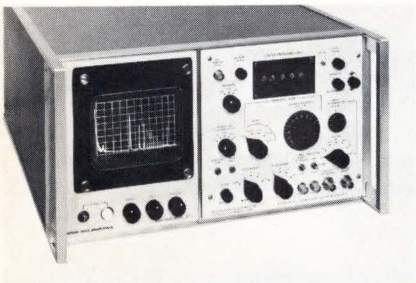
Five npn 450V power switching transistors, Types 40850 to 40854, are intended for 5V off-line supplies with 25, 50, 100 or 200A current ratings and for 30V off-line supplies with 5, 10, 20 or 40A current ratings. Prices (1000 quantity) range from $2.51 to $9.95. RCA Commercial Engineering, Harrison, N J 07029. **372**

Chroma IF amplifier MC1398P, a 14-lead device, performs color processing for TV receiver. The unit features an internal feedback oscillator that locks into phase at levels above 200 μV. In lots of 1000 to 4999, price is $198. Motorola Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. **373**

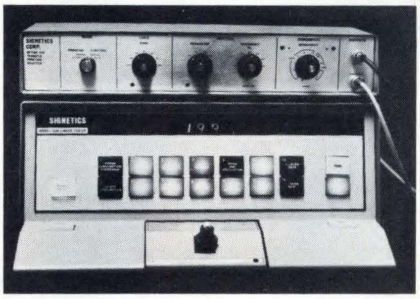
Photodiodes in a TO5 can have isolated leads that offer additional flexibility by permitting use in a differential mode. Typical characteristics include 10 mm^2 sensitive area, 50V max depletion voltage, 300V max operating voltage, 6-nsec rise time and from 3000 to 1000Å sensitivity. Solid State Radiations, Inc., 2261 S. Carmelina Ave., Los Angeles, CA 90064. **374**

DPM, the 2-1/2-digit Model VT-50, has full scale range of 1.99V dc and resolution of 10 mV with accuracy of ±1 digit. Input impedance is 100 MΩ. Power supply, display storage with automatic zero and built-in calibration reference source are provided. Size is 2.68 by 2.68 inches and price is $125 each. Dixson Instruments, Box 1449, Grand Junction, CO 81501. **375**

50 MHz combination data/pulse generator is priced at $925. As a data generator, the Model 218 produces 16-bit words in either NRZ or RZ format with pushbutton control of data content. As a pulse generator its pulse width is continuously variable from 10 nsec to 100 msec in seven ranges. Datapulse Div., Systron-Donner Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **376**

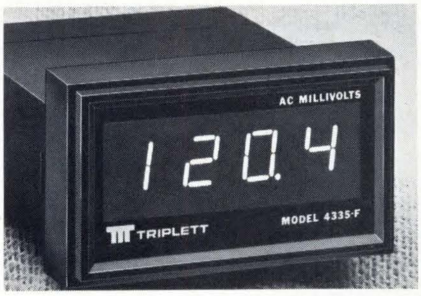


Spectrum analyzer main frame, Model MF-9, accepts any of 14 plug-ins that cover from 0.5 Hz to 6.5 GHz. Features include a 5-inch calibrated CRT, adjustable scale illumination and standard camera mount. Nelson-Ross Electronics Div., 5 Delaware Dr., Lake Success, NY 11040. **377**



Transfer function analyzer, the Option 440 for use with Model 1420 linear tester, permits detailed engineering analysis of individual linear ICs as well as volume production testing. Op amps, comparators and voltage regulators are readily handled. Price for the Option 440 is $980 (Model 1420 is $7950). Signetics Corp., Measurement Data, 341 Moffett Blvd., Mountain View, CA 94040. **378**

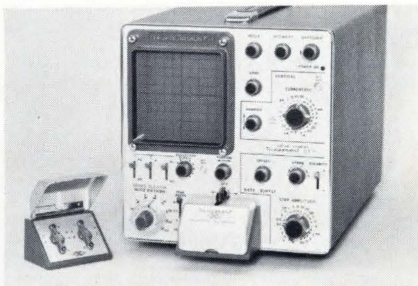
Digital nanovoltmeter with sensitivity to 10 nV, 4-1/2-digit display, automatic ranging, remote programming and isolated input and output has resolution up to five places. Display rate is adjustable from 2-1/2 readings/sec to 1/5 sec. Price is $1695. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. **379**



DPM is ac powered, has single-plane 7-bar fluorescent display and indicating capabilities to 1999 with accuracy from ±0.2%. The 3-1/2-digit Model 4335-F uses dual slope conversion, and to prevent errors its display blanks when overranged. Triplett Corp., Bluffton, OH 45817. **380**

Acoustic data coupler is a 300-baud unit for communicating between a "Teletype" and another terminal or computer via ordinary voice-grade telephone lines. The "Design 76" line includes provisions for both acoustic and magnetic pickup, along with many refinements to improve transmission reliability. Design Elements, Inc., 1356 Norton Ave., Columbus, OH 43212. **381**

Digital thermometer that sells for $750 is complete with internal reference junction, digital linearization and BCD outputs. Standard thermocouples accommodated by the Series 2600 instruments include types J, K, T, S, R and E. Readings are made directly in degrees, thanks to 58-segment drift-free digital linearization. Newport Laboratories, Inc., 630 E. Young St., Santa Ana, CA 92705. **382**



Curve tracer, the "Telequipment" CT71, displays the characteristic curves of a wide range of transistor, FET and diode semiconductor devices on its 10 by 10 cm (5-1/2 inch) CRT. Price complete is $795. Tektronix, Inc., Box 500, Beaverton, OR 97005. **383**

Equipment

Digital correlation and probability analyzer is a 400 point, real-time device that operates in correlation, probability and signal-enhancement modes. Analyzer outputs can be displayed or read out on analog or digital devices. Price is $7800. Signal Analysis Industries Corp., 595 Old Willets Path, Hauppage, NY 11787. **384**

50-MHz pulse generator offers variable rise and fall time plus baseline offset. The Model 5113 delivers 10V into a 50Ω load at duty cycles up to 100%. The price is $950 each. Data Dynamics Div., 240 Humphrey St., Englewood, N J 07631. **385**

Water test kit, Stock No. 71,472, contains everything needed to test for dissolved oxygen, hardness, chlorides, phosphates and hydrogen sulphide in water samples. Price for the complete kit is $15.95 postpaid. Edmund Scientific Co., 380 Edscorp Bldg., Barrington, N J 08007. **386**

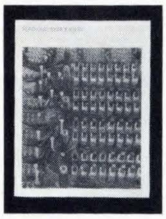
Differential ac preamplifier with 500 MΩ input resistance, gain of 100 and minimum output signal of 5V has CMR of 50,000 at 60 Hz. Model DAM-6 is battery powered. W-P Instruments, Inc., Box 4059, Hamden, CT 06514. **387**

DC power supplies with 100 dB attenuation of low-frequency noise, the PDC Series, totally filter transients at frequencies below 1 MHz. Noise attenuation is 100 dB with virtually no noise/spike response time. Both 0 to 40V dc at 1.6A and 0 to 16V dc at 4A versions are available. Wanlass, Div. of AMBAC, 525 Virginia Dr., Fort Washington, PA 19034. **388**

Infrared thermometer, the ThermoProbe Model T1000, measures areas as small as 0.05 inch with temperatures from 20 to 500°C at an accuracy of 1°C (below 120°C). Raytek Inc., 1277 Terra Bella Ave., Mountain View, CA 94040. **389**

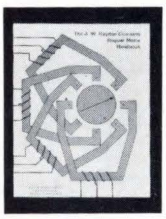
Digital and countdown clocks of the Model 9100 series are precise time standards. The digital clock provides both a 9-digit time display and a parallel BCD time output. The countdown clock provides precise time for use in elapsed-time applications. Count range is 0 to ±99 hrs, 59 min, 59 sec. Datum, Inc., 170 E. Liberty Ave., Anaheim, CA 92801. **390**

Frequency response analyzers are featured in Catalog No. 7172, with 26 pages providing complete specifications, model numbers, dimensions, ranges and prices. Bafco, Inc., 717 Mearns Rd., Warminster, PA 18974. **201**



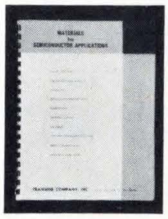
U-core ROMs are the subject of this eight-page brochure which outlines the theory, operation and use of ROMs. Datapac, Inc., 3180 Redhill Ave., Costa Mesa, CA 92627. **202**

Isolation amplifier with 5000V input-to-ground rating is described in a four-page data sheet with specifications, performance curves and application information. Analog Devices, Inc., Box 280, Norwood, MA 02062. **203**

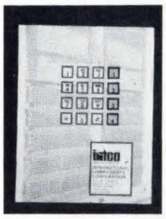


"Stepper Motor Handbook" contains 28 pages covering the design, application and selection of permanent magnet stepper motors along with mechanical and performance specifications. Compensation networks, logic boards and variable-speed stepper drives are also discussed. A. W. Haydon Co., 232 N. Elm St., Waterbury, CT 06720. **204**

Circuit breakers for OEM front-panel applications are briefly described and illustrated in a six-page brochure featuring Type J hydraulic-magnetic breakers. Heinemann Electric Co., 127 Magnetic Dr., Trenton, N J 08602. **205**



"Materials for Semiconductor Applications" is a 32-page catalog covering new products used in research and the manufacture of solid-state devices. Transene Co., Inc., Rte. 1, Rowley, MA 01969. **206**



"Touch-Tone" receivers are covered in a 12-page brochure detailing a complete line ranging from small key systems receivers to central office receivers. International Components Corp., Asbury Ave. & Bowne Rd., Asbury Park, N J 07712. **207**

"An Introduction to MOS/LSI" describes a unique approach to obtaining prototype custom MOS circuits. A six-page fold-out brochure details process steps, process and electrical parameters, recommended design layout guidelines and masking specifications. Advanced LSI Technology, Inc., 639 N. Pastoria Ave., Sunnyvale, CA 94086. **208**

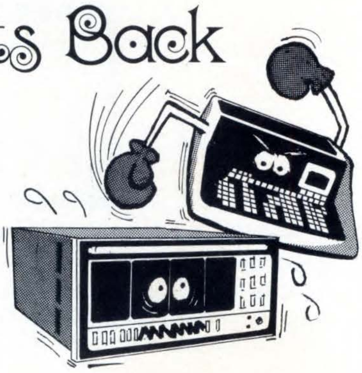
Condensed semiconductor catalog contains 72 pages showing entire line of transistors, FETs, diodes, and linear, digital, hybrid and MOS microcircuits. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **209**

PC card guides, brackets, card racks, card storing and shipping containers are covered in this 12-page catalog. UNITRACK, Div. of Calabro Plastics, Inc., 8738 W. Chester Pike, Upper Darby, PA 19082. **210**

Magnetic disc recorders used to record and reproduce bandwidths up to 12.6 MHz are described in Brochure D-171 and Specification Sheet D-170. Ampex Corp., M.S. 7-13, 401 Broadway, Redwood City, CA 94063. **211**

Microprogramming handbook covers the subject in a practical and comprehensive manner. In precise terms it tells how to microprogram, why the concept is effective and when it is most appropriate. This 352-page handbook may be obtained by writing on company letterhead to Microdata Corp., 644 E. Young St., Santa Ana, CA 92705.

Calculator Fights Back



Gentlemen:

This is to request the publication of a few comments on Mr. Nigberg's prophecies on "Minicomputer vs Programmable Calculator" which I read with bemusement in your April 1 issue. The statement "programs written for minicomputers are more readily understood by persons other than their authors" seems particularly puzzling. Could I submit, as an illustration, a minicomputer program and a calculator program for printing out the values −9, −8, . . . through +9. (See illustration).

After comparing these two programs for ease of reading, let us examine the question of the "language", mentioned by Mr. Nigberg. While the calculator program is immediately executable, the minicomputer program is always written in a "language" (in our example, assembler), and must first be compiled, or assembled. This step may involve reading in a compiler, or an assembler (sometimes a 20-min procedure). Ever more often it will involve use of a large computer.

CALCULATOR PROGRAM

ADDRESS	PROGRAM STEP	COMMENTS	ADDRESS
00	9	9 → KEYBOARD REG.	50
01	S #	CHANGE SIGN	51
02	M	- 9 → MEM. I	52
03	#	PRINT - 9	53
04	1	}	54
05	A	} ADD 1 → MEM. I	55
06	R	RECALL MEM. I	56
07	#	PRINT MEM. I	57
08	+	MEM. I → ADDER	58
09	9	}	59
10	-	} - 9 → ADDER	60
11	T	RECALL TOTAL	61
12	B	}	62
13	-	} IF NEGATIVE, BRANCH	63
14	0	} BACK TO 04	64
15	4	}	65
16	E	ELSE, LINESPACE	66
17	K	STOP	67

MINICOMPUTER PROGRAM

LABEL	OPERATION	OPERAND	COMMENTS
	REL		ASSEMBLE IN RELOCATABLE MODE
	RSST		RESTORE SYMBOL TABLE
VAL	DEC	-9	-9 → "VAL"
CRLF	HEX	X'8DØA'	HEX 8DØA → "CRLF"
	JMP X	*-1	RESET PROGRAM COUNTER
	JAM X	PRT9	JUMP AND MARK TO ADDR.WORD
	JMP X	[PRT9]	RETURN TO PROGRAM
STRT	SIZ	1	WORD LENGTH
LOOP	OUT	CRLF,X'312Ø'	OUTPUT "CRLF",HEX,TTY,2 W.
	OUT	VAL,X'Ø11Ø'	OUTPUT "VAL",DEC,TTY,1 W.
	LDA	VAL	"VAL" → REG.A
	ADD	I,+1	+1 REG.A
	STA	VAL	REG.A → "VAL"
	SDG	I,+9	SKIP DEC IF > 9
	HLT		HALT
	SVST		SAVE SYMBOL TABLE
	END	STRT	END ASSEMBLY; JUMP TO "STRT"

May I venture to predict that there will be an ever growing number of repetitive applications, where the user wants a large variety of immediately available programs on his desktop! And may I promise that the calculator people, too, are likely to develop interesting novelties!

It is quite likely that the economic philosophy of the Seventies should be favorable to an increasing use of economical equipment. And the programmable calculator will become more and more powerful. One more generation, and the difference between the new programmable calculators and the minicomputers may be in the simplicity of programming and ease of use only!

Thomas P. Bun
Sr. Staff Engineer
Marchant Electronics
Oakland, CA 94608

More on Engineering Lobby

Sir:

Re the comments on lobbying in Signals and Noise, June 15 issue.

A lobby has been set up and in operation for nearly 40 years. It is the National Society of Professional Engineers. For years, it was possible to become a permanent member of NSPE only if you were a registered professional engineer in a state. (Student memberships and associate (engineer-in-training) memberships of limited duration were and are available to nonregistered engineers). Now, however, permanent membership with essentially full rights (Senior Associate Member) is available to certain grades of members of the technical societies. Also available to any engineer, is the affiliate grade (Government Action Affiliate). This grade can cost as little as $10 (state only), $15 (national only) or $25 (state and national), with additional charges for optional services such as magazine subscriptions. Details can be obtained from your local chapter of NSPE or from NSPE at 2029 K St. N.W., Washington, D C 20006.

I suggest that the $1 per engineer lobby hypothesized by Mr. Jack Wiens is not realizable—collection costs would eat up the money. The NSPE services come fairly close in cost—and have been proven by the test of time.

Robert Irving
Senior Member, IEEE
Senior Assoc. Member, NSPE

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Index to Ads, Products and Literature

Application Notes

RFI shielding effectiveness of "Sticky-Fingers" copper finger contact strips is evaluated in a report giving results of certified tests, including descriptions of test conditions and evaluation results when exposed to magnetic, electrical and plane wave fields. Instrument Specialties Co., Inc., 244 Bergen Blvd., Little Falls, N J 07424. **225**

Voltage regulator an 8-page application note shows how to evaluate and apply voltage regulator specifications to realize their full potential in circuits. Subjects discussed include constraint and performance specifications for monolithic, hybrid and discrete dc regulators. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **226**

"Predicting Servomechanism Dynamic Performance Variation from Limited Production Test Data" is an article reprint dealing with the type of data necessary to determine production spreads for large families of electrohydraulic servos, and methods by which adequate performance can be guaranteed with a minimum of check points. Weston Instruments, Inc., County Line Rd., Hatboro, PA 19040. **227**

Electrical connections to incremental shaft angle encoders are the subject of a 12-page technical note, TRN-101. The note deals with proper encoder loading, voltage drops in the power lines and recommended procedures for connecting cables to encoders. Trump-Ross Industrial Controls, Inc., 265 Boston Rd., Billerica, MA 01862. **228**

Custom analog computational systems are the subject of a 22-page set of application bulletins which describe the versatility and simplicity of putting together systems that will meet practically any specification. Systems are described with illustrations for a variety of applications. Bell & Howell, Control Products Div., 706 Bostwick Ave., Bridgeport, CT 06605. **229**

"Alphanumeric Devices, Application Notes" is a 12-page brochure describing basic circuits that may be used to operate GE alphanumeric tubes in display applications. Technical data are presented in tabular and graphical form, and general characteristics of the tubes are included. Imaging and Display Devices, General Electric Co., 309 Nolan Building, 2100 Gardiner Lane, Lousville, KY 40205. **230**

"Power Failures Can Be Security Failures" is an article reprint which explains the problems that can occur when the normal source of electric power is interrupted in a manufacturing or commercial facility, and suggests that these problems can be minimized with a "Power Failure Plan". Onan Corp., 1400 73rd Ave. N.E., Minneapolis, MN 55432. **231**

"Elements of Spectropolarimetry" is a five-page application note which gives definitions and equations for plane, circular and elliptically polarized light. It explains optical rotation and circular dichroism and the relation between the two. A brief introduction to optical activity measurement in molecular spectroscopy is provided. Durrum Instrument Corp., 3950 Fabian Way, Palo Alto, CA 94303. **232**

"Bridge Balancing and the Two-Phase Lock-In Amplifier" is the title of Application Note AN-104 which describes the use of two-phase lock-in amplifiers in balancing ac bridges. In addition, the brochure provides diagrams of 13 types of impedance bridges, their balance equations and the advantages and disadvantages of each. Princeton Applied Research Corp., Box 565, Princeton, N J 08540. **233**

Reprints Available in this issue are offered as follows:

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L63	How to Measure SCR Currents	40

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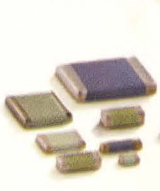

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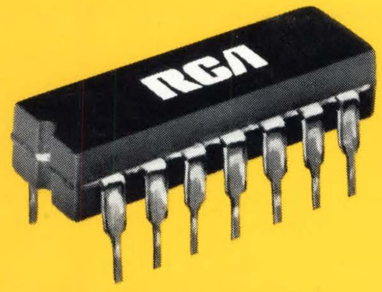

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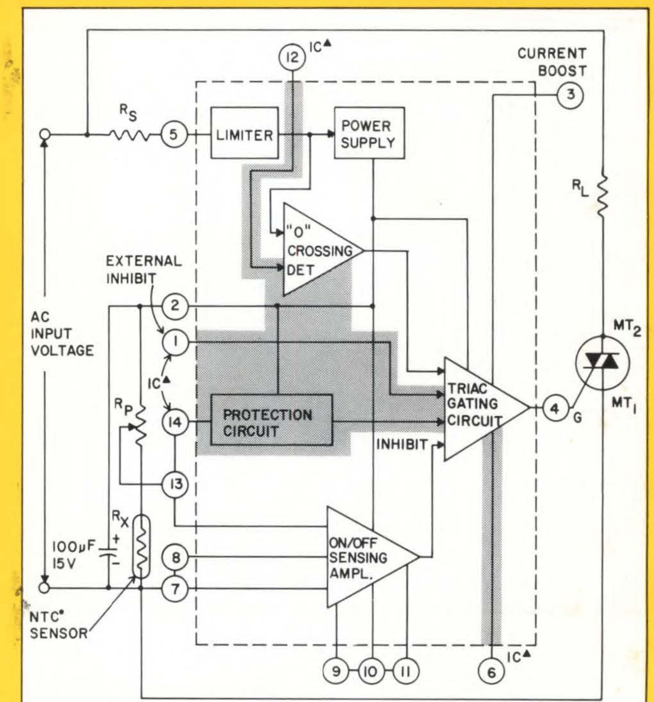

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• External trigger & inhibit (Terms. 6 & 1)	√	√	
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