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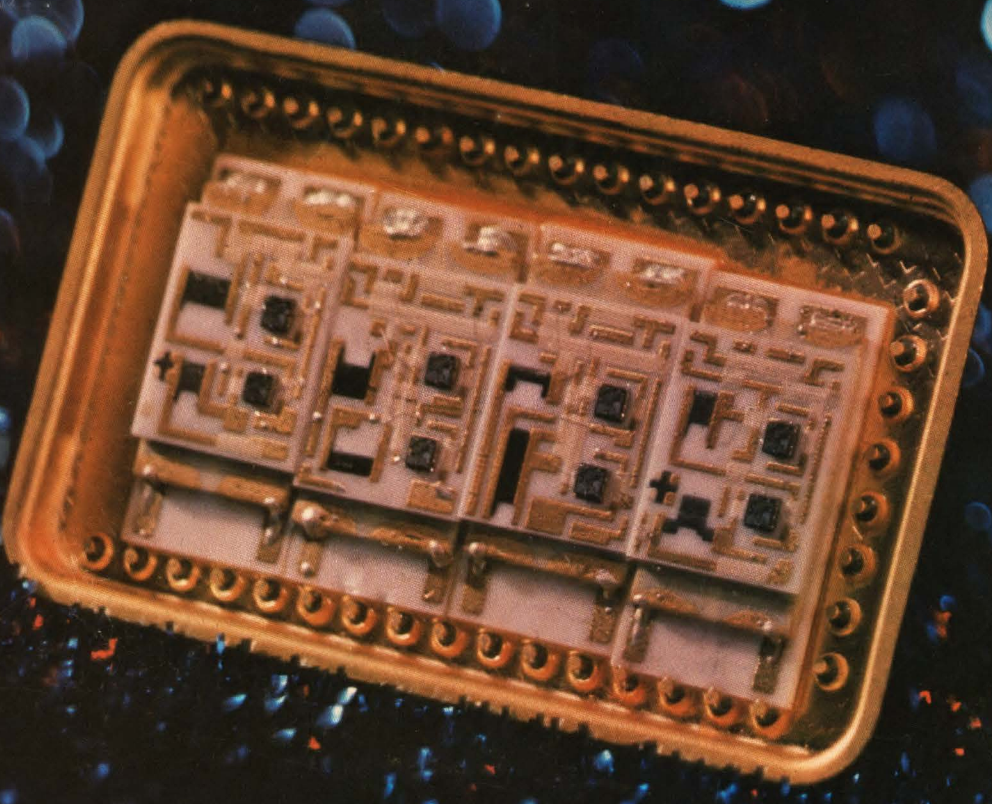
Trends in Active Filters
One Pot Controls Many VRs
Compare Phase and Frequency
Improve FET Diff Amp CMR



A CAHNERS PUBLICATION

NOVEMBER 1, 1970

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Frequency Range	0.1-400 MHz	0.4-1.3 GHz	30-300 MHz	0.1-1300 MHz	0.1-1300 MHz	0.1-1300 MHz
Nominal Gain	20 dB	22 dB	30 dB	23 dB	22 dB	45 dB
Gain Flatness	±0.5 dB	±1 dB	±1 dB	±1.5 dB	±1.5 dB	±3 dB
Noise Figure	<5 dB	<5 dB to 1.0 GHz <6 dB, 1.0-1.3 GHz	<10 dB	<8 dB	<10 dB	<8 dB
Output Power @ 1 dB Gain Compression	>+7 dBm	>—3 dBm	>+19 dBm	>+7 dBm	>+14 dBm	>+14 dBm
Price	$550	$600	$450	$700	$800	$1225

CIRCLE NO. 35

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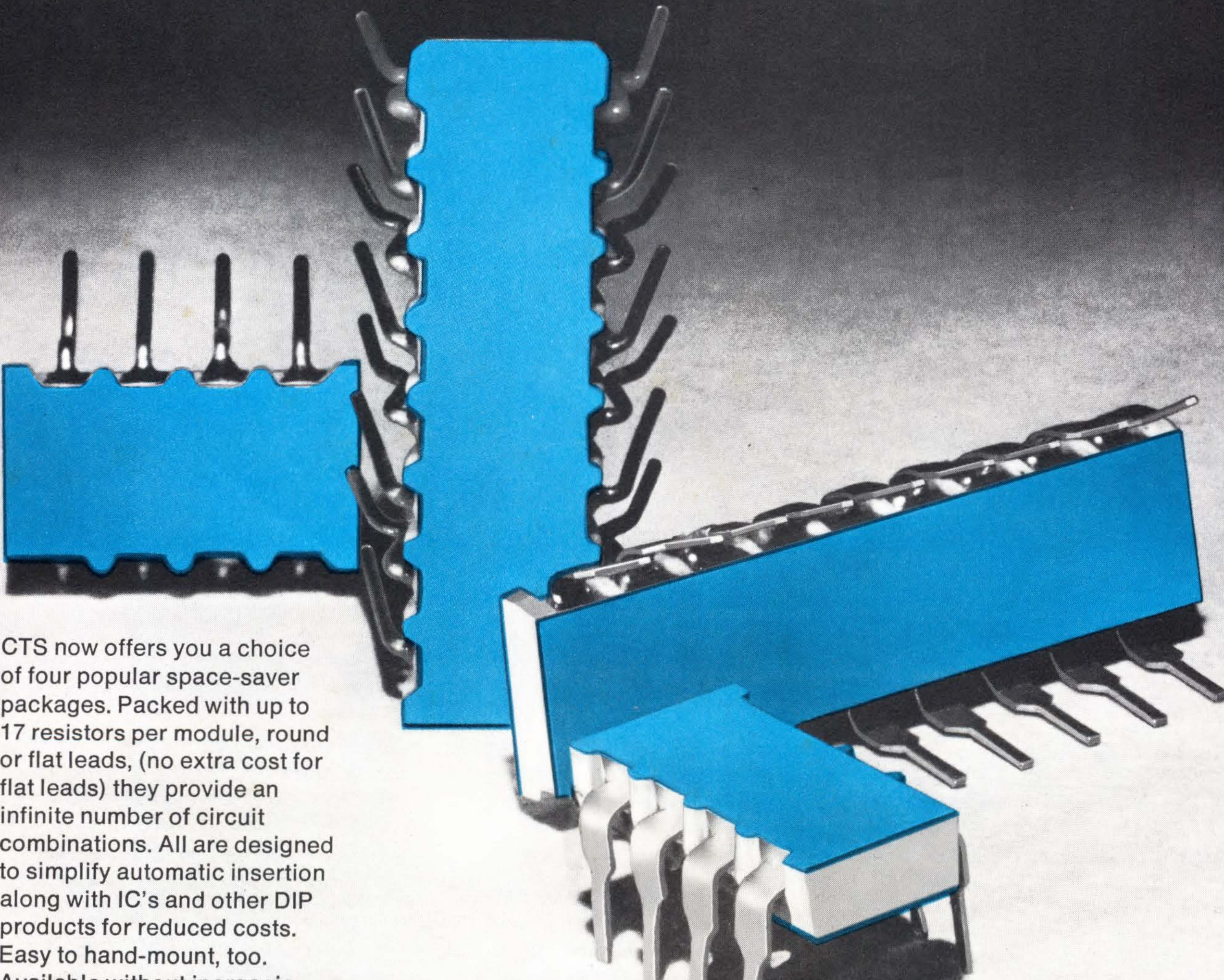

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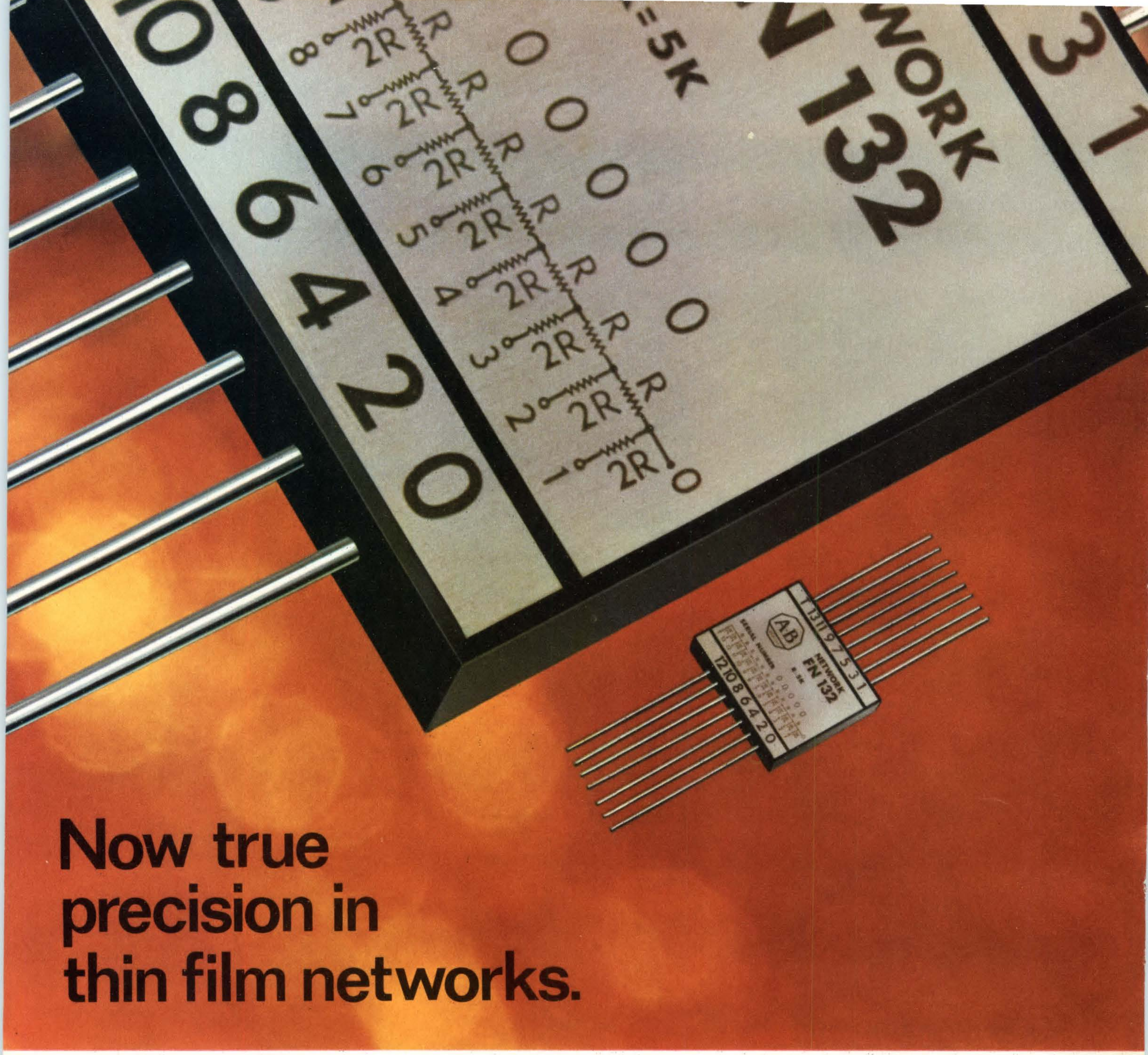

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TCR TRACKING	$\pm$ 5 ppm/°C standard to $\pm$ 1 ppm/°C special
TOLERANCES	Absolute to $\pm$ .01% @ +25°C Matching to $\pm$ .005% @ +25°C
RESOLUTION	Line width and spacing to .0001 inch
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NEW DIMENSION ELECTRONICS

CIRCLE NO. 8

NOVEMBER 1, 1970
VOLUME 15, NUMBER 21

EDN

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photo depicts Varadyne's 8-pole active filter. Special 3-part hybrid stacking includes a base substrate, a capacitor that serves as a substrate and another substrate. See article on p. 17.

EDN's DESIGN ACTIVITY FILING SYSTEM is used to classify all Design Feature and Design Idea articles. The first word indicates the activity discussed in the article. The second word denotes the principal product being used in the activity. The third word modifies the second word. Finally, a number is used to specify frequency, where applicable. This number is the $\log_{10}$ of the frequency in hertz.

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CIRCLE NO. 5

Editorial

Is It Time for Engineering WPA?

Because the supply end of the engineer supply-and-demand teeter-totter is up and demand is down, many engineers are out of work. The situation developed as a direct result of an artificially inflated market for engineers created by defense and aerospace spending.

In retrospect, it is not difficult to follow the cause-and-effect relationships that have led to the current low level of government spending and, hence, the technical manpower surplus. Yet, we feel that calls for federal programs to restore demand for engineers can be potentially dangerous.

In the first place, many jobs with large aerospace firms paid handsomely, but demanded very little. In some instances, paperwork accounted for as much as one third of total program cost, and many paper-pushing engineers stagnated technically. Perpetuating this situation by creating new heavily-funded agencies would be economic idiocy. It is a luxury we once could afford but no longer can.

Second, "positions" created solely for the sake of giving people work don't work. Today as never before, work must be meaningful if an employee is to be motivated and satisfied. This country has seen enough of the interminable games of "battleship", stockmarket plotting and other diversions that were too often the rule during periods of "full employment". We would be deceiving and cheating engineers to again make available "positions" instead of meaningful work.

Third, the theory that technological achievement is a straight-line function of the number of engineers does not hold up in today's competitive marketplace. Important advances come from relatively small groups of highly-motivated engineers who work in creative environments – not from large numbers whose initiative is stifled.

Fourth, any company with one customer is on thin ice, and any engineer who works for such a company is on equally thin ice. Companies who will emerge from the present economic mire will be those whose markets are diverse enough to withstand the cancellation of a contract or two.

Fifth, any engineer who plans to wait for the return of a warm-body season in defense and aerospace may have a very long wait. The Pentagon is showing signs of demanding products commensurate with the asking price, so the outlook for clerks with EE degrees is growing bleak.

In previous columns we have criticized the destruction of capable engineering teams. Yet, we are not sympathetic with programs that would perpetuate the causes for our present dilemma. This is no time to begin WPA for engineers.

G Boe

Editor

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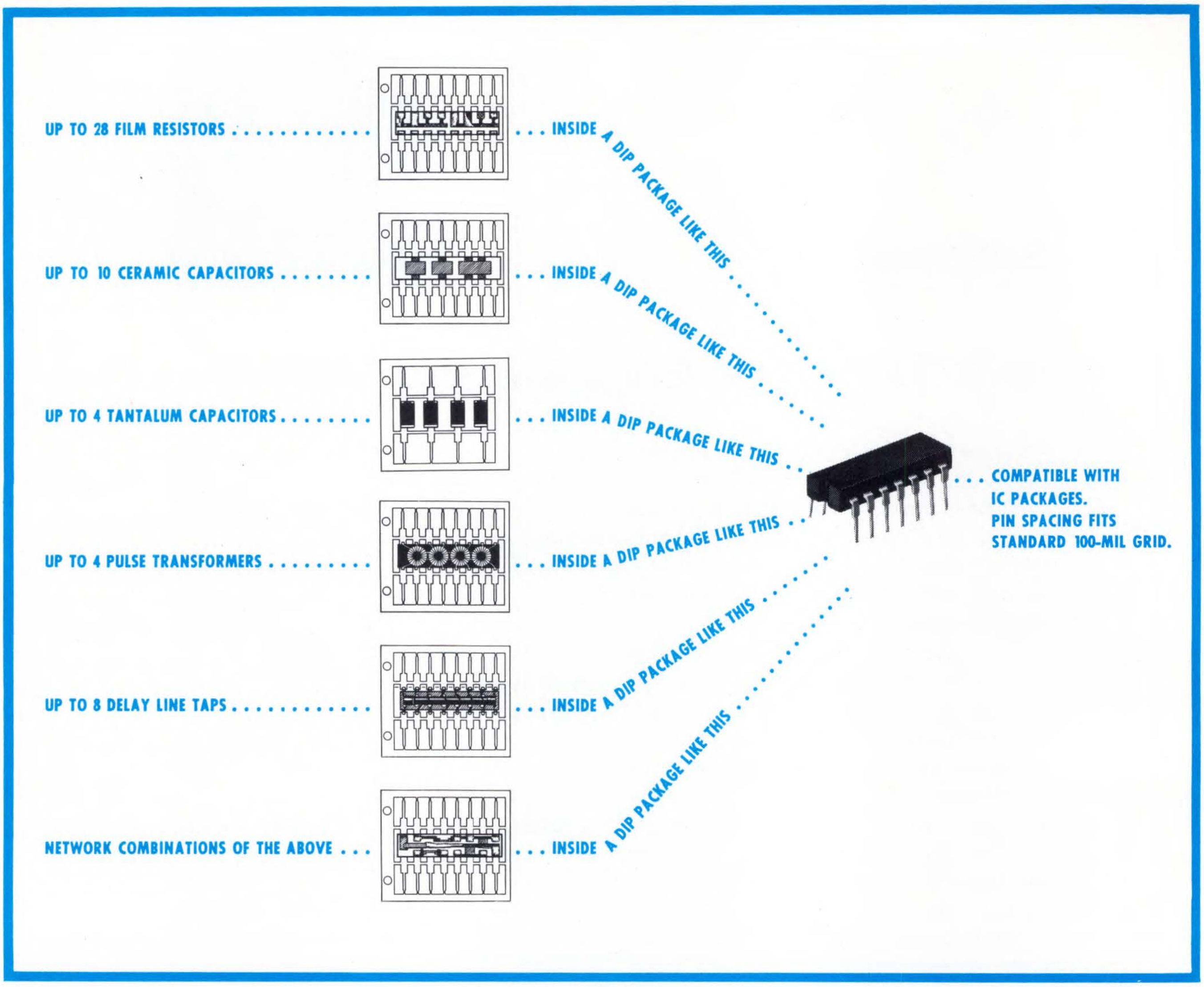

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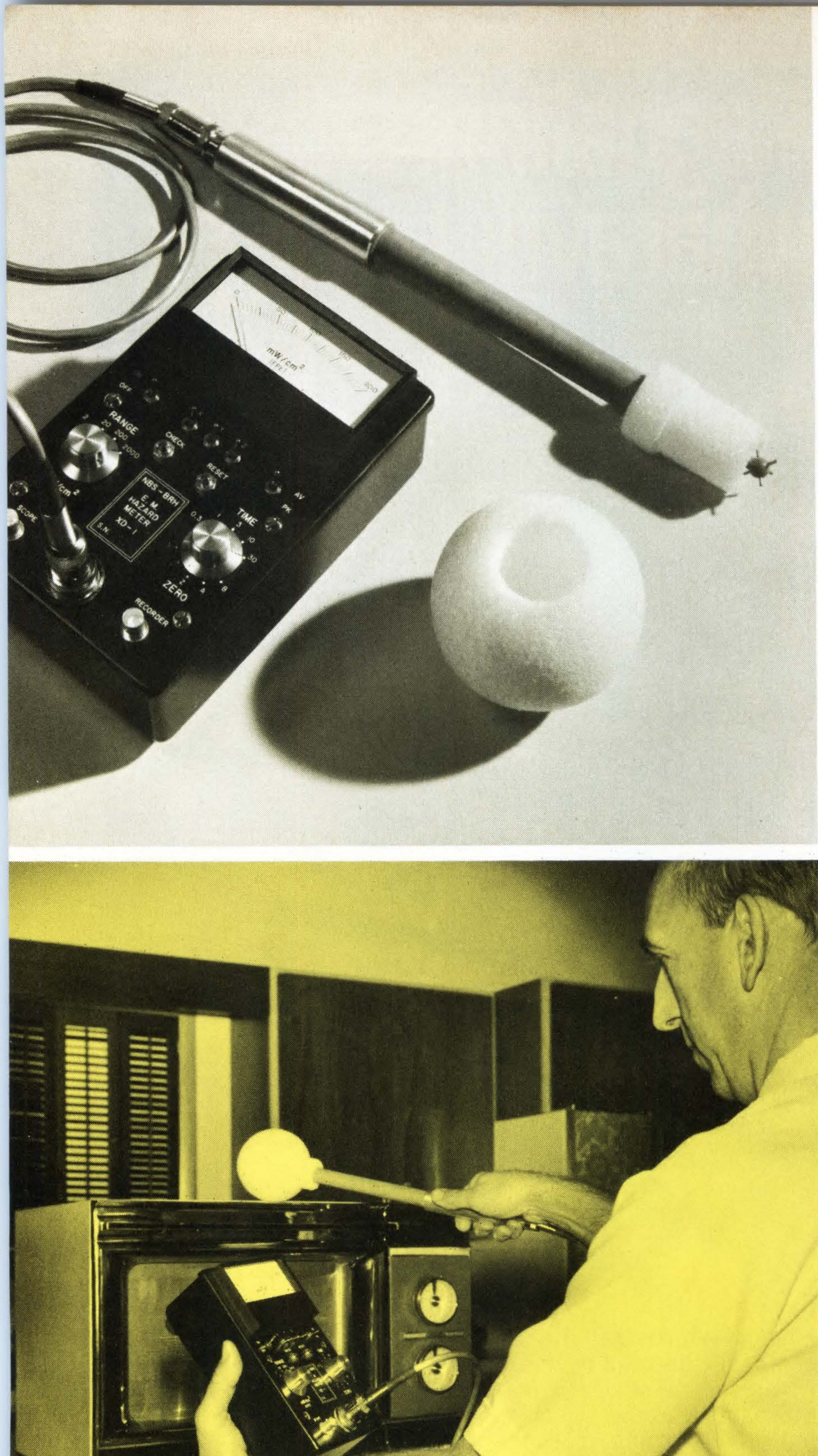


Signals from three orthogonal dipoles at wand's end (top) are detected by hot-carrier diodes and transmitted to remote amplifier by parallel-wire high-resistivity plastic conductors that also filter the rectified voltage. Non-linear summing amplifier in meter produces signal composite, gain-controlled for sensitivity. Plastic foam ball protects probe head in use (bottom) as operator takes reading at microwave oven wave-trap opening. Battery-powered instrument operates from below 1 GHz to 3 GHz with dynamic range of 40 dB and rise time of 300 μs. Instrument is capable of 10 μs rise time with modification. (NBS photos)

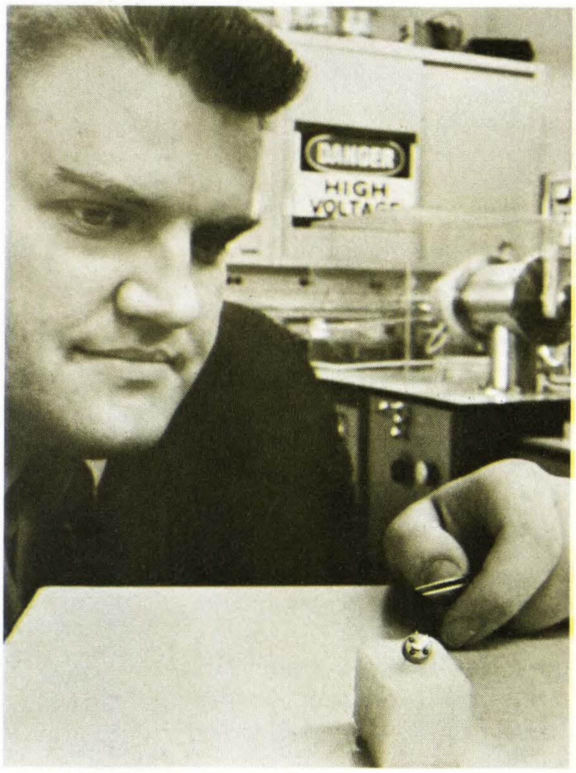
NBS Develops EM Hazard Meter

A giant step toward easier measurement of potentially hazardous electromagnetic radiation has been taken with development of an energy density type sensor by the Electromagnetics Div. of the National Bureau of Standards Boulder Labs. It provides an easy, practical means of measuring complicated EM radiation from radars, high-power radio transmitters, and especially from microwave ovens. This is an area of mounting concern because of proliferation of these appliances.

Funded by HEW's Bureau of Radiological Health, NBS research aimed at complicated fields near microwave oven cracks that heretofore have not been easily measured. Present prototype instruments consist of three short, equal dipoles mounted on the end of a wand. Each dipole responds independently to an orthogonal component of the field, and its signal is summed with the other two in the metering instrument. Instrument responds to energy density (a good indicator for complex fields), translates to equivalent power density in mW/cm^2 (the terms of present radiation standards). Average or peak values are switch-selectable, and scope and recorder outputs are provided.

The beauty of the new probe is that any orientation in the field gives the same reading. The orthogonal relationship of the dipoles yields near-perfect isotropic response for any polarization, regardless of multipath or reactive near-field components. This feature implies minimal training for operators.

Ion Implantation Forms LEDs in SiC



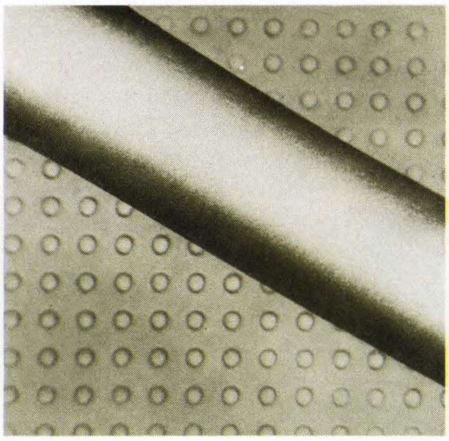
Newest use of ion implantation is making light-emitting diodes in silicon carbide. General Telephone and Electronics' experimenters have formed LED junctions in boron- and aluminum-doped p-type material by implanting n-type nitrogen ions. The resulting junctions emit, respectively, orange and green light.

Experimental models under development at GT&E's Bayside, N.Y., labs look like promising replacements for many of the small light sources presently used in industry, business and homes. Dr. Lee Davenport, president of GT&E Labs. foresees a "much greater selection of colors" from the ion implantation process, since emitted wavelength depends on the magnitude of the energy band gap. This, in turn, is an inherent property of the dopant used in the silicon carbide.

Ion implantation is performed at room temperature, and this makes possible the use of difficult materials. This is in distinct contrast to the high temperature necessary in the diffusion process by which LEDs have heretofore been fabricated.

Dr. John C. Miklosz, physicist, and Dr. Rubin Summergrad, chemist for GT&E Labs. also cited the higher legibility of LED alphanumerics that would result from this process. GaAsP LEDs have a characteristic red emission which sometimes inhibits legibility.

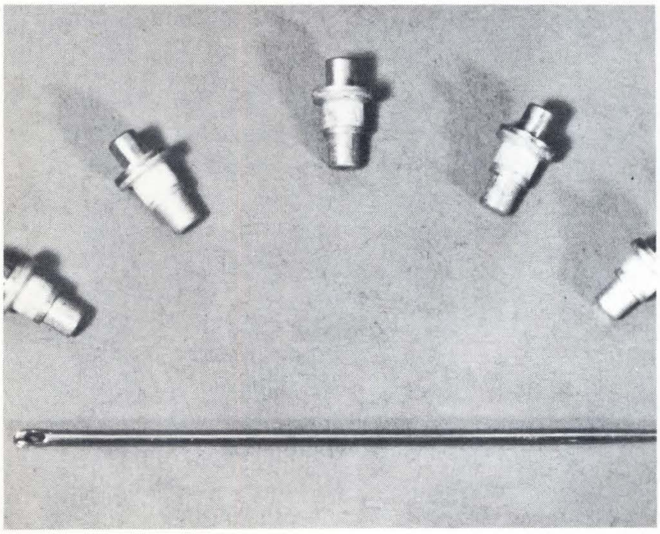
Picturephone Packs in Photodiodes



No bigger than a nickel, Bell System's Picturephone silicon target (left) contains 850,000 photodiodes, so small they are dwarfed by a human-hair-sized wire (right). Photodiode density makes operation possible at a wide range of light levels. First commercial Picturephone sets are now in production at Western Electric's Reading (Pa.) plant. Ultraclean facilities are necessary, since a single dust speck could block several photodiodes. Silicon target's inherent characteristics reduce lag, enable single-frame recovery from high light levels and reduce target fatigue.

Test Buoy Detects Ocean Pollutants

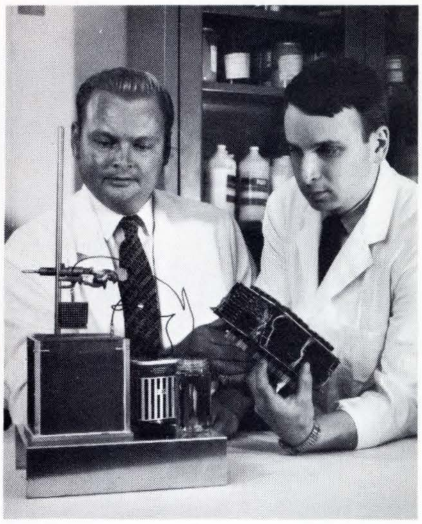
Instrumented buoys, anchored untended in ocean or inland waterway, could form a network of reporting stations for weather forecast, pollution control, fishing and other industry. A Lockheed-California Co. research project may be the prototype. A standard aid-to-navigation buoy anchored in San Diego bay (photo), instrumented with sensor systems and automatic data handling equipment, measures changes in water and air temperature, wind speed and direction, barometric pressure, and other environmental conditions every 6 min and transmits the information to the shore-based computer center every 2 hr. Compact instrument package, its accuracy, low power requirements and long life expectancy provide easily-maintained, low-cost environmental monitoring.



Fast Pulses from Fe-Doped GaAs Diode

New gallium arsenide diode which Matsushita Electric calls a "jump diode" opens up new applications as a fast pulse generating element. A high resistive layer in the GaAs crystal was created by doping it with iron, which acts as a "deep level impurity". The device generates fast pulses on the order of 300 ps at 100 times as large output as the tunnel diode. Pulse repetition rate can also be modulated by varying applied voltage. Its developers anticipate that conventional pulse generating circuits in radar or other equipment can thus be made small and simple. The company has applied their "jump diode" in a small, light weight pulse generator, a pulse frequency modulator, and a decoder.

Coats Dunked Parts



IBM chemists are applying a century-old process, "electrophoretic deposition", to coat computer parts against corrosive environments. Biologists once used the process to separate and collect proteins. An anode and a cathode are immersed in a suspension of plastic particles. Voltage applied causes the plastic particles to collect on and adhere to one of the metals. Coatings are smooth, high-quality, and pinhole-free, from 0.1 to 50 mils thick.

Sylvania Bails Out

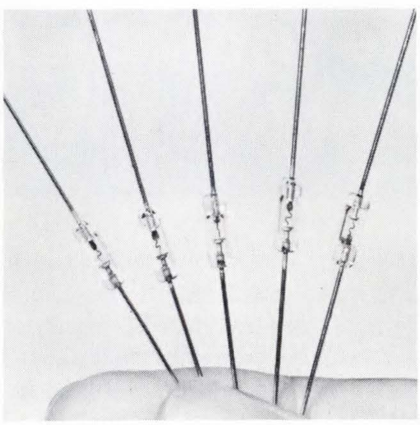
Citing defense spending cuts and extreme price competition in computer industry sales, Sylvania's Semiconductor Div. is in the process of phasing out. Everything goes but the microwave diode department, said company President Garlan Morse, as he decried "disorderly conditions (in) this branch of the industry". Sylvania was one of WWII's first microwave diode producers.

EIA Bucks the Fed

Electronic Industries Association (EIA) has filed a statement opposing the Federal Trade Commission adoption of a regulation on power output ratings of consumer electronic amplifiers. Several different power ratings are used by manufacturers and retailers in describing and advertising hi-fi equipment. EIA's Consumer Products Div. states that it expects to have a new EIA industry standard on this subject ready by Dec. 1, 1970, and that FTC regulation is unnecessary.

Piezo Resonator Bows

Resonators, almost impossible to make in solid-state because they depend on coils, have gone solid-state with piezoelectric ceramics. Matsushita Electric has developed a new ceramic resonator, the "Piezonator", that works at frequencies between 30 and 200 MHz. It uses a $PbTiO_3$ (lead titanate) ceramic, which operates at high temperature and high frequency, and a new fabricating method. Applications include tuned TV video circuits and filters for video circuits.



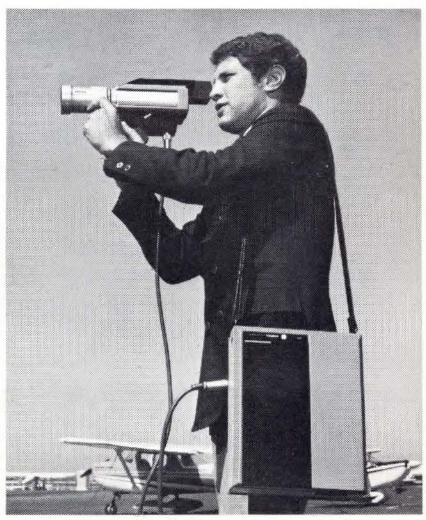
Previews Acoustics

Subtle design differences can produce a concert hall with brilliant acoustics, or one full of ringing echoes. Now, with a computer's help, a listener, seated before a bank of loudspeakers in a small echo-free chamber, can experience the sounds of a large concert hall—while the hall is still in the planning stage.

While reverberations add a rich, familiar quality to church services and concert performances, they must be kept to a minimum in lecture rooms and theatres. By using a computer, Dr. Manfred R. Schroeder, Drittes Physikalisches Institut, Goettingen University, Germany, is able to determine how long a sound in a hall will reverberate. Starting with reverberation-free speech or music, Dr. Schroeder has the computer add echoes and reverberations characteristic of the hall being planned. When the sound is played through several loudspeakers in a special, echo-free chamber, the listener experiences the sensation of being in the hall.

Incredible Shrinking VTR

New Ampex "Instavision" system is the smallest cartridge-loading videotape recorder/player to date for color or B/W home recording and playback as well as CCTV. Hand-held camera weighs 5 lb and recorder/player is easily portable at less than 16 lb with batteries. Trigger control operates both camera and recorder, which can also operate from household current.



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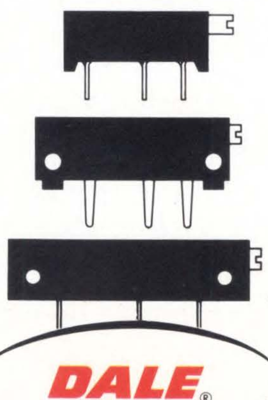
8300 SERIES Sealed/Unsealed; 10Ω to 2 Meg., ±10% 100Ω thru 500K, ±20% all other values; .75 watt at 25°C, derated to 0 at 105°C; T.C. 150 ppm/°C, 100 ppm available; .36 H x .28 W x 1.00 L.

8100 SERIES Industrial counterpart RJ-11; 10Ω to 2 Meg., ±10% 100Ω to 500K, ±20% other values; .75 watt at 70°C, derated to 0 at 125°C; T.C.150 ppm/°C, 100 ppm available; .28 H x .31 W x 1.25 L.



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2400 SERIES Sealed/Unsealed; 10Ω to 50K, ±10%; 1 watt at 40°C, derated to 0 at 125°C; .31 H x .16 W x .75 L.

2300 SERIES Sealed/Unsealed; 10Ω to 50K. ±10%; 0.5 watt at 25°C, derated to 0 at 105°C; .36 H x .28 W x 1.00 L.

2100 SERIES Industrial counterpart RT-11; 10Ω to 100K, ±10%; 1 watt at 70°C, derated to 0 at 125°C; .28 H x .31 W x 1.25 L.

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CIRCLE NO. 7

ONE-CHIP COMPUTER—HOW SOON?

By 1990, the computer industry may well be larger than the gross national product was in 1940 predicts Robert E. Markle, Vice-President of Cogar Corp.

Large-scale integration will be the driving force behind the fulfilment of this prophecy. LSI will be absolutely essential to the future expansion of the knowledge industry. If the industry is to solve its problems of reliability, service and maintenance; if the industry is to broaden the applications of the computer; if the industry is to solve the man-machine interface and the software problems, then LSI must permeate our machines.

While one group of engineers battles LSI production problems, systems designers face another set of even more perplexing problems. These cannot be ignored, because they limit the speed at which LSI technology can pervade machine designs.

First comes the designer's dilemma when partitioning his system to fit the technology. He soon finds that each design is unique and that he has two alternatives. He may elect to back off the level of integration to medium scale in order to obtain a greater degree of commonality. The other alternative is to make a greater effort toward the creation of common functions, even to the extreme of new machine design.

Utilization of the technology is also a long and involved cycle. It begins with a concept and progresses through design, followed by the building and evaluation of a prototype. All this must be completed before production. Under all but the most exceptional circumstances, 4 to 10 years elapse before a new technology sees commercial application.

Then there are the non-technical problems. To be successful, the technologist and the system designer must communicate on a real-time basis. Yet each may feel threatened by the other because of the change in relationship and the increasing need for each to know more of the other's business.

Effective strategy for applying the technology is even more difficult to formulate. The business risks are considerable, and the payoff can be fairly uncertain. Industry has more prophets than implementers, and prophets generally underestimate the time needed for implementation. Now, more than ever, choice of a supplier is critical, because a manufacturer's dependence on his capability may become absolute. If, on the other hand, the computer manufacturer attempts to reduce risk by the strategy of using "tried-and-true" technology, he faces the threat of early obsolescence through the LSI user's competition.

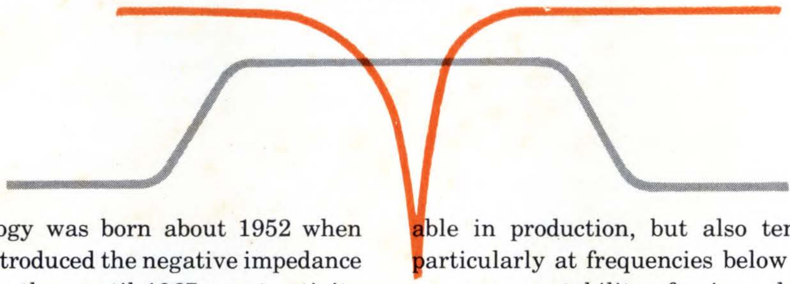
Obviously, then, the change to LSI computers will be more evolutionary than revolutionary. Potentially, the step up to LSI is a much bigger one than the step from transistors to simple integrated circuits was. Even so, it will still take many years for semiconductor manufacturers and systems designers to deliver on the promise of this new technology.

None of these problems can prevent the dominance of LSI in future computers. Benefits that only LSI can provide are absolutely essential.

SENSITIVITY— KEY TO ANALOG ACTIVE FILTERS

You've written the transfer function and have solved for all component values. Now don't make the mistake of reaching for any "old" components to configure that active filter. If you do, sensitivity problems are likely to catch up with you.

EDN Staff



Analog filter technology was born about 1952 when Linvill of Bell Labs. introduced the negative impedance converter (NIC). From then until 1967, most activity centered around the NIC, positive feedback and the gyrator. Very little attention was paid to sensitivity, now considered a very critical parameter. By sensitivity we mean the percent change in a filter characteristic caused by the percent changes in the components that make up the active filter. Gunnar Hurtig of Kinetic Technology, Inc. (KTI) refers to the 1952-1967 period as the presensitivity era and states that practical active filters did not emerge until designers paid more attention to this characteristic.

Today, with sensitivity a byword among active filter suppliers and with the combination of integrated-circuit operational amplifier costs coming down as the use of computers for design goes up, the active filter market appears to be in for a great future.

Why Active Filters?

In one of its application notes on active filters, Analog Devices provides a comparative assessment of active and passive filters. This note states that, in general, active filters overcome the RLC filter problems of insertion loss, critical tuning, and loading while readily achieving low-frequency operation. Below 100 Hz, active filters using RC networks and feedback amplifiers are generally advantageous. Above 20 kHz, combinations of amplifiers and LC networks should be considered for "realizable" filters. In the frequency range from 100 Hz to 20 kHz, it may be a close decision between active and passive filters, considering performance vs cost.

ACCURACY: Inductors have losses in their cores and they also have copper windings that are not only variable in production, but also temperature sensitive, particularly at frequencies below 100 Hz. Where high accuracy or stability of gain and cutoff frequency are required in the passband, as in data transmission systems, active filters have a distinct advantage, since their gain can be determined entirely by stable resistors, capacitors, and feedback amplifiers. In contrast to passive filters, there is a noise threshold associated with active filters which establishes the minimum level for signal discrimination.

COST: Using integrated circuit designs, active filters have a tendency to be lower in cost than passive LC circuits below 100 Hz. In frequency range from 100 Hz to 20 kHz, the manufacturing costs of active vs realizable passive filters depend upon specified accuracy and component count, and each approach has to be considered on its own merits. LC circuits tend to be more economical for extremely sharp cutoff filters, while active RC filters tend to be more economical where high accuracy is required.

For a look at active filter performance limits, Burr-Brown Research supplied the list in **Table I**. These figures indicate what manufacturers generally can supply today in a single pole-pair bandpass filter. Each parameter must be considered separately because obviously all could not be pushed to the limits simultaneously.

Manufacturer Suggestions

Whether to let a manufacturer supply the required filter, or to buy a universal building block and add passive components is a decision all users must make.

While practical Qs to 100 can be obtained in a completed filter, manufacturers like Burr-Brown recommend that users not fool with adding components and

(Continued)

doing their own tuning for Qs above 10. Engineers at Burr-Brown claim that their ability to hand select matched components from production provides much value added for the customer where characteristics like temperature drift and tracking are concerned. To assess this value added, Burr-Brown claims the filter cost to a user can be considered to consist of three equal parts: one third for material, one third production and one third for testing and tuning.

PARAMETER	PRACTICAL PERFORMANCE LIMITS
Center Frequency, f_c	0.01 Hz to 1 MHz
Center Frequency Tolerance	±0.25%
Center Frequency vs. Temp. as low as	50 ppm/°C
Passband Gain Accuracy @ 25°C	±1%
Gain vs. Temp. as low as	500 ppm/°C for Q = 50
Q = f_c/bandwidth	1 to 100
Q tolerance at 25°C	±2%
Q vs. Temperature as low as	500 ppm/°C
Input Impedance	up to $10^{11}\Omega$
Output Impedance	0.1Ω and up
Output Range	up to ±100V (depending on supply voltage)
Output Current	up to ±100 mA at ±10V with ±15V power supplies
DC offset voltage @ 25°C	as low as 50 μV
DC drift (−25°C to +85°C)	as low as 1 μV/°C)
Noise (wideband)	as low as 50 μV, rms
Power Consumption	as low as 10 mW

Table I. Performance limits for single pole-pair band-pass active filter. (*BURR-BROWN RESEARCH*).

Other companies prefer to offer both completed units and a universal building block to which a user can add external components to obtain the filter characteristics he requires. Motorola engineers claim that when they enter the market with a standard line of active filters sometime around mid-1971, tables will be offered to the user from which component values can be determined. Then, with additional material on sensitivity, a user can select the type of components required to meet the sensitivity needs of his circuit. For its completed filter line, Motorola will use thin-film resistors to cancel the temperature coefficient of the capacitors used.

State Variable Approach

To configure their standard line of active filters, most suppliers use the state variable approach to design in which three active elements comprise the loop. The circuit of **Fig. 1** illustrates this technique as used by Genisco Technology to configure both complete and programmable filters.

According to Genisco, state variable methods offer the most stable characteristics, highest Q of any technique, easy independent f_0 and Q adjustment and the greatest versatility with simultaneous low-pass, band-pass and high-pass outputs. Motorola, in its publication "Motorola ICs for Modem and Terminal Systems", provides a succinct treatment of this state variable approach to filter design. Portions are repeated here to place this technique in its proper perspective. This description focuses on biquadratic filter techniques which have been known for a long time, but which have become popular only recently because the low-cost integrated-circuit operational amplifier made them economically feasible. These techniques require several active elements instead of only one, but this trade-off today usually results in production cost savings.

The general form of transfer function is:

$$\frac{V_2(s)}{V_1(s)} = \frac{ms^2 + cs + d}{s^2 + as + b}$$

where the denominator coefficient of s^2 is normalized

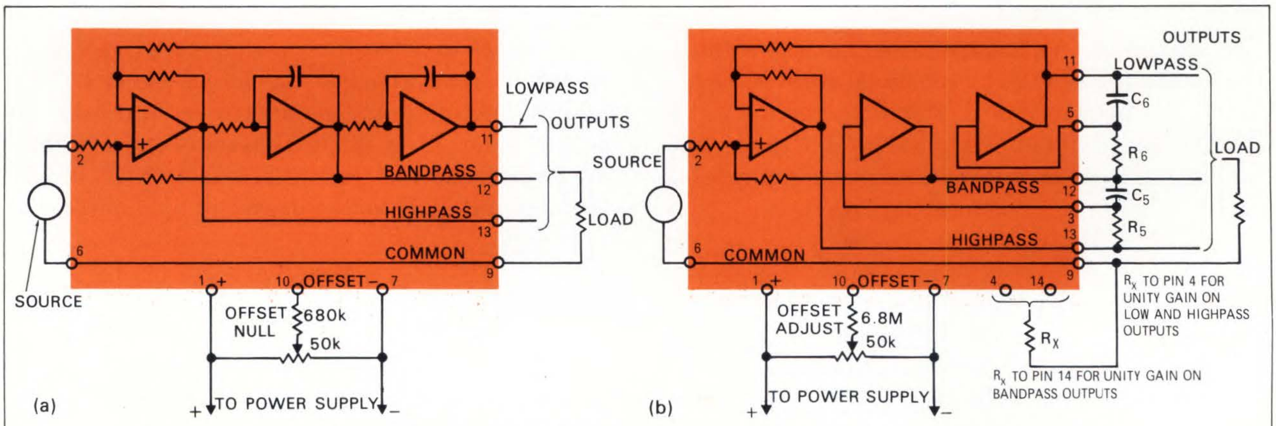


Fig. 1 – **State-variable** completed active filter (a) with passive components internal and (b) programmable filter with provision to add passive components externally. (*GENISCO TECHNOLOGY*).

to unity. This expression has been dubbed a "biquad" because of the quadratic form of both numerator and denominator.

In a control system approach either the numerator or denominator may be rewritten in a different, more understandable form from a steady-state frequency point of view:

$$s^2 + as + b = s^2 + 2\zeta\omega_0 s + \omega_0^2$$

where ω_0 is the "natural" frequency and ζ (zeta) is the damping factor.

The general form may be rewritten as:

$$\frac{V_2(s)}{V_1(s)} = \frac{m(s^2 + 2\zeta_z\omega_z s + \omega_z^2)}{s^2 + 2\zeta_p\omega_p s + \omega_p^2}$$

Some general approximations of filter performance can aid in the design and evaluation of this approach without resorting to a complete frequency analysis of any particular design. In particular we're interested in coefficients contributing to dc gain, stop-band attenuation, and maximum out of band attenuation.

The initial item of concern, dc gain, can be readily discerned from the last equation if "s" is allowed to go to zero, leaving the condition:

$$\frac{V_2(0)}{V_1(0)} \quad \frac{m\omega_z^2}{\omega_p^2} = \text{dc gain} = T(0)$$

which allows one to calculate m knowing the other factors. As frequency increases, $s \rightarrow \infty$, and the eventual transfer function diminishes to a single value:

$$\left.\frac{V_2(s)}{V_1(s)}\right|_{s \longrightarrow \infty} = m = T(\infty)$$

This makes it possible to calculate the magnitude of attenuation between stopband and passband as:

$$\frac{T(0)}{T(\infty)} \quad \frac{\omega_z^2}{\omega_p^2}$$

This last expression describes correctly the attenuation for a high-pass filter ($\omega_p > \omega_z$) and must properly be inverted to show eventual stopband rejection in a low-pass section ($\omega_z > \omega_p$). For example, a low-pass section with ω_p at 1000 rad/s and ω_z at 10,000 rad/s would show an eventual stop-band rejection of 40 dB (1/100), which would be expected from the conventional 40 dB/dec rolloff of a second-order low-pass section.

Before values of resistors and capacitors are calculated or selected, the coefficients "a", "b", "c", "d", and "m" should be related to the more relevant parameters ω_z, ω_p, ζ_z, ζ_p, and gain. With the aid of the first two equations, these solutions can be derived:

$$a = 2\zeta_p\omega_p$$
$$b = \omega_p^2$$

$$m = \frac{T(0)\,\omega_p^2}{\omega_z^2}$$

$$c = 2m\zeta_z\omega_z$$
$$d = m\,\omega_z^2$$

The Circuit

The general biquadratic filter circuit (**Fig. 2**) leaves the interconnection of several summing resistors at the mercy of the particular polynomials that have been generated above. There are four distinctly different connections that depend on the relationships of "a", "b", "c", "d" and "m". The relationships have been tabulated here for easy selection (**Table II**). Once the case and interconnect have been established, one may go to (**Table III**) for design formulas covering each resistor, given arbitrary values of capacitors.

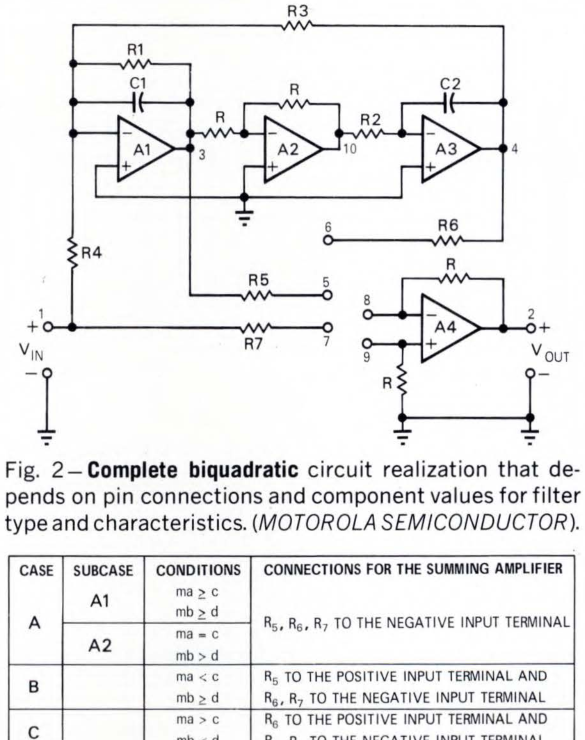


Fig. 2 – **Complete biquadratic** circuit realization that depends on pin connections and component values for filter type and characteristics. (*MOTOROLA SEMICONDUCTOR*).

CASE	SUBCASE	CONDITIONS	CONNECTIONS FOR THE SUMMING AMPLIFIER
A	A1	ma ≥ c mb ≥ d	R_5, R_6, R_7 TO THE NEGATIVE INPUT TERMINAL
	A2	ma = c mb > d	
B		ma < c mb ≥ d	R_5 TO THE POSITIVE INPUT TERMINAL AND R_6, R_7 TO THE NEGATIVE INPUT TERMINAL
C		ma > c mb < d	R_6 TO THE POSITIVE INPUT TERMINAL AND R_5, R_7 TO THE NEGATIVE INPUT TERMINAL
D	D1	ma < c mb > d	R_7 TO THE POSITIVE INPUT TERMINAL AND
	D2	ma = c mb < d	R_5, R_6 TO THE NEGATIVE INPUT TERMINAL

Table II. Conditions for four cases and their input connections to amplifier A4 in **Fig. 2**. (*MOTOROLA SEMICONDUCTOR*).

Biquad Example

Use a biquad high-pass section as an input filter

(Continued)

which is to pass 2025 Hz while attenuating 1270 Hz. For the transfer minimum to be at 1270 Hz let the numerator factors assume:

$$\omega_z = 1270 \times 2\,\pi \approx 7960$$
$$\zeta_z = 0.01$$

and for a corner near 2025 Hz the denominator factors may be:

$$\omega_p = 1900 \times 2\,\pi = 11900$$
$$\zeta_p = 0.4$$

and for the final parameter let T(0) = 1.

Solving the coefficient equations:

$$a = 9.53 \times 10^3$$
$$b \approx 1.42 \times 10^8$$
$$m = 2.25$$
$$c = 358$$
$$d = 6.3 \times 10^7$$
$$ma = 2.14 \times 10^4$$
$$mb = 3.2 \times 10^8$$

From the calculations its easy to see that ma > c and mb > d, which puts this filter in case A1. At this point we're ready to calculate real resistor values after assuming some standard value of capacitor and letting the scaling factors K_1 and K_2 equal unity. For this instance let $C_1 = C_2 = 0.1\ \mu$F. From **Table III**:

$$R_1 = \frac{1}{aC_1} = 1050\ \Omega$$

$$R_2 = \frac{1}{\sqrt{b}\,C_2} = \frac{1}{\omega_p\,C_2} = 840\ \Omega$$

$$R_3 = \frac{1}{\sqrt{b}\,C_1} = \frac{1}{\omega_p\,C_2} = R_2 = 840\ \Omega$$

$$R_4 = \frac{1}{(ma-c)\ C_1} = 476\ \Omega$$
$$R_5 = R\ (\text{let } R = 10\ k\Omega)$$
$$R_5 = 10\ k\Omega$$
$$R_6 = \frac{ma-c}{mb-d}\sqrt{b}\ R = 9.73\ k\Omega$$
$$R_7 = \frac{R}{m} = 4.45\ k\Omega$$

It's obvious from the values of R_1 through R_4 that the capacitor chosen was too large. Since their values are all inversely proportional to C, they may be accurately determined by inspection if C is changed to 0.01 μF:

$$R_1 = 10.5\ k\Omega$$
$$R_2 = 8.4\ k\Omega$$
$$R_3 = 8.4\ k\Omega$$
$$R_4 = 4.76\ k\Omega$$
$$R_5 = 10\ k\Omega$$
$$R_6 = 9.73\ k\Omega$$
$$R_7 = 4.45\ k\Omega$$

This filter was constructed with components ordinarily available in most labs (5% resistors, 10% capacitors) and the results are plotted in **Fig. 3** together with the "ideal" response.

CASE		R_4	R_5	R_6	R_7
A	A1	$\frac{1}{k_2\ (ma-c)\ C_1}$	k_2R	$\frac{k_2}{k_1}\frac{ma-c}{mb-d}\sqrt{b}R$	$\frac{1}{m}R$
	A2	$\frac{\sqrt{b}}{k_2\ (mb-d)\ C_1}$	INFINITE	$\frac{k_2}{k_1}R$	$\frac{1}{m}R$
B		$\frac{1}{k_2\ (c-ma)\ C_1}$	$\left[k_2\ (1+m) + k_1\frac{mb-d}{(c-ma)\ \sqrt{b}} - 1\right]R$	$\frac{k_2}{k_1}\frac{c-ma}{mb-d}\sqrt{b}R$	$\frac{1}{m}R$
C		$\frac{1}{k_2\ (ma-c)\ C_1}$	k_2R	$\left[\frac{k_2}{k_1}\frac{(ma-c)\sqrt{b}}{d-mb}\left(1+m+\frac{1}{k_2}\right)-1\right]R$	$\frac{1}{m}R$
D	D1	$\frac{1}{k_2\ (c-ma)\ C_1}$	k_2R	$\frac{k_2}{k_1}\frac{c-ma}{d-mb}\sqrt{b}R$	$\left[\frac{1}{m}\left(1+\frac{1}{k_2}+\frac{k_1}{k_2}\frac{d-mb}{(c-ma)\ \sqrt{b}}\right)-1\right]R$
	D2	$\frac{\sqrt{b}}{k_2\ (d-mb)\ C_1}$	INFINITE	$\frac{k_2}{k_1}R$	$\left[\frac{1}{m}\left(1+\frac{k_1}{k_2}\right)-1\right]R$

NOTE: $R_1 = \frac{1}{aC_1}$ $R_2 = \frac{k_1}{\sqrt{b}C_2}$ $R_3 = \frac{1}{k_1\sqrt{b}C_1}$

(where C_1, C_2 and R are arbitrary; k_1 and k_2 are arbitrary and positive)

Table III. Element values for the realization of biquadratic circuit in **Fig. 2**. (*MOTOROLA SEMICONDUCTOR*).

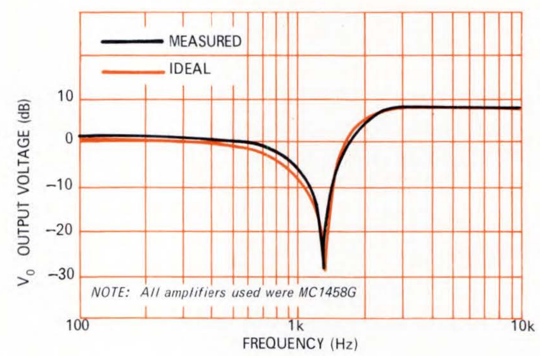


Fig. 3—**Biquad filter response,** with 5% resistors and 10% capacitors, compares ideal and measured results. (*MOTOROLA SEMICONDUCTOR*).

Denominator Sensitivities (Component Tolerances)

Biquadratic realizations are popular because of their relative insensitivity to passive and active component variations. Sensitivity is classically defined as:

$$S_B^A = \frac{B}{A}\frac{dA}{dB}$$

where S_B^A is defined as the percentage change in A for a percentage changed in B. For the critical resistors (R_1, R_2, R_3) and capacitors (C_1, C_2) these parameters are:

$$S^Q_{R_1} = 1 \qquad S^Q_{R_2} = \frac{-1}{2} \qquad S^Q_{R_3} = \frac{-1}{2}$$

$$S^Q_{C_1} = \frac{1}{2} \qquad S^Q_{C_2} = \frac{-1}{2}$$

$$S^{\omega 0}_{R_1} = 0 \qquad S^{\omega 0}_{R_2} = \frac{-1}{2} \qquad S^{\omega 0}_{R_3} = \frac{-1}{2}$$

$$S^{\omega 0}_{C_1} = \frac{-1}{2} \qquad S^{\omega 0}_{C_2} = \frac{-1}{2}$$

Overall sensitivity may be approximated as the sum (magnitude) of all the individual values (assuming an ideal op amp) to arrive at a "worst case" deviation of the performance parameter. This "worst case" takes into account the fact that the resistor may drift in either direction. From the sensitivity equation for Q the total sensitivity may be computed for Q:

$$S^Q_T = 1 + 1/2 + 1/2 + 1/2 + 1/2 = 3$$

which means that if 1% components were chosen, the final value of Q will be within 3% of the design value.

This is in direct contrast with most other attempts at active filtering where the sensitivity factors are usually proportional to Q. Even for circuits of relatively "mild" selectivity ($Q \approx 5$), this represents an order of magnitude degradation in needed component accuracy and drift. Here lie the economics for biquad realization: less component selection and trimming, both in manufacture and in the field, versus an extra gain block or two. At the current rising cost in labor and dropping prices in op amps, the cost advantage has shifted to using more ICs rather than more pots and 1% components.

Component Selection

For their state variable filters, most companies today use the popular 741 op amp in combination with metal film resistors and NPO and/or mica capacitors. Burr-Brown, in a text that should be published by McGraw-Hill early in 1971, provides a definitive comparison of the different types of passive component materials available. Because users will have to make knowledgeable selections of their components to meet the sensitivity requirements of their filters, this component evaluation is repeated here as a stepping-off point.

Resistors

Three types of resistors most often used are carbon composition, metal film and wirewound. Carbon composition resistors have a rather poor temperature coefficient of resistance (200-500 ppm/°C) and are used for "room temperature" applications or in filters which may have rather loose performance tolerances with temperature, as in the low-Q stages of 2- or 3-pole high-pass or low-pass filters. Composition resistors are useful for trimming and padding metal film or wirewound resistors where the relatively poor temperature coefficient causes only a small percentage change in the overall value. Carbon resistors are relatively inexpensive and are available in a wide range of values.

Bandpass filters and the high-Q states of a high-pass or low-pass multiple-pole filter require metal film or even wirewound resistors. Two popular temperature coefficients for metal film resistors are ±100 ppm/°C ($T0$) and ±50 ppm/°C ($T2$). Metal films can be purchased that have a positive- or negative-only temperature coefficient and also with lower temperature coefficients (±10 ppm/°C). The metal film resistor is probably the most commonly used resistor for filter applications and is available in a wide range of values. High-Q filters and/or filters which require especially stable parameters with temperature changes may require wirewound resistors with temperature coefficients as low as a few ppm/°C. High frequency applications will require noninductive wound resistors. Integrated circuit technology offers alternatives to discrete resistors. These include diffused, thin- and thick-film resistors.

Base-diffused, emitter-diffused, base pinch and collector pinch resistors are formed simultaneously with the diffusions for the transistors of the circuit. Temperature coefficients and initial tolerances make this type of resistor marginal for active filter applications unless the filter can be designed so that its parameters depend primarily on resistance ratios.

Thin-film resistors are deposited on ceramic or glass substrates. Materials such as nichrome, tantalum or cermet, may be deposited by evaporation or sputtering. The electrical properties of these resistors are considerably superior to those of diffused silicon resistors. An advantage of thin-film over diffused or thick-

TYPE	RANGE Ω	TEMPERATURE COEFFICIENT ppm/°C	TOLERANCE %	MATCHING %
BASED-DIFFUSED	100 - 30k	500 - 2000	±10	1
EMITTER-DIFFUSED	5 - 100	900 - 1500	±15	2
BASE PINCH	5k - 200k	4000 - 7000	±50	5
COLLECTOR PINCH	10k - 500k	4000 - 7000	±50	10
THIN FILM (ra or Ni-Cr)	30 - 100k	0 ± 400	±2	0.5
THICK FILM	1 - 10M	0 ± 500	±20	10

Table IV. Typical parameters of IC resistors. (*BURR-BROWN RESEARCH*).

(Continued)

film resistors is their superior long term stability.

Thick-film resistors consist of special resistive inks screened and fired on ceramic substrates. Thick-film resistors are trimmable using sand blasting or laser techniques. **Table IV** gives typical (untrimmed) parameters for several integrated circuit resistors.

Capacitors

Capacitors present the most severe problem to active filter designers. Capacitors which have superior characteristics, such as polystyrene, "Teflon", NPO ceramic or mica, are expensive and large. NPO ceramic is available in sizes up to about 0.05 μF for catalog items. Good quality polystyrene capacitors can be used for the large values (10 μF) in critical applications but they are physically very large. Mica capacitors are available in values up to 0.01 μF, but are larger than "Mylar" or polycarbonate capacitors of the same value. Physically small ceramic capacitors, such as ceramic disc capacitors and others that have large dielectric constants (from 1200 to 6000), have relatively poor characteristics. Capacitance changes with temperature, frequency, voltage and time amount to several percent. For high-Q applications, these changes can make a filter stage unstable or have severe amplitude peaking or attenuation. Such filter stages are usually highly Q-sensitive to element value changes.

The merit of a capacitor dielectric from the point of view of freedom from losses is expressed in terms of the power factor of the capacitor. The power factor is the sine of the angle by which the current flowing into the capacitor fails to be 90° out of phase with the applied voltage. The tangent of this angle is called the dissipation factor. The reciprocal of the dissipation factor is termed the Q and is the ratio of the capacitor reactance to the equivalent series resistance.

With ordinary dielectrics, phase angle is so small that the power factor, the dissipation factor, and the reciprocal of the capacitor Q are, for all practical purposes, equal to each other and to the phase angle expressed in radians. For high quality capacitors, these are practically independent of capacitance, voltage and frequency. Although the power factor of a capacitor is determined largely by the type of dielectric, it also is affected by the environment in which it operates: it tends to increase with temperature and is affected by humidity and by the absorption of moisture.

The effect of a capacitor with its power factor can be taken into account by replacing the capacitor with an ideal capacitor associated with a resistance. This resistance may be represented in series or in parallel. For lower power factors ($R_s \ll \frac{1}{\omega C}$), R_s is given by:

$$\text{Series Resistance} = R_s = \frac{\text{power factor}}{2\,\pi f C}$$

For the parallel resistance, we have approximately

$$\text{Parallel Resistance} = R_p = \frac{1}{2\,\pi f C\ (\text{power factor})}.$$

A list of dielectric materials and representative performance features are given in **Table V**.

Integrated circuit capacitors are of three types; pn junctions, MOS structures and thin-film types. These capacitors have small values that vary greatly with temperature.

The most suitable capacitors for integrated circuit filters are those utilized in hybrid construction and are NPO ceramic chips or, for low-frequency work, tantalum capacitor chips.

DIELECTRIC	POWER FACTOR	TEMPERATURE COEFFICIENT OF CAPACITANCE
MYLAR	8×10^{-4} TO 14×10^{-4}	+250 ppm/°C 0 - 70°C, LARGER AT EXTREMES
HIGH QUALITY POLYSTYRENE	1×10^{-4} TO 2×10^{-4}	-50 TO -100 ppm/°C -60 TO +60°C
HIGH QUALITY MICA	1×10^{-4} TO 7×10^{-4}	0 - 70 ppm/°C
NPO CERAMIC	5×10^{-4} TO 20×10^{-4}	0 ± 30 ppm/°C
POLYCARBONATE	30×10^{-4} TO 50×10^{-4}	NON-MONOTONIC TOTAL ±1%
TEFLON	0.5×10^{-4} TO 1.5×10^{-4}	0 - 70°C, LARGER AT EXTREMES −250 ppm/°C −60 TO 150°C

Table V. Typical capacitor parameters for different dielectrics. (*BURR-BROWN RESEARCH*).

What About Programmability?

When a need for varying a filter's characteristics exists, the programmable filter should be considered. However, the constraints imposed on component selections by sensitivity requirements should be kept in mind.

Two types of programmable filters now are available. These are the fixed frequency types where external resistors and capacitors control center frequency and Q, and the electronically-tunable types that are programmed by a control voltage or current.

Fixed frequency types are the most widely used. While the Genisco programmable type (**Fig. 1b**) permits the user to select both *Rs* and *Cs*, other makers choose to have the user select *Rs* only. In this latter case, two resistors of equal value program center frequency and a third resistor controls Q.

Analog Devices supplies 1-Hz to 20-kHz filters that can be tuned over a 20:1 range with resistors. If the frequency response must be changed over decades, units are supplied where C can be changed first, then fine tuning is completed with resistors.

Both Optical Electronics and KTI offer units that have independent adjustment of gain, center frequency and Q. The Optical Electronic units cover the range from dc to 500 kHz with Qs from 1 to 500. KTI's universal filter offers simultaneous high-pass, low-pass and bandpass from dc to 10 kHz and max Q of 500 with low power requirements of only 120 μA at $\pm$2V.

Electronically tunable types can be programmed either by switching in different resistors in a ladder network or by supplying a control voltage to a temperature compensated internal or external FET network or similar network for continuous programming control. Aritech Corp. has just recently announced a voltage-controlled filter (VCF) in either high-pass or low-pass (**Fig. 4**) from 0.1 Hz to 20 kHz, variable over a 50:1 frequency range from a 0.1 to 5V dc control voltage. At any control voltage, units are stable to 0.1%/°C. These 4-pole, 0-50°C units are said to offer the advantage that they are ready to use, needing no extra calculations or components for the required frequency response.

Western Microwave has developed a frequency-agile bandpass filter specifically intended for audio frequency processing and decoding applications. It is a single-pole device whose center frequency can be tuned over the range of less than 1 Hz to 3 kHz by varying the resistance R_F between two external terminals (**Fig. 5**). The bandwidth and gain are mutually dependent variables and are also set by a single external resistor, R_{BW}. The outstanding characteristic of the design, and that which makes it ideally suited for tone coded pulse train processing is that both the chosen bandwidth and the overall gain remain constant for any center frequency within the range of the device. For example, if the bandwidth is fixed at 20 Hz, the gain, being a dependent variable, will be 40 dB. The advantage is that transient response is then constant and processed pulse trains will have the same rise, fall and amplitude characteristics, regardless of their encoded frequency.

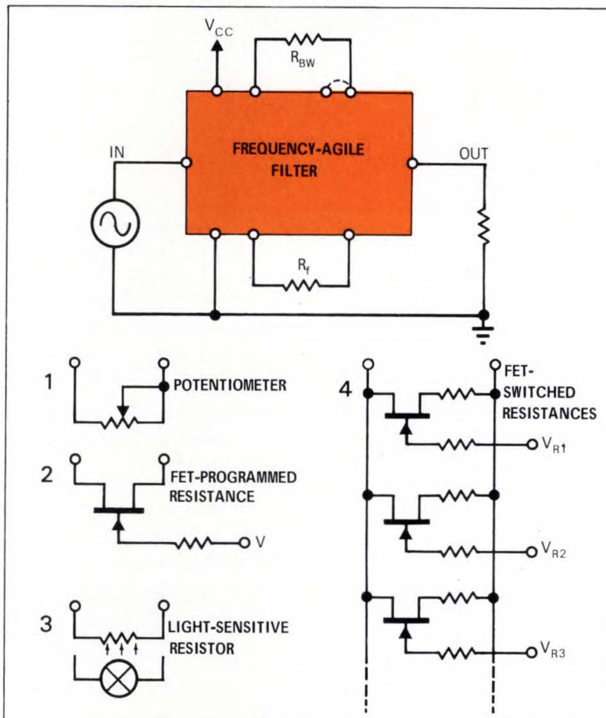
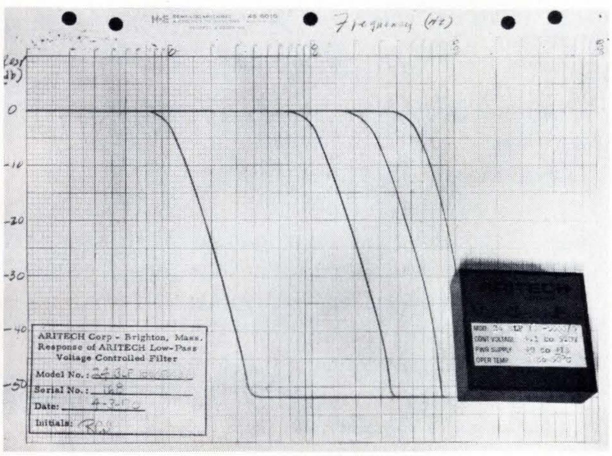


Fig. 5 – **Frequency-agile filter**, showing four techniques for programming both center frequency and the mutually dependent variables of bandwidth and gain. (*WESTERN MICROWAVE*).

Fig. 4 – **Response curve** of low-pass type active filter, showing four different settings of dc control voltage. (*ARITECH*).



Two versions of the device are being produced: A millipower circuit requiring up to 4 mA at supply voltages from 10 to 38V dc and a micropower version whose current drain is less than 200 μA at 35V.

KTI's voltage tuning technique (**Fig. 6**) supplies a controlled on-off ratio pulse to pairs of series-shunt FETs. Here the frequency of Q and $\bar{Q}$ signals must be at least 2× higher than the highest frequency of interest used in the filter.

With two ganged pots. Peter Zicko of Analog Devices has developed the tunable low-pass filter (**Fig. 7**) that can be controlled from 100 Hz to >20 kHz.

Dynamics Instrumentation supplies a third-order

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Analog Filters *(Cont'd)*

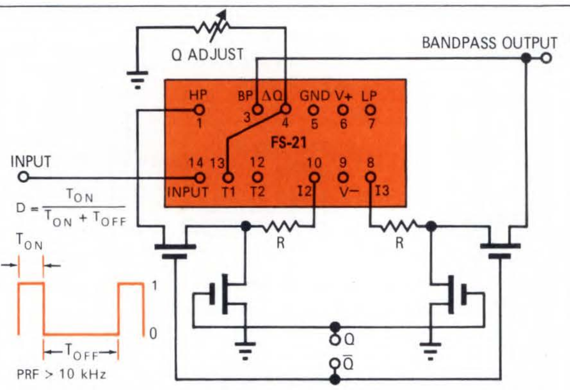


Fig. 6—**Controlled on-off ratio pulses** to pairs of series-shunt FETs provide resistance needed to select center frequency of filter. (*KTI*).

low-pass unit with or without gain that is programmed from a 3-bit binary input to select any of eight cutoff frequencies within the range of 1 Hz to 20 kHz. This unit is programmed either remotely with a digital signal or manually from front panel controls. Other units in this line include fourth- or sixth-order units with cutoff frequency from 1 Hz to 50 kHz, and a unit that offers switchable low-pass from dc-1 Hz to dc-1

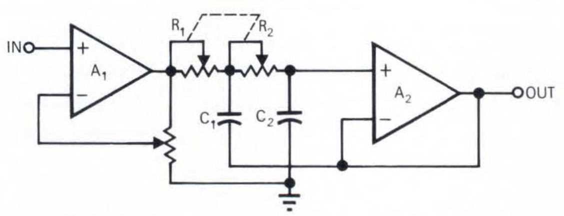


Fig. 7—With $C_1 = C_2 = 1120$ pF and $R_1 = R_2 =$ two ganged 1 MΩ potentiometers, a continuously-variable 2-pole low-pass Butterworth filter results with $|A| = -40$ dB/decade and f_0 variable from 100 Hz to >20 kHz. Passband gain will be unity, noninverting, <± 0.1 dB. Depending upon A_1 and A_2, Z_{in} will generally be >1 MΩ and Z_{out} <10Ω. (*ANALOG DEVICES*).

MHz and high-pass from 100 Hz-1 MHz to 0.1 Hz-1 MHz.

Also being considered for programmable filter implementation is the use of IC multipliers in front of the frequency selection resistors. At this point in time, however, the high cost and temperature sensitivity of IC multipliers hold off all but curious R&D efforts.

Higher Order Filters

State variable filters not only offer good sensitivity characteristics, but they also can be cascaded quite readily to form higher-than-second-order filters.

For these higher order complex units, suppliers often elect to use the hybrid circuit technology where active trimming, by sandblast or laser, of resistive elements is done quite easily. Here the op amps are IC chips, and the capacitors are external chips mounted to a substrate containing thin- or thick-film resistors. Thin-film nichrome offers excellent stability while the thick-film pastes offer low cost.

An example of the use of hybrid techniques is in Varadyne's 8-pole units (see cover photo and **Fig. 8**) that use all-metal eutectic hybrid techniques and are packaged in 40-pin containers that withstand 5×10^{-7} specifications.

Hints for Users

If you're about to get involved with the make-or-buy decision for an active filter, keep these hints in mind.

If you buy, you receive a filter that is already tuned, packaged, and tested under extremes of temperature.

With unstable components, filters can have great variability in passband and can lose top band discrimination completely, Q can be altered drastically and instability can result.

As you require filters with higher Qs, use circuits where parameters are not so sensitive to temperature changes.

Always keep Q in mind and use as low a Q as possible to do the job.

Positive feedback circuits are OK if the op amp is used in a unity gain configuration. This gives low passive element sensitivities.

NPO capacitors will eliminate temperature problems with capacitors.

All manufacturers stand ready to discuss your needs, whether those needs require standard or custom design.

The following check list provided by Varadyne is vital to the design and specifying of any hybrid active filter:

Understand completely the characteristics needed in the system.

Define the selectivity of the filter.

Define unwanted signal levels.

Define minimum and maximum error in passband.

Define noise characteristics in that particular band.

Define the physical size constraints.

Define the power consumption.

Define the weight considerations.

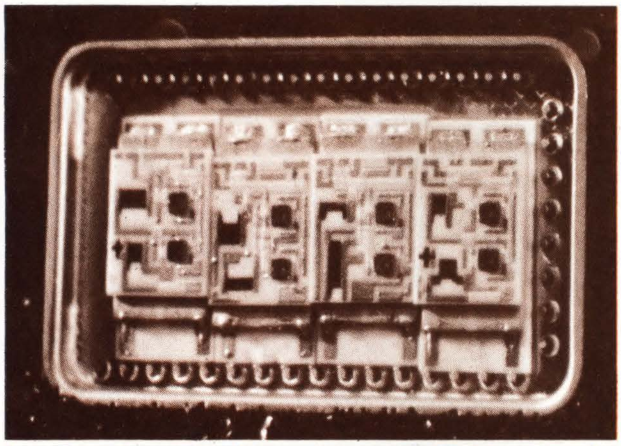
Define whether a hybrid or discrete component would best serve the system. ▭

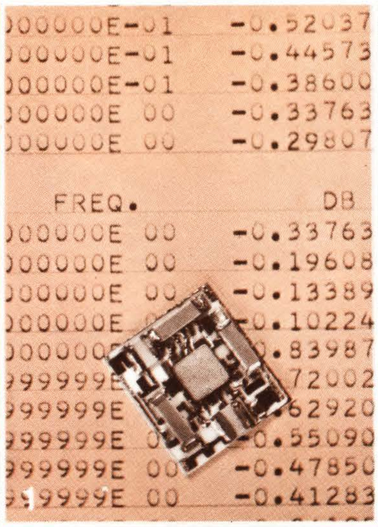
ACKNOWLEDGMENTS

EDN thanks the many people involved from the following companies who gave generously of their time and effort in support of this feature.

ANALOG DEVICES, Cambridge, Mass.; ARITECH, Brighton, Mass.; BURR-BROWN RESEARCH, Tucson, Ariz.; DYNAMICS INSTRUMENTATION, Monterey Park, Calif.; GENISCO TECHNOLOGY, Compton, Calif.; KINETIC TECHNOLOGY, Los Gatos, Calif.; MOTOROLA SEMICONDUCTOR, Phoenix, Ariz.; OPTICAL ELECTRONICS, Tucson, Ariz.; SPRAGUE ELECTRIC, North Adams, Mass.; TRW SEMICONDUCTORS, Lawndale, Calif.; TEXAS INSTRUMENTS INCORPORATED, Dallas, Tex.; VARADYNE, Santa Monica, Calif.; WESTERN MICROWAVE, Los Gatos, Calif.

Fig. 8 – **Active filter with 8 poles** offers cutoff frequency from 10 to 160 Hz, phase-shift laser trimmed to within 2 deg, in-band ripple 1/2 dB, maximum stop band attenuations 90 dB and a power consumption of 500 mW. (*VARADYNE*).





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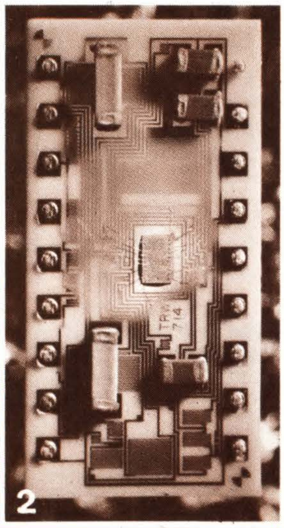

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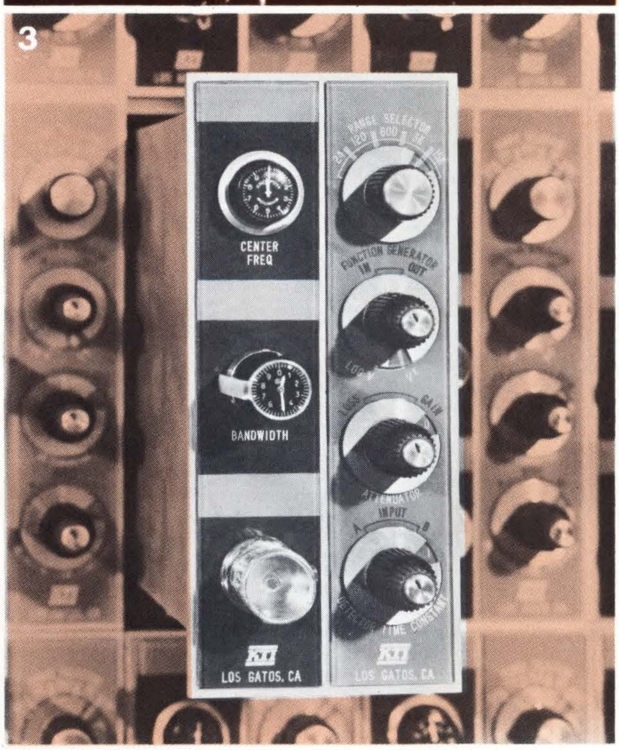

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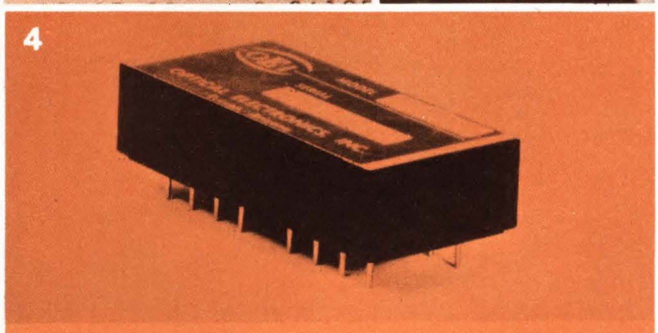

4

(1) Thick-film active filter is notch type with one third-order low-pass section. (*SPRAGUE ELECTRIC*).

(2) Active filter made using one silicon monolithic chip. Chips contain three separate operational amplifiers and chip capacitors to make 10-frequency pretuned band-pass filter. (*TRW SEMICONDUCTORS*).

(3) Tunable audio spectrum analyzer channel is a tunable fourth-order bandpass active filter (24 Hz to 15 kHz) (*KTI*).

(4) Filters that cover the frequency range to 500 kHz are packaged in small dual in-line containers. (*OPTICAL ELECTRONICS*).

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- SN54/7447 BCD-to-7-Segment Decoder/Driver*(15V)
- SN54/7448 BCD-to-7-Segment Decoder*
- SN54/7449 BCD-to-7-Segment Decoder*
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■ New circuit introduced 1970 ★Multi-source product

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- ■ SN74S40 Dual 4-Input NAND Buffer
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- SN54/74104 Gated J-K Master-Slave Flip-Flop*
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- SN54/74H01 Quad 2-Input NAND Gate, Open-Collector Output*
- SN54/74H04 Hex Inverter*
- SN54/74H05 Hex Inverter, Open-Collector Output*
- SN54/74H10 Triple 3-Input NAND Gate*
- SN54/74H11 Triple 3-Input AND Gate*
- SN54/74H20 Dual 4-Input NAND Gate*
- SN54/74H21 Dual 4-Input AND Gate*
- SN54/74H22 Dual 4-Input NAND Gate, Open-Collector Output*
- SN54/74H30 8-Input NAND Gate*
- SN54/74H40 Dual 4-Input NAND Buffer*
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- SN54/74H53 Expandable 4-Wide 2-2-2-3-Input AND-OR-INVERT Gate*
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- SN54/74H76 Dual J-K Flip-Flop, Preset and Clear Inputs*
- SN54/74H78 Dual J-K Flip-Flop, Preset and Clear Inputs*
- SN54/74H101 J-K Flip-Flop, AND-OR Inputs
- SN54/74H102 J-K Flip-Flop, AND Inputs
- SN54/74H103 Dual J-K Flip-Flop, Separate Clock Inputs
- SN54/74H106 Dual J-K Flip-Flop, Preset and Clear Inputs
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- ■ SN54/74L03 Quad 2-Input NAND Gate, Open-Collector Output
- SN54/74L04 Hex Inverter*
- SN54/74L10 Triple 3-Input NAND Gate*
- SN54/74L20 Dual 4-Input NAND Gate*
- SN54/74L30 Single 8-Input NAND Gate*
- SN54/74L51 Dual 2-Wide 2-Input/2-Wide 3-Input AND-OR-INVERT Gate*
- SN54/74L54 2-2-3-3-Input AND-OR-INVERT Gate*
- SN54/74L55 2-Wide 4-Input AND-OR-INVERT Gate*
- SN54/74L71 R-S Master-Slave Flip-Flop*
- SN54/74L72 J-K Master-Slave Flip-Flop*
- SN54/74L73 Dual J-K Master-Slave Flip-Flop*
- SN54/74L74 Dual D-Type Edge-Triggered Flip-Flop*
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■ New circuit introduced 1970 ★Multi-source product

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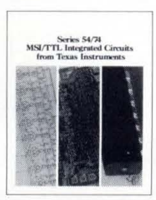

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TEXAS INSTRUMENTS
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FREQUENCY COMPARATOR PERFORMS DOUBLE DUTY

Using digital techniques, this simple circuit determines both the phase and frequency relationship between two frequencies.

REGINALD C. E. THOMAS, Sundstrand Aviation

Few phase-comparing circuits possess the property of producing an error signal with correct polarity for large frequency errors. Consequently, applications having the need for such a comparator use either a dual-mode phase comparator or a phase and frequency comparator.

Take, for example, the alternator control system in **Fig. 1**. Normally, the output of such a system is a periodic signal that is compared, by means of a phase comparator, with a reference frequency, and a corrective signal is generated for plant control.

A number of digital circuits for determining both phase and frequency relationships have been described. Because the response of these comparators is indeterminate when the input pulses occur simultaneously, a circuit preceding the comparator is needed to eliminate the coincidence of pulses. However, combining the eliminator and comparator becomes complex and costly. An additional disadvantage is that the transfer from frequency to phase comparison mode does not occur until the controlled frequency overshoots the reference frequency. Both deficiencies can be overcome at the cost of increased complexity.

Analysis of a simple phase comparator (**Fig. 2**) reveals that information pertaining to the frequency as well as the phase relationship between inputs is available. Applying this knowledge, the design of two frequency comparators and a phase and frequency comparator will be discussed. These circuits will transfer from frequency to phase comparison mode when the input frequencies are equal. Response of these circuits will be definitive when the input pulses occur simultaneously. Also, positive logic notation will be used (logic "1" high, logic "0" low).

Basic Phase Comparator

The comparator in **Fig. 2** generates a pulse-width modulated waveform. When the reference frequency, f_1, leads the signal frequency, f_2, by 360°, the width of the pulses is maximum, and when the reference lags

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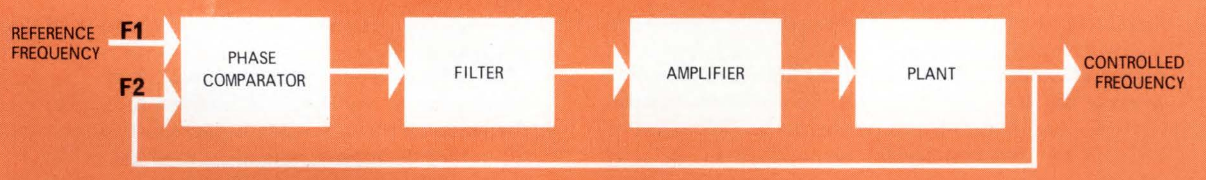


Fig. 1—**Typical phase-control system** generates corrective signal in plant-control application.

(Continued)

Frequency Comparator (Cont'd)

the signal frequency by the same amount, the pulse width is minimum.

Transfer characteristic of the comparator (**Fig. 2b**) is derived from the waveforms in **Fig. 5**. Division of the input frequencies extends the central-portion range of the characteristic curve. However, when a phase-control system uses this comparator, the time required for phase changes to propagate through the frequency dividers may constitute an unacceptable delay.

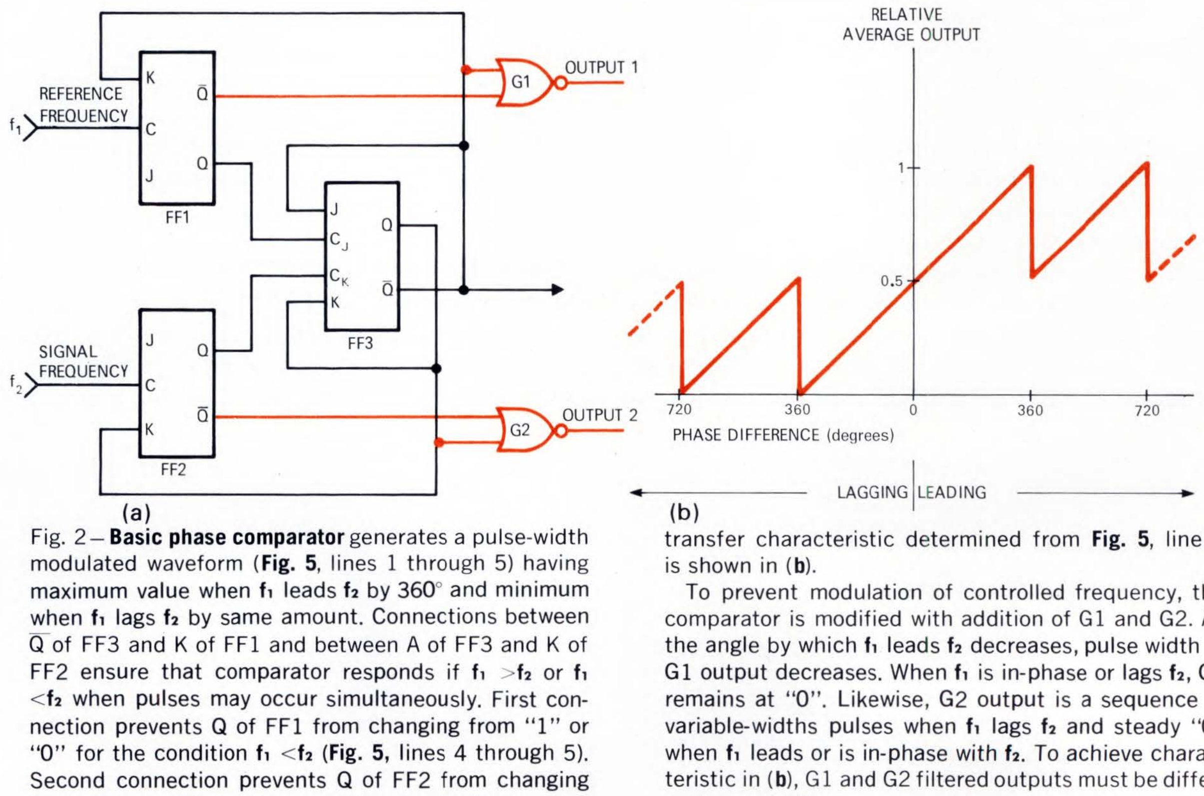
Again consider the control system in **Fig. 1**. When the reference and controlled frequencies are in phase, the phase-comparator output is a square wave having a period twice that of the inputs – a frequency 1/2 that of the inputs and a symmetrical waveform. If the plant responds to the control signals of this frequency, then the controlled frequency will be modulated. To prevent this modulation, the filter and amplifier must substantially attenuate the fundamental frequency of the comparator output. The amount of required attenuation may be reduced by modifying the comparator.

Since the predominant frequencies present in the output of the gates is greater than the input frequencies when they are close to being in phase, the amount of required filtering is reduced.

Frequency Comparators

From the basic phase comparator, two frequency comparators evolved. The simplest, shown in **Fig. 3a**, connects a R-S flip-flop (G3 and G4) to the output gates of the modified phase comparator. From **Fig. 5**, lines 6 and 7, it is apparent that G1 output is a sequence of pulses only when the reference frequency leads the signal frequency and G2 output is also a sequence of pulses when the reference lags the signal. Consequently, the transition of the comparator output from logic "0" to logic "1" or vice versa occurs when both input frequencies are very close to being in phase.

Another circuit (**Fig. 3b**) was developed for applications requiring a frequency comparator with phase hysteresis. From **Fig. 5**, line 8 and 9, the R-S flip-flop output changes from "0" to "1" when the reference leads the signal frequency by 180° and from "1" to "0"



(a) (b)

Fig. 2 – **Basic phase comparator** generates a pulse-width modulated waveform (**Fig. 5**, lines 1 through 5) having maximum value when f_1 leads f_2 by 360° and minimum when f_1 lags f_2 by same amount. Connections between $\bar{Q}$ of FF3 and K of FF1 and between A of FF3 and K of FF2 ensure that comparator responds if $f_1 > f_2$ or $f_1 < f_2$ when pulses may occur simultaneously. First connection prevents Q of FF1 from changing from "1" or "0" for the condition $f_1 < f_2$ (**Fig. 5**, lines 4 through 5). Second connection prevents Q of FF2 from changing from "1" to "0" for the condition $f_1 < f_2$. Comparator transfer characteristic determined from **Fig. 5**, line 5 is shown in (**b**).

To prevent modulation of controlled frequency, the comparator is modified with addition of G1 and G2. As the angle by which f_1 leads f_2 decreases, pulse width of G1 output decreases. When f_1 is in-phase or lags f_2, G1 remains at "0". Likewise, G2 output is a sequence of variable-widths pulses when f_1 lags f_2 and steady "0" when f_1 leads or is in-phase with f_2. To achieve characteristic in (**b**), G1 and G2 filtered outputs must be differentially amplified.

when the reference lags the signal by a similar angle – a total hysteresis of one cycle. Division of the input frequencies increases the amount of hysteresis.

Phase and Frequency Comparator

A phase and frequency comparator will, when the signal frequency is far removed from the reference frequency, indicate whether the signal is greater or less than the reference. When the signal approaches reference, the comparator switches from frequency to phase comparison mode, in which the phase difference between the frequencies is indicated by a symmetrical waveform at the comparator output.

A phase and frequency comparator having the transfer characteristic shown in **Fig. 6b** combines the properties of both frequency comparators with those of the phase comparator. Flip-flops FF1, FF2 and FF3 in **Fig. 6a** form the basic phase comparator. The output of gate G1 is a logic "1" except when the reference leads the signal frequency by more than 180°; then the output is a sequence of pulses. When the reference lags the signal frequency, the output of G3 is a sequence of pulses and a logic "1" when the reference leads the signal. An R-S flip-flop (G8 and G7) toggles from a "1" to "0" only when the reference leads the signal by more than 180° and from "0" to "1" when the reference lags the signal frequency by more than some very small angle. Gates G2 and G4 control the output of G5, which forms another R-S flip-flop with G6, so that it changes from "1" to "0" when the reference signal lags by more than 180° and from "0" to "1" when the reference leads the signal.

If the comparator input signals are short pulses instead of a symmetrical square wave, the central-linear portion of the transfer characteristic (**Fig. 6b**) would extend almost to the ±360° points and the discontinuities would virtually disappear. To extend the linear portion of the characteristic further, it is necessary to divide down the input frequencies.

The circuit in **Fig. 4**, using a split clock master-slave flip-flop fabricated from NAND gates, requires six 7400 Series integrated circuits – equivalent to 37 gates.

(Continued)

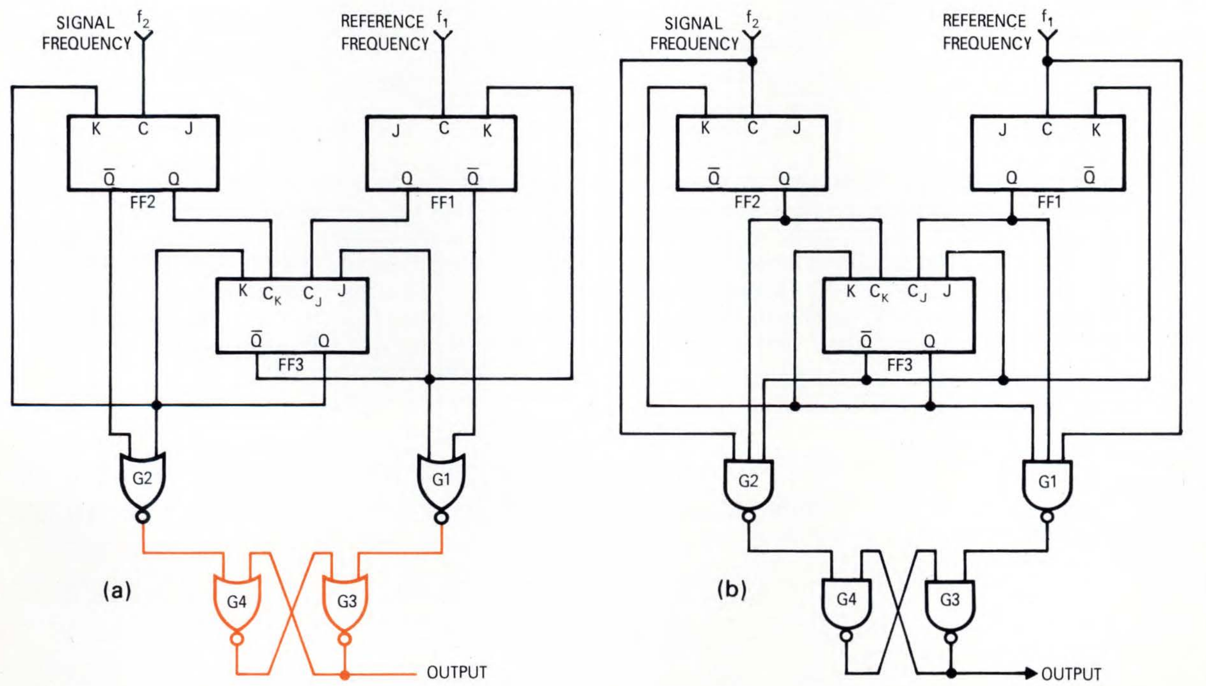


Fig. 3 – **Frequency converter** is easily realized by connecting an R-S flip flop to phase-converter output gates as shown in (a). From **Fig. 5** lines 6 and 7, a pulse sequence is generated at G1 only when f_1 leads f_2. Similarly, G2 output is a pulse sequence only when f_1 lags f_2. For other conditions, G1 and G2 outputs are "0". Modified comparator (b) exhibits a total hysteresis of one cycle. R-S flip-flop (G3 and G4) switches from "0" to "1" when f_1 leads f_2 by more than 180° and from "1" to "0" when f_1 lags f_2 (**Fig. 5** lines 8 and 9).

(Continued)

Frequency Comparator (Cont'd)

As integrated circuits with a similar number of gates are commonplace, it should be possible to construct a general purpose phase and frequency comparator on a single silicon chip.

When used in conjunction with a frequency reference, circuits similar to those discussed should prove of value in many linear and ON/OFF speed-control systems. An advantage of this arrangement is that the reference frequency, and therefore the controlled speed, may be readily changed by a digital command if a dividing network having a controlled modulus follows the frequency reference. □

Reginald C. E. Thomas was a project engineer in the research department at Sundstrand Aviation, Rockford, Ill. and is currently a senior electronic engineer with Instron Ltd. in High Wycombe, England. Mr. Thomas's duties involve advanced development of control systems—mainly aircraft secondary power generation. He is an associate member of I.E.E. in London, England.

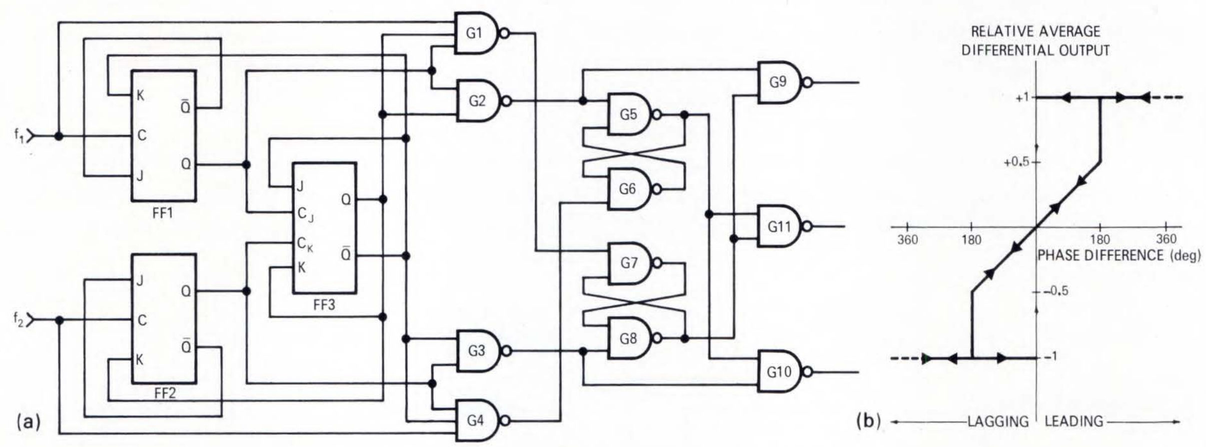
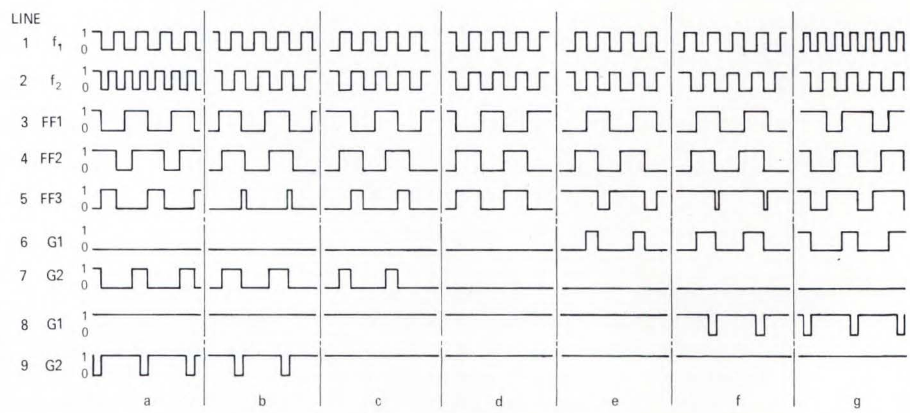


Fig. 4—**Phase and frequency comparator** combining properties of both frequency comparators and phase converter exhibits transfer characteristic of (**b**). DeMorgan's theorem shows that G2 output is complement of G1 output in **Fig. 2a**. Similarly, G3 generates the complement of G2 in **Fig. 2a**. NAND combination, by G9, of G2 and G8 outputs gives an output similar to that shown in **Fig. 5**, line 6 except that when f_1 leads f_2 by more than 180°, G9 switches to "1". Similarly, G10 combines G3 and G5 outputs to generate line 7 of **Fig. 5.** However, when f_1 lags f_2 by more than 180°, G10 output is "1". Differential amplification of G9 and G10 outputs generates characteristic of (**b**). Output of gate G11 indicates, as a logic "0", when phase difference between f_1 and f_2 is less than 180°.

Fig. 5—**Timing diagram** illustrating comparator operations for:

a $f_1 < f_2$
b f_1 lags f_2 by 300°
c f_1 lags f_2 by 180°
d f_1 and f_2 in phase
e f_1 leads f_2 by 180°
f f_1 leads f_2 by 300°
g $f_1 > f_2$



FOR A FREE REPRINT OF THIS ARTICLE **CIRCLE NO. L62**

ONE ADJUSTMENT CONTROLS MANY REGULATORS

A single potentiometer can adjust any number of regulators simultaneously. Accuracy of this technique, however, depends on output voltage differences between the regulators.

ROBERT C. DOBKIN, National Semiconductor Corp.

Today's integrated-circuit voltage regulators deliver high performance at reasonable prices. Both positive and negative regulators are available that achieve better than 0.1% regulation under normal fluctuations of input supply and load. Because of production variations, though, the internal-reference voltage of these regulators may vary as much as 10% from unit to unit. Normally this causes no problem, since most power supplies have a potentiometer for adjusting the output voltage.

In systems that have more than one regulated output voltage, it is often desirable to adjust all supplies with a single potentiometer. This not only eliminates one or more potentiometers, but it also eliminates the need to adjust the supplies individually.

One Pot, One Adjustment

In **Fig. 1**, a single potentiometer controls both outputs of the 5 and 15V regulators. Although the technique is not exact, the results are good, with error typically <2%. To insure that both regulators operate with the same reference voltage, their internal refer-

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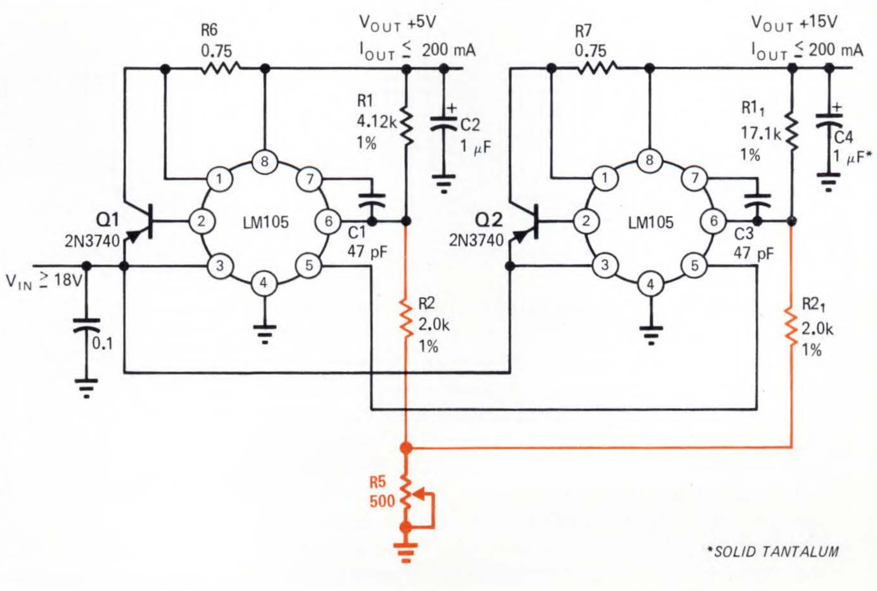

Fig. 1—**Single potentiometer** controls a 5 and 15V regulator. Resistors R2 and $R2_1$ are fixed at 2 KΩ. Resistor R1 is calculated for output voltage using 1.6V as reference voltage. Following expression is used to determine either R1 or $R1_1$:

$$R1(R1_2) = \frac{(V_{out} - 1.6)2000}{1.6}$$

Potentiometer R5 will adjust both regulators within 2% of desired output for reference variations from 1.6 to 2V. If reference is 2V, R5 is 324Ω and output voltages are 5.1 and 14.9V. If reference is approximately 1.8V, both outputs are within 1% nominal.

(Continued

One Adjustment (Cont'd)

ence voltages are tied together (**pin 5**).

Potentiometer R5, connected between the lower section of the output voltage divider network and ground, compensates for any variations from the nominal 1.8V reference of the regulators. Note that the wiper of R5 is connected to one side of the potentiometer. If a rheostat connection were used, the arm might open-circuit during adjustment, causing large transients on the output.

Computation of the resistor values for the output divider in **Fig. 1** is performed with the consideration that the adjustment is not exact and that both regulators have to be adjusted. To help compensate for any inaccuracies, the output voltages are calculated slightly off from the desired value. For the 5 and 15V regulators, R2 and $R2_1$ are fixed at 2K. Using a 1.6V reference voltage, R1 and $R1_1$ are calculated to establish an output voltage of 2% below the 5V nominal output and 2% above the 15V nominal output. Now, R5 can be used to adjust both regulators to within 2% of the desired output for reference variations from 1.6 to 2V. Both outputs will be 1% of nominal if the reference is near the typical value of 1.8V.

However, the above calculations do not account for resistor inaccuracies. If 1% resistors are used, there is an additional worst-case error of 2% for each regulator. Resistor errors are inherent in any type of tracking regulator system, even if the adjustment is proven to be exact theoretically.

Actually any number of regulators may be connected to a single potentiometer. Accuracy of this technique depends on the output voltage differences among the regulators. The previous example was a severe difference. By using closer output voltages, such as 12 and 15V, the error becomes smaller. With a 1.6V reference, the low margin for the 12V regulator and the high margin for the 15V regulator is 0.5%. Therefore, both regulators will be within 0.5% for reference variations from 1.6 to 2V. This method of adjustment is, of course, exact if the regulator outputs are equal.

Negative-Positive Regulation

Using a negative regulator to track a positive regulator is a somewhat easier task. An inverting operational amplifier may be used to provide a negative output voltage while using a positive voltage as a reference.

For example, the LM104 negative regulator is easily adapted for use as an inverting amplifier, and it provides several advantages over conventional operational amplifiers. Operation of the LM104 is explained in **Fig. 2** and the tracking ±15V regulator in **Fig. 3** is an example of an application.

Also, the LM104 may be used with an inverting gain for negative output voltages greater than the positive reference voltage, as illustrated in **Fig. 4**, where the

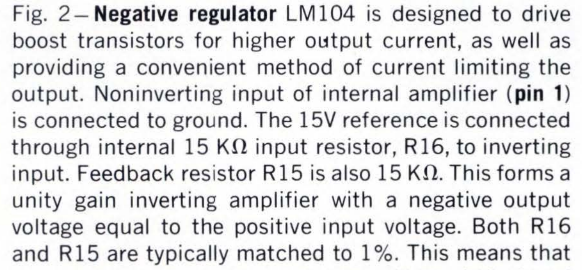

Fig. 2 – **Negative regulator** LM104 is designed to drive boost transistors for higher output current, as well as providing a convenient method of current limiting the output. Noninverting input of internal amplifier (**pin 1**) is connected to ground. The 15V reference is connected through internal 15 KΩ input resistor, R16, to inverting input. Feedback resistor R15 is also 15 KΩ. This forms a unity gain inverting amplifier with a negative output voltage equal to the positive input voltage. Both R16 and R15 are typically matched to 1%. This means that the negative output of the regulator will be within 1% of the positive input.

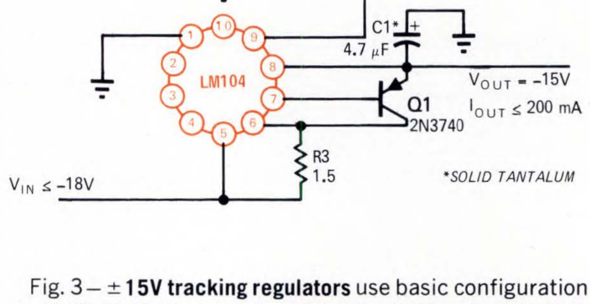

Fig. 3 – **±15V tracking regulators** use basic configuration of LM104. Both regulators are adjusted by changing R1.

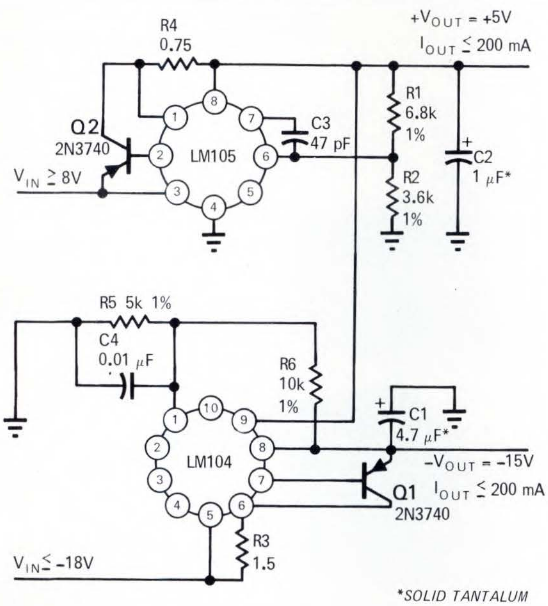

Fig. 4—**Regulator uses LM104** where −15V supply tracks a 5V supply. Noninverting input is not grounded but tied to resistor divider R5 and R6 between negative output and ground. Output voltage equals

$$V_{out} = V^{+} \frac{R5 + R6}{R6 - R5}$$

where V^{+} is positive reference.

−15V supply tracks a 5V supply. In this configuration, the noninverting input is not grounded, but is tied to the divider network R5 and R6 between the negative output and ground. Primarily, the positive reference determines the line regulation and temperature drift with the negative output tracking. The reference (LM105) must be a low impedance source to insure that current drawn by LM104 (pin 9) does not affect the reference voltage. Because the LM104 is connected to a positive voltage instead of ground, it sees a total voltage equal to the sum of the unregulated negative input plus the positive reference voltage. This reduces the maximum unregulated negative input voltage allowable and should be considered during design. If the negative output voltage must be less than the positive reference or the decrease in maximum unregulated input voltage cannot be tolerated, an alternate method of designing tracking regulators must be used. Of course, many negative regulators may be slaved to a single positive regulator.

Using the standard linear integrated circuit, multiple output (positive and negative) supplies may be adjusted to within 2% or less by a single resistor. Although the absolute output is not exact, the regulation accuracy is still within 0.1%. A more complex system, providing regulated outputs of 15, 5 and −15V, is shown in **Fig. 5**. These techniques save both time and materials. ☐

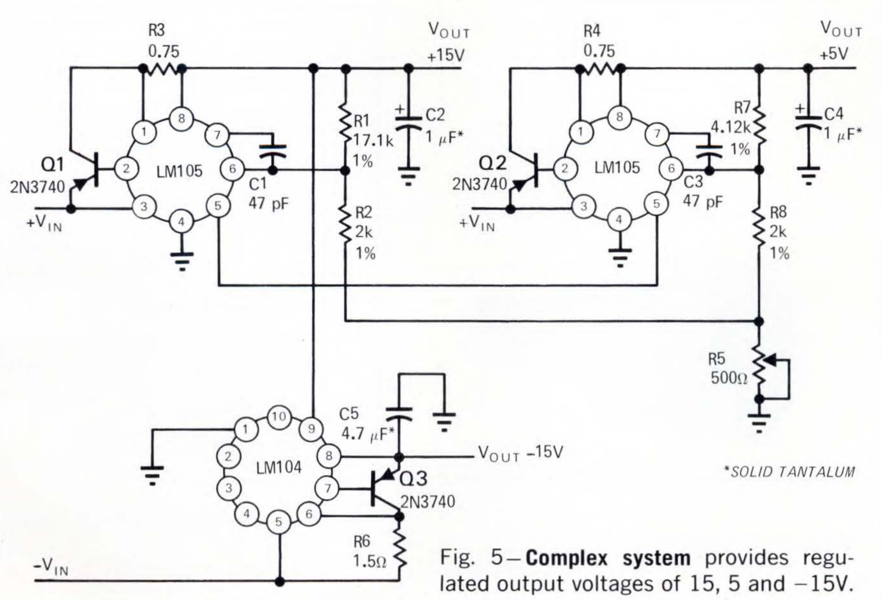

Fig. 5—**Complex system** provides regulated output voltages of 15, 5 and −15V.

Robert C. Dobkin is a staff engineer in advanced circuits development at National Semiconductor Corp., Santa Clara, Calif. Mr. Dobkin's present duties include design of monolithic linear integrated circuits. He has been granted one patent.

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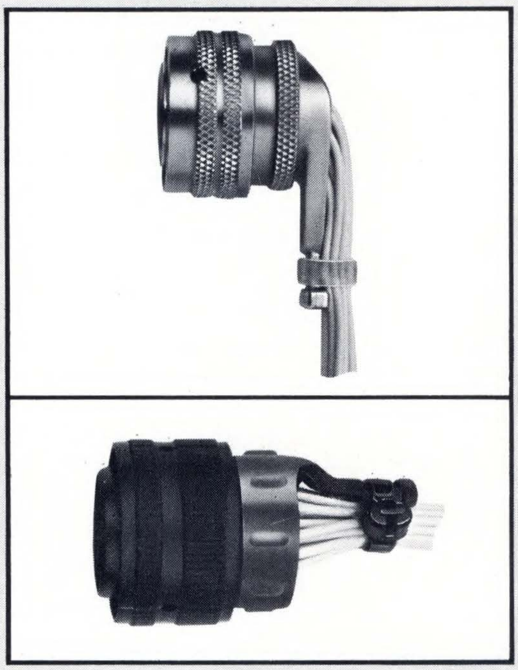

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CIRCLE NO. 11

Improving CMR in FET Diff-Amps

Extremely low input bias and offset currents make field effect transistor diff-amps very attractive once their inherently low common-mode rejection ratio (CMRR) has been tamed.

STEVEN MORRISON, Westinghouse Electric Corp.

Dual matched FETs frequently are found in the front-end differential stages of high-accuracy comparators. Their very low input bias and offset currents, coupled with input offset voltage drifts almost as good as those of dual matched transistors, make them well suited for this application.

However, FET diff-amps do have rather low inherent common-mode rejection. This characteristic is detrimental when a comparator is used differentially with high common-mode input signals. In this case the error in comparison is equal to the common-mode input voltage divided by the CMRR. The small-signal low-frequency equivalent circuit of a field-effect transistor is as shown in **Fig. 1a**. Here, g_m is the transconductance and g is the output conductance. A second equivalent circuit is shown in **Fig. 1b**. In it, μ is equal to g_m/g.

A typical differential amplifier configuration is shown in **Fig. 2a**. Here R_s can be comprised of either (1) a resistor to the negative supply voltage, (2) a transistor current sink or (3) a field-effect current regulator. Both (2) and (3) can be designed to have several megohms of dynamic impedance. An equivalent circuit for the diff-amp of **Fig. 2a** is shown in **Fig. 2b**, and the flow graph derived from that equivalent circuit is given in **Fig. 2c**.

As is explored in detail in the mathematical analysis, CMRR can be maximized by using FETs that have: (1) high transconductance, (2) low output conductance and (3) a close match on both those parameters. Also, the current sink should present a high impedance.

Theoretically it is possible to have an infinite CMRR under certain conditions, but of more practical interest is what is typically achieved. Typical CMRR is calculated to be 23,200 for 2N5452 FETs when teamed with a 1N5288 field-effect current regulator for the current sink. Minimum CMRR, 2800, occurs when g_{m1}/g_{m2} is maximum.

For parameter values as shown in the 2N5452 table, it is evident that g_m and g_2-g_1 have the largest effect on CMRR. ▭

Steven Morrison, a senior engineer currently engaged in circuit design for analog and hybrid computers, has been with Westinghouse 9 years. He holds a B.S. from Rutgers and an M.S. from George Washington University and is a registered professional engineer in Maryland.

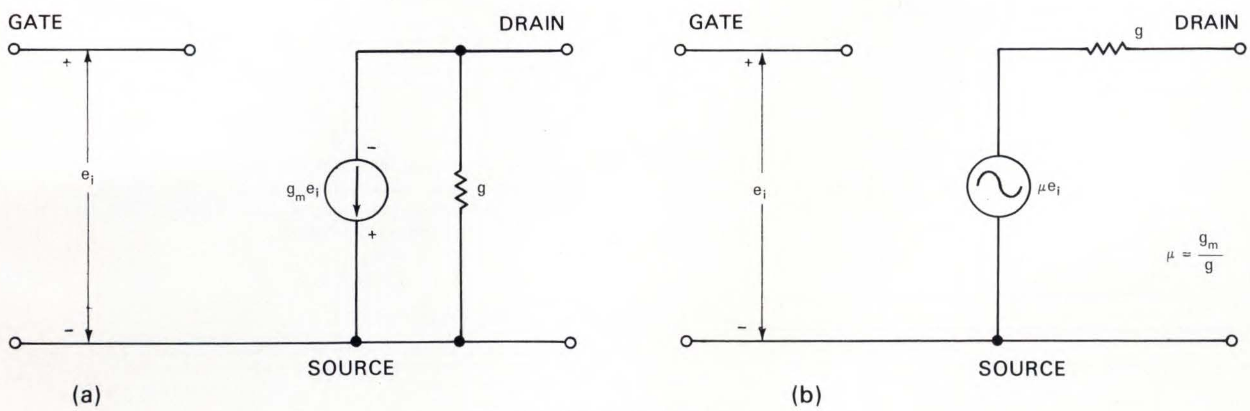

Fig. 1 – **FET equivalent** circuits.

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Improving CMR (Cont'd)

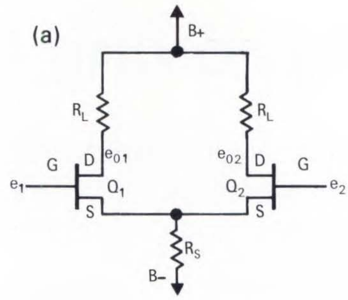


Fig. 2—**Typical differential amplifier:** (a) circuit, (b) equivalent circuit (c) flow graph of equivalent circuit.

CMRR Analysis

It is desired to obtain an expression for the output voltages (e_{01} and e_{02}) in terms of the input voltages (e_1 and e_2), and to accomplish this, Mason's Rule will be employed. According to Mason the gain of a flow graph is:

$$G = \frac{\Sigma_k G_k \Delta_k}{\Delta} \tag{1}$$

Where:

$$\Delta = 1 - \Sigma_m P_{m1} + \Sigma_m P_{m2} - \Sigma_m P_{m3} + \ldots \tag{2}$$

P_{mr} = gain product of the m^{th} possible combination of r nontouching loops, Δ_k = the value of Δ for that part of the graph not touching the k^{th} forward path. Hence:

$$\Delta = 1 + \frac{\mu_1 R_s}{R_1} + \frac{\mu_2 R_s}{R_2} + \frac{R_s}{R_1} + \frac{R_s}{R_2} \tag{3}$$

e_{01} in terms of e_1 and e_2 is:

$$e_{01} = \frac{-\mu_1 R_L}{R_1 \Delta}\left\{1 + \frac{R_s}{R_2} + \frac{\mu_2 R_s}{R_2}\right\} e_1 + \frac{1}{\Delta}\left\{\frac{\mu_2 R_s R_L}{R_1 R_2} + \frac{\mu_1 \mu_2 R_s R_L}{R_1 R_2}\right\} e_2 \tag{4}$$

Equation **(4)** can be rewritten as shown in Eq. **(5)**.

$$e_{01} = -\frac{\mu_1 R_L}{R_1 \Delta}\left\{1 + \frac{R_s(\mu_2+1)}{R_2}\right\} e_1 + \frac{\mu_2 R_L}{R_2 \Delta}\left\{\frac{R_s(\mu_1+1)}{R_1}\right\} e_2 \tag{5}$$

Similarly

$$e_{02} = \frac{\mu_1 R_L}{R_1 \Delta}\left\{\frac{R_s(\mu_2+1)}{R_2}\right\} e_1 - \frac{\mu_2 R_L}{R_2 \Delta}\left\{1 + \frac{R_s(\mu_1+1)}{R_1}\right\} e_2 \tag{6}$$

The output voltage of a difference amplifier is the difference between the two single ended outputs. Hence:

$$e_0 = e_{02} - e_{01} \tag{7}$$

The expressions for e_{01} and e_{02} are now substituted into Eq. **(7)**.

$$e_0 = \frac{\mu_1 R_L}{R_1 \Delta}\left\{\frac{2R_s(\mu_2+1)}{R_2} + 1\right\} e_1 - \frac{\mu_2 R_L}{R_2 \Delta}\left\{\frac{2R_s(\mu_1+1)}{R_1} + 1\right\} e_2 \tag{8}$$

Equation **(8)** can be rewritten as shown in Eq. **(9)**

$$e_0 = G_1 e_1 + G_2 e_2 \tag{9}$$

Where:

$$G_1 = \frac{\mu_1 R_L}{R_1 \Delta}\left\{\frac{2R_s(\mu_2+1)}{R_2} + 1\right\} \tag{10}$$

$$G_2 = -\frac{\mu_2 R_L}{R_2 \Delta}\left\{\frac{2R_s(\mu_1+1)}{R_1} + 1\right\} \tag{11}$$

Equation **(9)** can also be written in the following form:

$$e_0 = \frac{(G_1 + G_2)(e_1 + e_2)}{2} + \frac{G_1 - G_2(e_1 - e_2)}{2} \tag{12}$$

In equation **(12)** $(e_1 + e_2)/2$ is the common mode input voltage and $G_1 + G_2$ is the common-mode gain. Also $e_1 - e_2$ is the differential input voltage and $(G_1 - G_2)/2$ is the differential gain. The common-mode rejection ratio (CMRR) is the ratio of the differential gain to the common-mode gain. That is

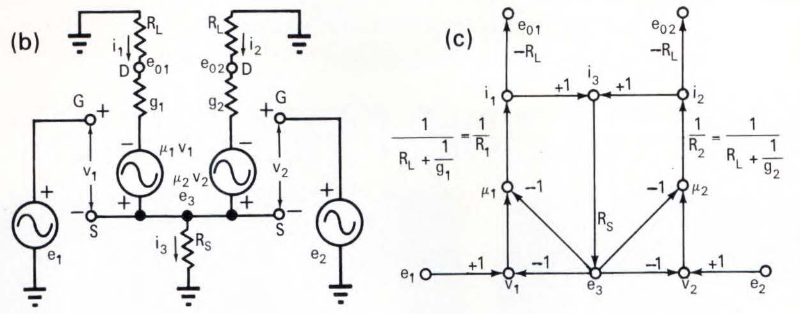
$$CMRR = \frac{G_1 - G_2}{2(G_1 + G_2)} \tag{13}$$

The sum of G_1 and G_2 using Eqs. **(10)** and **(11)** is:

$$G_1 + G_2 = \frac{R_L}{\Delta}\left\{\frac{2R_s(\mu_1 - \mu_2)}{R_1 R_2} + \frac{\mu_1}{R_1} - \frac{\mu_2}{R_2}\right\} \tag{14}$$

The difference between G_1 and G_2 is:

$$G_1 - G_2 = \frac{R_L}{\Delta}\left\{\frac{4\mu_1 \mu_2 R_s}{R_1 R_2} + \frac{2\mu_1 R_s}{R_1 R_2} + \frac{2\mu_2 R_s}{R_1 R_2} + \frac{\mu_1}{R_1} + \frac{\mu_2}{R_2}\right\} \tag{15}$$



The 2N5452 matched dual field effect transistors have a typical g_m of 1000 μmho and a typical output conductance, g, of 0.35 μmho. This yields

$$\mu = g_m/g = (1000 \times 10^{-6})/(0.35 \times 10^{-6}) = 2900.$$

With this value of μ in mind, it is obvious that the last four terms within the brackets of Equation **(15)** are negligible with respect to the first term. Hence:

$$G_1 - G_2 = (4R_L\,\mu_1\,\mu_2\,R_s)/(\Delta R_1\,R_2) \tag{16}$$

Now substitution of Eq. **(16)** and Eq. **(14)** into Eq. **(13)** yields after a little manipulation.

$$CMRR = \frac{1}{\dfrac{1}{\mu_2} - \dfrac{1}{\mu_1} + \dfrac{1}{2R_s}\left(\dfrac{R_2}{\mu_2} - \dfrac{R_1}{\mu_1}\right)} \tag{17}$$

Where

$$R_1 = R_L + (1/g_1) \tag{18}$$

$$R_2 = R_L + (1/g_2) \tag{19}$$

$$\mu_1 = g_{m1}/g_1 \tag{20}$$

$$\mu_2 = g_{m2}/g_2 \tag{21}$$

Substitution of Eqs. **(18)** through **(21)** into Eq. **(17)** yields:

$$CMRR = \frac{g_{m1}}{(1 + \dfrac{R_L}{2R_s})(g_2 - g_1) - \left[(1 + \dfrac{R_L}{2R_s})\,g_2 + \dfrac{1}{2R_s}\right](1 - \dfrac{g_{m1}}{g_{m2}})} \tag{22}$$

Since $2R_s >> R_L$, Eq. **(22)** can be simplified to:

$$CMRR = \frac{g_{m1}}{(g_2 - g_1) - (g_2 + \dfrac{1}{2R_s})(1 - \dfrac{g_{m1}}{g_{m2}})} \tag{23}$$

It is interesting to note that the CMRR becomes infinite when

$$g_2 - g_1 = (g_2 + \frac{1}{2R_s})(1 - \frac{g_{m1}}{g_{m2}}) \tag{24}$$

From Eq. **(23)** it is apparent that the CMRR can be maximized by:

1) Using high transconductance and low output-conductance field-effect transistors.
2) Employing a high-impedance current sink.
3) Using field-effect transistors with closely matched transconductance and output conductance.

A useful table for the evaluation of Eq. **(23)** follows. The data were obtained from the 2N5452 data sheet.

PARAMETER	SYMBOL	MIN.	TYP	MAX.	UNITS
Transconductance	g_m	700	1000		μ mho
Output Conductance	g		0.35		μ mho
Magnitude of Difference of Output Conductance	$g_2 - g_1$		0.05	0.25	μ mho
Ratio of Transconductances	g_{m1}/g_{m2}	0.97	0.985 (est.)	1.0	–

Assume that the current sink is a 1N5288 field-effect current regulator. This device has a dynamic impedance of 4.1 MΩ. The typical CMRR obtained with this configuration is:

$$CMRR_{typ} = \frac{1000 \times 10^{-6}}{0.05 \times 10^{-6} - \left(0.35 \times 10^{-6} + \dfrac{1}{2 \times 4.1 \times 10^6}\right)(1 - 0.985)} \tag{25}$$

$$CMRR_{typ} = 23{,}200$$

The minimum CMRR of this configuration is obtained with the maximum value of g_{m1}/g_{m2}. Hence

$$(CMRR)\ min = (700 \times 10^{-6})/(0.25 \times 10^{-6}) = 2800$$

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EDN CARAVAN ROUTING

November 2 - November 30, 1970

DATE / DAY / TIME	AREA	SITE
Monday, November 2		
9:00 - 12:00 noon	Orlando, Florida	Dynatronics, Inc.
1:30 - 4:30 p.m.	Melbourne, Florida	Radiation, Inc.
Tuesday, November 3		
9:00 - 12:00 noon	Palm Beach Gardens, Fla.	RCA (EDP Div.)
2:00 - 4:30 p.m.	Ft. Lauderdale, Fla.	Bendix Corp. (Avionics Div.)
Wednesday, November 4		
9:00 - 12:00 noon	Miami, Florida	Milgo Electronics Corp.
Thursday, November 5		
9:00 - 12:00 noon	Sarasota, Florida	Electro-Mechanical Research
1:30 - 4:30 p.m.	St. Petersburg, Fla.	General Electric (Nuclear Energy Div.)
Friday, November 6		
9:00 - 12:00 noon	St. Petersburg, Fla.	Electronic Communications, Inc.
1:30 - 4:30 p.m.	St. Petersburg, Fla.	Honeywell Inc. (Aerospace)
Monday, November 9		
10:00 - 12:00 noon	Houston, Texas	Texas Instruments Incorporated
1:30 - 4:30 p.m.	Stafford, Texas	Texas Instruments Incorporated
Tuesday, November 10		
9:00 - 12:00 noon	Austin, Texas	IBM Corp.
1:30 - 4:30 p.m.	Austin, Texas	Texas Instruments Incorporated
Wednesday, November 11		
9:00 - 12:00 noon	Austin, Texas	Tracor Inc.
Thursday, November 12		
9:00 - 12:00 noon	Dallas, Texas	Texas Instruments Incorporated
1:30 - 4:30 p.m.	Dallas, Texas	Recognition Equipment Inc.
Friday, November 13		
9:00 - 12:00 noon	Garland, Texas	LTV Electrosystems
2:00 - 4:30 p.m.	Ft. Worth, Texas	Westronics, Inc.
Monday, November 16		
9:00 - 12:00 noon	Albuquerque, N. M.	Sandia Corp.
Tuesday, November 17		
1:30 - 4:30 p.m.	Scottsdale, Arizona	Motorola Inc.
Wednesday, November 18		
9:00 - 12:00 noon	Phoenix, Arizona	Honeywell Information Systems Inc. (Computer Operations—Phoenix)
1:30 - 4:30 p.m.	Phoenix, Arizona	Sperry Flight Syst. Div.
Friday, November 20		
9:00 - 12:00 noon	La Jolla, Calif.	Control Data Corp. (Analog-Digital Systems)
1:30 - 4:30 p.m.	San Diego, Calif.	NCR (Data Processing Div.)
Monday, November 23		
9:00 - 12:00 noon	Fullerton, Calif.	Hughes Aircraft Corp.
1:30 - 4:30 p.m.	Fullerton, Calif.	Beckman Instruments Inc.
Tuesday, November 24		
9:00 - 12:00 noon		
1:30 - 4:30 p.m.	El Segundo, Calif.	Xerox Data Systems
Wednesday, November 25		
9:00 - 12:00 noon	Hawthorne, Calif.	NCR (Data Processing Inc.)
1:30 - 4:30 p.m.	Canogo Park, Calif.	Hughes Aircraft Corp.
Monday, November 30		
9:00 - 12:00 noon	Sunnyvale, Calif.	Memorex Corp. (Periferal Systems Corp.)
1:30 - 3:30 p.m.	Santa Clara, Calif.	Hewlett Packard Co.

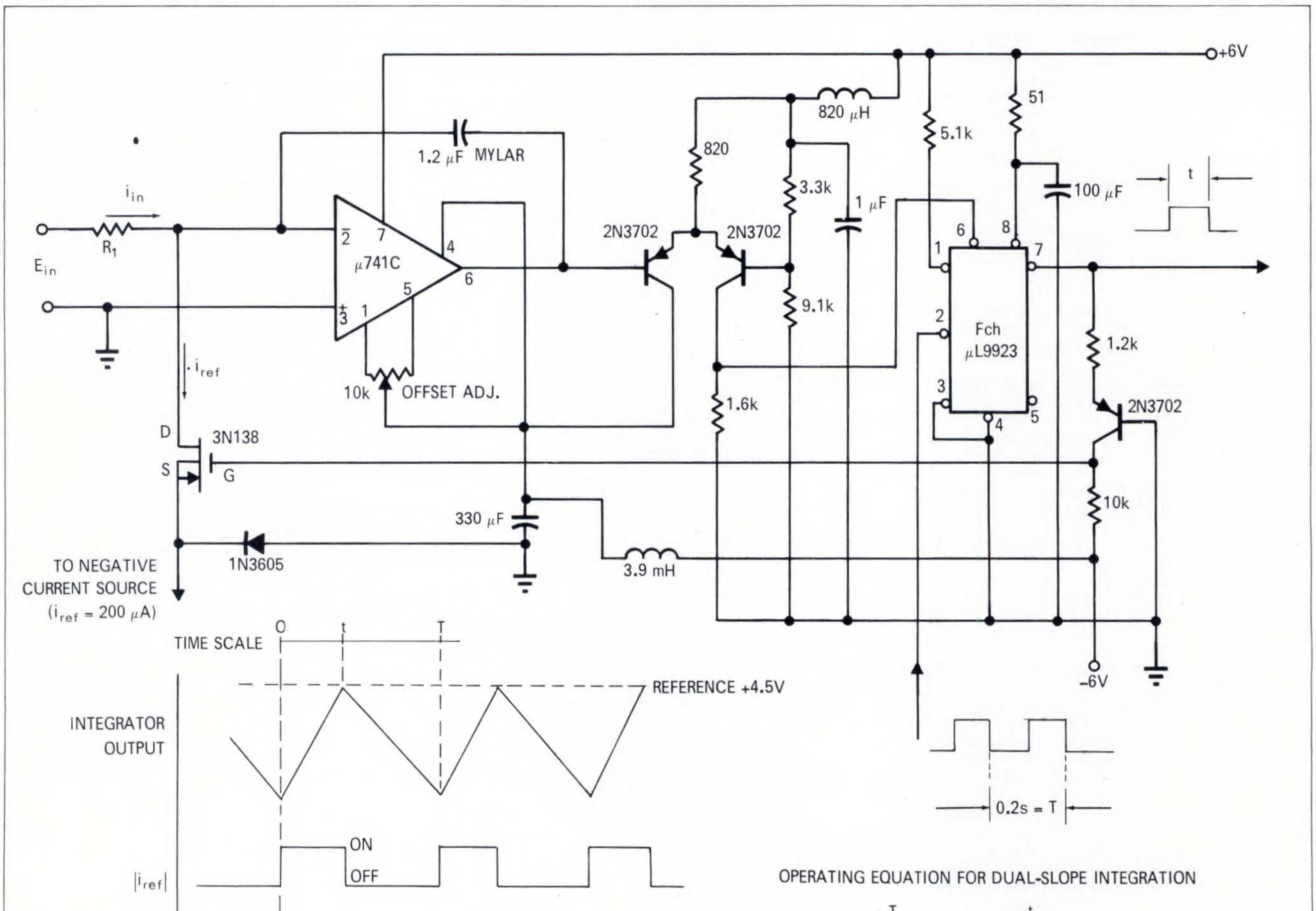
Analog-to-Pulse-Width Converter Yields 0.1% Accuracy

NEIL A. ROBIN, Tektronix Inc.

Fine for making a 0.1% DVM, this stripped-down version of a dual-slope A/D converter integrates the input current constantly but switches the reference current into the integrator each time the clock pulse occurs.

Here is a simple analog-to-pulse-width converter that, together with a conventional digital time-interval meter, makes a 0.1% DVM. Essentially it is a stripped-down version of a dual slope type A/D converter, but without the digital counter section. We now have a converter that retains the potential accuracy of the conventional method, but at much less cost. If desired, conversion accuracy can be increased by taking greater care with both the offsets and the reference-current tolerance.

Input current, i_{in}, can be supplied by a voltage source through the resistor R_1, for the op amp side of the resistor is at virtual ground. By de-



OPERATING EQUATION FOR DUAL-SLOPE INTEGRATION

$$0 = \frac{1}{C}\int_t^T i_{in}\,dt + \frac{1}{C}\int_0^t (i_{in} - |i_{ref}|)\,dt$$

SOLVING YIELDS:

$$t = \frac{T \times i_{in}}{|i_{ref}|}$$

($|i_{ref}|$ = absolute value of reference current)

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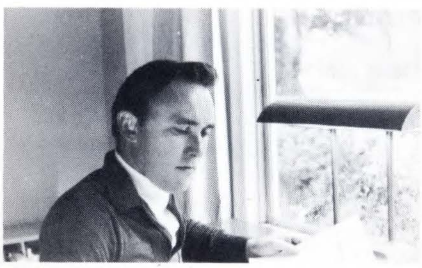
riving the clock signal, (T = 0.2s), from the crystal time base of a digital time-interval meter, and measuring the period of the output pulse we have a digital voltmeter.

From the timing diagram and formulas, the pulse width **t** is seen to be directly proportional to i_{in} and inversely proportional to i_{ref}. Thus, if i_{ref} is made the input variable and i_{in} is held constant, the inverse (reciprocal) relation can be obtained. This can be quite valuable for making velocity measurements. By using suitable values for the scaling resistor R_1, monitoring of a large range of voltages is possible.

Complete descriptions of the dual-slope integration technique can be found elsewhere. In this approach, conversion is obtained by integrating the input current, i_{in}, constantly, but switching i_{ref} into the integrator each time the clock pulse occurs. I_{ref} is switched out of the integrator when its output voltage reaches the +4.5V level. With the component values shown, i_{in} is 80 μA maximum (R_1 = 100 kΩ) and full scale voltage is 8.0V. Calibration can be performed by making small adjustments of i_{ref}. □



Neil A. Robin, a project engineer in circuit and IC design at Tektronix, expects that circuits such as he discusses in this article will soon be completely integrated with LSI techniques. He holds a B.S.E.E. from Heald's Engineering College and is a member of the IEEE.

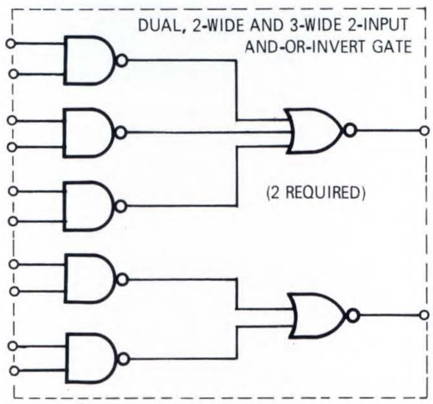
Discrete Devices Solve IC Problem

Four discrete components provide a third two-input AND gate to an existing dual-gate IC. In addition to saving space, this approach avoids the expense of having to buy and inventory two additional ICs.

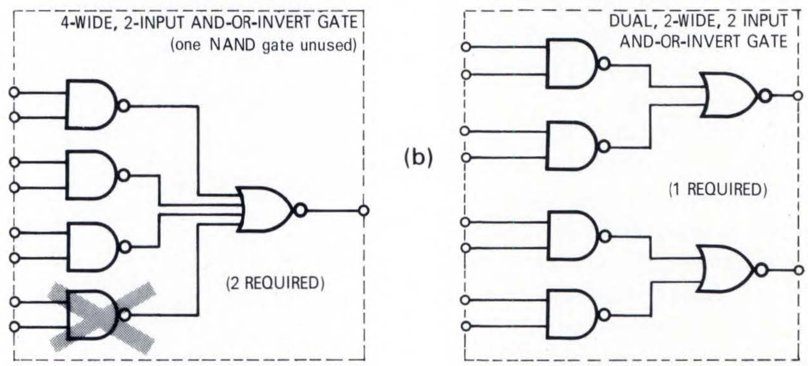
Adding a resistor, two diodes and a transistor transforms an expandable two-wide, two-input AND-OR-INVERT gate into a three-wide, two-input AND-OR-INVERT gate. In at least one application, this low-cost modification (less than $1.50) avoided the necessity of buying another IC, providing space for it on a PCB and interconnecting it with the original circuits.

Auto-trol Corp., Arvada, Colorado, has a digitizer application in which they needed two nonexistent two-wide and three-wide, two-input AND-OR-INVERT gates in the same package. They could buy a pair of four-wide units and not use one of the AND gates, but they would also have to buy an additional dual gate—a total of three ICs not fully utilized or stocked in their regular inventory.

The resistor, two diodes and transistor (already in stock) added another high-speed two-input AND gate to each IC, conserved valuable PCB space and avoided having to buy and stock two additional ICs. □

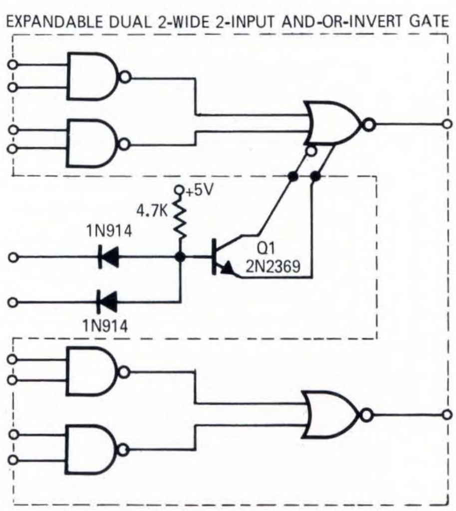


(a)



(b)

Nonexistent IC (a) would meet needs of digital circuit (two required). Closest solution using existing ICs is (b) a pair of four-wide, two-input AND-OR-INVERT gates plus one dual two-wide, two-input AND-OR-INVERT gate. One NAND gate in each of former is unused. Additional IC (three compared to two) takes space and interconnections on PCB.



Four discrete components added to expandable dual two-wide, two-input AND-OR-INVERT gate provide another two-input AND gate. Duplicating this circuit meets user's needs and avoids necessity of purchasing and stocking two additional ICs.

Bill Barnes, who designed this cost-saving idea into their digitizers, is Chief Engineer doing R & D at Auto-trol Corp., Arvada, Colo.

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J-K Properties Ease Karnaugh Map Application

Combining the unusual properties of a J-K flip-flop with the flexibility of a Karnaugh map yields a simple method for designing sequential circuits.

RONALD E. RUFF, University of Washington

Properties of a J-K flip-flop allow a Karnaugh map to be simplified into two parts—one representing the "J" input logic, the other representing the "K". To demonstrate the effectiveness of this approach, the logic for the transition table in **Fig. 1** will be developed.

Since the maximum number of possible states for "R" flip-flops is 2^R, the eight-state transition table requires at least three flip-flops. A clock pulse causes the transition of these flip-flops to go from A^n, B^n, C^n, to A^{n+1}, B^{n+1}, C^{n+1} (superscript "n" implies that $A^n = A$, $B^n = B$, etc). The problem is to determine the logic that will establish the sequence in the truth table using the J-K flip-flops A, B and C as the storage elements.

Referring to the block diagram in **Fig. 1**, the input logic for each flip-flop is a function of all outputs. However, this is only an assumed general condition because the simplified input logic often excludes some of the outputs. In general

$$A^{n+1} = f(A, \bar{A}, B, \bar{B}, C, \bar{C}) \quad \textbf{(1)}$$

where f is a Boolean function in the nonsimplified minterm form with the variables A, B and C present in each term (example, $A^{n+1} = A\bar{B}C + \bar{A}BC + \bar{A}\bar{B}\bar{C}$). The general expression for a J-K flip-flop is $Q^{n+1} = J_Q\bar{Q} + \bar{K}_QQ$ where J_Q and K_Q represent the input logic.

Applying these general expressions to flip-flop A, the J-K expression becomes

$$A^{n+1} = J_A\bar{A} + \bar{K}_AA \quad \textbf{(2)}$$

To relate expression (2) to the stan-

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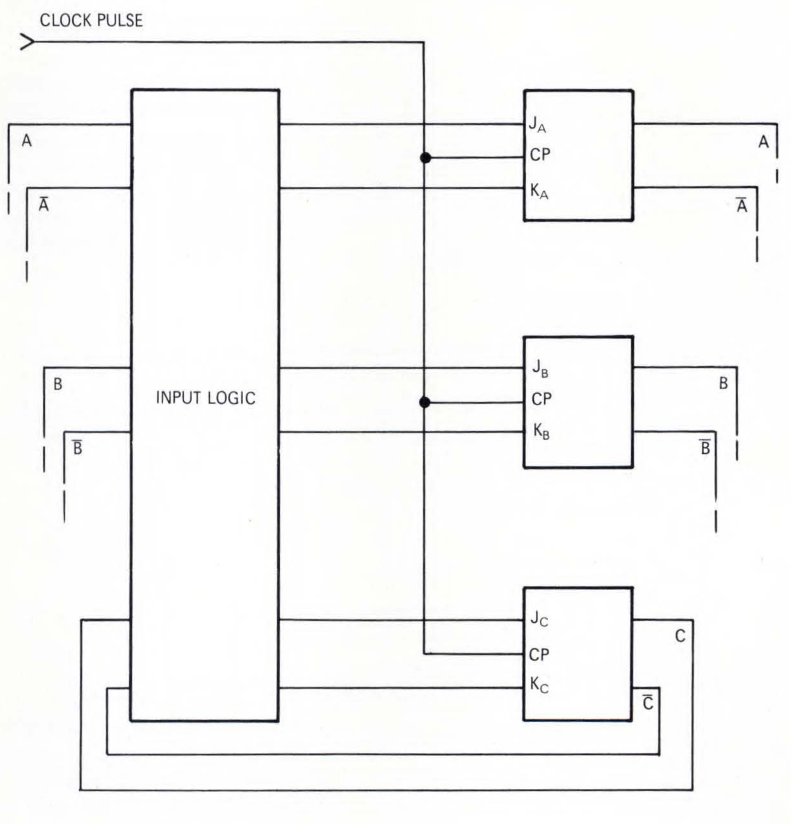


A^n	B^n	C^n	A^{n+1}	B^{n+1}	C^{n+1}
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	1	0	0
1	0	0	0	1	1
0	1	1	1	1	0
1	1	0	1	0	1
1	0	1	1	1	1
1	1	1	0	0	0

TRANSITION TABLE

Fig. 1—**Transition table** shows operational sequence of the block diagram.

dard mintern expression, all A and Ā terms are factored out of expression (1) and the result is

$$A^{n+1} = f_1(B, \bar{B}, C, \bar{C})\bar{A} + f_2(B, \bar{B}, C, \bar{C})A \qquad \textbf{(3)}$$

Comparing equations (2) and (3), it is observed that

$J_A = f_1(B, \bar{B}, C, \bar{C})$ and

$K_A = f_2(B, \bar{B}, C, \bar{C})$

Therefore, factoring out the Ā and A terms from **Eq. (1)** generates the simplified expression for J_A and K_A. Similarly, the input logic for B and C can be simplified.

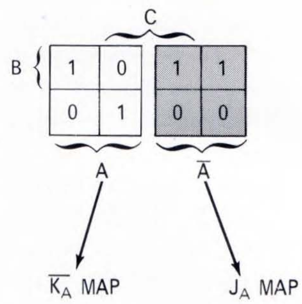
The graphical approach using Karnaugh maps (**Fig. 2**), achieves simplification based on factoring. Flip-flop A, referring to **Fig. 1** transition table, is plotted on a Karnaugh map. Recognizing that half of the Karnaugh map represents A and the other half represents Ā, we may then separate the map into two parts. One part contains all the Ā factors and represents J_A; the other has the A factors, which are $\bar{K}_A$. The simplified logic for J_A is obtained directly from the map. However, the $\bar{K}_A$ map must be inverted and then simplified to obtain the K_A input expression. For ease in graphical factoring it is convenient to always assign whichever variable is to be factored to the same

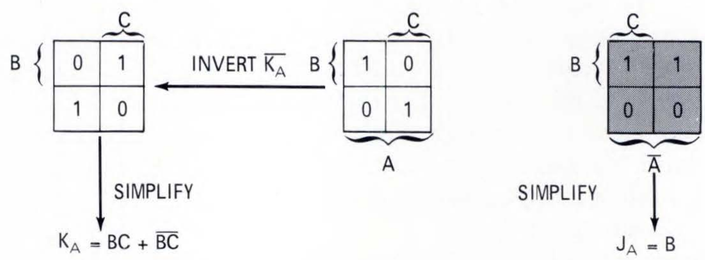
A^{n+1} MAP

A	B	C	A^{n+1}
0	0	0	0
0	0	1	0
0	1	0	1
1	0	0	0
0	1	1	1
1	1	0	1
1	0	1	1
1	1	1	0

TRUTH TABLE FOR A^{n+1}

Fig. 2—**By arranging the Karnaugh map** so that half the map represents true function (A) and the other portion is the complement (Ā), the map may be divided into two separate maps. "J" logic is obtained directly from the complement map (Ā), and "K" is the inverse of the true map (A).



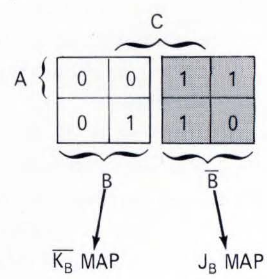


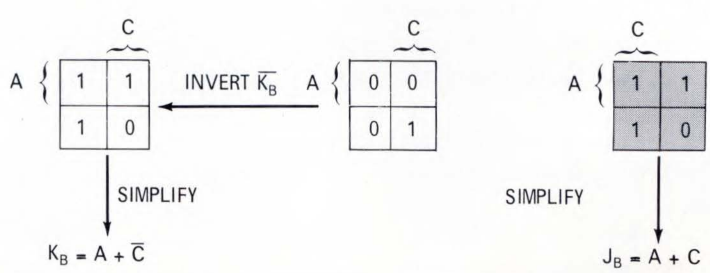
B^{n+1} MAP

A	B	C	B^{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
1	0	0	1
0	1	1	1
1	1	0	0
1	0	1	1
1	1	1	0

TRUTH TABLE FOR B^{n+1}

Fig. 3—**Factored variable B** has been assigned to the same location on the map that was occupied by A in **Fig. 2**. Other location assignments are completely arbitrary.





position on the map. The simplification for the B input logic, **Fig. 3**, illustrates this feature. The desirability of doing this becomes apparent in more complex problems. The C flip-flop logic is obtained in the same manner.

The simplified input logic equations are used to synthesize the input circuit. Any number of representations is possible. For this example, the circuit in **Fig. 4** uses Texas Instruments' Series SN7400 NAND gates and SN7473 flip-flops. Simplicity is the main advantage of this graphical approach. There are other techniques that are based on Karnaugh maps or Veitch diagrams, but they are more complex. However this method takes advantage of the J-K flip-flop properties and is not easily applied to other types of flip-flops. More complicated sequential circuits can be handled readily by this method. □

Ronald E. Ruff is an associate electrical engineer at the Applied Physics Laboratory of the University of Washington. Presently, Mr. Ruff is also a full-time student at the University of Washington pursuing a Ph.D. in engineering.

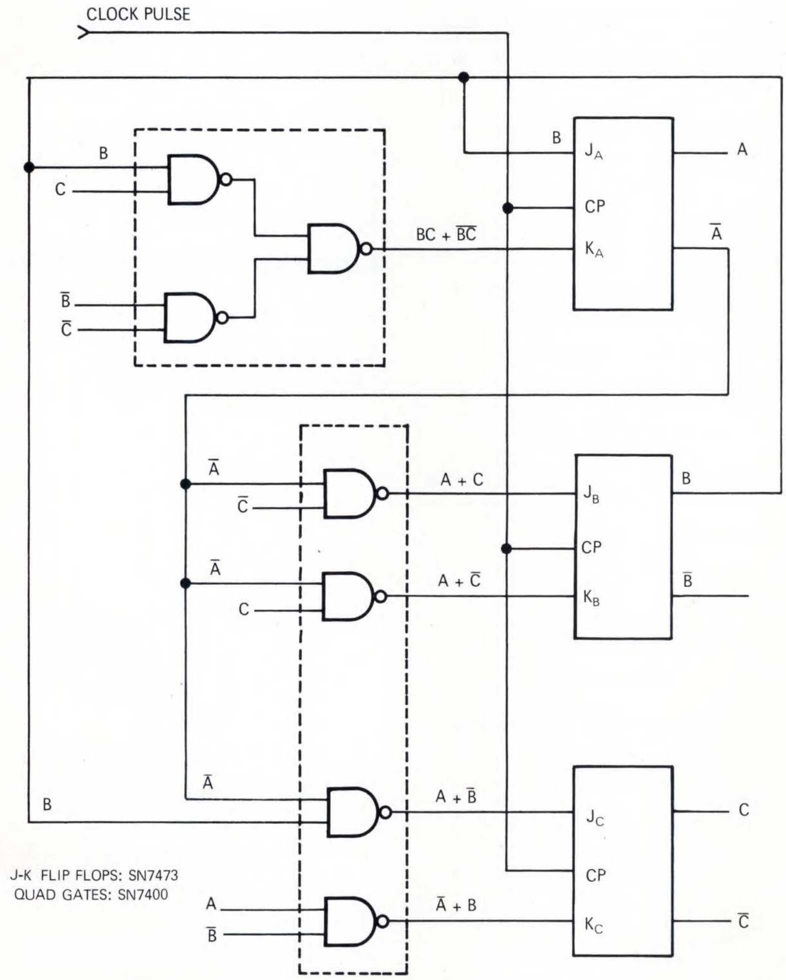


Fig. 4 – **Circuit performs** sequential operation of transition table in **Fig. 1**.

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CUSTOMER ENGINEERING CLINIC

Switch Bounce Eliminator Does Double Duty

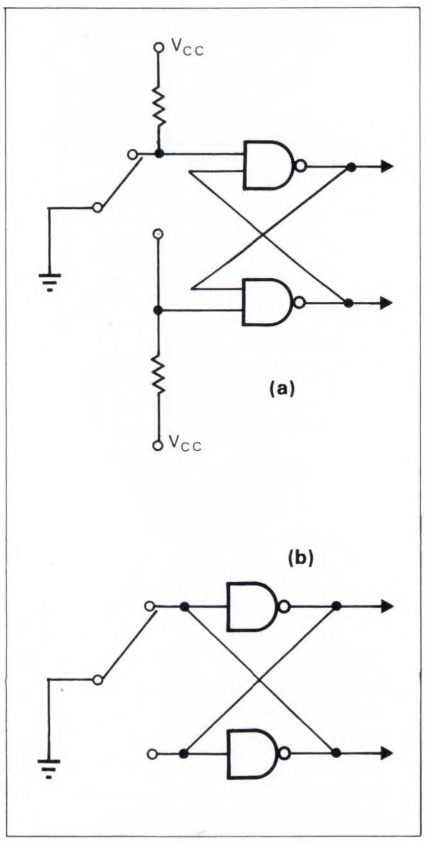
LEON MEGGERSON, JR., Litton Systems, Inc.

Problem: Eliminate switch bounce problems and still maintain sufficient current to insure wiping action.

Discussion: A well-known technique for debouncing manually operated switches is illustrated in (**a**). However, for a typical TTL gate and resistor combination, the current through the switch ($I_{sw} = 1.2^{+} + V_{cc}/R$) is fairly low. In some instances, this current is insufficient to provide "wiping" action on seldom-used or oxide-coated contacts. The several actuations necessary to "wipe" the contacts before a positive action is obtained can be annoying. Mounting and extra wiring needed for discrete resistors present a supplementary problem.

Solution: A cursory glance at the solution in (**b**) might cause some concern regarding the short circuit condition. Nevertheless, most TTL gates possessing totem-pole output configurations are capable of sustaining a short circuit current on the order of 100 mA for short periods of time. This period is the thermal time constant of the device, and it typically lies between 2 and 10s depending upon the manufacturer. Configuration (**b**), however, reduces this time to two-gate propagation delays. For most TTL gates, this time is on the order of 10 to 30 ns, with even the worst-case devices being <60 ns.

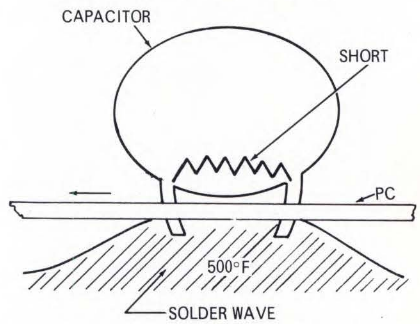
Comparison of the two circuits shows that, in addition to providing the requisite "wiping" action through increased switching current, the need for resistors has been eliminated, as have two input points. It is the latter feature that permits the use of cross-coupled hex inverters and increases debounce capability 50%/14-pin DIP package. Using devices such as Motorola's MC525L and Texas Instrument's 54/7405, switches have operated reliably for more than 2000 hours with positive debouncing and no indication of intermittency or failure. □



EDN will pay $50 for any problem-solution article accepted for publication.

NEXT ISSUE'S PROBLEM

Mil Spec Capacitors Short During Soldering



Large numbers of military-specification quality capacitors failed by shorting during the wave-soldering operation. See the next issue for the reason why this could happen to you, too.

Engineers—Liberate Yourselves

Every secretary wants to help that second man in her life—her boss. Her capacity to help is greater than ever before, now that engineers are providing her with that modern marvel, the programmable calculator.

THOMAS G. BRIGHAM, Hewlett-Packard

The design engineer is the man who controls today's standard of living. But no one professional in our society faces more adversaries in his quest for the innovation, the breakthrough and the next generation—especially in an era of economic slowdown.

Throughout our nation, engineers are waiting for an unemployment check instead of checking out the new schematic. Those that are working face frustrating budget cutbacks. Yet, the engineer's greatest adversary is one that always faces him, the lack of time. It takes time to innovate, to analyze, to recreate, set up for production, iron out the bugs and other problems, big and small, that plague the designer.

One of the greatest time-consumers comes forth in the area of computation, routine computations—the same problems faced day after day. Although computational aids have come a long way since the paper, pencil and slide rule, no one departure seems to have the significance as does the advent of the programmable calculator.

The desk-top computer is the designer's dream. Sitting right on the engineer's desk, this computational device allows the designer to analyze and modify or alter parameters and variables without waiting for that seemingly endless turn-around time. Using these machines, engineers can design filters, antenna arrays, or whatever in fractions of the time taken by traditional methods.

With all this help, what more could the busy engineer ask for? The innovative engineer has taken the aid furnished by his programmable calculator a step further. Because of the inherent simplicity in operating

(Continued)

these modern marvels, engineers are having their secretaries run their programs for them. Now, all these engineers need to bother with are the results.

Second Most Important Man

To the secretary enthusiastically engrossed in her job, the boss is the second most important man in her life. When he's down, she's down. When he succeeds, she succeeds. She has followed the big deal, the new innovation, the breakthrough and the cancellation from its inception to its completion.

These feelings were expressed by **Cindy Dykstra**, secretary for Don Schultz, divisional manager of

Hewlett-Packard Instrument Division in Loveland, Colo. Cindy feels that a secretary should always be interested in finding ways of performing a better and more efficient job. It is her duty to take some of the smaller burdens off Don's shoulders, that plague him and free him for bigger and more important duties.

One job that Cindy regularly performs is determining actual versus target dollars to determine how the Instrument Division is doing. Instead of numerous repetitive computations on a small adding machine, she inserts a magnetic card, enters the data, presses the "continue" button and within minutes she provides her boss with a print-out.

However, Cindy is not satisfied. She wants to learn more about the calculator because: "Don is involved with many other important jobs and his time is limited. I know it would not take long to learn how to operate the full keyboard. And if I could get a complete understanding of programming, like some of the other secretaries, I could save him many hours of work.

"For example, now Don has to personally go to his engineers, sit down and figure out the program involving their particular phase of the operation. Then they record it on a mag card with operating instructions for me. If I know the machine, the engineers could tell me and I could generate the necessary instructions; program the mag card; and then perform the final calculations. You know, the secretaries could save the engineer a lot of time—time they take for granted!"

Why the Excitement?

One girl that has to know how to operate the calculator is **Bonnie Dykes**—secretary to Hewlett-Packard's Calculator Applications Group. Responsibil-

ity of this group is to generate industrial oriented software packages for the Hewlett-Packard 9100 System.

Bonnie's biggest and initial impression came when she joined the group: "There it was, sitting on my desk. I thought 'great, but I'll never understand it.' Yet, I remember how strange it was that everybody was so excited about it."

Her abbreviated formal training began with a more-or-less explanation on what a programmable calculator is and the difference between this machine and a regular calculator that performs arithmetic operations only. After learning the key functions and modes of operation, she was able to perform simple routines such as making the calculator count to 100, stop, then reverse the counting sequence. "Actually," Bonnie says "once you know what each key does, you just use logic. My only real handicap is that I don't know math well."

Bonnie's job is to be the "guinea pig" in the group. The application engineers write the programs and follow through by having her run them. After keying in the program, she generates the mag cards, and then checks them for accuracy. If there is a hitch in running any of the programs, the engineer responsible for that program knows he has more work to do.

Al Sperry, manager of the applications group says, "Actually, it is unfair having Bonnie interviewed for an article like this because running the calculator is her job. Yet, it does prove a point. Bonnie has only a high school background in math; has received about three hours of formal training; yet, she fully understands everything the calculator is doing and can often spot the bugs in the program. About fifty percent of her time is spent checking out programs, and in dollars, I cannot begin to tell you what a savings that is for us."

What does Bonnie think about being a small bit of femininity surrounded by a group of engineers from various disciplines, each with their own buzz-words? "It's really exciting. One of the fellows rattles off a series of nineteen syllable words, then gives me a program to run. But by the time I've typed and checked it out, I have kind of an idea what it is about. It's a continual learning process.

"I also think that I could learn the computer now. Of course, the calculator is easy because there is no language, but the languages of the computers have some of the calculator principles. I really think I could do it."

Profit from Education

Another secretary who enjoys using the calculator is **Lucille Lester** of the Educational Group. Not only is it a fun job, it's a satisfying one. Needless to say, the students that profit most from the Educational Group's work are all future engineers.

Lucille's major job is developing educational workbooks for schools and teaching aids for calculator applications for the students. It is her responsibility to assure that all answers are correct. In doing this, she uses both the calculator and computer.

She takes the magnetic card with the program and

puts it into a calculator linked to a coupler and Teletype. The Teletype, in return, punches out a tape with the register number and an octal code of each program step. This tape is entered into a computer programmed to translate the tape language from Teletype to Flexowriter while adding the mnemonics. The computer punches out a new tape with the register numbers, mnemonics and octal codes. This new tape is fed through the Flexowriter which prints out a form that is sent to the publisher for printing.

Then the magnetic card is replaced in the calculator for a printout which is checked against the computer printout. If the two match, the project is complete. If not, it is up to Lucille to determine the fault.

Lucille says that "Equivalent computer functions performed on the calculator are easier to do and less frustrating. The reason is that it is easier to make modifications with the calculators."

Terry Gildea, head of the Educational Group feels: "Any secretary with a basic understanding of math can operate a programmable calculator. This is true of whatever manufacturer's model you're talking about. After all, we are developing aids to teach seventh graders. These same aids can be used to teach the secretary. Lucille saves us a lot of time; time we need to meet our schedule."

In working with the calculator, Lucille says: "It is a lot of fun and very satisfying." However, she

(Continued)

makes one confession—"Students take to the calculator much more quickly than the teacher does. Yet, this a good omen for the future of engineering. With the various computer aided instruction programs now in practice, think of the background the average engineer will have by the time he graduates. Also, think of the background the average secretary will have to aid her in helping out her boss."

Eliminate the Old Routine

Where a secretary really stands out in saving her boss time is when she learns to perform those routine, yet vitally important calculations quickly and accurately. **Nancy Cannon**, a secretary in Hewlett-Packard's Instrument Marketing Group, is such a girl. With the aid of a 9100B, a printer and plotter, Nancy projects the monthly forecasts for the division.

Originally, this job was drudged through with a regular adding machine, performing columns of multiplication and addition. For example, Nancy would multiply the number of units sold in a month by the price of the unit. After this, the results for all the units and the different instruments were combined. The complete project took approximately 4 hours. With the programmable calculator, the time has been reduced to

Mrs. Martha Jayne, a clerk-typist, works for the Pacific Northwest Forest and Range Experiment Station's Forest Engineering Research Project in Seattle, Wash. Engineers in this project work with various aspects of forest engineering. They rely on a computing system to analyze the running and standing skylines, balloons and other logging methods.

Their system includes a Hewlett-Packard 9100B, 9125A plotter, 9120A card reader and a 9160A printer. Beginning with instruction for using the calculator one of the engineers trained Martha to use all the equipment. Then he continued with instructions on entering and recording engineering related programs on magnetic cards for future use. Next, she was told about the plotter and how to use it for plotting skylines as well as for other applications. This included the entering of data for these programs and setting up the plotter's origin points and limits.

In the past, this work used programs already written but needing to be recorded or plotted. Recently, with instruction and examples, Martha began to develop her own programs to help the engineers with their analysis. They would hand her sections of their analysis in flow chart form and she would generate the program from these charts. Eventually, these small routines are combined into one large computer program. Also, she became knowledgable in drawing flow charts from the programs presented to her by the engineering staff.

Writing these programs is not the final step. Martha assumed responsibility for checking them on the calculator and working with them until they are correct. When certain that the program will run, she will discuss it with the engineer who assigned it. He in turn checks it for accuracy and suggests step savers.

The programming aspect is the most important function performed for the project. It allows the engineers more time for research and also relieves them of the time-consuming task of checking programs for accuracy, preparing flow-charts, etc.

Writing programs is a challenge for Martha and with further practice and instruction, she hopes to write larger and more complicated programs, thus becoming of more assistance to the project.

thirty or forty-five minutes. Nancy just loads the mag card and follows the instructions of the program card.

Another forecasting job involves a calculator and plotter combination. Nancy accumulates the sales of a group of instruments such as digital voltmeters on a monthly basis. She then plots the history of sales for this group over a 5-year period to determine a trend line. The result is a series of bar graphs on a plotter paper. In the past, this operation involved 15 different people for 8 hours. Now, everything is attained in less than 2 hours.

Nancy says, "It would make no difference to me whether I'm running a marketing problem or a lab problem. All I need to have is the mag card with operating instructions. I only wish I could do more!"

With just a few instructions plus a basic understanding of what you are doing and what you need, your secretary can save you not only minutes, but hours. All the girls interviewed enjoy working with the calculators and in some cases computers, but that was not an end in itself. Every girl wanted to help that second man in her life – her boss. ▭

Thomas G. Brigham is advertising/public relations manager for Hewlett-Packard Company's calculator products division in Loveland, Colo. He is a graduate of the University of Wisconsin.

It is predictable that an engineer's secretary would learn to use the programmable calculator easily and quickly. But EDN was curious about how a nontechnical secretary would take to such a machine. To find out, we asked an EDN secretary, **Sumi Yamashita**, to spend a day learning to operate the programmable calculator. Here are her reactions.

"Expecting the programmable calculator to be a monstrous machine comprised of huge units, I instead found an instrument about the size of my typewriter. After a short briefing on the basic operations, I was then left by myself with an instruction book and two magnetic cards to deal with the machine.

"After working with the machine for about 4 hours I was able to use the programmable calculator as a calculator. Also, I had gained enough knowledge so that I could run simple routines.

"There seems to be a personal satisfaction for any secretary who is willing to accept the challenge of learning to use such a machine. I believe anyone with a basic math background could learn how to write and run programs with a few hours of instructions. The main hurdle is learning the functions that each key will perform. I also see where these machines are time savers for both the secretary and her boss, in addition to improving the overall efficiency of their work."

Sumi's mathematical background includes high school algebra and geometry.

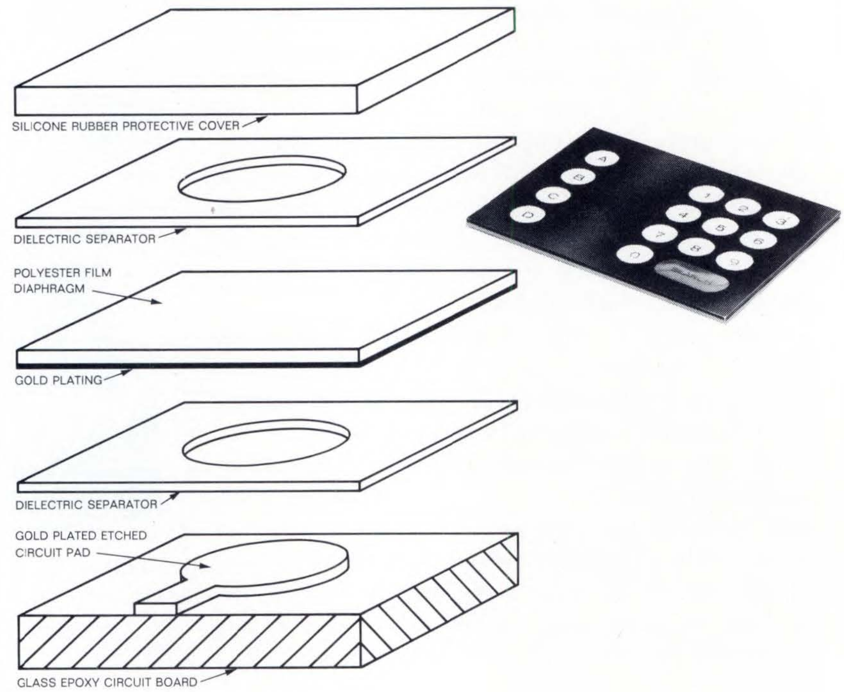
(Continued)

Low-profile Keyboard Boasts High Reliability

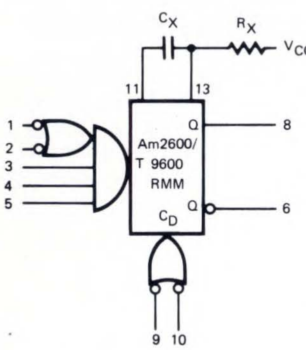
Super-slender keyboards are here – and they're reliable. Developed by Datanetics Corp., the new low-profile keyboard (photo) employs a wafer-thin (0.15 in) elastic-diaphragm switch. The West Coast firm reports that they have recorded more than 100 million contact closures (at rated load) without failure or any sign of mechanical degradation.

The company-designed elastic-diaphragm switch (diagram) is a "layered" environmentally sealed structure that comprises a gold-plated diaphram, dielectric separators and a gold-plated pad (etched on a circuit board). Applying 1 oz of pressure to a key joins the conductive surfaces of the diaphragm and circuit board through a hole in the dielectric separator. Each key has a Form A contact which closes to a single common. Already, this noiseless keyboard is being designed into credit-card verification systems.

Capable of operating over the −40 to 65°C temperature range, the new keyboards measure 3.75 by 5.40 by 0.15 inches. Maximums for voltage and current are specified at 12V and 20 mA, respectively. Designated Model DC-402, this thin keyboard is quantity-priced (100 up) at $8.60. Datanetics Corp., 2828 Spreckels Lane, Redondo Beach, CA 90278. **325**



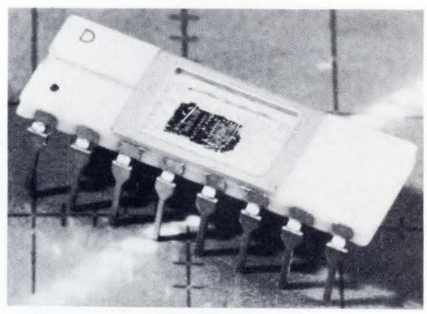
One-Shot Guarantees Pulse-Width Over Full Temp Range



Advanced Micro Devices, Inc. aims to become the foremost second source for Fairchild's 9000/MSI series. Recently added to their growing product line are five retriggerable monostable multivibrators. Three of these "one-shots" are second source items for Fairchild's 9600, 9601 and 9602 – while the remaining two, designated Am2600 and Am2602, are proprietary products. These latter entries can electrically and pin-for-pin replace the 9600 and 9602, respectively. Though the Am2600 and Am2602 are cost-competitive with their Fairchild counterparts, they boast performance advantages. Besides improved switching characteristics, the new one-shots guarantee that the pulse width will not vary more than 0.6% over the 0 to 75°C temperature range. Available in hermetic or silicone plastic DIPs – as well as in dice form, their quantity prices (1000 mix) are typically $2 to $5 for the Am2600; $6 to $11 for its dual, the Am2602. Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **326**

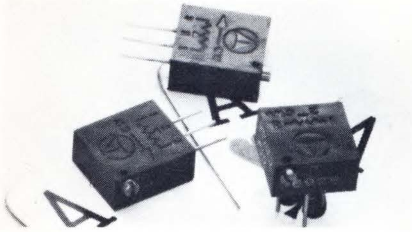
Hybrid D/A Converter Handles 10 Bits

Through its newly-formed subsidiary, Analog Integrated Microsystems (AIM), Precision Monolithics, Inc. has just introduced its first hybrid circuit. Designated the aimDAC-01, the new entry is a two-chip D/A converter with 10-bit resolution.

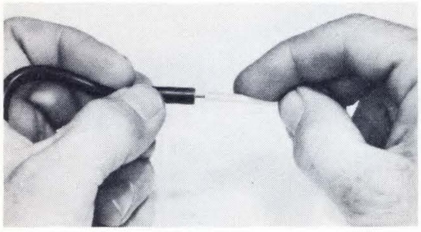


The aimDAC-01 combines a fast, monolithic D/A current source (monoDAI-01) with a precision film-resistor network (monoDAR-01). In hybrid form, both are contained in either a standard DIP (photo) or flat-pack.

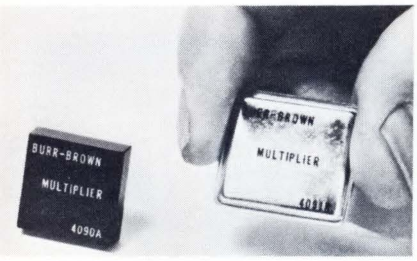
With a settling time specified at 350 ns (±0.1%), the aimDAC-01 is designed to operate over the −55 to 125°C temperature range. Consuming only 250 mW, the new hybrid allows customers to choose one of four output voltage ranges; 0 to +5V; 0 to +10V; ±2.5V; ±5V. With temperature coefficients ranging from 12 to 150PPM/°C and accuracies spanning 0.05% to 0.3%, quantity prices (1000 up) vary from $25 to $121. Precision Monolithics, Inc., 1500 Space Park Drive, Santa Clara, CA 95050. **327**



3/8-in wirewound trimming potentiometers designated 2300 Series qualify for MIL-R-27208, RT24 and come in P, W and X configurations. Three configurations—printed circuit card mounting, side adjust or top adjust—have a resistance range of 10 to 20,000Ω and a power rating of 0.75W at 85°C. Resistance tolerance is ±5%. Amphenol Controls Div., The Bunker-Ramo Corp., Janesville, WI 53545. **328**

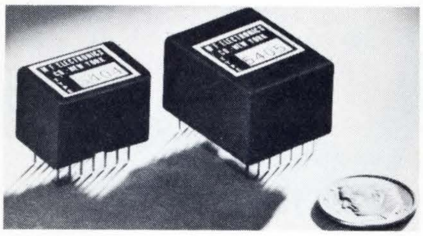


RFI/EMI suppressible flexible tubing replaces ferrite beads. The tubing provides easy retrofit for existing installations requiring RFI suppression. Diameters from 0.1 to 0.5 ±0.005 in and lengths of 12 in are now available. Flexibility in terms of bend radius is from 0.5 to 1 in depending on diameter. This tubing may be ordered either shielded or unshielded. Lundy Electronics & Systems, Inc., Glen Head, NY 11545. **329**

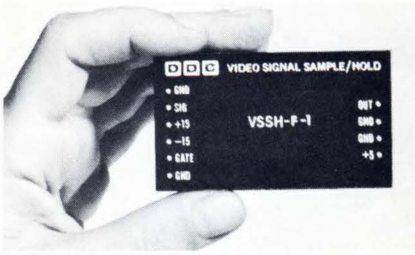


Hybrid analog multiplier comes in two versions—the 4090 epoxy encapsulated unit for operating from −25 to 85°C and the 4091, cold-welded hermetically-sealed flatpack for −55 to 125°C. These units are scaled for compatibility with commonly available IC operational amplifiers. The miniature package measures only 3/4 by 3/4 by 1/4 in. Unit quantity price starts at $45. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **330**

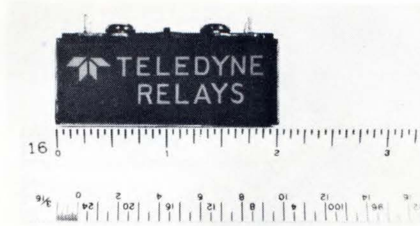
Card reader photo array uses advanced thick-film technology and the latest phototransistors in a slim package with a glass cover. Cards will slide by easily with no restrictions or dust problems. Mounting holes for precise alignment are provided, and available models have 12, 13 and 14 sensors. Price is $20 each/100 lot. HEI, Inc., Jonathan Industrial Center, Chaska, MN 55318. **331**



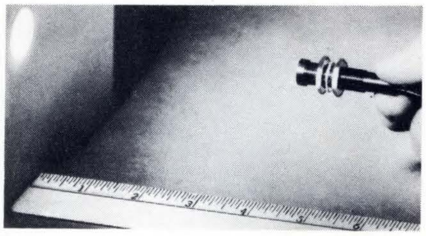
Two series of clock oscillators 5404 and 5405 are socket pluggable and, depending upon the frequency, take the space of one or two dual in-line packages. The 5404 generates 5 to 15 MHz with an accuracy of ±.005% (0 to 65°C), and 5405 generates 80 KHz to 4.9 MHz with an accuracy of ±.02%. The output is a square wave that can drive TTL logic. MF Electronics Corp., 118 E. 25th St., New York, NY 10010. **332**



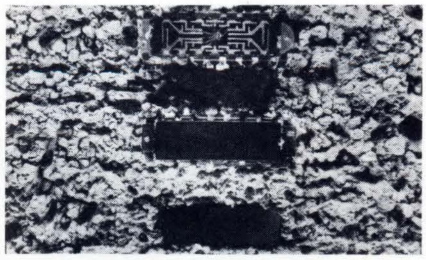
Video signal sample/hold modules VSSH Series are available in three models—VSSH-F, VSSH-M and VSSH-S. These devices provide $10^{11}\Omega$ input impedance and an input signal range of ±5V. Aperture time is 300 ps. Specifications include: acquisition time of 10 to 100 ns, small signal bandwidth of 25 to 100 MHz, and 0.2 to 2 mV/μs drift in the "hold" mode. Price (1-9) is $395 or $495 depending on temperature range. DDC, 100 Tec St., Hicksville, NY 11801. **333**



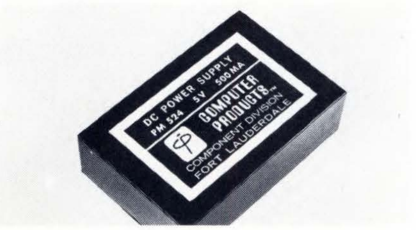
Solid state, low-cost relay Series 601 is comprised of 70 relays with prices peaking at $12 to $13 in small quantities. They are available in a wide range of control voltages from 3 to 75V dc and 9 to 140V ac. Available current range is 1 to 10A. In addition, no external heat sink is required for the 1 to 7 amp units. Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. **334**



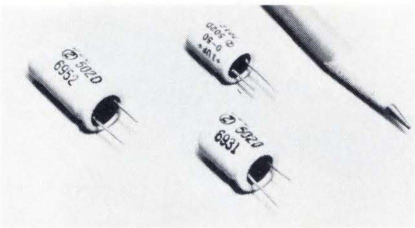
Beam emitter, Series CM-20, projects narrow cones of infrared and luminous energies over distances of 7 to 20 in. Minimum measurement of illumination across the target is 20 fc for CM-20-8-01 at 7 in and 15 fc for CM-20-9-01 at 14 in. The CM-20 devices consume only 850 mW, and operating voltage is 2.5V nominal with a current drain of 340 mA. Chicago Miniature Lamp Works, 4433 N. Ravenswood Ave., Chicago, IL 60640. **335**



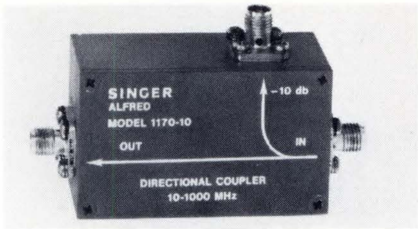
Devitrifying solder sealing glass, Code 7588, is designed specifically for sealing alumina ceramics. Code 7588 is available as a powder in a variety of mesh sizes with or without coloring additives. When used for thin seals, as in integrated circuit packages, sealing is accomplished at temperatures under 500°C. Preglazing operations require around 400°C. The material's flow characteristics assure closure of all cracks and fissures. Corning Glass Works, Corning, NY 14830. **336**



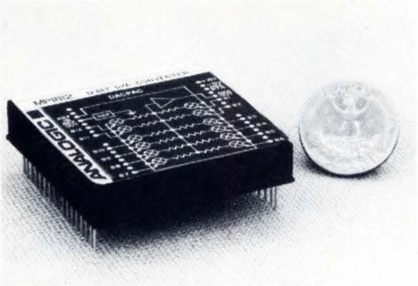
DC power supply PM524 is a potted module for powering IC logic gates. Measuring 2.5 by 3.5 by 0.875 in, the PM524 provides 5V at 500 mA and operates from 115V ±10V ac, 50 to 400 Hz. Units are available, at slightly extra cost, that operate from 230V ac, 50 Hz. Unit price is $43.95. Computer Products, 1400 NW 70th St., P.O. Box 23849, Ft. Lauderdale, FL 3307. **337**



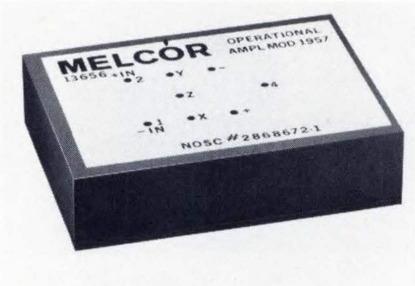
Electrolytic capacitors, identified as Type 502D Verti-lytic capacitors, can be installed vertically on high-density wiring boards. Furnished as polarized units, these capacitors have voltage ratings of 3, 6, 16, 25 and 50V dc with capacitance values ranging from 1 to 330 μF. Sprague Products Co., North Adams, MA 01247. **340**



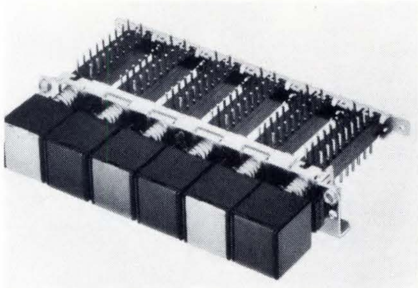
Directional coupler Model 1170-10 has a frequency response that is flat within 0.25 dB and directivity of at least 20 dB. The VSWR does not exceed 1.3 from 50 to 1000 MHz and 1.54 from 10 to 50 MHz. Maximum power level is 5W—ideally suited for system applications. Price is $180. Singer/Electronic Products Div., 915 Pembroke St., Bridgeport, CT 06608. **343**



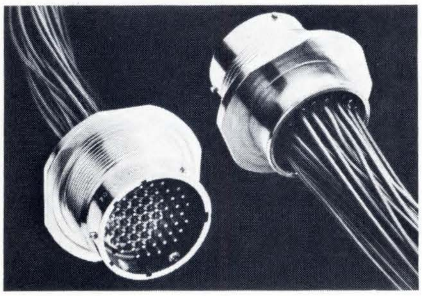
High-speed digital to analog converter "DACPAC" MP1812 is available in standard unipolar or bipolar 12 binary bit or 3 BCD digit configurations. Settling time to ±0.02% full-scale accuracy is 10 μs with a temperature compensation of 40 PPM/°C. Output slewing rate is 10V/μs. The 2- by 2- by 0.39-in module is electrically and mechanically shielded. Price is $89 in unit quantities. Analogic Corp., Wakefield, MA 01880. **338**



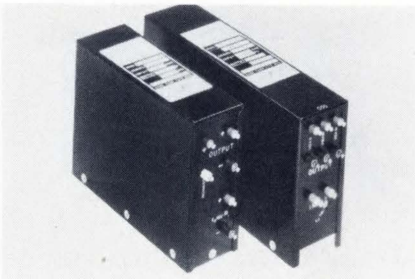
Operational amplifier Model 1957 features an output voltage range of ±100V at 10 mA. This low drift FET amplifier has unity gain frequency of 1 MHz and guaranteed minimum output of 200V pk-pk at 20 KHz. Input voltages of 200V pk-pk will not damage the amplifier. These 1.8- by 2.4- by 0.6-in units are priced under $40 in production quantities. Melcor Electronics Corp., 1750 New Highway, Farmingdale, L.I., NY 11735. **341**



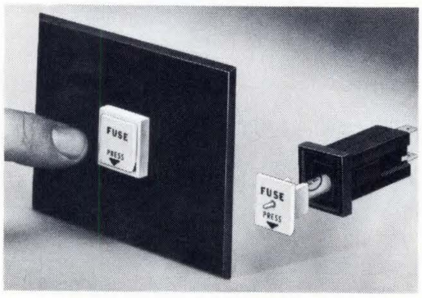
Push-button switches PB-20 come with a 20 mm center-to-center module spacing. These switches are suited for printed-board mountings as well as panel mountings. Lamp replacement is conveniently accomplished from the front of the switch without disassembly. Available functions for this line of switches include push-push, momentary and interlocking. Centralab, 5757 N. Green Bay Ave., Milwaukee, WI 53201. **344**



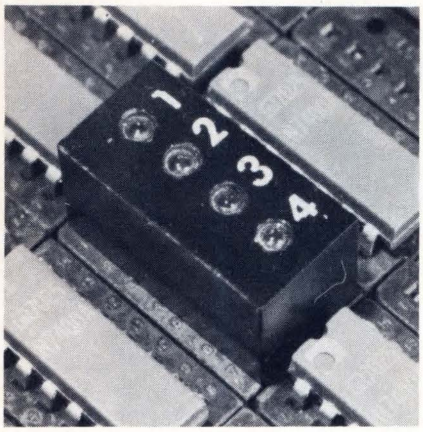
Connectors feature a one-piece filter pin permanently mounted in a metal and plastic insert. Since the crimp-terminated contacts eliminate soldering, there is no possibility of damaging the filter by overheating. Filter pin connectors are available in sub-miniature versions with size #22 contacts and in miniature versions with size #20 contacts. Deutsch Co./Electronic Components Div., Municipal Airport, Banning, CA 92220. **339**



Power supplies that operate from 115V 400 Hz ac furnish dc output voltages from 2 to 200V at up to 7A. Models PEL (three output), PEG (two output) and PEB (single output) feature 0.05% regulation, current limiting, conduction cooling and light weight. Options include crowbar overvoltage protection and external programming. Size is 2-1/8 by 4-1/2 by 5 in. Farrell-Bergmann, Inc., 15233 Ventura Blvd., Suite 1014, Sherman Oaks, CA 91403. **342**

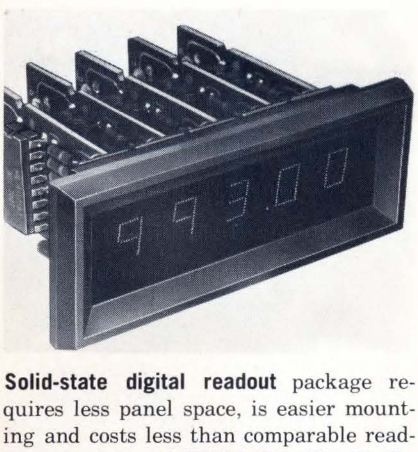


Square cap fuseholder (patent pending) snaps into chassis without mounting hardware and is styled to compliment modern instrument panels. Two basic series are available: Series 348000 for 3AG (1-1/4 by 1/4 in) fuses and Series 378000 for 8AG (1 by 1/4 in) fuse. Both series have 3/16- or 1/4-in wide quick-connect and solder-type terminals that are "end" mounted for easy installation of wires. Littlefuse, Inc., 800 E. Northwest Hwy., Des Plaines, IL 60016. **345**



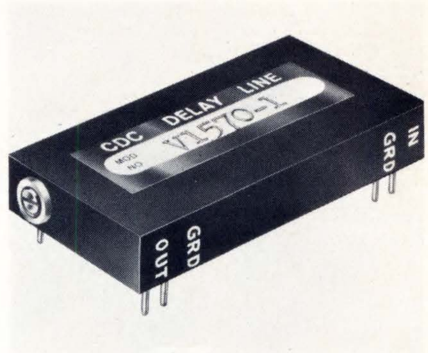
Logic Lite LL-4 provides four bits of logic status in a dual in-line package. Inputs are TTL/DTL compatible and represent only one unit load. Device requires 5V dc power. Price is $9 each in single quantity. Unique Devices Co., P.O. Box 786, Reseda, CA 91335. **346**

Core memory system has several new options which extend the capability of the 900 ns 480 Fast-Line system. Byte control is now available on 4, 8, and 16K word systems with 18- or 36-bit word lengths. Two new power supplies and a rack mounted system exerciser have been added. Typical price is under $0.02 per bit for 16K by 18 in hundred-lot quantities, board sets. Fabri-Tek, Inc., 5901 S County Rd. 18, Minneapolis, MN 55436. **347**



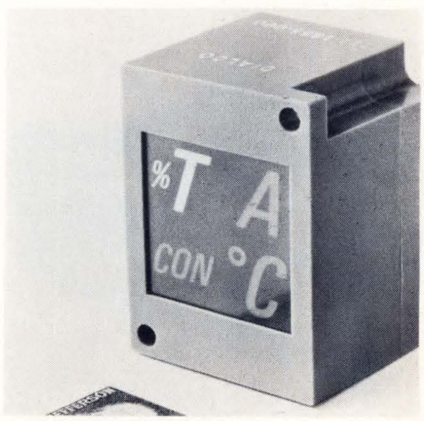
Solid-state digital readout package requires less panel space, is easier mounting and costs less than comparable readouts. Designated TEC-LITE SSR-70 Series, the device combines a rugged, infinite-life seven-bar segmented LED display, decoder/driver, current limiting resistors and mounting provisions within a 1.9- by 0.4- by 1-in assembly. Prices range from $34.10 to $42. TEC, Inc., 6700 S. Washington Ave., Eden Prairie, MN 55343. **348**

Components

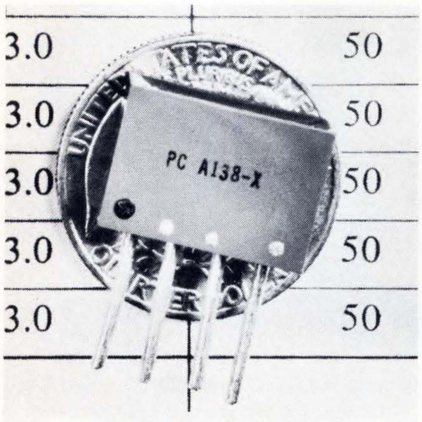


Variable delay-line series Model V1570 offers six delay variations ranging from 0-10 ns to 0-360 ns. Designed for compatibility with DIP, the lines have a 0.25 in overall thickness. The delay lines are of lumped constant construction and have a temperature coefficient of 50 PPM/°C. Price is $60 each in sample quantities with quantity discounts. Computer Devices Corp., 63 Austin Blvd., Commack, NY 11725. **349**

Voltage controlled filters find use in signal processing applications. Stock units cover a 50:1 frequency range in the region from 0.1 to 20 kHz. Frequency is determined by a 0 to 5V dc control voltage. Single unit price is $275 with production quantities available at less than $100. Aritech Corp., 130 Lincoln St., Brighton, MA 02135. **350**



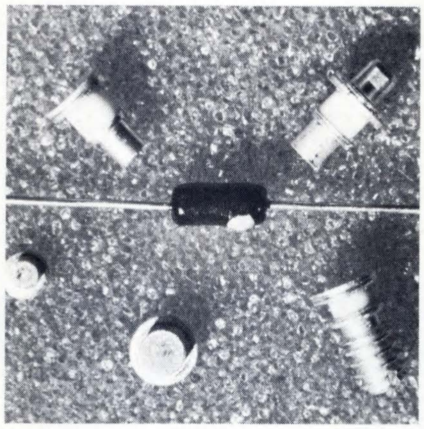
Caption modules, 711 Series, provide a high degree of flexibility by displaying from one to six lighted areas, either singly or in combination. Modules enable error-free reading at over 30 ft and are suited for close-up viewing as well. Incandescent lamps of 5, 6 and 14 to 16V are used, and, depending upon lamp selected, an average life of up to 100,000h can be expected. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **351**



Bridge rectifiers suitable for printed circuit boards with lead centers of 0.15 in can handle 3A and are available in voltages to 800V. In lots of 1000 units price is $1.60 each for a 400V unit. Power Components Inc., Box 421, Scottdale, PA 15683. **352**

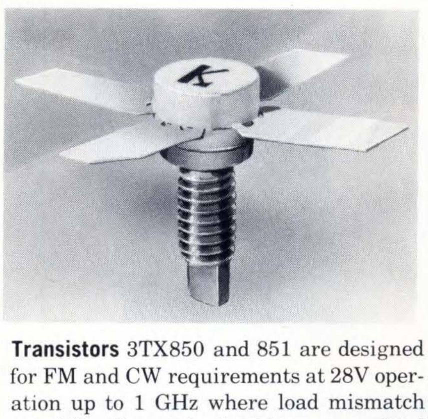
Dual four-bit latch (9308) and demultiplexer (9311) have been added to an MSI product line, The 9308 includes active pull-up outputs for high speed (typically 25 ns) and diode clamps on each input. The 9311 1-of-16 decoder has an active low and enable, allowing easy cascading for multilevel decoding. Prices in the 100-up mix quantity for 0 to 75°C units are $4.85 and $4.95 each, respectively. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **353**

Silicon npn emitter-ballasted overlay transistor 2N5918 features 10W output power at 400 MHz with 8 dB minimum gain. Other characteristics include a V_{CEO} of 30V, V_{CBO} of 60V, V_{EBO} of 4V, broadband performance over the range of 225 to 400 MHz and a low-inductance ceramic-metal hermetic package. In lots of 1000 units, price is $15 each. RCA Electronic Components, Harrison, N J 07029. **354**



PIN microwave switching diodes in the GC-4000 Series consist of 12 basic types that feature fast transition speed with voltage breakdown as high as 750V. Operating temperature range is from −65 to 150°C. GHZ Devices, Inc., Kennedy Dr., North Chelmsford, MA 01863. **355**

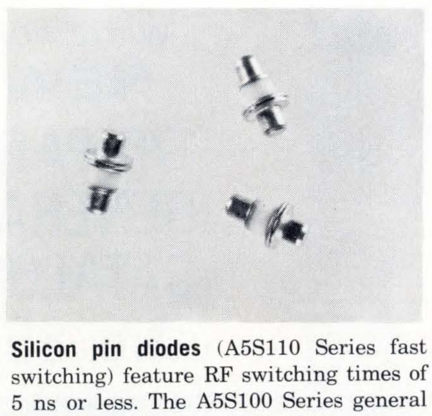
Phototransistor STPT60 offers 1.5 μs typical rise time, 5 μs fall time and is capable of 50 mW power dissipation. Sensor Technology Inc., 7118 Gerald Ave., Van Nuys, CA 91406. **356**



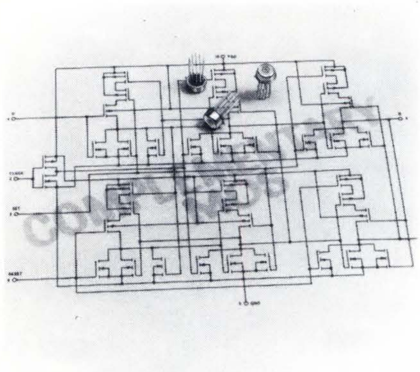
Transistors 3TX850 and 851 are designed for FM and CW requirements at 28V operation up to 1 GHz where load mismatch capability is required. Units are specified at 5.2 dB power gain at 1 and 2.5W respectively. All leads are isolated from the case and in lots of 1 to 99 units prices are $13 and $26 respectively. Kertron Inc., 7516 Central Industrial Dr., Riviera Beach, FL 33404. **357**

High voltage silicon power transistors in the SDT Series offer a BV_{CBO} to 700V, BV_{CEO} (sus) to 500V and low thermal resistance of 0.5°C/W typical. Units are packaged in a JEDEC TO-3 case. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. **358**

Dual 100-bit dynamic register V002 requires only a single phase clock and operates from 10 KHz to 2 MHz over a range from −55 to 125°C. Inputs and clock are TTL compatible without external bias resistors, using +5 and −12V supplies. Output buffers can drive two standard TTL loads, power dissipation is typically 1 mW/bit at 2 MHz and price in lots of 100 units is $3.75 each. Varadyne, Inc., MOS Operation, Semiconductor Division, 10432 N. Tantau Ave., Cupertino, CA 95014. **359**

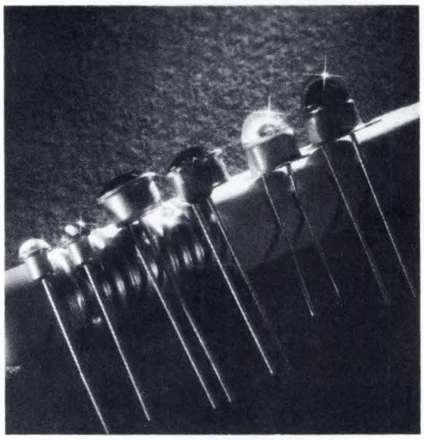


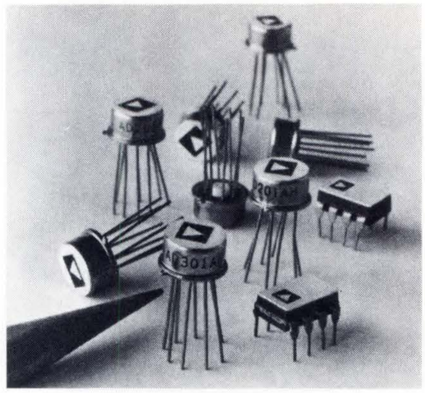
Silicon pin diodes (A5S110 Series fast switching) feature RF switching times of 5 ns or less. The A5S100 Series general purpose PIN diodes feature peak power handling capabilities to 300W and RF switching times of <100 ns. Prices range from $16 to $22 each in lots of 10 items and chips are available at $3.50 each in lots of 10. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. **360**



Complementary MOS ICs in the MCMOS family include two gates and a flip-flop. The MC2501L quad 2-input NOR gate and MC2502L dual 4-input NOR gate typically dissipate 10 nW while the MC2503L dual type flip-flop dissipates 50 nW typical. Units operate over the −55 to 125°C temperature range, package is the 14-pin dual in-line ceramic, and prices in 100-up quantities are \$5.70, \$5.40 and \$9.60, respectively. Technical Information Center, Motorola Semiconductor Products Inc., Box 20924, Phoenix, AZ 85036. **361**

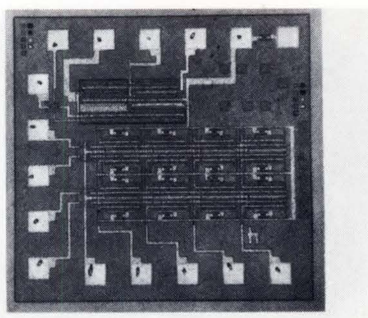
Light-emitting diodes have had six new units added that offer the user a choice of three package variations. Designated TIL203-208, these units offer either a clear or red dome-shaped plastic lens and feature a brightness of 750 fL typically when biased at 20 mA. In lots of 100 to 999, price is \$1.60 each. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **362**



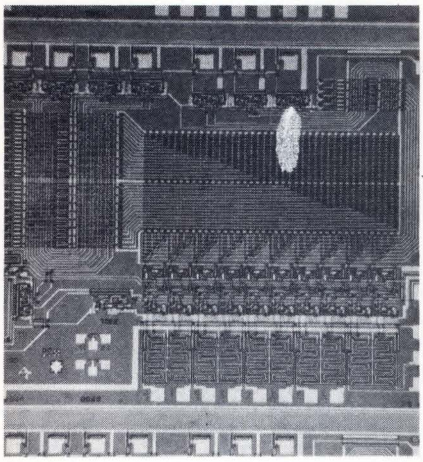


IC op amp series Models AD101A, 201A and 301A feature full short-circuit protection, external offset voltage nulling, wide operating voltage range and total absence of latch-up. The AD101A operates from −55 to 125°C, the 201A operates from −25 to 85°C and the 301A unit operates from 0 to 70°C. Maximum voltage and current drifts in this series are as low as 15 μV/°C and 0.2 nA/°C. Price in lots of 100 to 999 units ranges from \$3.45 each to \$30 each. Analog Devices, Inc., 221 Fifth St., Cambridge, MA 02142. **363**

IC op amps SG748/SG748C offer 5 mV input offset voltage, 200 nA input offset current, 500 nA input bias current, minimum gain of 50,000 and operating temperature range of either 0 to 70°C or −55 to 125°C. In lots of 100 items, prices are as low as \$1.25 each. Silicon General Inc., 7382 Bolsa Ave., Westminster, CA 92683. **364**

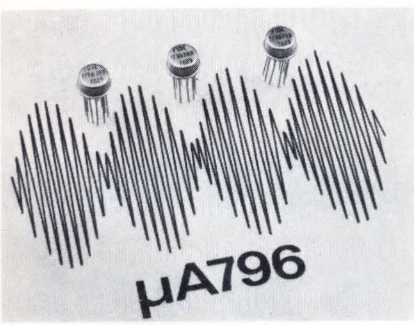


Programmable read-only memory SCL5510 is a 16-bit C-MOS unit organized as 16 words by 1 bit employing an X-Y select addressing scheme. The memory initially contains all "1" states leaving to the user the option to write a "0" in any location. Unit offers 400 ns cycle time and static dissipation of 50 nW at 10V. Operating supply range is from 5 to 20V, and price in lots of 100 units is \$25 each. Solid State Scientific Inc., Commerce Dr., Montgomeryville, PA 18936. **365**



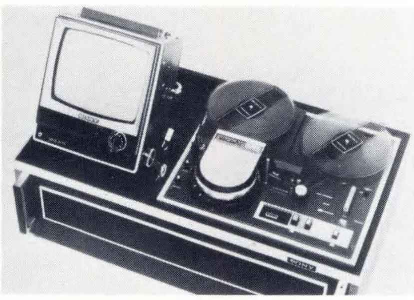
Dynamic MOS/LSI read-only memory TMS-2300JC is organized as a 256 by 10 bits unit and can be custom programmed at little or no extra cost. Operation is from +5 and −12V power supplies, dissipation is 200mW and price in lots of 100 to 249 units is $22.25 each. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, Texas 75222. **366**

Epoxy-encapsulated silicon planar transistors in the Econoline series now include over 60 standard device types that span the current range from 10 μA to 750 mA. Units offer TO-18 pin configuration, complementary types, up to 600 mW free air dissipation and excellent h_{FE} linearity. Sprague Electric Company, North Adams, MA 01247. **367**



Double balanced modulator/demodulator μA796 features excellent carrier suppression and low cost. It achieves a typical carrier suppression of −65 dB at 0.5 MHz and −50 dB at 10 MHz. Other characteristics include an input offset current of 0.7 μA, drift of 2 nA/°C and a differential output swing of 8V pk-pk. Prices in lots of 100 to 999 units are $2.25 (0 to 70°C) and $4.80 (−55 to 125°C). Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, CA 94040. **368**

TV system, the Standard IV Series, offers very high resolution out to the corners of the picture area. Features include tailored video response, 45 dB S/N ratio, sweep rates from 289 to 1891 lines/frame, better than 1% sweep linearity, and selectable 0.5, 0.7 or 1.0 gamma. System price is under $4000, depending on options. Sierra Scientific Corp., 2189 Leghorn St., Mountain View, CA 94040. **375**



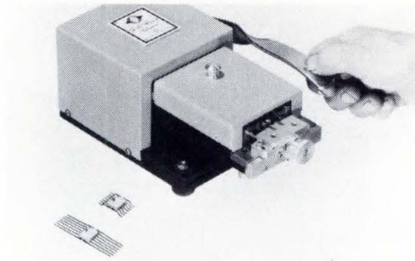
Video tape recorder by Sony uses 1/2-inch tape and has built-in monitor/receiver. The Model TAV-3610 provides 1 hour of monochrome recording and playback on 1/2-inch tape (EIAJ-1 format). It features stop action and audio-after-video recording capability, and it provides for an optional RF modulator to enable playback through regular TV sets. Sony Corp. of America, Video Products, 47-47 Van Dam St., Long Island City, NY 11101. **376**

Spectrum analyzer, Series SA-70, can single-scan the range from 0 to 1300 MHz and can examine a selected portion through a window as narrow as 1 kHz. Sensitivity is −120 dBm at 200 Hz bandwidth. Incidental FM is less than 100 Hz, allowing resolution and measurement of equal-amplitude signals only 300 Hz apart. Price is $5730. Singer, Electronic Products Div., 915 Pembroke St., Bridgeport, CT 06608. **378**

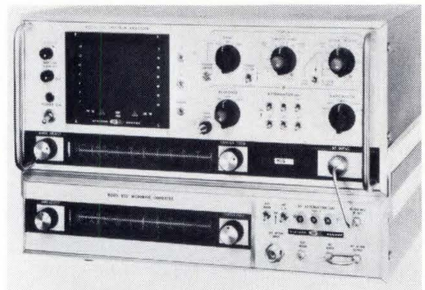
Digital clocks with solid state display are available with either 60 Hz power line-, internal crystal oscillator- or external input-time reference. The Series 2400 units feature simplified front panel presetting, power failure indication, BCD outputs and an option to operate directly from 28V dc. Electronic Research Co., 10,000 West 75th St., Overland Park, KS 66204. **379**

Function generator, Model 5100, has frequency range of 0.002 Hz to 3 MHz and delivers 20V pk-pk open circuit. Functions include sine, square, triangle and positive and negative ramp. Also provided is a 5V pk-pk squarewave output with less than 15 ns risetime. Frequency may be controlled externally by a control voltage, with resulting maximum sweep of 1000:1. Krohn-Hite Corp., 580 Massachusetts Ave., Cambridge, MA 02139. **380**

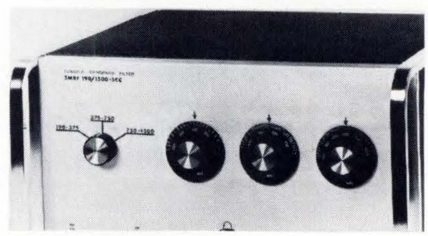
Pulse generator, compact and priced below $175, uses a 1 MHz crystal oscillator as the basic clock. The Model 3200 provides pulse width from 1 μs to 20 ms and repetition rate from 1 to 500,000 pulses/s. Simultaneous positive and negative output pulses have a fixed 5V amplitude and are isolated from internal circuitry by a dual buffer. Rise and fall times are less than 100 ns. Houston Magnetics, 6214 Royalton St., Houston TX 77036. **381**



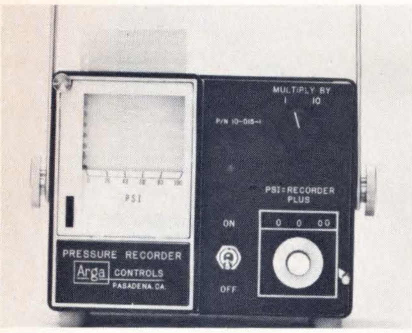
Portable lead bender automatically forms and trims flatpack leads for PC mounting and handles up to 600 pieces per hour safely. Model 100B features both mechanical damping clamps and single motion operation. Standard dies handle TO 84 through 91 and TO 95 flatpack types. Price with one set of standard dies is $675. D-Vel Research Labs., Inc., 555 Bedford Rd., Bedford Hills, NY 10507. **382**



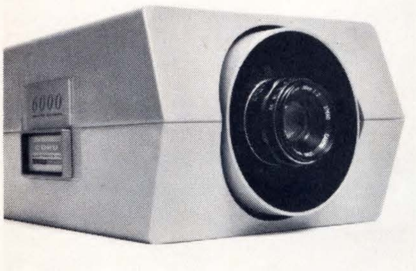
Microwave spectrum analyzer features battery operation and fundamental mixing at X and KU bands. The Model 761 covers the range from 10 MHz to 40 GHz and features calibrated scan widths from 100 kHz to 500 MHz with 5 IF bandwidths ranging from 1 kHz to 1 MHz. Battery power is available and the price of the Model 761 is $5950, excluding mixers. Systron-Donner Corp., 14844 Oxnard St., Van Nuys, CA 91409. **383**



Tunable bandpass filters of the MBF Series incorporate three tunable units that are selected with a precision coaxial switch. Total coverage, depending on filters selected, is from 48 to 2000 MHz. Three-dB bandwidth is held at a constant percentage of center frequency—typically 5%. Price range is from $1500 to $1900. Tex-scan Microwave Products Corp., 7707 No. Records St., Indianapolis, IN 46226. **384**



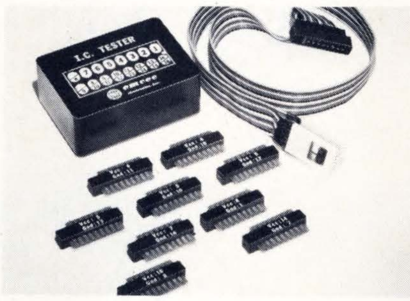
Portable recorders feature expanded scale readout and are available for the recording of volts, amps, frequency, watts, temperature, pressure, rpm, or any other quantity whose value can be transduced to a dc voltage. Span width is variable by a factor of 10 and accuracy is ±2% of the span. Prices range from $250 to $500. Arga Controls, 35 E. Glenarm, Pasadena, CA 91105. **385**



CCTV camera, Model 6120, has 32 MHz bandwidth and offers superior corner detail and flatness of field. Resolution is up to 1500 lines horizontal center, 775 lines vertical center and 900 lines in the corners. A 1-1/2 inch vidicon is used. Cohu Electronics, Inc., Box 623, San Diego, CA 92112. **386**

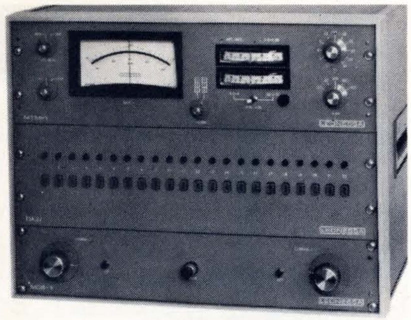
Swept frequency spectrum analyzer operates from 10 Hz to 50 kHz with 10 Hz resolution. The Model 710/801 is portable and battery operated and combines the virtues of a spectrum analyzer and a tracking sweep generator. Display may be either linear or log, and the heterodyne technique used permits on-screen response measurements of greater than 120 dB. Price is $3,250. Systron-Donner Corp., Microwave Div., 14844 Oxnard St., Van Nuys, CA 91409. **387**

Video terminal, VDT-7 Model 40, has 800 characters in a 40 by 20 format and will drive any standard home television set or display monitor without modification. A complete terminal consists of basic keyboard/controller, monitor and acoustic coupler. Character set is 64 ASCII characters. Vernitron Corp., Data Devices Div., 176 Central Ave., Farmingdale, NY 11735. **388**



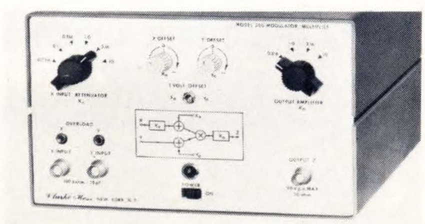
IC tester for in-system testing of both 14- and 16-pin DIP TTL or DTL features flexible cable extension. Logic states of all pins are displayed simultaneously. Price, complete with cable and nine adaptor plugs, is $120. Emcee Electronics, Inc., 177 Old Churchman Rd., New Castle, DE 19720. **389**

Waveform generator, Model F280A, covers the frequency range of 0.01 Hz to 1.1 MHz and delivers up to 11V pk-pk into 50Ω in the manual mode, or it can be programmed to deliver up to 16V pk-pk. Outputs include sine, square and triangle waveforms plus triggered single cycle or gated burst of cycles. A fixed offset control allows square-wave pulsing and 0 or 180 degree phase selection. Microdot Inc., Instrumentation Div., 220 Pasadena Ave., South Pasadena, CA 91030. **390**



Transistor matching system for bipolars and FETs, Model MTMS-1, simultaneously evaluates transistor pairs for gain, gain ratio and differential V_{EB} characteristics at a preset emitter current and collector voltage. Emitter current and collector voltage are variable at any time for observing tracking. Price is $4700. Leonessa Engineering, 74 Loomis St., Bedford, MA 01730. **391**

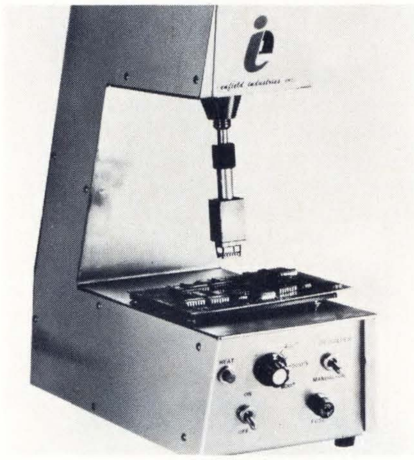
Modular electronic balance, Model 2020, has capacity of 25g and accuracy of 0.001g plus 0.1% of weight. Operating speed is 10 weighings per second. Supplied complete with electronics, it has an output compatible with most data processing equipment. Scientech, Inc., 1724 14th St., Boulder, CO 80302. **392**

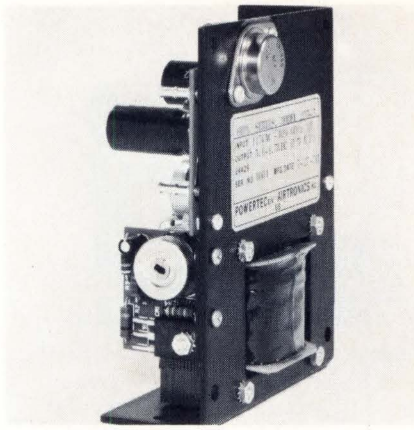


Four-quadrant multiplier with wide band, low noise and wide dynamic range may also be used as a wideband AM or suppressed-carrier modulator, or as a variable gain, low distortion lab amplifier. Multiplier linearity of the Model 200 is better than 1% for outputs up to 20V pk-pk. Phase shift between channels is less than 1° at 1.5 MHz. Self-contained, the unit sells for $455. Clarke-Hess Communication Research Corp., 43 West 16th St., New York, NY 10011. **393**

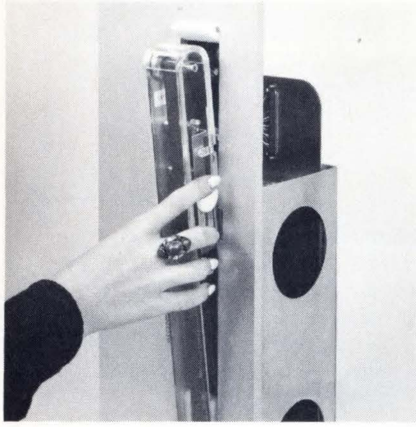
Electronic count/control unit offers predetermining by bidirectional switches with one or two independent levels. Output is either single- or two-level control, and each level can be programmed to latch until reset, until customer contact actuation, until the other level actuates or until completion of time delay. Operation is to 20,000 counts/s. Prices begin at $180. Durant Digital Instruments, 622 N. Cass St., Milwaukee, WI 53201. **394**

Component extractor for ICs removes both them and the retaining solder in 30s or less. Model ACE-700 features thermostatic control for PC board protection and requires both line power and 35 to 70 psi shop air for operation. Basic unit price is $900. Enfield Industries, Inc., Box 225, Flourtown, PA 19031. **395**



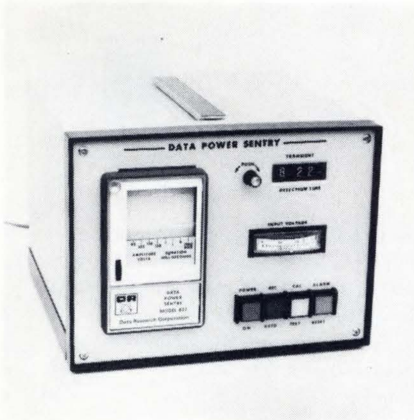


OEM power supplies feature adjustable output voltage, and series regulation with fold back current limiting. Specifications include regulation of ±0.25% for line or load, 1 mV RMS ripple and operating temperature range of 0 to 50°C. Models are available with output voltage from 4-1/2 to 26V and output current from 1 to 12A. Prices range from $25 to $75. Powertec, 9168 De Soto Ave., Chatsworth, CA 91311. **396**



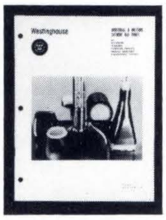
Random access memory system, called COMFILE, contains a 30-in long magnetic tape loop capable of providing any mini- to medium-sized computer with up to 72,000 characters of data storage. Data are accessible within an average of 350 ms. Recording is serially by bit on one track at a time, at a density of 3000 bits/in. Price of the system is $1200. Compat Corp., 177 Cantiague Rock Rd., Westbury, NY 11590. **397**

Digital microvoltmeter offers 0.01% accuracy and sensitivity of 1 μV/digit. Bipolar and with isolated BCD outputs, the Model 2400 units provide digital readout from transducers with microvolt sensitivity. Full scale sensitivity is ±19.999 mV. Price is $585. Newport Labs, Inc., 630 E. Young St., Santa Ana, CA 92705. **398**

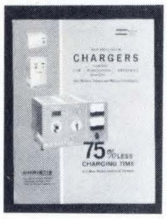


Data Power Sentry monitors and records power malfunctions continuously for weeks without surveillance. Included are a recorder, transient-detecting electronics and a timing reference. Transients as short as 0.1 ms are analyzed and recorded at levels of ±10% and ±20% of the nominal voltages (115, 208 or 230V). Price is $1,470. Data Research Corp., 2601 E. Oakland Park Blvd., Fort Lauderdale, FL 33306. **399**

"A Guide to Processing Logic Diagrams for Computer Aided Design" is a detailed plan for preparing information for an automatic wiring service using plug-in dual-in-line ICs. Electronic Engineering Co. of California, EP Div., 1441 E. Chestnut Ave., Santa Ana, CA 92701. **250**

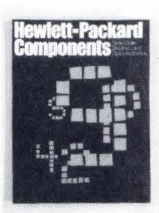


Industrial and Military Cathode Ray Tubes contains 20 pages of data on over 100 CRTs. Catalog B-9474B also lists technical literature available. Westinghouse Electric Corp., Electronic Tube Div., Box 284, Elmira, NY 14902. **251**



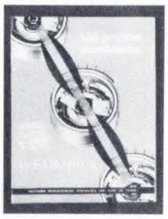
High-speed nickel-cadmium chargers are described in eight-page bulletin, BC-70. A complete line of SCR precision chargers is included, covering dc output voltages from 6 to 120V and currents from 6 to 150A. Christie Electric Corp., 3410 West 67th St., Los Angeles, CA 90060. **252**

Precision film capacitors that include 23 types are detailed in 28-page Catalog A-14. It includes specifications and photos of miniature capacitors of polystyrene and hermetically sealed mylar and mica capacitors. PFC Div., Arco Electronics, Community Dr., Great Neck, NY 11022. **253**

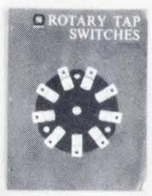


Optoelectronic and solid-state display components are described in a four-page brochure. Visible and infrared emitters, photodetectors and photon-coupled isolators are listed. Hewlett-Packard, Public Relations Dept., 1501 Page Mill Rd., Palo Alto, CA 94304. **254**

Flexible electrical insulation catalog includes applications, tolerances, standard sizes and typical data for each of 34 materials. Natvar Corp., Box 67, Rahway, N J 07065. **255**



Potentiometer and variable resistors catalog contains 32 pages on a complete line of 1/2 through 5 in diam wirewound and conductive plastic units with a resistance range from 50 through 1,000,000Ω. Samarius, Inc., 300 Seymour Ave., Derby, CT. 06418. **256**

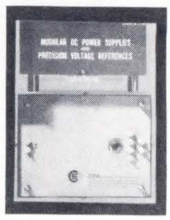


"Rotary Tap Switches", Catalog 401, provides electrical characteristics and specifications on an expanded line of tap switches, including a miniature power tap switch, Model 711, the smallest switch available in its rating. Ohmite Mfg. Co., A North American Philips Co., 3601 Howard St., Skokie, IL 60076. **257**

Miniature rectangular and hexagonal plug and socket connectors are covered in a 48-page catalog. Designated Series 20, the group includes various contact sizes between 4 and 104, plus a variety of options. Continental Connector Corp., 34-63 56th St., Woodside, NY 11377. **258**

"Fixed Composition Resistors", Bulletin No. 80-100, is an eight-page product bulletin that also includes application guidelines. Electronic Components Div., Stackpole Carbon Co., Kane, PA 16735. **259**

Illuminated pushbutton switches and matching indicator lights are covered in 28-page catalog L-210. Snap-in and panel mounting switches and indicators in round, square and rectangular configurations are included. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **260**



"Modular DC Power Supplies and Precision Voltage References" is a 32-page catalog that covers a line of high efficiency constant voltage and constant current power supplies and dc-to-dc converters. Converters supply from 3 to 500V output. CEA, Div. of Berkleonics, Inc., 1221 S. Shamrock Ave., Monrovia, CA 91016. **261**

Programmable calculators in the 700 Series are described in a new six-page brochure. Wang Labs., Inc., 836 North St., Tewksbury, MA 01876. **262**

Logic card selection guide offers 12 pages of basic data on more than 150 standard products, including DTL, TTL and analog cards. Data Technology Corp., 1050 E. Meadow Circle, Palo Alto, CA 94303. **263**

Ceramic chip capacitors, Types NPO and K 1200, are described in six-page Technical Bulletin No. 123. Monolithic Dielectrics, Inc., Box 647, Burbank, CA 91503. **264**

Microcircuit trimmer capacitors Series 7200 are reported to be the smallest devices of their type available and provide a means for "tweaking" a circuit after encapsulation. Johanson Mfg. Corp., 400 Rockaway Valley Rd., Boonton, N J 07005. **265**

Hybrid FET input op amps, GPS 8500 Series, range in price from $25 to $35 and are described in a new brochure. GPS Corp., 14 Burr St., Framingham, MA 01701. **266**

PDM 13 random-access core-memory system with a range from 512 eight-bit words to 4096 nine-bit words is described in a four-page technical bulletin. Dataram Corp., Rt. 206, Princeton, N J 08540. **267**

High-current mercury displacement relays are covered in an eight-page catalog. Included are load ratings from 20 to 100A, load voltages as high as 550V ac or 240V dc and contact resistances from 2 to 10 mΩ. Data Sheet 859 is available from C. P. Clare & Co., 3101 Pratt Blvd., Chicago, IL 60645. **268**

Solid-state VOM, Model 602, features autopolarity and is discussed in Bulletin 51570. Triplett Corp., Advertising Dept., Bluffton, OH 45817. **269**

Precision-terminated bundles of glass flexible fiber optics are covered in a two-page data sheet, Bulletin No. 3. Dimensions, pricing and performance characteristics are included. Corning Glass Works, Corning, NY 14830. **270**

Linear ICs available in chip form are described in a 12-page chip catalog. Silicon General, Inc., 7382 Bolsa Ave., Westminster, CA 92683. **271**

Circuit Test System J283, popularly known as the SLOT Machine because of its application in *S*equential *LO*gic *T*esting, is covered in a 24-page brochure. Teradyne, Inc., 183 Essex St., Boston, MA 02111. **272**

Beam lead type chip resistors for microwave use are covered in "Tab-Chips" bulletin from IGE, Box 63, Watertown, MA 02172. **273**

"Lots of Pots" is the title of a six-page bulletin on trimming potentiometers that covers 73 general purpose cermet, wirewound and military grade potentiometers in square, rectangular and round styles. Weston Components Div., Weston Instruments Inc., Archbald, PA 18403. **274**

Dual in-line IC 14-pin sockets, type 561, are described in Technical Bulletin 49A. Connector Corp., 6025 N. Keystone Ave., Chicago, IL 60646. **275**

Electronic keyboard provides all ASCII characters and is described in four-page Data Sheet 102. Control Research Corp., 2100 S. Fairview, Santa Ana, CA 92704. **276**

Microwave circuit modules (MCMs) are featured in a 16-page Brochure ETD-5034A that covers packaged circuits from VHF to X-band multipliers to K-band and integrated isolators and circulators. Inquiry Processing, General Electric Co., Tube Dept., 316 E. Ninth St., Owensboro, KY 42301. **277**

Digital tape drive Model TM-7 and tape memory system TM-7200 are described in Brochure C090. Ampex Corp., 401 Broadway, Redwood City, CA 94063. **278**

Power controller module, Series 9000, is covered in a two-page data sheet. Inputs and outputs, functions available and applications are included. Data Instruments, Inc., 1821 University Ave., St. Paul, MN 55104. **279**

Power supply Catalog No. 701 gives complete data on more than 3000 power modules and accessories. Technipower, Inc., Benrus Center, Ridgefield, CT 06877. **280**

Test equipment, including sweep, marker and noise generators and audio spectrum analyzers, is covered in an eight-page short form catalog from Kay Elemetrics Corp., 12 Maple Ave., Pine Brook, N J 07058. **281**

Etch-resist marking pen Dalo 33 for PC board design is discussed in two technical bulletins. Dalomark Corp., 161 Coolidge Ave., Englewood, N J 07631. **282**

Twelve-bit D/A converter, Model DAC-12Q, is based on monolithic IC switch and thin-film resistor components. The 7 ppm/°C, −55 to 125°C unit is described in a two-page bulletin. Analog Devices Inc., Pastoriza Div., 221 Fifth St., Cambridge, MA 02142. **283**

Zener regulators, rectifiers and assemblies are the three sections of a comprehensive catalog. Power Components, Inc., Box 421, Scottdale, PA 15683. **284**

Heat sinks, semiconductor bases, discs, washers, transistor retainer and mounting clips are covered in six-page Bulletin 302. National Beryllia Corp., Greenwood Ave., Haskell, N J 07420. **285**

Timing and control devices including stepping motors, "BITE" fault indicators, elapsed-time indicators, events counters, timers, relays, time-code generators, stepping switches and stop clocks are covered in six-page Brochure MR-100-R3. A. W. Haydon Co., 232 N. Elm St., Waterbury, CT 06720. **286**

Product Lighting Guide, Cat. No. 1-70, covers a line of indicator lights. Leecraft Mfg. Co., Inc., 21-16 44th Rd., Long Island City, NY 11101. **287**

Solid state relay brochure covers a line with current switching capacities from 1 to 25A and a frequency range of operation from 50 to 400 Hz. Philadelphia Scientific Controls, Inc., 1135 Cedar Ave., Croydon, PA 19020. **288**

Patent Law Revision as Incentive

Dear Sir:
The Moss bill, relating to patent rights for employed inventors, could well operate to the benefit of the American electronics industry as a whole, even though individual companies are not likely to favor it. The reason is that similar measures are working elsewhere. When a law stimulates invention, the inventions lead to products that are better or cheaper, and so more saleable in international trade.

West Germany and Japan already have laws that guarantee the employed inventor "a piece of the action" based on the actual profits from the use of the invention. In these countries the number of patent applications per million population is about twice the U.S. rate. We know how the electronic products of these countries are doing on the international market.

Many American corporations state that the patent system is of little use to them. This does not mean, however, that inventions are not useful to the country as a whole. Many of our largest industries are not equipped to generate any inventions or innovations (railroads, financial institutions, importers, distributors and operating public utilities). Others do some R&D but use little of it, such as autos and oil. Others are so large or dominant that they are deterred from making outside profits on patents by the activities of the Antitrust Division of the U.S. Justice Department. Still others are government contractors, and the government takes title to the inventions of their employees. All this adds up to a big segment of the national economy. Its opinions carry a lot of weight. However, if Detroit automakers say that *they* don't need patents, it does not mean that the U.S.A. should dispense with them.

If you ask a young firm that depends for its existence on inventions and innovations whether patents are useful, you get a very different answer than you would get from a big, "mature" corporation.

It is simply a legal definition of what an invention is and what it includes, with the legal power of exclusive rights for seventeen years. A patent is legally a piece of property. Generally speaking, if an inventor has no patent, he can't get paid for making the invention. Accordingly, anyone who says that we don't need a patent system is saying that nobody should get paid for an invention. Moreover, every industrial country in the world has a patent system, and a good many countries that are not so industrial. As of 1968, seventy-six countries had patent systems, including Russia, Poland, Rumania, Turkey, Iceland, Algeria, Singapore and Jordan. We can also add Zambia, Malawi, Burundi and Rwanda.

In reading through the testimony of various Congressional hearings on patent bills, I get the impression that there is an imbalance in favor of the point of view of the bigger and older industries, those who have the least to gain from innovation. In addition, there seems to be too little representation of smaller businesses, and too little consideration of the experiences of other countries.

In the last analysis, an invention is simply an unusually clever, creative piece of engineering. The more of this we have, if it gets used, the better shape we will be in and the more employment we will have. If laws along the lines of the Moss Bill are working in West Germany and Japan to produce more creative contributions to engineering, it would appear worthwhile to try them here.

Lawrence Fleming
Registered Patent Agent
Pasadena, Calif.

ElectroZodiac Delights

Dear Sir:
I was delighted to read Mr. Rigoli's predictions article on "Electronics and Astrology" in the May EDN which I have just recently seen.

If he has any further comments/writings on the subject, I'd be very interested in receiving them. Also, may I reproduce his article and distribute it to a class I'm conducting this fall on Correlative Problem Solving? In my class I'll try to convey the concept that all knowledge may be interrelated and that problems are best resolved if we break out of the traditional "box" we're in as engineers, physicists or other "scientists".

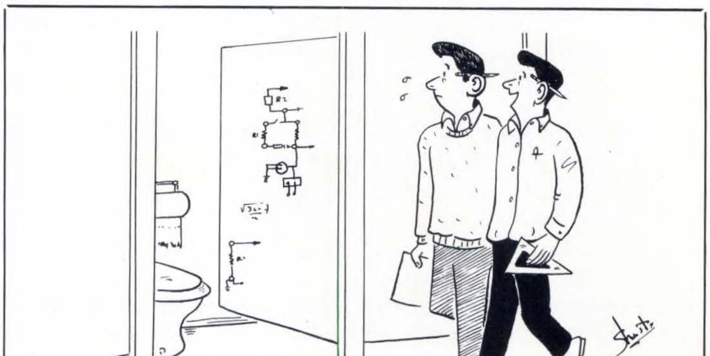
Sincerely,
Dr. Ephriam M. Howard
Vestal, N.Y.

Everybody has a special responsibility in the field in which he has either special power or special knowledge. Just as *noblesse oblige*, so now *sagasse oblige.*— Karl Popper.

Directory Assist

Roy Forsberg, EDN's man in the Boston area, notes that through an editorial malfunction, the news story about Inforex's "Infobond" backplane wiring system (Sept. 1, p. 14) omitted the company's address:

Inforex, Inc.
21 North Ave.
Burlington, MA 01803



"Here's a design I worked up a while ago . . . I'd like to see what you think of it!"

DC Amplifiers In Instrumentation

By Ralph Morrison; John Wiley and Sons, Inc., New York, N.Y.; 1970, 248 pages; Price: $13.95.

Written simply, and a veritable gold mine of practical information, this book starts with a discussion of such linear components as resistors and capacitors. It then touches on magnetic components, parasitic effects, feedback and feedback amplifiers. Further chapters cover modulation and demodulation, instrumentation amplifiers, specifications and evaluation and active devices.

The author notes that he expects this book to be of special value to all component engineers interested in complete system integration techniques. Mr. Morrison is no novice writer, having authored numerous technical articles on instrumentation and a previous book. For more information about this book, Circle No. **400**

Short Course: Active Filter Design

The George Washington Univ., Washington, D. C.; Dec. 14-16, 1970.

This course provides the circuit engineer with all technical background and design data needed for designing active filters. The main topics covered are filter transfer functions, RC networks, operational amplifiers, feedback theory, sensitivity analysis, RC-amplifier resonators and gyrators.

Philip R. Geffe is Fellow Engineer at the Westinghouse Defense and Space Center, Baltimore, Md.; author of over 30 research papers and technical articles on network theory, filter design, and miscellaneous subjects; author of a well-known book, "Simplified Modern Filter Design", Rider, 1963 and an article, "Toward High Stability in Active Filters". Fee: $215.00.

For further information, write J. E. Mansfield, Director of Continuing Engineering Education Program, The George Washington Univ., Washington, D. C., 20006, or Circle No. **401**

Direct-Current Magnetic Measurements for Soft Magnetic Materials

STP 371 S1 By American Society for Testing and Materials.

This text presents in a simple and understandable manner the theory and practice basic to the art of direct-current testing of magnetically soft, ferromagnetic materials.

It gives the apprentice technician a simple guide to sound testing practice, while also offering the student magnetician a more extensive understanding of specific devices and techniques for a broad approach to magnetic testing problems.

Emphasis is placed on the ASTM standard test procedures which find general application in the testing of soft magnetic materials such as magnetic irons, silicon-iron alloys, and nickel-iron magnetic alloys.

An extensive bibliography identifies reference materials for the reader seeking to investigate the subject in greater depth.

This publication is the second in a series of what will eventually become a comprehensive manual on magnetic testing. The first book previously published is "Magnetic Testing—Theory and Nomenclature—STP 371".

Copies of this book are available from ASTM, 1916 Race St., Philadelphia, Pa. 19103; 72 pages; soft cover price: $6.25 plus handling and shipping charges.

Circuit Optimization Manual

By Applicon Inc., Burlington, Mass.; 350 pages; Price: $20.

This manual deals with Applicon's circuit optimization program, MATCH. The book also describes how to design and optimize the behavior of two-port networks and has 15 worked examples useful in designing practical circuits.

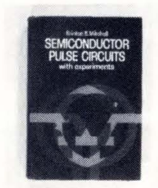
For further information write Mr. Dick Hersum, Advertising Assistance, Inc., 438 Boston Post Rd., Weston, Mass. 02193.

Transistor Basics on Videotape, By Hewlett Packard Co.

Practical Transistors, a new series of videotapes available from Hewlett-Packard, is a clear presentation of transistor and other solid-state devices without equivalent circuit explanations and advanced mathematics. Based on the text "Transistor Basics: A Short Course" by George Stanley (Hayden Book Co., New York), the tape goes beyond the text particularly in circuit troubleshooting.

Single tapes may be ordered as well as the complete series. Order includes a copy of the text and a set of homework questions and answers. Tapes are in Ampex or Sony 1- or 1/2-in formats. For more information, Circle No. **402**

Semiconductor Pulse Circuits With Experiments



By Brinton B. Mitchell; Holt, Rinehart and Winston Inc.; March, 1970; 379 pages; $10.50.

In this text, the author provides design, analysis and synthesis of basic pulse and switching circuits in their simplest form. This book is organized into twenty chapters, each presenting a typical basic circuit. In addition, each chapter includes a complete laboratory experiment that has been classroom tested—so the text eliminates laboratory manuals when used for instruction. The questions and exercises at the end of each chapter are designed to test the reader's comprehension of the theory, as well as his knowledge of applying this theory to practical applications. For more information about this book, Circle No. **403**

Electromagnetic Waves in Stratified Media

By Dr. James R. Wait: Pergamon Press, Ltd., Fairview Park, Elmsford, N.Y. 10523; 640 pages; Price: $21.50 at bookstore of the

(Continued)

Univ. of Colorado, Boulder, CO 80203.

The new revised edition of a work by a University of Colorado professor of electrical engineering will serve both as a reference and textbook for those dealing with the propagation of electromagnetic waves through a wide variety of stratified media.

It deals with the reflection of electromagnetic waves from inhomogenous media; propagation along spherical surfaces and in stratified magnetoionic media; fundamentals of mode theory of wave propagation; characteristics of the modes for VLF propagation; VLF propagation-theory and experiment; ELF propagation, superrefraction and the theory of tropospheric ducting; and other topics. Numerous references and a subject and author index are included.

The work is relevant to propagation of underwater sound and geophysical prospecting as well as to atmospheric wave propagation. Based in large part on research for which the author is well known, it affords a basic understanding and predictive capability in dealing with these propagation phenomena.

Switching and Finite Automata Theory

By Zvi Kohavi; Computer Science Series; McGraw-Hill Book Co.; May 1970; 592 pages; $16.50.

Intended for computer scientists, logic designers and control engineers, this book provides a better understanding of the structure, behavior and computational capabilities of the logic machine. Most of the material is not new, although many subjects appear for the first time in an introductory form. As a text, it is originally designed for use in undergraduate and introductory graduate courses in the field of computer science.

The book is divided into three parts with the first two chapters providing introductory background material. Another section is devoted to combinational logic techniques and the final portion is concerned with finite automata – sequential machines. At the end of each chapter, a number of problems are provided as well as a listing of the author's main source of information. For more information about this book, Circle No. **404**

Harry Howard

Linear Integrated Circuits; Testing And Application

By Frederick Gans; I. C. Metrics, Inc., 607 Industrial Way West, Eatontown, N J 07724; 190 loose-leaf pages; $6.70 plus $1.85 handling charge.

This reference contains information that has not been previously available under one cover; it has been scattered in technical literature such as LIC specifications, application notes, company reports, and official documents written on test standardization. Military Standard 883 (Test Methods and Procedures for Microelectronics) based its definitions on the work contained in this comprehensive paper.

The book is a reprint of a Master's Thesis. The technical material was provided by an 8 month research performed at Polytechnic Institute of Brooklyn and by the author's previous work experience at the Electronics System Center of Grumman Aerospace Corp. and at I. C. Metrics, Inc.

Project Management With CPM and PERT

Second Edition; By Joseph J. Moder; Univ. of Miami, Coral Gables, Fla.; and Cecil R. Phillips; Kurt Salmon Assoc., Inc., Atlanta, Ga.; 352 pages plus index; 170 illustrations; Van Nostrand Reinhold, N.Y.; $14.95.

This second edition incorporates the most meaningful developments in theory and practice which have occurred since the publication of the first edition in 1964.

According to the authors, new developments have tended to eliminate the practical distinctions between the original CPM and PERT techniques, evolving instead a body of knowledge that is common to both. Unfortunately, however, no single term has been accepted that describes the common discipline, so the authors continue to use the double name "CPM and PERT", along with "network methods", "critical path methods" and others.

Applications have expanded to every type of project. "The computer programs available for CPM and PERT processing have continued to increase in number and in capabilities," write Moder and Phillips.

The five chapters of Part I comprise a complete course in the fundamentals of the planning and scheduling features of critical path methods, and include manual and computer methods of calculation. In Part II, the reader is exposed to the variety of networking schemes developed in the last decade.

All other chapters have been updated to include the recent advances in the respective topics. At the end of most chapters are exercises, and problem solutions are included.

Data Communications – MODEMS

By High Technology West, 1060 Crenshaw Blvd., Los Angeles, CA 90019; 65 pages; $250.

A sixty-five page report on Data Communications – MODEMS covering one of the three fast-growing equipment sectors crucial to the data communications industry.

This report discloses the common carrier revenue is expected to jump from $20 billion in 1970 to $35.5 billion in 1980. Of greater significance, only 10% of these revenues come from data communications today, but in 1980, 50% of their revenues will be from data communications.

The MODEMS (Data Sets) study completes a three study series. Multiplexers (60 pages) and Interactive Data Terminals (60 pages) were published earlier.

Each report discusses markets, technologies, product comparisons and companies. The MODEM study discusses 101 companies and their 324 products.

Applied Mathematics in Engineering Practice

282 pages plus index; 41 illustrations; McGraw-Hill; $12.50.

Modern Mathematical Methods in Engineering. 245 pages plus index; 38 illustrations; McGraw-Hill; $12.50.

by Frederick S. Merritt, Consulting Engineer, Syosset, New York.

Written by an engineer for engineers, these are the latest volumes in the McGraw-Hill Series in Continuing Education for Engineers. The main objective of each book is to teach practicing engineers how to solve complicated problems with mathematics. Each book follows the explanation of a mathematical method with an example of its application to an engineering problem, worked out in detail. Examples are taken from virtually every field of engineering. Additional problems are given in each chapter, offering the reader an opportunity to check his grasp of the subject against the solutions and explanations that are provided. Circle No. **405**

Indexes

Advertiser's Index

Subject Index to Articles

Index to Ads, Products and Literature

Application Notes

True rms measurements are discussed in detail in eight-page application note AN-124. Graphs are included that show the effects of distortion on measurements by average-responding instruments. Inquiries Manager, Hewlett-Packard Co., 1601 California Ave., Palo Alta CA 94304. **475**

Selection and application of reed switches is covered in a 12-page application guide which includes a key to the selection of reed switch designs for any type and magnitude of switching job. Hamlin, Inc., Lake and Grove Sts., Lake Mills, WI 53551. **478**

COS/MOS Reliability Report RIC-103 describes manufacturing controls and test procedures and gives initial reliability data including histograms on some of the significant life test parameters. RCA Solid State Div., Somerville, N J 08876. **481**

Nonlinear dc circuit analysis program, RELCAP, analyzes and evaluates circuit design validity and provides accurate, computer-generated design criteria for determining the practicality and suitability of specific circuit designs. Davis Computer Systems, Inc., 280 Park Ave., New York, NY 10017. **476**

"Ceramic to Metal Sealing" is an authoritative technical article that, besides explaining the underlining concepts of the various sealing processes used, details seal geometry and typical electro-optical applications. ILC Labs., Inc., 164 Commercial St., Sunnyvale, CA 94086. **479**

"Ecological Surveys from Space" deals with possible survey applications in seven major areas of natural science: geography, agriculture, forestry, geology, hydrology, oceanography and cartography. Aerospace Industries Assoc. of American, Inc., 1725 De Sales St. N.W., Washington, D C 20036. **482**

Ultraclean Fluids for IC Masks is a four-page application report that explains how Millipore membrane filtration can eliminate particles responsible for pinholes in IC masks. Application Note AN-311 is available from Millipore Corp., Bedford, MA 01730. **477**

"Bibliography of Liquid Crystals in Nuclear Magnetic Resonance (NMR)" is the title of Publication No. JJ-15 that lists 45 journal papers about the application of liquid crystals to NMR studies. Eastman Kodak Co., Dept. 412-L, Rochester, NY 14650. **480**

Various techniques for reducing radio frequency interference (RFI) on critical electrical systems are covered in a new 16-page brochure entitled "Deutsch Techniques for Reducing Radio Frequency Interference". The Deutsch Co., Municipal Airport, Banning, CA 92220. **483**

Reprints Available

in this issue are offered as follows:

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L63	One Adjustment Controls Many Regulators	33
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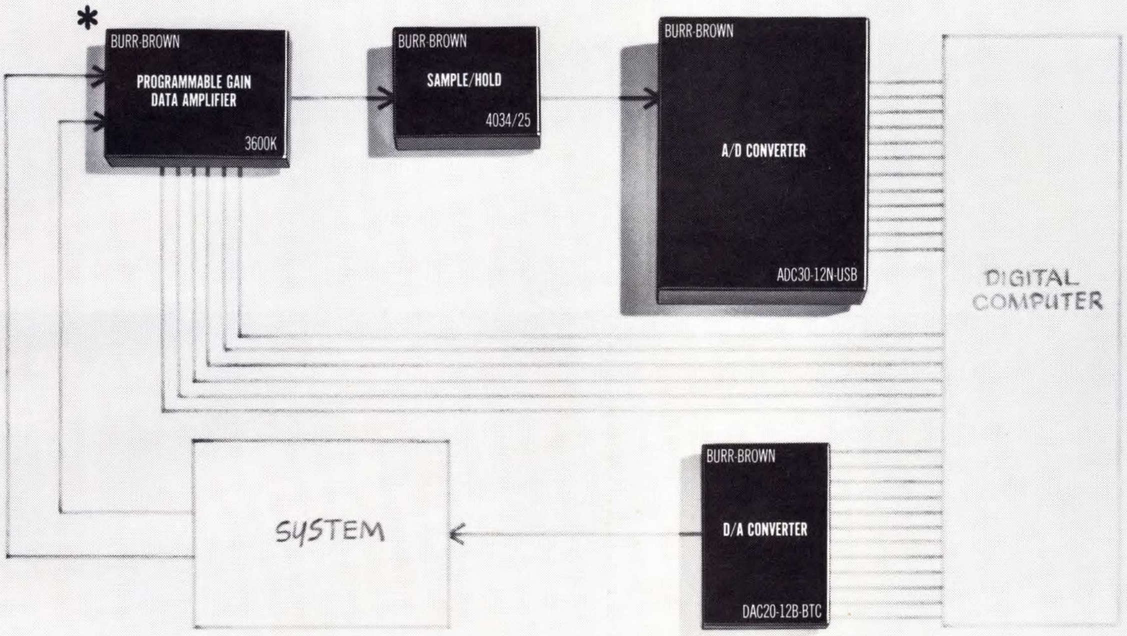

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