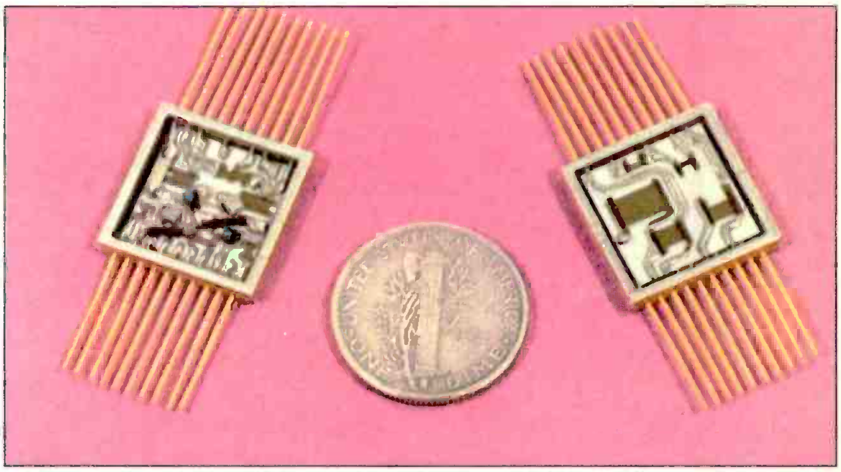
Electronics World

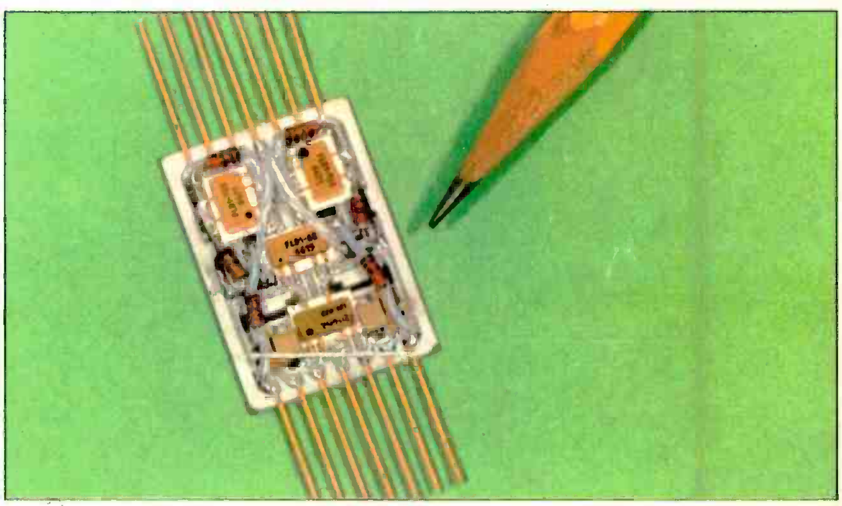
JULY, 1968
60 CENTS

NEW COLOR-TV SET SHOWS SLIDES WITH SOUND

PARTICLE ACCELERATORS FIND NEW APPLICATIONS

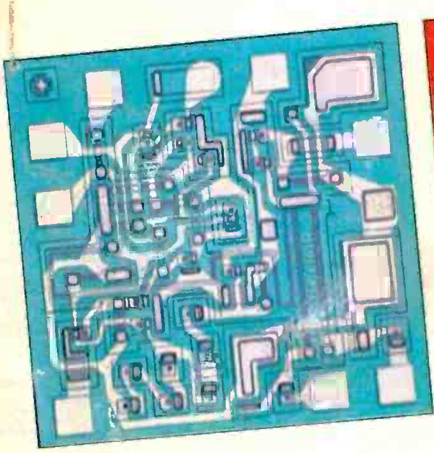
INTEGRATED CIRCUIT PREAMPLIFIER

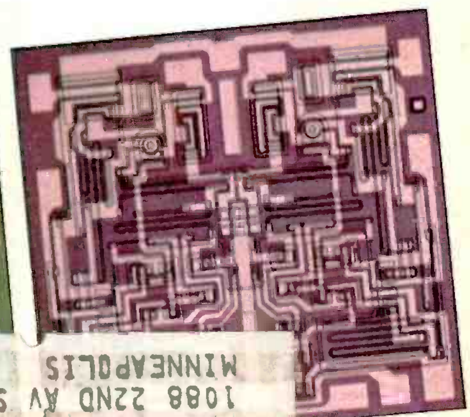




SPECIAL ISSUE

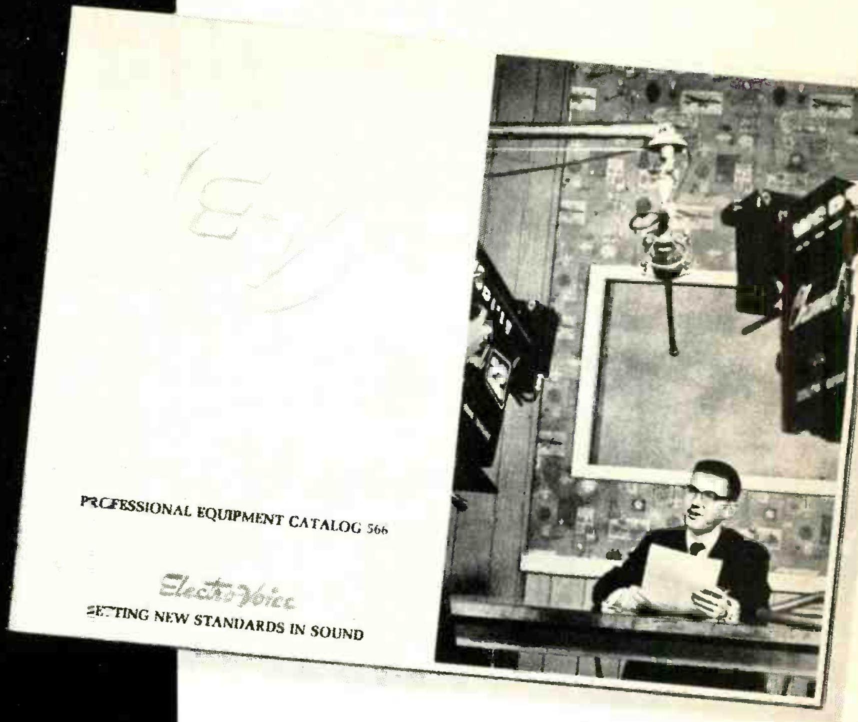
LINEAR INTEGRATED CIRCUITS





Our current catalog shows the entire Electro-Voice professional microphone line.

Strangely enough, so do Life, Time Newsweek, and U.S. News & World Report! Year after year after year!



For the 7th consecutive year we've counted microphones—by brand—in the four major newsweekly magazines. And, once again, Electro-Voice dominates the picture at major world news events.

We studied every editorial photo, in every issue, for a year. There were more Electro-Voice microphones seen than all other U.S. brands *combined!* E-V microphones were pictured 4.82 times more often than the next most popular brand.

We think this survey tells an important story about Electro-Voice quality and dependability. A story that is continued in TV, radio, movie, and recording studios throughout the world.

If you don't yet have a copy of our current catalog, drop us a line today. We'll send you full details on the entire line. And to see E-V microphones in action . . . just keep reading.

Learn about the entire Electro-Voice line of professional, general-purpose, and communications microphones. Send for this handy E-V microphone brochure today, or see your nearby E-V dealer.

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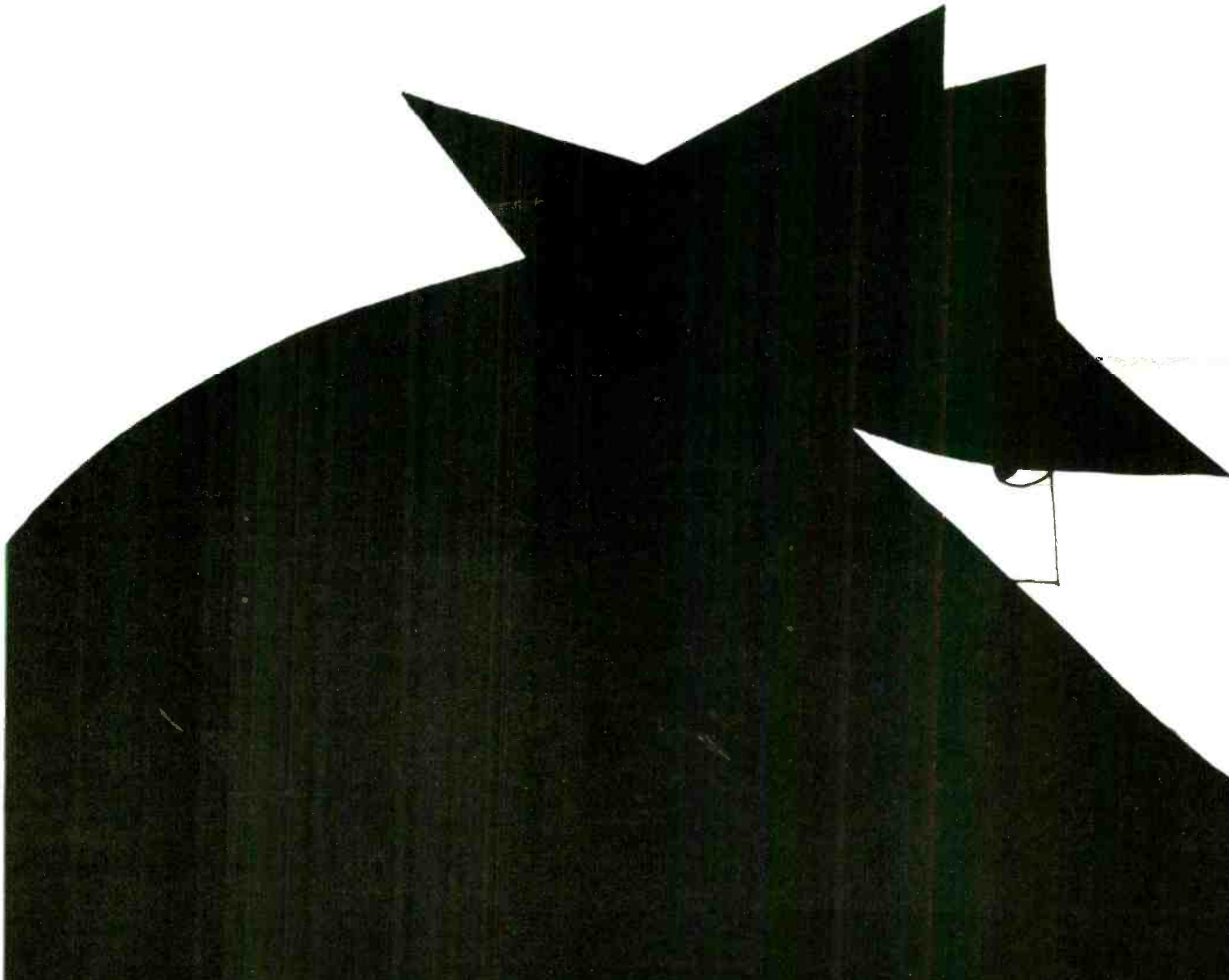
CIRCLE NO. 117 ON READER SERVICE CARD



The weed of crime bears sweet fruit

Here's Why

We've turned around the Shadow's old adage . . . because now crime does pay. It pays extremely well. if instead of committing crimes, you *prevent* them. Prevent them with the best burglar trap in the business: Radar Sentry Alarms.

Because the crime rate is rising astronomically, the demand for burglary protection is at an all-time high. Selling Radar Sentry Burglar Alarms is an excellent way to serve society—and make an extraordinary income at the same time! Sell just one Radar Sentry a week, and you can earn more than $15.000 a year! The weed of crime can indeed bear sweet fruit.

For less than $500 you can get started today on a career in crime prevention. There's no franchising fee. You can start selling Radar Sentry Alarms full or part time. No special experience is needed, though your electronics know-how will instill just the kind of customer confidence that helps build sales.

Foolproof, solid-state burglar trap

Radar Sentry Alarms saturate an area of 5000 square feet from wall to wall, floor to ceiling with invisible microwaves. Using multiple remote detectors, there is no limit to the area that can be covered. Any human movement will set off an earpiercing alarm. And nothing can thwart a Radar Sentry Alarm; it's completely foolproof!

All Radar Sentry Alarm units are solid-state. Installation is simple—no test equipment or special tools required. Maintenance is just as easy. Thanks to solid-state circuitry, the heart of the Radar Sentry Alarm's electronics is on a single printed circuit module. If a problem develops, the complete module is pulled out, and a new one plugged in. Instant repair, and no lapse in security.

Break into the burglary business today

RADAR DEVICES MFG. CORP. EW-7
22003 Harper Ave., St. Clair Shores, Mich. 48080

Please tell me how I can have a business of my own distributing Radar Sentry Alarm Systems. I understand there is no obligation.

Name ______________________

Address ______________________

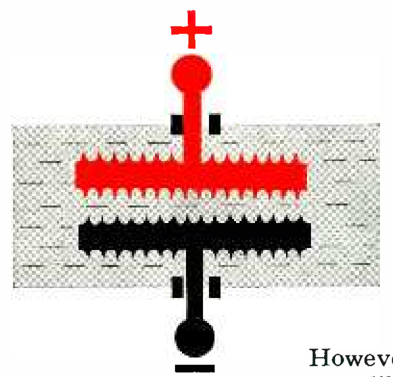
City ______________________

State ____________ Zip ____________

CIRCLE NO. 98 ON READER SERVICE CARD

MALLORY Tips for Technicians

Why some filter capacitors develop hum... and some don't



Aluminum electrolytic capacitors are widely used as filters in DC Power Supplies. This is because of their large capacitance in relatively small size. All in all, they do an efficient job of reducing ripple (hum) to acceptable levels.

However, all electrolytic capacitors are not alike. This is often why some types seem to allow hum to rise to objectionable levels more quickly than do others. In order to understand why, we must investigate actual construction methods.

As you know, electrolytics are basically made by depositing a film of aluminum oxide on aluminum foil to form the positive anode. The oxide is the dielectric. A semi-liquid electrolyte surrounds the anode and is actually the negative cathode. In order to connect this semi-liquid cathode to a terminal, a second piece of aluminum foil is used. This is often *called* the cathode, but it is not. It is actually only the *cathodic connection*. (The preceding describes a "polarized" electrolytic capacitor.)

When high ripple currents are applied to polarized electrolytics, a thin oxide film forms on the so-called "cathode". It begins to assume the characteristics of a second anode. This in turn, has the same effect as placing two capacitors in series. Consequently, overall capacitance is reduced. Inevitably hum increases.

This action is especially noticeable in electrolytics which use plain foil as the "cathode". This is simply because the oxide builds up over a relatively small area.

Mallory avoids this problem by etching the "cathode" on electrolytics. As a result, oxide build-up is spread over a vastly increased area. Therefore, ripple currents are maintained at very low levels for very long time periods.

Of course etched "cathodes" cost a lot more to make. But you get them from Malloy at *no extra cost.*

Meanwhile, see your local Franchised Mallory Distributor for capacitors, resistors, controls, switches, semiconductors, and batteries. Or write Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

DON'T FORGET TO ASK 'EM *"What else needs fixing?"*

CIRCLE NO. 108 ON READER SERVICE CARD

THIS MONTH'S COVER illustrates a number of linear integrated circuits and ties in with our Special Section on this important and timely topic. The two photos at the upper right are Sprague hybrid LIC's used as operational and differential amplifiers for peripheral computer equipment. They contain multi-layer ceramic capacitors, metal-film resistors, discrete diodes, and monolithic IC's. The ceramic frames are filled with epoxy encapsulating material. The strip of four photos at the bottom of the cover are, from left to right: a photomicrograph of an RCA multi-function LIC, consisting of FM i.f. amplifiers, discriminator, and a.f. amplifiers; Westinghouse complete audio amplifier LIC's are shown next packaged in 10-lead TO-5 case and flat pack; a G-E 8-lead plastic-packaged audio-amplifier LIC is next, mounted on the printed board of a phonograph amplifier assembly; and the photomicrograph at right is of a Motorola operational amplifier.

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CONTENTS

MONTHLY FEATURES

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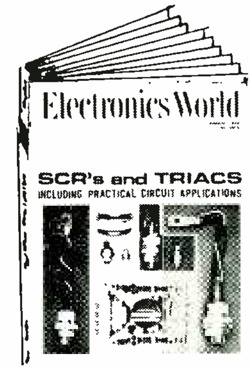
COMING NEXT MONTH



SPECIAL FEATURE ARTICLE:

SCR'S AND TRIACS

There have been many new developments in the packaging and technology of silicon controlled rectifiers and triacs (a bi-directional gate-controlled switch). In a special article in next month's issue, Dave Cooper of International Rectifier Co. discusses some new circuit applications and surveys the field of available devices.

TWIN-T's
Twin-T circuits are already being used as voltage-stable oscillators, ringing circuits, resonant amplifiers, and tone controls. A flock of new designs and applications have recently been developed. This article describes a few of them.

SOLID-STATE KITS
Are you a new arrival in the micrologic design field? RCA, Motorola, G-E, and Siliconix have developed a group of sampler kits which the fledgling IC or transistor user can employ in his breadboard developmental designs.

FUSE STANDARDS ARE WORKING FOR YOU
A survey of the field of fuses and fuse standards with special emphasis on the Underwriters' Laboratories and Military specifications which govern their manufacture, performance, and cost.

THE CO-OP ENGINEER
Look for the super engineer. He's a product of a growing industry-university team. Through cooperative educational programs, students are earning money for school expenses and gaining valuable industrial experience. Some companies say co-op students make the best engineers.

TV ALIGNMENT TECHNIQUES
Without proper alignment, color-TV is a dud. Some television technicians do anything to avoid set adjustments. The problem is they don't understand their test equipment or test procedures.

All these and many more interesting and informative articles will be yours in the ***August*** *issue of ELECTRONICS WORLD . . . on sale* ***July 18th.***

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NEW YORK OFFICE   212 679-7200
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MIDWESTERN OFFICE
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Booster Shots for Color-TV

More color-TV sets were sold last year than ever before but only 25% more than in 1966. The growth rate in earlier years was much greater. The sales pattern of color-TV this year worries set-makers a little. After a spurt the first two months of this year, sales took a long slump in March-April-May.

The Consumer Products Division of the Electronic Industries Association (EIA) plans a big national promotion campaign for color-TV this fall. The theme will be "Discover Color-TV". Results may not be felt before the spring 1969 retail selling season, although the impact might improve Christmas sales. The EIA promotion is part of a long-range plan to increase public awareness and use of consumer products of all kinds.

RCA recently kicked off a multi-million-dollar consumer-products promotion called "Entertainment on the Move". Color-TV portables share that promotion. With other manufacturers also emphasizing color portables in their new lines—in screen sizes from 10 to 18 inches—it's possible the color-TV industry can be prevented from becoming too anemic.

Another kick in the pants was aimed at the color-TV industry in general, and at the servicing business in particular, by an article in the May 1968 issue of *Consumer Reports*. The article says that *CR* readers write "over and over (about) put-off's, evasions, and buck-passing among manufacturer, service agency, dealer, and repairman—and, it would appear, just plain incompetence". The story sums up with: "Until there's a more reliable product and a more knowledgeable repair industry, the trouble with color-TV should give pause to any potential buyer of this expensive product". That kind of publicity is not likely to help color-TV sales much.

The Story Behind Long Warranties

Last month's issue had hardly been put to bed when more of the "big" color-TV manufacturers were climbing on the extended-warranty bandwagon (this column, June, page 17, "Extended Color-CRT Warranties"). They probably joined out of necessity; it's hard to imagine only one or two of them offering this sales-boosting gimmick. By now, *General Electric, Motorola, Packard Bell, Philco-Ford, RCA, Sylvania,* and *Zenith* all offer a 2-year warranty on the color picture tube. Not all the warranties are the same, though. Some are at extra cost to the dealer, who naturally passes it along to the buyer. Nevertheless, nationwide ad campaigns are touting the extended warranty as another reason for the consumer to buy color-TV now. *Admiral* still has an edge, with the only 3-year warranty policy.

From all quarters, except perhaps from the set-makers themselves, the question is: "Who pays for the labor of warranty replacement?" The answer is, unfortunately: "The customer". Even more unfortunately, that cost is a direct one—it can't be "hidden" in the price of something else. When a dealer replaces a color picture tube, in or out of warranty, the customer must be charged for service. So far, I've heard no indication that any manufacturer intends to reimburse a dealer for the time-consuming work of changing the CRT and the subsequent adjustments and purity, gray scale, and convergence. Several service and dealer association leaders express worry over how the customer is going to react. Badly, I'd say.

The technician and dealer are understandably wary of extended warranties. Too many have lost their shirts trying to make good on other long-term or non-reimbursed warranties. Furthermore, too often the terms of the warranty as explained to the set buyer are worrisomely vague. Until warranty conditions improve for both the dealer and the customer, there are a couple of possibilities for relief: (1) Be very sure the customer who buys a color-TV set understands the exact terms of the warranty, and knows what charges will be made if the warranty has to be honored. (2) Some dealers cover the cost of providing warranty labor by selling first-year service contracts, and find the customer then usually willing to buy a second-year contract (if, of course, service has been okay). These suggestions are not the final word on extended warranties, by a long shot. The whole idea needs a lot of refinement for all concerned.

Getting Rid of Color-TV X-Rays

Another onslaught in the battle of TV manufacturers to eliminate all possibilities of color-TV x-radiation has been won by *Motorola*. The weapon is a new all-solid-state, high-voltage rectifier. *Motorola* long ago eliminated the troublesome shunt regulator tube. The only possible x-radiator left in 1969 *Motorola* color models is the picture tube, and no manufacturer's set has any significant radiation from that source.

TV With No Picture Tube?

Not quite, although it may be closer than we know. *General Electric* scientists have come up with a tiny light-emitting diode in one of the labs. If enough of those diodes could be integrated into one solid bank, and a means provided for driving them in a regular scanning sequence, the result could be a flat-screen television display—and all solid-state. This screen could clear the way for a totally tubeless TV.

The principle for such a display is already incorporated in a giant (8-foot diagonal) color-TV display engineered by *Sony*. The "screen" consists of 78,000 tiny incandescent lamps, arranged in 28,000 triads of red, green, and blue. The triads are in 260 horizontal rows, and are scanned by regular video that has been changed to digital pulses which are applied to the lamps in sequence the same as video is swept across the usual TV screen. If the techniques used to scan the *Sony* display panel can be adapted to suit thousands of tiny electroluminescent diodes in a smaller display, and the diodes can be made to emit red, green, and blue, we'd have an entirely solid-state color-TV screen.

IC's Keep Coming in Home Entertainment

What had seemed only a tendency (this column, January, page 21, "Integrated Circuits—Reliable?") is becoming a trend. Linear integrated circuits are becoming so inexpensive and commonplace that more and more manufacturers are using them in favor of discrete components. *RCA* and *General Electric* hold the edge, but a good many others are in the picture: *Texas Instruments*, *Fairchild Semiconductors*, *Motorola Semiconductor*, *Westinghouse*, *General Instrument*, *Signetics*, *Mallory*, and *Sprague*, to name a few. Each of these companies has introduced one or more low-cost linear integrated circuits within the past few weeks, specifically tailored for the consumer electronics market.

In Japan, *Nippon Electric Co.* has recently developed an IC similar to the sound-i.f.-detector-preamp IC pioneered by *RCA*, even including the zener-diode voltage stabilizer. IC technology in Japan has lagged partly because *Texas Instruments* wouldn't license Japanese firms to produce IC's for the U.S. market—ostensibly due to a disagreement on terms under which *TI* was to build a plant in Japan. This dispute has been settled, now.

IC's are showing up in hi-fi equipment, as well as in home TV and radio receivers. *Hammond Corp.* will use them in its 1969 line of electronic organs. They are showing up in test equipment, particularly in imported models. *Motorola* auto radios have them already, and other brands will put them into next year's models. Keep an eye out; the consumer-IC trend may turn into a boom.

New One-Gun Color CRT

Remember the Chromatron color picture tube? It's a one-gun tube that uses color-switching grids to move the beam among red, green, and blue color stripes on its screen. The associated troublesome and expensive switching was later eliminated by a three-gun adaptation called the Chromagnetron. Neither version really caught on in this country, although some Chromatron color sets have been sold in Japan.

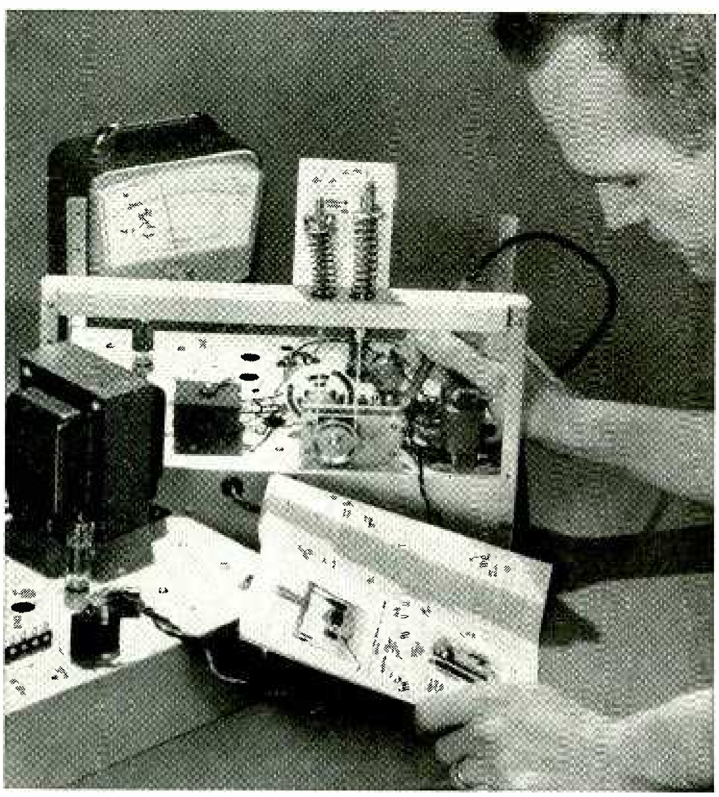
Now, *Sony* designers have taken advantages from both and built a color picture they call a Trinitron. It has only one electron-gun structure, but produces three beams from three cathodes. Color phosphors are still applied to the screen in vertical stripes. The three beams—from the red, green, and blue cathodes—go through three holes in the first two grids (the modulating grids). Then all three go through a succession of cylindrical grids that shape and focus them. In front of the gun are four flat plates that converge the three beams electrostatically.

The Trinitron has an aperture grille between gun and the screen. It is similar to the shadow mask of conventional color CRT's, except that instead of holes it has vertical slits that match up with the color-phosphor stripes on the CRT face. Image brightness is said to be as good and crisp as that in the Chromatron, which is pretty good.

Flashes in the Big Picture

CBS Labs suggests recording books on its new 8⅓ r/min, 7-inch records, which have playing time of 2 hours per side; takes new playback unit with special stylus to track microgrooves (700 per inch). . . . Begins to appear likely that land-mobile two-way radio services will get some TV channels, probably in u.h.f. band, but not without one more big fight by broadcasters. . . . Congress considering "all-channel-radio" bill requiring all radios to have both AM and FM. ▲

EXPERIENCE IS STILL YOUR BEST TEACHER



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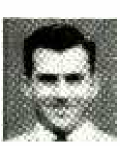
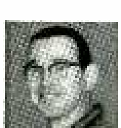


L. V. Lynch, Louisville, Ky., was a factory worker with American Tobacco Co., now he's an Electronics Technician with the same firm. "I don't see how the NRI way of teaching could be improved."

G. L. Roberts, Champaign, Ill., is Senior Technician at the U. of Illinois Coordinated Science Laboratory. In two years he received five pay raises. Says Roberts, "I attribute my present position to NRI training."



Don House, Lubbock, Tex., went into his own Servicing business six months after completing NRI training. This former clothes salesman just bought a new house and reports, "I look forward to making twice as much money as I would have in my former work."

Ronald L. Ritter of Eatontown, N.J., received a promotion before finishing the NRI Communication course, scoring one of the highest grades in Army proficiency tests. He works with the U.S. Army Electronics Lab, Ft. Monmouth, N.J. "Through NRI, I know I can handle a job of responsibility."

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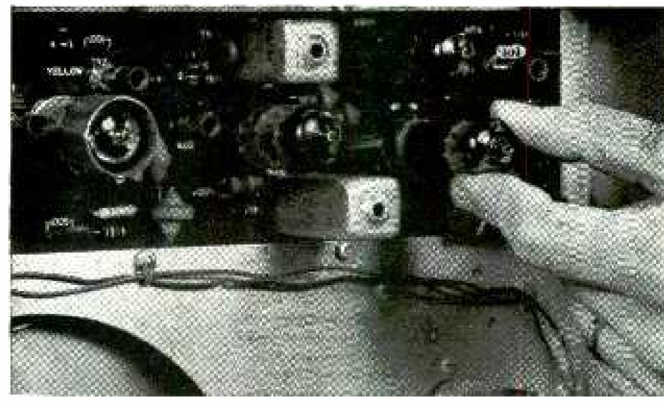

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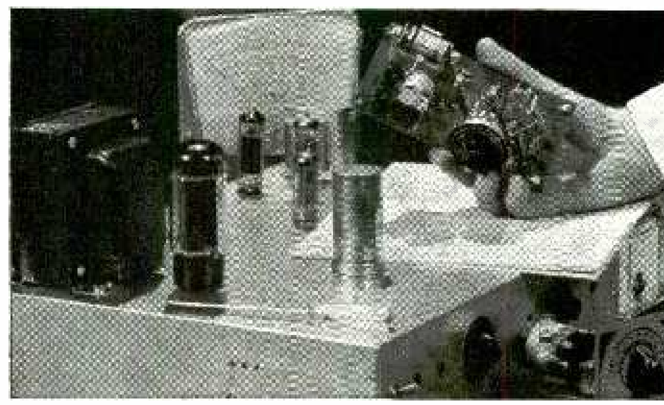

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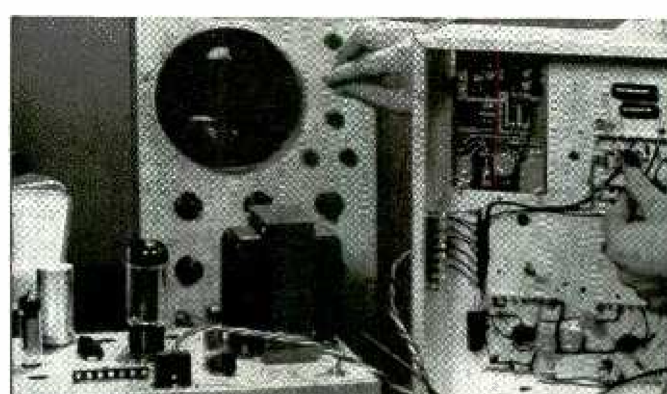

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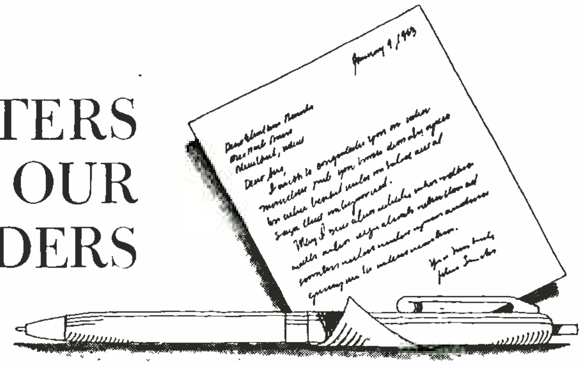

NEWSRAD RADIO STATIONS

To the Editors:

In your April issue ("Reflections on the News," p. 24) you covered the *Newsrad, Inc.* system for broadcasting up-to-the-minute national and local news to passenger planes prior to arrival at their destination airports. In your item you closed with the conjecture that the system might well be used for advertising purposes. Under no circumstances will the *Newsrad* broadcast to planes ever carry any advertising matter of any sort. The service is for the sole purpose of making available the latest news to in-flight air-carrier passengers and nothing else. We do not in any way want to mislead your readers as to the concepts and policies of our company.

Richard Hemingway
Pres., *Newsrad, Inc.*
New York, N. Y.

* * *

TECHNICAL-INSTITUTE GRADUATE

To the Editors:

I read with interest the article entitled "The Technical-Institute Graduate—How Does He Compare?" in the April issue of Electronics World and agree with the general theme that in many cases these individuals are neither effectively recruited nor utilized. *Honeywell* does, however, hire many graduates of various electronics institutes and uses these people in various capacities throughout the company in which they do make a real contribution.

My particular problem and the reason for my letter is somewhat different. We are interested in locating qualified engineering technicians with a variety of backgrounds ranging from chemical to mechanical for work in our Materials and Process Engineering R&D Laboratories. An education similar to that obtained by the electronics technicians described in your article would, needless to say, be invaluable. The problem seems to be where do you find these people? In this regard, I am wondering if you or any members of your staff might have a listing of institutions, trade, colleges, etc., that have programs of this nature in the physical sciences or in chemical or mechanical engineering, or if you might know where such a listing could be obtained. Information of this type would be most helpful in recruiting suitable engineering technicians for our operations.

Dr. K. E. Solie
Supervisor, Materials Engineering
Honeywell, Inc.
2600 Ridgway Road
Minneapolis, Minn. 55413

If any readers can help, please write directly to Dr. Solie.—Editor

* * *

SILENCE POLLUTION

To the Editors:

May I express my appreciation for the article in your March, 1968 issue on the subject of noise and noise control. I refer to Mr. John Frye's column on "Silence Pollution".

I have been a practitioner in this field for nearly thirty years, and like most I have been firmly convinced of the need for attention to the problem, and discouraged at the difficulty in accomplishing any improvement. There has been an increase in receptivity toward suggestions for improvement in the last few years, which seems very encouraging.

Mr. Frye might be interested to know that at the May meeting of the Analysis Instruments Division of the Instruments Society of America, in the session on air pollution, I presented a paper that is titled, "A Stink in the Ear: Noise."

Howard C. Roberts
Urbana, Ill.

Also, now that summer is here, our beaches are being "noise-polluted" by teenagers' transistor radios. This has become so much of a public nuisance that there are a number of local ordinances in effect prohibiting such use. —Editor

* * *

COIL TUNING RANGE NOMOGRAM

To the Editors:

In my article "Coil Tuning Range Nomogram" (March, 1968 issue, p. 36), I deliberately avoided showing the working equation or its derivation because it has been found that measured results usually differ from results found by calculations using idealized components. Items even more nebulous than distributed capacitance, such as inductance of hook-up wire, self-resonant frequency of the external capacitance.

HAAAAIH PROOF

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and others affect the results obtained.

Therefore, my approach was to start with the basic resonant-frequency equation, sketch the nomogram, and then adjust it with empirical correction factors I have developed from studying the papers of various investigators, and from my own laboratory notebooks and those of my associates. However, I overcompensated in locating the C_0 scale, and the answer in the example appears to be 6.5 pF. The answer was supposed to be 7.1 pF, a number which I used in the original manuscript. Apparently, after I checked the proof, the editor noticed that the solution drawn on the nomogram did not agree with the 7.1 in the text and, assuming the nomogram to be correct, he changed the text.

The nomogram would appear as I had intended, with the empirical correction factor, if the C_0 scale were physically slipped straight down about 3/16 inch so as to cause the example line to cross at 7.1 as stated in my original manuscript.

DONALD W. MOFFAT
San Diego, Cal.

* * *

ELECTRONICS MEMO PAD

To the Editors:

On page 14 of the March issue of ELECTRONICS WORLD (in "Radio & Television News") you speak about an electronics memo pad. You indicate in this article that only one such unit presently exists on the market. You refer to the *Grundig* Mini-Memo.

For your information, I am enclosing a chart of existing miniature dictating and transcribing systems already being sold in the United States. In addition to these, a unit similar to the Mini-Memo is ready for tooling by a U.S. manufacturing company in the New York City area. Another unit is now being tested by one of the American dictating machine manufacturers and this unit is scheduled for release within the very near future.

We quite agree with you that this is an important new market and should grow very rapidly. Our company was the first to introduce a pocket-sized executive recorder, the Memocord. This unit was introduced in the United States about seven years ago and is still being sold.

H. L. BARNHARDT
Sales Manager
Office Machines Division
Audio Applications, Inc.
Englewood, N. J.

Reader Barnhardt's chart includes, in addition to the Memocord *K-60, the* Fi-Cord *300,* IBM *224,* Norelco *85, and* Stenorette *EN-11. Most of these units are somewhat larger and heavier than the unit described in our column.—Editors* ▲

Reflections on the news

When X-Ray Photos . . .

of a skull were transmitted 210 miles over telephone lines between Wausau, Wisconsin and Chicago. technical and medical men stopped to listen . . . and look. Perhaps the most surprising thing was not what had been done, but how. The successful experiment was conducted by *General Telephone Company of Wisconsin* with ordinary, everyday equipment. A positive was made of the x-ray negative and put on a Telephoto machine used every day by *United Press International*. In Chicago. a Telephoto machine made a negative of the transmitted image. According to Dr. Jacob Martens of the Wausau Clinic, the reproduced picture was of diagnostic quality.

This accomplishment is of tremendous significance to the medical profession for it means that the services of a radiologist—a doctor who specializes in reading x-ray photographs—is just a phone call away. In many parts of the country, local physicians who need x-ray photographs interpreted must send them to the nearest specialist by mail. This procedure can take days.

The feat is also important to the phone company for it means that they have at last developed quality terminal and transmission equipment. Heretofore, the noise generated by switches and the like has made the transmission of fine-detailed pictures over telephone cable virtually impossible. Although much work remains to be done before the technique can be considered as reliable as the transmission of electro-cardiograms by wire, it is new evidence of improved medical care through electronics.

The new frontier for medical electronic development might very well be Israel, claims Dr. Leon Riebman. president of *American Electronics Laboratories*. Recently, Riebman, who is also chairman of the United States delegation to the subcommittee for science-based industries at the Prime Minister's Conference, predicted that "the availability of high-quality, low-cost medical research personnel and research centers in Israel will revolutionize the medical electronic equipment field".

Dr. Riebman's assertions were based on his assessment of the attitudes of professional medical men in the U.S. and in Israel. Apparently, the average American doctor would rather conduct a practice, privately or otherwise, because dollar rewards are much greater than in the research field. In Israel, it's the other way around. There are twice as many doctors *per capita* as in the U.S. and they prefer research work. In addition to *AEL*, a number of U.S.-based medical electronics companies have set up or are negotiating for plants in Israel. Among them are *Mennen-Greatbatch Co.* and *Star Dental Manufacturing Co.* There is just one hitch. Since the June war, Israel has suffered from a shortage of electronics engineers.

The Fidelity of Long-Haul Communications . . .

has always been a problem to military and commercial carriers alike. Analog signal transmission requires boosters (at predetermined spacings between major sub-stations) to assure intelligibility; digital signals require the use of multiple telephone channels. Both are costly in spectrum space as well as cash. But the very nature of digital signals makes them more reliable for transmissions. The digital signal is either present or absent at the receiver. and ambiguities inherent in analog signals do not exist.

Recently. *Radiation Inc.*, a company in Melbourne, Fla.. announced a new technique for digital voice transmission, called RACE (*R*adiation *A*daptive *C*ompression *E*quipment). RACE is a system designed to meet the particular problems posed by voice communications—the need to transmit in real-time, variations in signal quality. optimum voice quality, and recognition. Most importantly, the system adjusts automatically the inherent wide-band digital signal (typically 18 kilobits per second) to the narrow bandwidths of standard telephone (4-kHz military and 3-kHz commercial) lines. The principal difference between RACE and other voice-compression techniques is its ability to reject the redundant portion of voice waveforms and thus use fewer samples.

Briefly, here's how RACE works. The operation starts with a man speaking into a regular desk telephone set. The signal is fed to a presence detector and an a. g. c. amplifier which normalizes the level of the analog waveforms (within ± 1 dB). The signal is filtered—to eliminate spurious noise—sampled and converted to a digital stream. The digital stream passes through a reducer where redundant samples are eliminated; and a buffer memory which converts the output from parallel to serial. The resultant 9600 bits/sec signal is then sent to a modem where it is pulse-amplitude modulated and transmitted over standard voice-grade telephone lines. At the receive end, the information is demodulated and reconstructed into the original analog voice signals.

Although the RACE system was developed to provide a high-quality, secure long-haul communications capability for the military's Defense Communications Agency (DCA), its real value lies in future commercial applications—computer-to-computer communications, facsimile, and document transmissions. It should be noted that a digital voice transmission system has the potential of significantly lowering the cost of long-haul communications. For example, a 240-kHz multi-channel communications system from New York to Melbourne, Fla. costs $128,000 per year to lease. With the adaptive digital technique, the cost can be reduced to about $16,000.

Confusion and Lack of Security . . .

in police communications systems were startlingly evident in Memphis when an unauthorized radio call turned police cars in the wrong direction while chasing the alleged killer of Dr. Martin Luther King, James Earl Ray; it was again evident in New York and numerous other cities across the country during the riots that exploded in the wake of the assassination. There is not enough spectrum space and there are too many radios. Cities whose police departments had 200 mobile communications sets a couple of years ago have doubled and tripled that number. Overnight, many cities add another 100 sets by equipping their foot patrolmen with walkie-talkies. In an emergency, all of these stations fight hard to be heard, utilizing little or no communications procedures, and no scheduling. The result is a cacophony of garbled voices and missed or misunderstood messages.

What can be done about it? Well one answer is more spectrum space. But another, and even more important answer, is better utilization of the spectrum that is already available. To this end, *General Electric's* Communications Products Department has developed a direct mobile-to-computer access system which it claims lightens the loads of both police dispatcher and the mobile patrolman.

The benefits of a system like this are immediately obvious. Patrolmen in cars equipped with a computer terminal (coders, keyboard, and printer) could, without the necessity of voice transmission, obtain information on stolen property, known criminals, missing persons, etc., directly from the computer's memory bank. And since the computer's messages would be carried by frequencies other than those assigned to voice transmissions, more spectrum space would be available. There are a couple of hitches. The Federal Communications Commission has been slow making channel space available, and many police departments are having budget problems. But the efficiency of our police departments must be raised now. Law enforcement agencies cannot afford to wait for Federal grants to improve their departments. Perhaps the cities should try working closer together in sharing the expenses of developing a universal system, good in any part of the country.

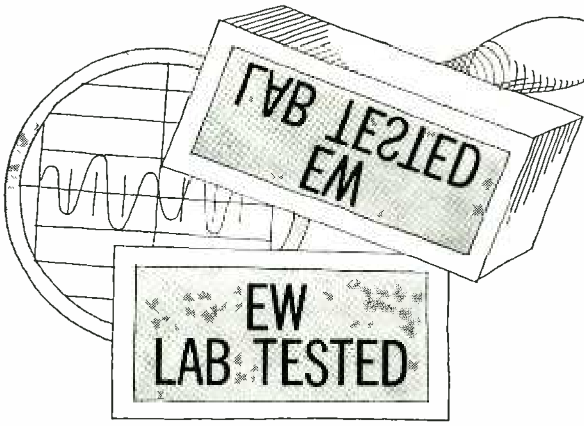
Commercial Inertial Navigation Systems . . .

for airliners have been as elusive as flying saucers. They've been so expensive and so wracked with technical problems that one airline company dropped an inertial guidance development program. Recently, *Litton Industries* and *American Airlines* announced that *AA* has become the first commercial carrier authorized to use an automatic inertial navigation system. According to *AA*, the *Litton* LTN-51 will go into service aboard the 707-323C cargo jets flying the 5000-mile transpacific run in support of the Military Airlift Command. *American* also has an application pending to provide passenger and cargo service to other Pacific areas such as Hawaii, Tokyo, and Manila.

The announcement is doubly important due to its effect on other over-ocean aircraft. The ill-fated *Sperry* SGN-10 system in which *Pan American, Alitalia,* and other airlines were interested, figured to cost about $110,000; the *AC Electronics* Carousel system for the *Boeing* 747 is expected to cost slightly under $100,000 (*AC* beat both *Sperry* and *Litton* for the *Boeing* award); but *American* says the LTN-51 will cost about $75,000. *Pan American,* which has rejected the SGN-10, was also testing a *Litton* inertial system, but decided to go back to Doppler radar for long-distance navigation.

Some Thoughts . . .

about things going on. As a group, engineers and scientists are unhappy with their jobs; 71% feel their talent is misused; 53% say they're improperly prepared for promotion; and 60% feel they are regarded as a commodity to be let go without concern for their welfare if business is poor. . . . . . National Bureau of Standards has developed an accurate means of measuring r. f. power. It's a dry-load calorimeter that extends the measurement range downward from 50 mW to 10 mW, reduces the measurement time to about 2 minutes, and can feed automatic digital readout and recording equipment. . . . *Cornell Aeronautical Laboratory, Inc.* has developed a radar technique which can detect and track bullets. *Cornell* says the system could be used to locate snipers during urban disturbances and to protect VIP's from assassins. ▲



HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

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Schober LSS-10A Speaker System

Acoustic Research Stereo Amplifier

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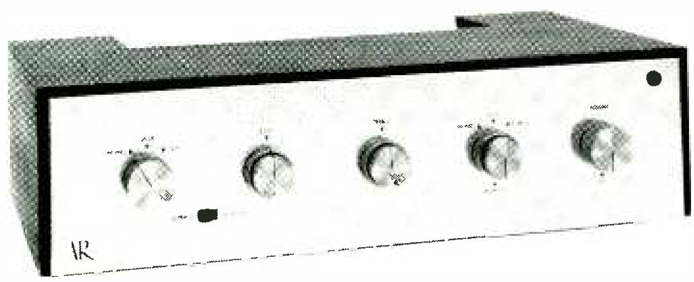


FROM past acquaintance with the *AR* design philosophy, we can deduce some of the design goals for its new integrated stereo amplifier, the company's first electronic product. First, it must be simple. Gadgetry and frills have never been a part of *AR* thinking. It must be reliable and fool-proof. (A two-year guarantee, covering parts, labor, and transportation both ways leaves no room for poor design or sloppy quality control.) The amplifier must be powerful; *AR* speakers thrive on drive levels that would destroy many lesser speaker systems. Furthermore, it must deliver its optimum performance with 4-ohm loads (the impedance of the AR-3 and AR-3a speakers) yet not compromise its performance at higher load impedances.

In addition, it should have the usual virtues of low distortion and noise and complete stability. It should be free from pops and clicks when it is turned "on" or "off" or when its controls are operated. Finally, it should be priced low enough to be a clear bargain in the marketplace.

The *AR* amplifier is all of these things —and more. It is an all-silicon solid-state integrated amplifier, measuring (in the optional wooden cabinet) 15¾" wide × 4½" high × 10" deep. Its rated continuous power output per channel with both channels driven, is 60 watts into 4 ohms, 50 watts into 8 ohms, and 30 watts into 16 ohms. Its IM distortion is rated at less than 0.25% and its harmonic distortion at less than 0.5% from 20 to 20,000 Hz, at any power up to rated maximum.

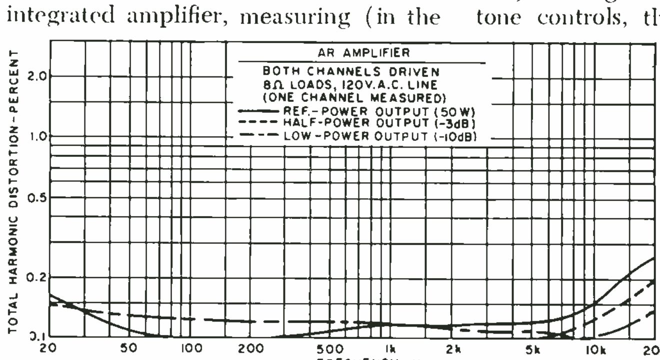
The input selector has three positions: Phono, Tuner, and Tape (high level). There is a tape-monitor switch for use with recorders having three-head monitoring facilities. The tone controls (concentric, with slip clutches for individual channel adjustment) have excellent characteristics. They are designed to supply loudness compensation for low-level listening, independent of volume-control setting. They can modify the response at the frequency extremes without affecting the mid-range response significantly. The manufacturer states that it is virtually impossible to produce an unnatural sound quality with these tone controls, and we agree. Their unusual effectiveness invites regular use and, although we take a dim view of tone controls, these are an exception.

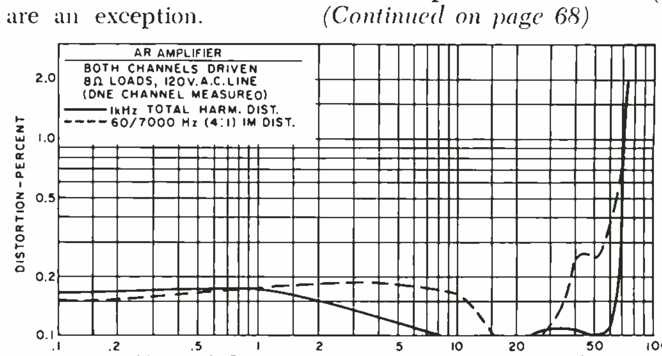
The stereo-mono switch is concentric with the balance control. A third position (Null) on this switch combines the two channels with the phase of one reversed, producing a null in the *electrical* output at the balance point. This does not necessarily result in a balanced *acoustical* output from the speakers, but it does assure that the two channels are balanced electrically.

The amplifier has a separate power supply that energizes all circuits except the output stages whenever the amplifier is plugged into the a.c. line, even though it is switched "off". This keeps all capacitors charged to their normal operating level and completely eliminates pops or thumps when the amplifier is turned "on" or "off". In normal operation, this supply is overridden by the regular power supply. The power amplifiers are driven through input transformers and are direct-coupled to the speakers, without blocking capacitors. The power transistors are protected by thermal circuit breakers that interrupt primary power if they become overheated. The speaker lines are individually fused.

Our laboratory tests showed the highly conservative rating of the amplifier. At 50 watts per channel into 8 ohms, the distortion was under 0.15% over most of the frequency range, and under 0.25% even at 20 and 20,000 Hz. At lower powers, distortion was even lower. At 1000 Hz, the harmonic distortion was about 0.17% under 1 watt, less than 0.12% in the 5- to 60-watt region and 0.5% at 70 watts (the *rated* power at 8 ohms is 50 watts). IM distortion was of similarly very low proportions. Into 4-ohm loads, the amplifier delivered a stag-

(Continued on page 68)





5-AMP 10-AMP PNP Silicon Power Transistors

from Solitron

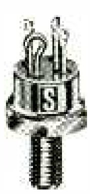
In addition to 20-Amp devices, Solitron has now expanded its line of PNP Power Transistors with a 10-Amp and 5-Amp Series. Both Series have a voltage breakdown range of 40 to 120 Volts. All have direct complements available.

10-AMP SERIES

TO-61 Isolated

Type Number TO-61 Isolated	MAXIMUM RATINGS			PRIMARY ELECTRICAL CHARACTERISTICS (T_C = 25 C)					
	V_{CEX} Volts	V_{CEO} Volts	V_{EBO} Volts	h_{FE}		V_{CE}(sat) Volts	V_{BE}(sat) Volts	I_{CEX} μA	f_T MHz
				I_C = 10A V_{CE} = −5V	I_C = 5A V_{CE} = −5V	I_C = 5A I_B = 0.5A	I_C = 5A I_B = 0.5A	V_{CE} = Rated V_{CEX}	I_C = 1.0A V_{CE} = −10V
				Min.	Range	Max.	Max.	Max.	Min.
SDT3105	−40	−40	−6	10	30-90	−1.0	−2.0	10	30
SDT3106	−60	−60	−6	10	30-90	−1.0	−2.0	10	30
2N5316	−80	−80	−6	10	30-90	−1.0	−2.0	10	30
2N5318	−100	−100	−6	10	30-90	−1.0	−2.0	10	30
SDT3109	−120	−120	−6	10	30-90	−1.0	−2.0	10	30

5-AMP SERIES



TO-111 Isolated

TO-5

Type Number TO-5	Type Number TO-111 Isolated	MAXIMUM RATINGS			PRIMARY ELECTRICAL CHARACTERISTICS (T_C = 25 C)					
		V_{CEX} Volts	V_{CEO} Volts	V_{EBO} Volts	h_{FE}		V_{CE}(sat) Volts	V_{BE}(sat) Volts	I_{CEX} μA	f_T MHz
					I_C = 5.0A V_{CE} = −5V	I_C = 2.0A V_{CE} = −5V	I_C = 2.0A I_B = 0.2A	I_C = 2.0A I_B = 0.2A	V_{CE} = Rated V_{CEX}	I_C = 0.2A V_{CE} = −10V
					Min.	Range	Max.	Max.	Max.	Min.
SDT3321	SDT3301	−40	−40	−6	10	40-120	−1.0	−2.2	10	40
SDT3322	SDT3302	−60	−60	−6	10	40-120	−1.0	−2.2	10	40
SDT3323	SDT3303	−80	−80	−6	10	40-120	−1.0	−2.2	10	40
SDT3324	SDT3304	−100	−100	−6	10	40-120	−1.0	−2.2	10	40
SDT3325	SDT3305	−40	−40	−6	5	20-60	−1.2	−2.5	10	40
SDT3326	SDT3306	−60	−60	−6	5	20-60	−1.2	−2.5	10	40
SDT3327	SDT3307	−80	−80	−6	5	20-60	−1.2	−2.5	10	40
SDT3328	SDT3308	−100	−100	−6	5	20-60	−1.2	−2.5	10	40
SDT3329	SDT3309	−120	−120	−6	5	20-60	−1.2	−2.5	10	40

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HEAR ACTUAL DEMONSTRATIONS OF

- A tape recording before and after editing.
- The sound of a battery-operated recorder at three tape speeds: $1\frac{7}{8}$, $3\frac{3}{4}$, and $7\frac{1}{2}$ inches per second.
- The improvement in fidelity when a quality microphone replaces the mike supplied as a recorder's standard equipment.
- How to reduce unwanted noise while recording.
- Acoustics: the sound of sound in the living room, kitchen, hallway, and street.
- Improving sound quality by re-recording a tape.

In addition to the tips on selecting and using equipment, you learn how to create complete sound stories with children—even recreate a situation that has already taken place! Actual sound demonstrations enable you to hear the effects of various tape speeds, microphones, and acoustical conditions. You also learn how to eliminate unwanted noise and to improve your tapes by re-recording them. In less than one hour, you get the benefit of years of experience and recording know-how!

EXTRA!

You'll be intrigued and thoroughly entertained by Side II of this superb new album. It's devoted entirely to three of Tony Schwartz's most famous sound essays, all acclaimed as "works of great artistry that will surely be enjoyed by anyone who enjoys and appreciates the sounds of children."

"CHILDREN AND GOD"—a fascinating composite of thoughts expressed by youngsters of various religious faiths. Their naively reverent concepts of God, heaven, good and bad, and prayer will be a revelation to you. This unique presentation is unlike anything you have ever heard before!

"NANCY GROWS UP"—a remarkable sound portrait of a girl's developing personality. In just two minutes, you hear her voice from 20 minutes after her birth, through the years until she's 13—when she reveals: "I've discovered boys!"

"SOUND SNAPSHOTS"—a potpourri of chuckles . . . once-in-a-lifetime sayings that could come only from the mouths of babes. These uproarious remarks, all said in the innocence of childhood, include delightfully ingenuous observations like these:

"I'm so hot I'd like to take my skin off!"

"I had growing pains yesterday."

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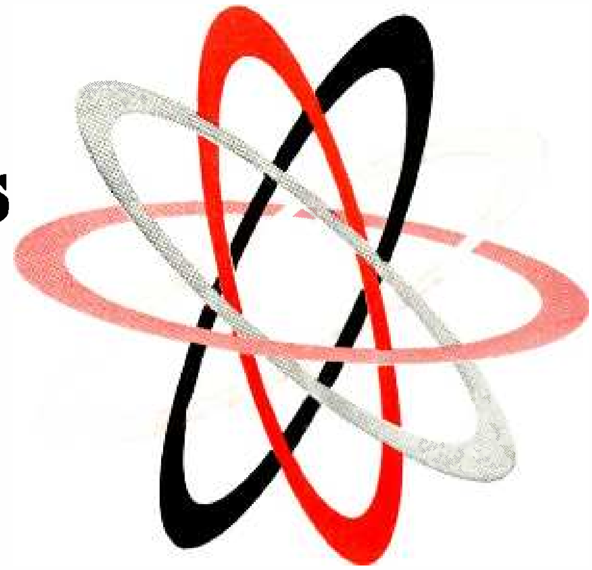
Particle Accelerators Find a New World



By JOHN R. COLLINS

Closeted deep within the recesses of research laboratories, particle accelerators have been used almost exclusively for theoretical studies. Today, industry is busy developing new materials with this old tool.

THE 33 billion electron volt (GeV) synchrotron, the world's most powerful particle accelerator, is at the Brookhaven National Laboratory on Long Island. Soon it will be dwarfed by a 70-GeV Russian accelerator now nearing completion at Serpukhov, U.S.S.R. And, if our own government's plans materialize, both of these machines will be overshadowed by a huge 200-GeV unit to be constructed at Weston, Illinois.

Hopefully, the accelerators at Serpukhov and Weston will uncover new clues to the nature of matter—a subject that has become increasingly complicated as new elementary particles continue to be discovered. Already experiments are being devised for the new machines that may establish the reality of "quarks"—the hypothetical subatomic particles that some physicists believe are the blocks from which all other particles are built.

While super accelerators are engaging the attention of many high-energy physicists, interest in smaller machines is also increasing. Some instruments which were used almost exclusively for research, such as those in a range from about 100 keV to 20 MeV, are now finding novel industrial, scientific, and medical applications (Fig. 1). These activities have resulted in the development of a number of new products and improved processes. Although it is too soon to anticipate what future developments will bring, the number of applications is almost certain to multiply in the years to come.

Radiation Chemistry

Research in radiation chemistry (an almost unexplored field) has been spurred by the discovery of new kinds of chemical reactions that cannot be duplicated by other methods. In conventional chemistry, heat transfer is introduced to promote molecular activity and thus increase the probability that a chemical reaction will occur. Typically, the heat is evenly distributed throughout the system and the energy imparted to any one molecule is comparatively small. But when a substance is irradiated with electrons or *gamma* radiation, energy is applied directly to the molecules of interest and little or none to other molecules. The affected molecules may thus be raised to any number of possible excitation states in which electrons jump to orbits farther and farther from the nucleus. This makes the formation of new chemical bonds more probable.

If a fast electron passes close enough to an atom, it may cause the atom to lose one of its orbital electrons, creating an ion. But because of the way the atom receives and loses energy, the ion has a very short life since it tends to react immediately with other particles near it. When a complex molecule is bombarded by accelerated particles, an atom may be dislodged and, if the change takes place fast enough, there is little alteration of the molecular structure. Basically, reactions produced by particle bombardment are more controllable than those produced by heat energy, since the energy can be instantaneously applied and withdrawn, or concentrated on a single atom of a molecule.

Among the byproducts of electron bombardment are atoms with unpaired electrons, called free radicals. The life span of these fragments is extremely short, usually measured in milliseconds. They are studied through the use of a source capable of delivering concentrated radiation in short pulses. Although these reactions are difficult to predict, they constitute an important field of research in radiation chemistry.

The radiation dosage needed to accomplish a given result is based on the amount of energy absorbed per unit of material. The standard measure is the rad, defined as 100 ergs per gram. For practical calculations it is convenient to remember that one kWh is equivalent to 800 rads per pound.

New Plastics

Irradiation can be used to convert simple compounds, or monomers, to more complex compounds with superior qualities. In this process, called polymerization, the molecules are united to form a new substance which has the same ratio of elements as the monomer but a higher molecular weight. Resins and rubber as well as plastics may be synthesized this way.

Plastics can be further improved through a process called crosslinking. The benefits of crosslinking may be illustrated by reference to polyethylene, a material made up of long chains of carbon and hydrogen atoms. In its natural state, the molecules in each chain are linked by carbon atoms

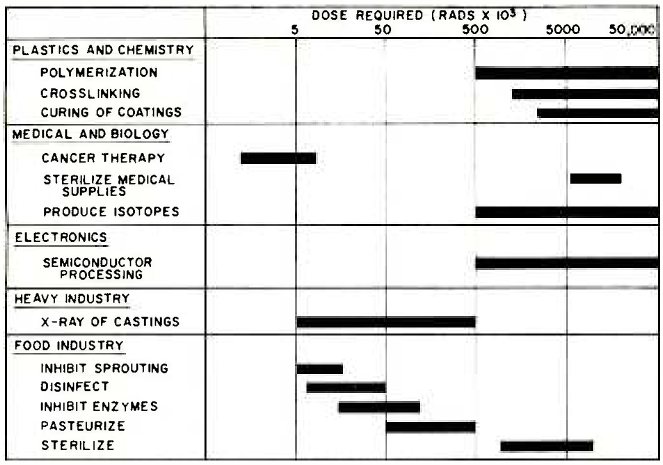


Fig. 1. Some applications of particle accelerators.

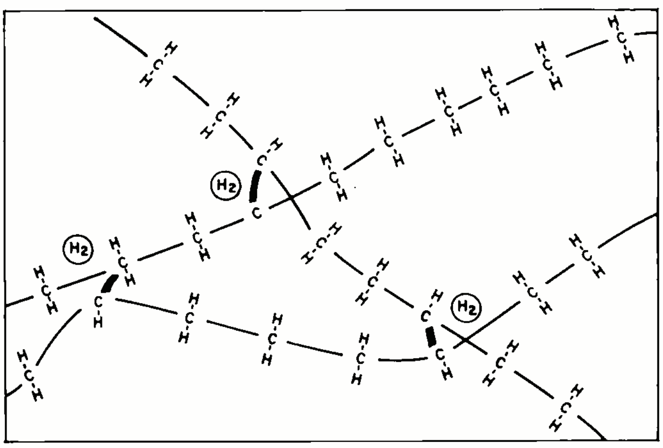


Fig. 2. When polyethylene is irradiated, hydrogen atoms are removed and the ionized carbon-hydrogen chains crosslinked.

and there is no true chemical bond between the individual chains. But when the material is irradiated, some of the hydrogen atoms are ejected from the chains and pass into the atmosphere as hydrogen gas. The remaining ionized carbon atoms unite in a strong, chemical bond (Fig. 2).

Although relatively few molecules are crosslinked, crosslinking produces differences in the properties of the polyethylene. The melting point is increased from about 135° C to 325°C—an extremely important property for military and space use. Perhaps the most interesting feature is the "shrink memory" which irradiated polyethylene and several materials exhibit. When heated above the melting point of unirradiated polyethylene (135° C), the material can be stretched into any desired shape and, when cooled, it will retain that shape. If it is again heated above 135° C, however, it will return to the shape it had before it was stretched.

Irradiated polyethylene has a number of practical uses. For example, it can be used to make plastic packages for foods and other products since a little heat will cause a previously stretched polyethylene container to shrink and fit tightly around its contents. In the electrical industry, tubes made from polyethylene provide moisture-proof seals for connectors and splices. The tubing is made large enough to fit easily over the connections in its stretched state, but forms a snug seal when heated.

In the textile industry, attempts have been made to crosslink dissimilar fibers and obtain materials that incorporate the best characteristics of each. Crosslinking has also been tried on wood. A soft wood, such as pine, is soaked in a monomer and then subjected to *gamma* radiation. The result is an extremely hard wood that is almost impervious to scratches or burns.

Curing of Coatings

A new system for curing coatings by irradiation with fast electrons may eventually replace previous methods of coating materials for protection and decoration. The technique is applicable to wood, paper, textiles, concrete, and aluminum, but it is of especial interest to the automobile industry because of the vast amount of sheet steel that must be coated. Oxygen tends to absorb the free radicals produced by irradiation and inhibit polymerization, so until recently an inert atmosphere was required to produce a satisfactory coat. This difficulty has been overcome and it is now practical to perform the complete radiation curing operation in air at ambient temperature within just a few seconds.

From an industrial standpoint, irradiation curing offers a number of additional advantages. The accelerator installation, in size and operating cost, is far smaller than the huge drying ovens normally used. Also, a cheaper acrylic monomer can be used instead of the customary acrylic polymer, since the monomer is polymerized in the irradiation curing process. In addition, the solvent which represents about 60 percent of ordinary acrylic paint is unnecessary because bonding is accomplished without the need for a carrier. Another advantage is that adhesion to the substrate surfaces is better. In many situations the radiation brings about a true chemical bond between the coating material and the substrate, producing a monolithic material. Finally, irradiation causes crosslinking of the molecules in the coating, thus producing a tougher material with a higher softening temperature and greater resistance to scratches and chemicals.

A particle accelerator designed especially for curing is made by *Radiation Dynamics Inc.* (Fig. 3). The same type of accelerator may be used to fast-cure adhesives.

Medical Applications

Particle accelerators provide the high-energy x-ray beams needed for the treatment of deep-seated tumors. Machines intended for medical use have potentials in the range of 4 MeV to 8 MeV. In addition to the high energy requirement, the machine must have the capability of focusing the x-rays into a very narrow beam. This is done to concentrate maximum radiation on the desired area without affecting neighboring tissue. Fig. 4 shows a particle accelerator manufactured by *Varian Associates* specifically for medical x-ray treatment. The accelerator is designed to focus the x-ray beam on the same spot while the apparatus is revolved completely around the patient. In this way, it is possible to apply the maximum amount of radiation to the tumor while keeping the dosage absorbed by other tissue within safe limits.

Another important use of particle accelerators is in production of short-lived isotopes for analysis, diagnosis, or therapy. Many of these have such short lives that hospitals find it impractical to obtain them from outside sources and must produce them in their own facilities. The half-life (the average time required for half the atoms of a radioactive substance to lose their radioactivity by decaying into stable atoms) of iodine-129, for example, is only 25 minutes, and that of magnesium-27 is about 10 minutes.

Many medical devices that cannot withstand either chemical or thermal treatment can be sterilized by irradiation. Among the candidates for such processing are medicines, bandages, surgical sutures and sponges. Teflon arteries, gloves, and instruments. Sterile conditions can be assured by irradiating both the package and its contents after the items have been sealed in their containers.

Semiconductor Processing

Several methods have recently been devised to produce superior semiconductors through the use of irradiation. The lattice structure of the silicon in transistors, for example,

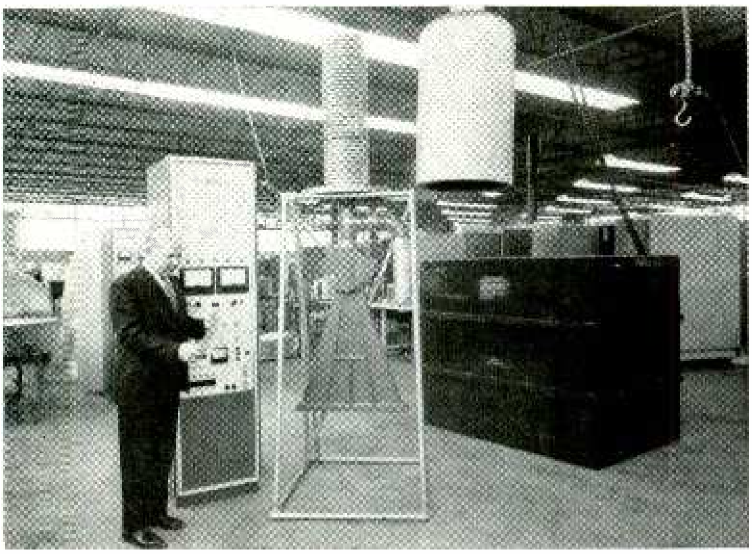


Fig. 3. When completely assembled, this particle accelerator will be used to cure acrylic monomers and to bond adhesives.

can be altered by bombarding the devices with 1-MeV electrons. Some of the silicon atoms are knocked from their normal position in the lattice, leaving vacancies and interstitial atoms. This change in structure has the effect of reducing carrier lifetime, thereby increasing the switching speed of the transistors. While it is true that gain suffers in the process, electronic designers may find it desirable to sacrifice gain for speed.

Particle accelerators capable of handling isotopes are being used to dope semiconductors used in many critical applications. The doping process can be precisely controlled since the depth of penetration of an ion beam is determined by the target material, the nature and energy of the incident ion, and the angle of incidence. If the energies of the ions exceed 50 keV, useful junctions can be formed without "channeling" along preferred crystal planes. In practice, spectroscopically pure boron-11 and phosphorus-31 ion beams are accelerated to energies between 50 keV and 400 keV to produce p and n layers, respectively, in silicon. Such junctions may be formed through a passivating surface oxide. State-of-the-art solar cells, radiation detectors, unipolar field-effect transistors, and bipolar transistors have been produced in this manner.

A related process involves neutron bombardment of silicon-30. When the p-type silicon-30 absorbs neutrons, it is transmuted into n-type phosphorus-31. The distribution of the neutrons is controlled by placing strips of neutron-absorbing cadmium in desired patterns over the silicon, permitting distinct p-n-p sandwich configurations to be formed. The shaping of the p and n regions thus obtained cannot be achieved by conventional methods.

Industrial X-ray

Particle accelerators can provide the extremely high-energy x-rays needed to make x-ray photographs of heavy castings. These radiographs are used to detect subsurface flaws that might prove costly if undisclosed. An even more demanding application is in the inspection of missiles. Accelerators having energies up to 25 MeV have been developed to provide the x-rays needed to inspect the propellants of missiles such as the Polaris and the Minuteman. They look for defects that exist deep within the propellant or at the bond between the casing (missile) liner and the fuel. A flaw at either location would affect burning rate and thus flight trajectory.

The Food Industry

Irradiation can be used to prolong the shelf life of foods. This method is especially attractive in parts of the world where refrigeration is scarce, but it also is important here in the United States. For example, the New England fishing fleet loses a large part of its catch because the fish becomes unsuitable for human consumption before it can be brought to market. A relatively small dose of radiation, however, will triple the shelf life of fish, shrimp, and clams.

The Food and Drug Administration regulates radiation-processed food. Before permission is granted to irradiate food, evidence must be submitted that the irradiated food is safe for human consumption, that the radiation is no higher than needed to accomplish the desired effect, that the food itself is not radioactive, and that the process is safe and effective under simulated commercial conditions with no significant adverse effects on flavor, odor, texture, or appearance.

Among the projects already approved are the sterilization of bacon, the insect deinfestation of wheat and wheat flour, and sprout inhibition of white potatoes. Some companies have applications pending for permission to use radiation to sterilize ham; to reduce spoilage and extend shelf life of oranges and strawberries, and to soften and reduce cooking time of dehydrated vegetables. Future plans include sterilization of almost all meats and meat products, spoilage reduction of many fruits, sprout inhibition of onions, and shelf life extension of many kinds of seafoods.

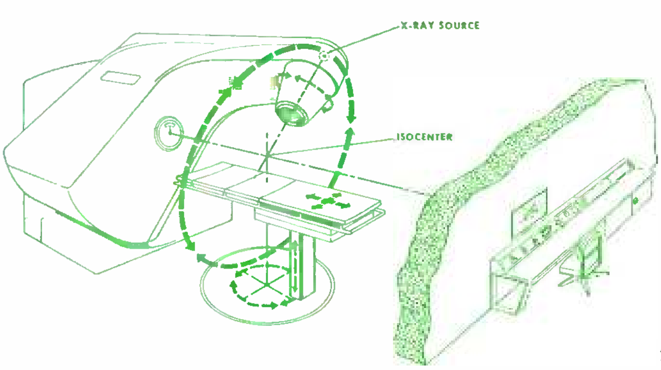
Radiation Sources

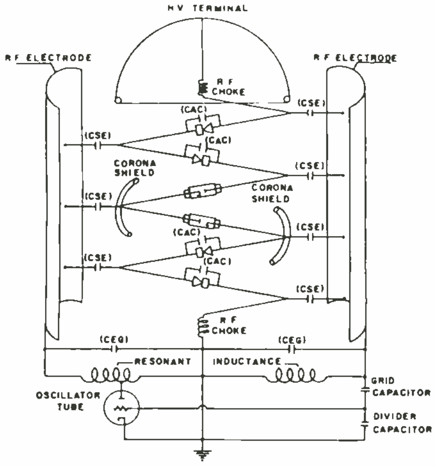
There are many ways to obtain the high voltage needed for particle acceleration. The choice depends upon how much energy is required and whether the radiation must be continuous or pulsed. Often, an accelerator may be used to supply fast electrons or, through the use of a tungsten target, high-intensity x-rays. Some accelerators can also be used for ion acceleration if they are fitted with a suitable ion source.

A high-current d.c. accelerator, made by *Radiation Dynamics Inc.*, utilizes a cascaded rectifier system in which a high-frequency oscillator and parallel driver rectifiers provide the high voltage. Called the Dynamitron, the accelerator is capable of achieving energies up to 3 MeV. The principle of operation is shown in Fig. 5. Two large r.f. electrodes are placed inside a cylindrical pressure vessel and are capacitively coupled to corona rings mechanically attached to each rectifier tube. A high-pressure dielectric gas provides insulation. The r.f. potential across each of the rectifiers and the direct-component currents add in series to establish the desired d.c. potential at the output terminal. Charged particles are produced by an electron gun and are accelerated through an evacuated beam tube. The accelerator used to process surface coatings (Fig. 3) is one type of Dynamitron. Similar accelerators are made in different configurations to handle other jobs.

A recent addition to the field of accelerators is the ICT (Insulating-Core Transformer) made by *High Voltage Engineering Corporation.* Like the Dynamitron, it has no

Fig. 4. A particle accelerator manufactured by Varian Associates specifically for x-ray therapy. The x-ray beam remains focused on the same spot while the apparatus revolves around the patient.





SYM	CAPACITANCE
(CSE)	SHIELD TO ELECTRODE
(CAC)	ANODE TO CATHODE
(CEG)	ELECTRODE TO GRD

Fig. 5. This diagram shows the cascaded rectifier system which generates the high voltage for Dynamitron particle accelerator.

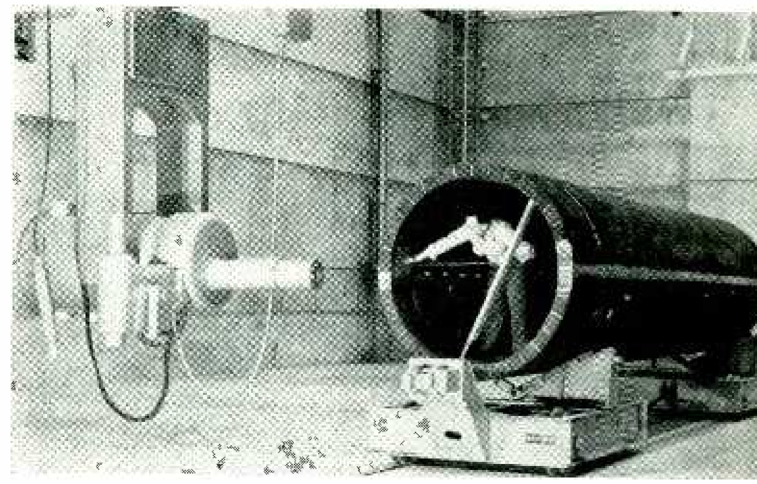


Fig. 6. This giant particle accelerator built by the High Voltage Engineering Corp. is used for x-ray radiography of heavy casting.

moving parts. Essentially, an ICT is a three-phase power transformer with multiple secondaries, each of which is insulated from the other. The alternating current in each secondary is rectified, and the individual d.c. outputs are connected in series. An advantage of the ICT is that voltage can be transferred from a physically separated power source to the acceleration system by means of a flexible cable or rigid transmission line. Up to three accelerating tubes may be remotely located and powered by a single ICT.

One of the earliest high-voltage devices, the Van de Graaff machine, is still widely used. In principle, it resembles electrostatic generators used for demonstrations in physics laboratories. An electric charge is sprayed on a rapidly moving insulated belt and is carried to a rounded, metallic terminal where a high d.c. potential is established and maintained. This terminal is connected to ground through a high-resistance voltage divider. Particles to be accelerated are introduced into an evacuated tube, one end of which is located in the charge terminal. They are progressively focused and accelerated as they pass through the tube, away from the high-voltage terminal, emerging at the end in a narrow, high-energy beam. Both voltage and current can be precisely regulated.

Single-stage Van de Graaff machines are rated to about 5.5 MeV. Higher energies, up to about 30 MeV, are possible through tandem operation, a process which involves acceleration through two or more successive stages.

A Van de Graaff generator forms the basis of a flash x-ray system made by *Ion Physics Corporation* (Fig. 7). Unlike the conventional generator which provides a constant output, the *Ion Physics* generator is pulsed, delivering huge radiation fields in short bursts. A gas-insulated coaxial line housed in the same vessel as the generator is charged to several megavolts. A triggered, pressurized gap delivers the stored energy into an evacuated field-emission diode. The grounded anode of the diode is usually a target which provides high-intensity x-rays, but a thin window and focusing system may be used instead for the emission of high-energy electrons. The duration of the pulse is directly proportional to the length of the coaxial line. Existing systems utilize lines from 3 to 11 meters, yielding pulses of 5 nanoseconds to 30 ns.

Bursts of high-intensity x-rays or electrons up to about 2 MeV may also be obtained by charging a number of capacitors while they are connected in parallel and discharging them while they are connected in series. Equipment of this kind is usually smaller and more mobile than most other particle accelerators and have been used in smaller industrial applications. ▲

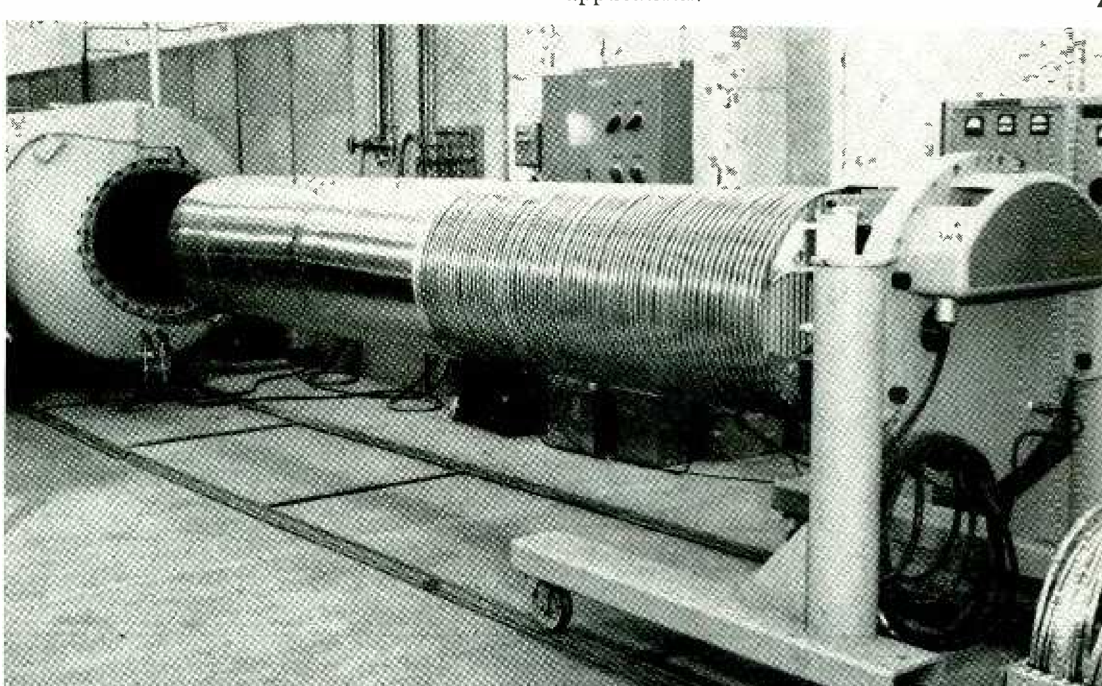


Fig. 7. A flash x-ray system manufactured by Ion Physics Corporation showing the high voltage generator before the final assembly operation when it is placed inside of its pressure vessel.

INTEGRATED CIRCUIT EQUALIZED PREAMPLIFIER

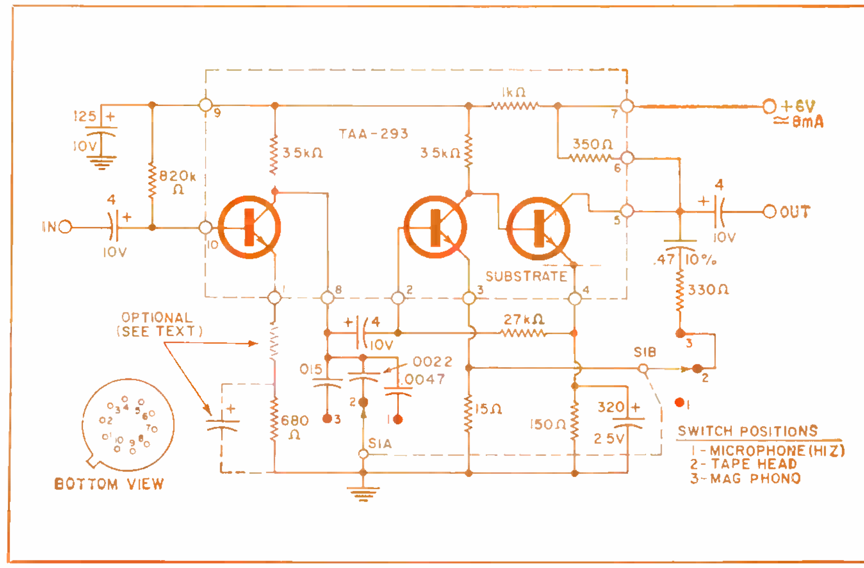


Fig. 1. Complete schematic of the IC equalized preamplifier. All components within the dashed rectangle comprise the IC.

By DAVID R. PRYCE /Head, Audio & Special Products, Amperex Electronic Corp.

The Amperex TAA-293 IC is well suited for low-level audio preamplifier applications. Here is a high-gain, low output impedance circuit that is equalized for general-purpose mike, magnetic phono, or tape-head use.

INTEGRATED circuit prices, still dropping, have in some cases reached a level competitive with transistor prices. What this really means is that IC's are less expensive than transistors because part of the final circuit comes along with the IC, inside the can. This arrangement saves size as well as cost. Here is a simple, useful circuit design for an equalized audio preamplifier that will serve as an introduction to IC applications.

The key device is an *Amperex* TAA-293 integrated circuit.

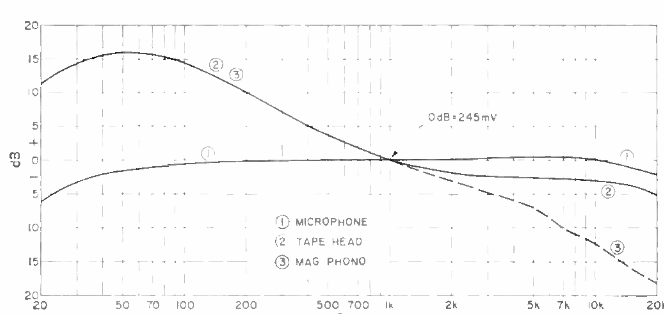
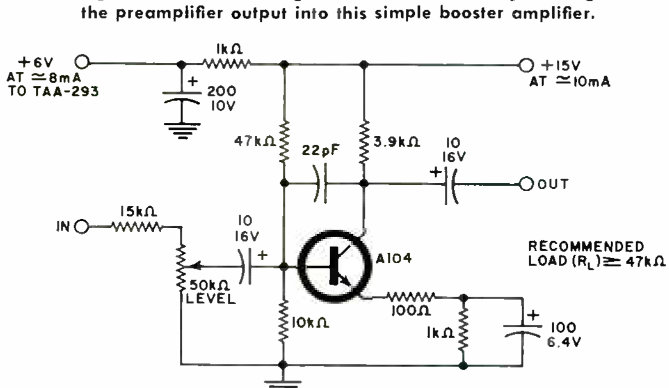


Fig. 2. Frequency dependence of the preamplifier output at three equalization settings, relative to 1-kHz gain.

Fig. 3. Another 18 dB gain can be achieved by feeding the preamplifier output into this simple booster amplifier.



It is available from the company's stocking distributors at $2.70 each, and should be easy to find. This IC contains three transistors and four resistors in a general-purpose amplifier configuration.

A printed-circuit or Vectorboard construction is indicated. Because there is a lot of circuit gain in a small area, some care in parts layout may be required to avoid persistent high-frequency oscillations. The usual routine of keeping input components away from the output components, and the leads short, should be sufficient.

Circuit Operation

The schematic of Fig. 1 breaks down into four parts. There is a one-transistor input circuit, a two-transistor gain circuit, and a pair of feedback circuits. Let's examine these one at a time.

Because the input circuit has an unbypassed large emitter resistor, its gain is low. But the base terminal sees the emitter resistor multiplied by the transistor *beta*, added to the normally low base resistor. This gives an effective input resistance, as seen by the signal source, of roughly 50,000 ohms. This is a good value for general-purpose applications, and will work well for microphone, tape, or phono-cartridge inputs.

A capacitor and some resistors are eliminated by direct-coupling the second gain stage to the third gain stage. This is excellent engineering practice, since the d.c. biasing problems relating to direct coupling are easily handled in IC work. The resistor from IC pin 6 to the +6-volt line is the output load resistor.

The first feedback loop is completed by a 27,000-ohm load resistor from the IC's pin 4 to pin 2. This resistor stabilizes the d.c. operating point of the two direct-coupled transistors.

A second feedback loop extends from the IC's output terminal, pin 5, back to the emitter of the second transistor. Some output signal is returned through this loop, and acts to reduce the effective signal applied to the transistor. The resistor and capacitor in series in this loop give its transmission characteristics a frequency (*Continued on page* 73)

RC Differentiator Design Nomograms

By DONALD W. MOFFAT

Timing and triggering spikes become smaller in amplitude as they are made to have shorter time duration. This chart permits optimum RC circuit design to produce such pulses.

SHARP spikes for timing and triggering are created by applying a step waveform to a passive *RC* differentiator, as shown at the bottom of Fig. 1. But designers are often bothered by the trade-off in which sharpening up the output pulse by reducing the *RC* time constant causes a reduction in the pulse amplitude.

How are pulse width and amplitude related? How narrow can a pulse be made before its amplitude becomes smaller than a predetermined limit? The nomograms in this article enable one to quickly design a circuit to meet his requirements.

The factor that causes the output pulse to decrease in amplitude as it is made narrow is the rate at which the input step rises; no real waveshape can change level in zero time. A reasonable assumption that applies to a majority of realizable steps is that they are generated in an ideal (zero rise time) form but practical circuits have unavoidable stray resistances and capacitances which, however minute, cause all steps to have a finite rise time. Small charging circuits formed by these stray resistances and capacitances give the leading edge a shape which is described by the *RC* charging formula:

$$e = E_{step}\,(1 - \varepsilon^{-t/RC})$$

where *RC* is the time constant formed by the strays. According to this equation, the step will reach 63.2% of its maximum in one time constant.

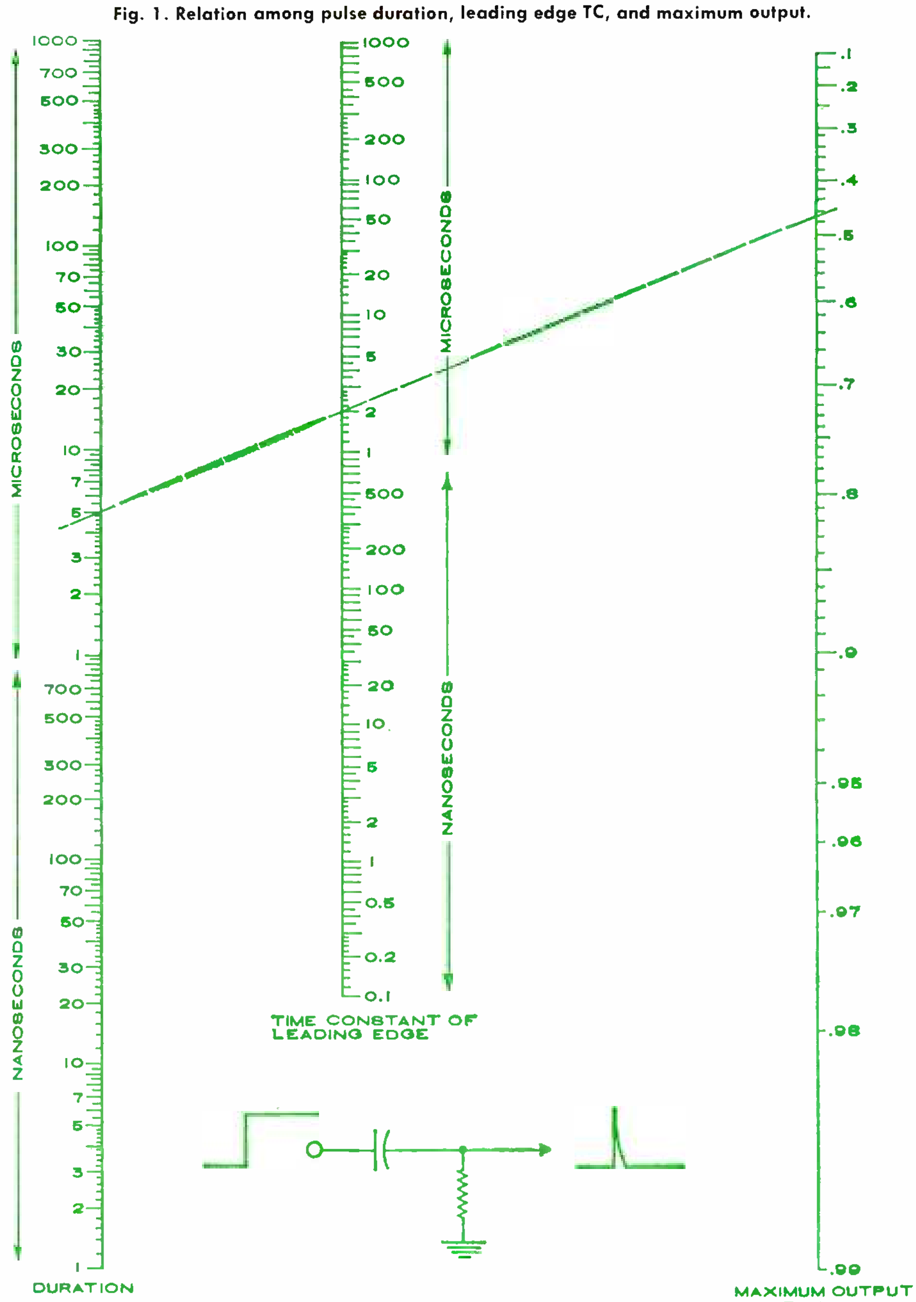
Therefore, one of the quantities which must be known in order to design an *RC* differentiator for a critical application is the *time constant of the leading edge*. This value is obtained by noting, on a fast oscilloscope, the time it takes the step to reach 63.2% of maximum.

Using the Nomograms

The first nomogram (Fig. 1) gives the relation among input leading edge, output duration, and output amplitude. In most applications, the leading-edge time constant has been made as short as possible and therefore is a fixed parameter of the problem. A typical objective is to design a differentiator that will give a pulse output of less than some given duration. A straight-edge laid across the scales of Fig. 1 will show what amplitude output can be expected, based on the two constraints of leading-edge time constant and maximum allowable output width. Output duration is defined as the pulse width at 50% of its maximum amplitude.

The output amplitude is shown on the third scale for a step input of one volt.

Fig. 1. Relation among pulse duration, leading edge TC, and maximum output.



The numbers shown can be converted to volts output by multiplying by the actual voltage of the step input.

It would be worthwhile for the reader to experiment with a few sets of numbers on Fig. 1 to establish some rules of thumb as to what conditions are physically realizable. For instance, it will be seen that if the output pulse is to have an amplitude which is nearly as large as the input step, the output width will have to be many times greater than the leading-edge time constant. If the output width is ten times the leading-edge time constant, the output amplitude will be three-fourths of the step's amplitude. Conversely, if a sharp, narrow spike is desired, it will have to be obtained at a sacrifice of amplitude. If the output pulse is no wider, at its 50 percent point, than the leading-edge time constant, the output at its peak will be less than 10 percent of the step's amplitude.

These observations are made relative to the leading-edge time constant because in most applications that quantity will have been made as small as practicable and is a factor inherent to the situation rather than a variable. However, if the designer does have control over this factor, he can place a straight-edge on the desired values of output duration and output amplitude and the straight-edge will cross the middle scale at the value of leading-edge time constant which will result in the given output conditions. A situation in which the leading-edge time constant can be controlled is most likely to arise when the output pulse must have a given minimum width in order to contain enough energy in order to trigger the following stage.

The second nomogram (Fig. 2) is used to determine values of resistance and capacitance that will result in the conditions established by Fig. 1. The value which was found on the last scale of Fig. 1 is now located on the first scale of Fig. 2, and the leading-edge time constant is located on the second scale. A point on the Turning Scale is established by drawing a line through the values located on the first two scales. About that point on the Turning Scale a straight-edge can be rotated and then every combination of capacitor and resistor values it connects will give the desired results in any particular situation.

On each of the nomograms there is a pair of scales that can be extended to include values outside the range of those shown. In Fig. 1 the first two scales are both in units of time and can be extended by moving the decimal point the same number of places *simultaneously on both scales.* Perhaps a more convenient way of viewing it is to say that the prefixes on *both* scales can be changed to others, such as milliseconds for the bottom halves of the scales while seconds are used for the top halves.

In Fig. 2, the Capacitor and Resistor scales can be extended by moving their decimal points any number of places simultaneously, on *both* scales, but in *opposite* directions. For instance, if all numbers on the Resistor scale are multiplied by ten, making the largest resistor 1 megohm, all numbers on the Capacitor scale must then be divided by a factor of ten.

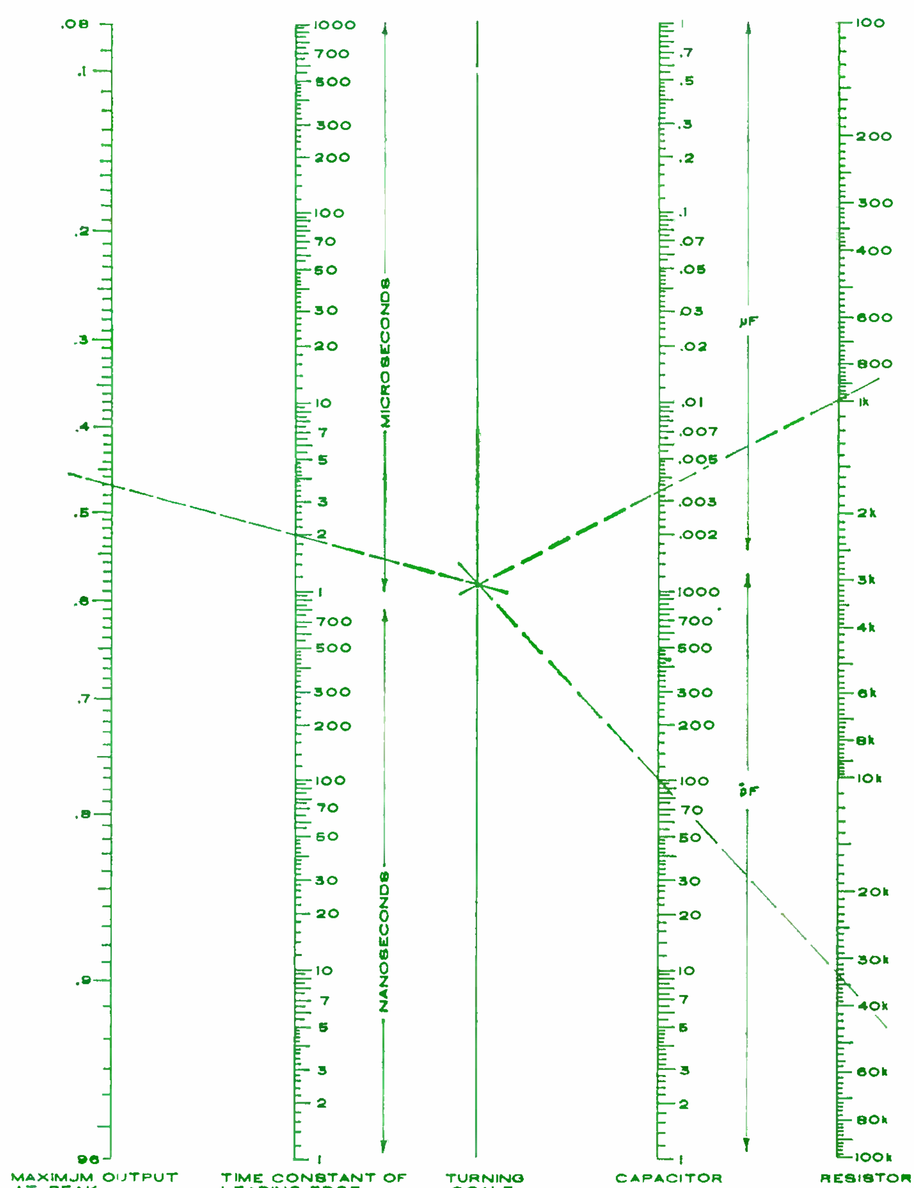
Example

A step of 10 volts is carefully measured with a fast oscilloscope and it is found that the step's leading edge reaches 63.2% of its maximum level (6.32 volts) in 2 microseconds. Design an *RC* differentiator that will accept this step and produce a pulse 5 microseconds wide.

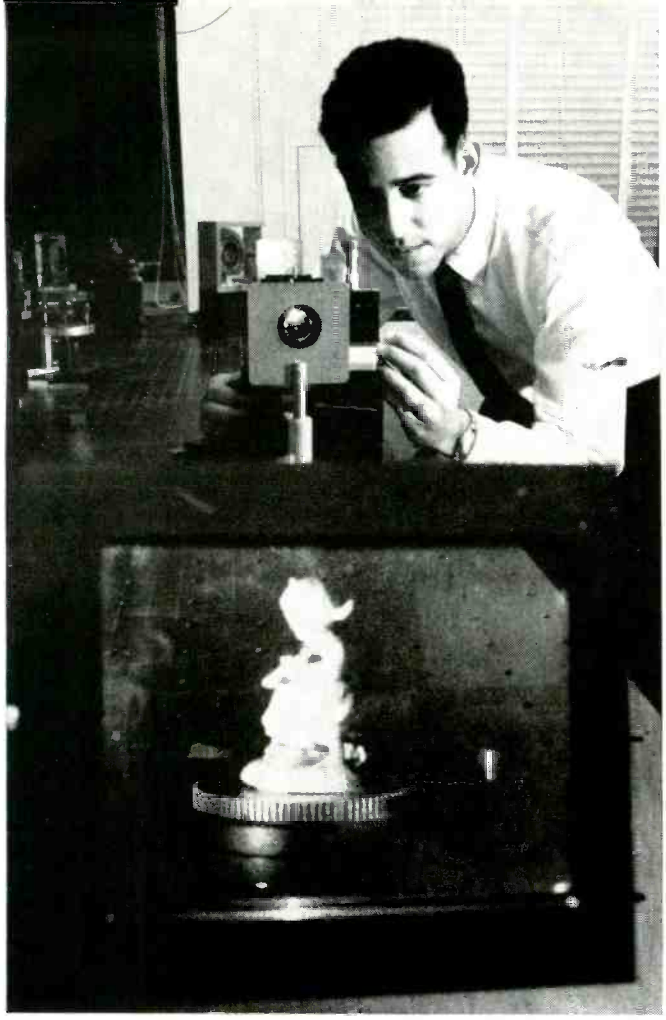
On Fig. 1, locate 5 microseconds on the Duration scale and 2 microseconds on the Time Constant of Leading Edge scale. Draw a straight line through those two points and continue the line to the last scale where it will cross at 0.47, indicating that for every volt of the input step, the output pulse will peak at 0.47 volt. Since the input in this example is 10 volts, the output will peak at 4.7 volts.

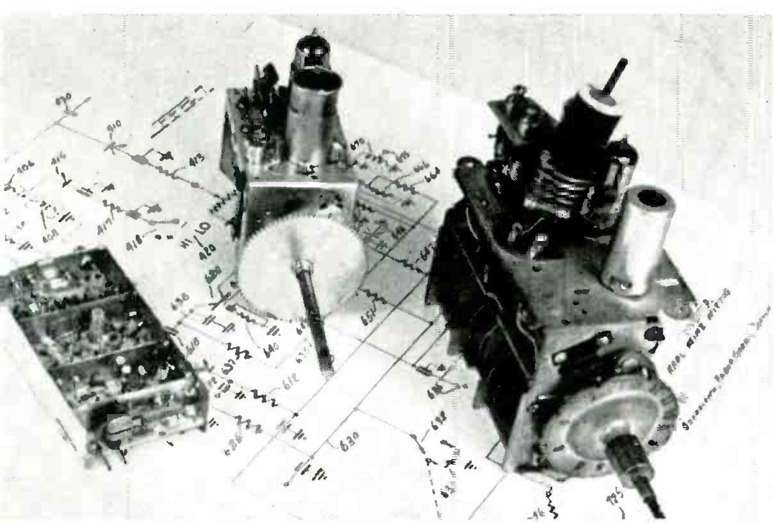
Transfer the output of 0.47 to the first scale of Fig. 2 and again locate the leading-edge time constant of 2 microseconds on the second scale. Draw a line through those two points and note where that line crosses the Turning Scale. Values of resistance and capacitance are then selected by rotating the straight-edge about that point on the Turning Scale and picking a pair of values which is convenient to use. Dashed lines on Fig. 2 show that 0.0033 microfarad and 1 kilohm, or 100 picofarads and 33 kilohms are two of the combinations that meet the requirements of the problem. ▲

Fig. 2. Nomogram used to find proper combination of resistor-capacitor values.



RECENT DEVELOPMENTS IN ELECTRONICS

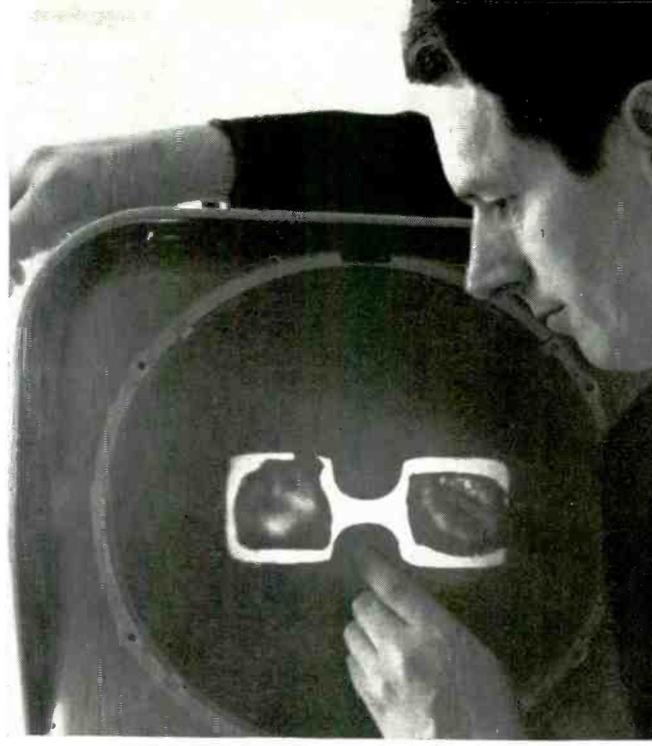


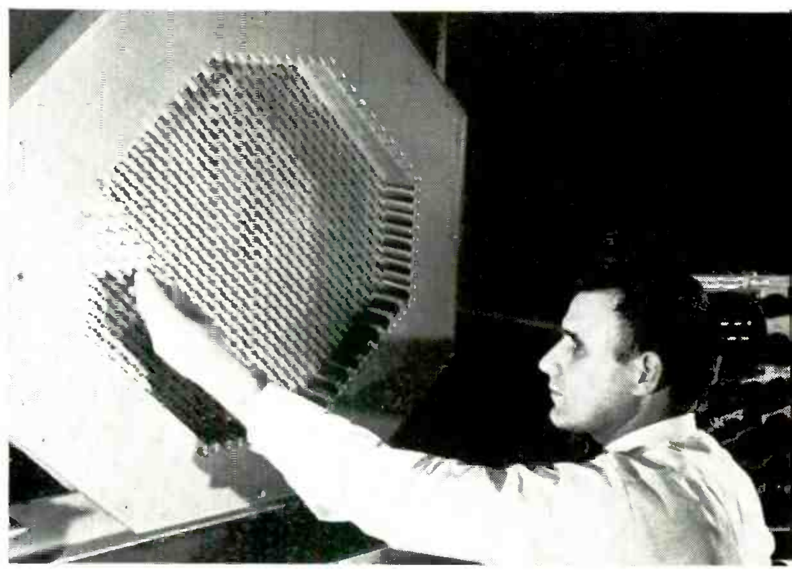


Laser Hologram Produces 360° Image. (Top left) A new kind of hologram has been demonstrated which allows viewer to see a three-dimensional image rotate through a full circle simply by moving his head from side to side. Conventional laser holograms present a 3-D image of only a limited angular view of an object. The new hologram is a composite of many narrow holograms, each showing a 3-D image of a different view of the subject. Future physics or biology texts could use the display to show complete in-the-round views of complex molecules and organisms, or art books could show sculpture more effectively. The holograms can be viewed with a monochromatic filter and a strong white light source. To make a flat hologram with a 360° view, vertical strips of a photographic plate are exposed sequentially from left to right through a mask with a narrow slit. Each narrow strip is a complete hologram of one view of the object. After the first view at the extreme left of the plate, the object is rotated slightly, the mask is moved by one slit width, and another exposure is taken. Eventually the entire plate has been exposed and the object has been rotated through 360°. Technique was developed at Bell Labs.

Varactor-Diode TV Tuner. (Center) The compact, flat unit at the extreme left is a completely solid-state TV tuner that uses varactor diodes to replace the 157 electromechanical switch contacts normally used to change channels. It is about 70 percent smaller than the electron-tube tuner at the center, the type most commonly used in present TV sets. The tube type must be mounted directly behind the channel-selector knob, while the new varactor tuner can be mounted anywhere on the TV chassis. At the right is a ganged capacitor tuner commonly used by set makers about 15 years ago. A v.h.f. version of the new tuner has already been demonstrated by the developer, Standard Kollsman, to major TV set manufacturers. In the works is a prototype of a v.h.f./u.h.f. version. The varactor diodes exhibit varying amounts of capacitance, depending on the amount of d.c. voltage applied. This capacitance tunes the r.f. amplifier, mixer, and oscillator circuits to resonance. Other diodes, when forward-biased, short out parts of the tank coils for channel switching. The only mechanical switches that are used in the system control the d.c. voltages and not signal.

Thermistors Check Hot Tires. (Below left) Tire blowouts at high speeds are dangerous. In an effort to investigate some of the causes of tire failure, the National Bureau of Standards is using thermistors to measure tire temperatures at road speeds. Heat is the enemy of rubber and fabric, and by knowing just how much heat is produced in normal driving it should be possible to improve tire durability and reliability. The thermistor, protected by epoxy encapsulation and coated with silicone rubber, is inserted into a tiny hole drilled in the tire shoulder. Output is connected to a matchbox-sized telemetering transmitter on the circular plate replacing the hub cap. The vertical antenna shown picks up the FM signal produced and applies it to a receiver and to a recorder located in the car.





Computer Teaches School. (Top left) These students at PS 244 in Brooklyn are receiving individualized daily instruction in elementary arithmetic from a computer located miles away in a Manhattan skyscraper. A total of 200 student terminals in 15 widely separated New York City schools are connected to the central computer, providing individual instruction to 6000 pupils every day. After school, the computer is used in various remedial and adult education programs, as well as for handling administrative data processing jobs for the school system. In the fall of this year, elementary reading and spelling will be available to pupils from the RCA Spectra 70 computer system.

Simple Electroluminescent Laser. (Top right) Still a lab curiosity, this new gallium arsenide laser, shown in the photo magnified 150 times, produces infrared light from the connecting bridge between the ends when an electric pulse is applied to it. The new device is the first of its kind to operate without built-in electric fields or junctions. The relatively large end pieces have indium alloyed contacts capable of handling the high electric current required to produce lasing action. A high-voltage pulse, applied across the dumbbell ends, produces a large number of fast-moving domains of high electric fields in the center bridge. (This is called the Gunn effect.) Electrons are freed from atoms in the high-field domains, and start the lasing action when they recombine with these atoms after the field has passed. RCA Laboratories has produced the device.

IC Radar Modules Eliminate Rotating Antennas. (Center) Each of the 604 modules in the radar antenna shown contains a microwave integrated-circuit radar transmitter and receiver within a $1\frac{1}{2}$-cu in package topped by a tiny antenna. Electronic scanning of the 604 modules provides the same kind of sweeping vision delivered by present rotating-antenna radar systems, without the failure-prone motors and mechanical equipment that cause more than half of all radar system breakdowns. The new radar is being developed for the U. S. Air Force by TI.

Philippine Earth Station for Intelsat. (Below right) This 97-ft dish antenna, just being completed, will serve as the Philippine ground station for the Intelsat II satellite. It will handle voice, television, and data communications to and from the satellite which is now in synchronous orbit 22,300 miles over the Pacific Ocean. The ground station is located about 25 miles east of Manila. The station complex is being constructed under a contract awarded to GT&E International, Inc.

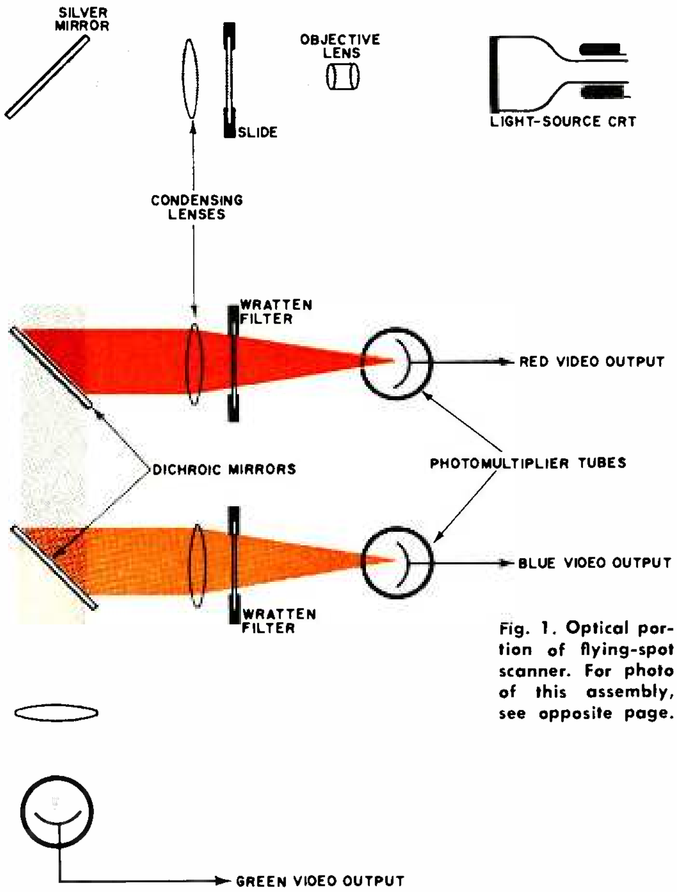


Fig. 1. Optical portion of flying-spot scanner. For photo of this assembly, see opposite page.

COLOR TV Set Shows Slides

By JOSEPH V. DeMARINIS
Manager, TV Engineering
Sylvania Entertainment Products

A new home-entertainment center combines flying-spot scanner with a color receiver to permit color slides to be displayed on the picture tube. Built-in cassette audio tape recorder synchronizes slides with recorded commentary.

HERE is a new home-entertainment center that combines a color-TV receiver and flying-spot scanner in order to let you view your color slides just as conveniently as you watch color-TV. The center, which includes a cassette tape recorder for synchronizing sound with the slides, will be sold by *Sylvania* for about $1000. The units (which are referred to as "Color Slide Theaters") are expected to be available at the company's dealers by the time this publication appears.

A single push-pull switch changes over from color-TV to slide viewing. Slides are changed forward or reverse with a conventional projector remote cable. The slide-changing mechanism is the well-known *Kodak* Carousel. Loaded slide trays are interchangeable with any other similar projector. Up to 80 2" x 2" 35-mm or #126 slides can be accommodated in a single tray.

The entertainment center includes a cassette cartridge tape recorder/playback unit. You can record a complete slide show with your own narration. By putting practically inaudible, 60-Hz pulses on the tape, you can do away with the need to change slides with the remote cable; the pulses will do it for you automatically. Depending on the particular cassette used, as much as 2 hours of recording can be made.

This same unit can be used to play prerecorded cassette tape cartridges along with your slides or with the TV portion turned off.

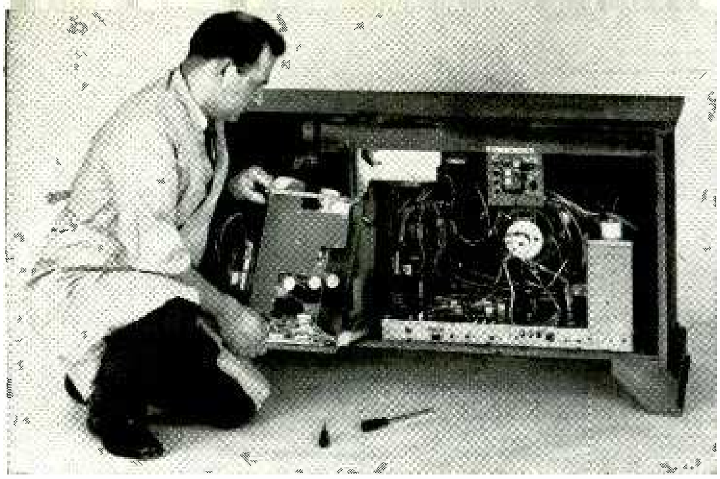
In the flying-spot scanner, the light source is a small (5-inch) cathode-ray tube with a blank raster. This raster is focused on the slide to be shown. Thus, the slide is scanned with a moving spot of light. Beyond this point, the optical system merely gathers light and breaks it down into the three color-TV primaries; red, blue, and green (Fig. 1). Photomultiplier tubes pick up these optical color outputs and convert them into video signals. From there on, we have video amplifiers, *gamma* correction, and a matrix.

The output of the scanner chassis is fed into the color-TV set as *Y* or black-and-white video and into the color-difference amplifiers as *X* and *Z* axis color, the same as is generated by the receiver's own color demodulators (Fig. 2).

The light-source CRT "borrows" its deflection and high voltage from the color picture tube. It operates at 25 kV with a beam current of about 70 microamperes (the color pix tube requires about 1000 μA). Focus voltage is about 4.5 kV, obtained from a supply similar to, but independent of, the color picture tube.

A feedback system in the scanner chassis adjusts the beam current of the light-source CRT to compensate for the average transparency of the slide being shown: producing more light for an underexposed slide and less light for an overexposed slide. This is a feature not available with optical projectors and improves the quality of many slides.

The requirements for the small CRT are stringent. Besides the obvious need for good focus and a small spot,



Rear of the new entertainment center. The color-TV set is at the right, while the flying-spot scanner chassis is being installed at the left. Above the scanner and under a hinged cover will be found the slide changer and tape recorder.

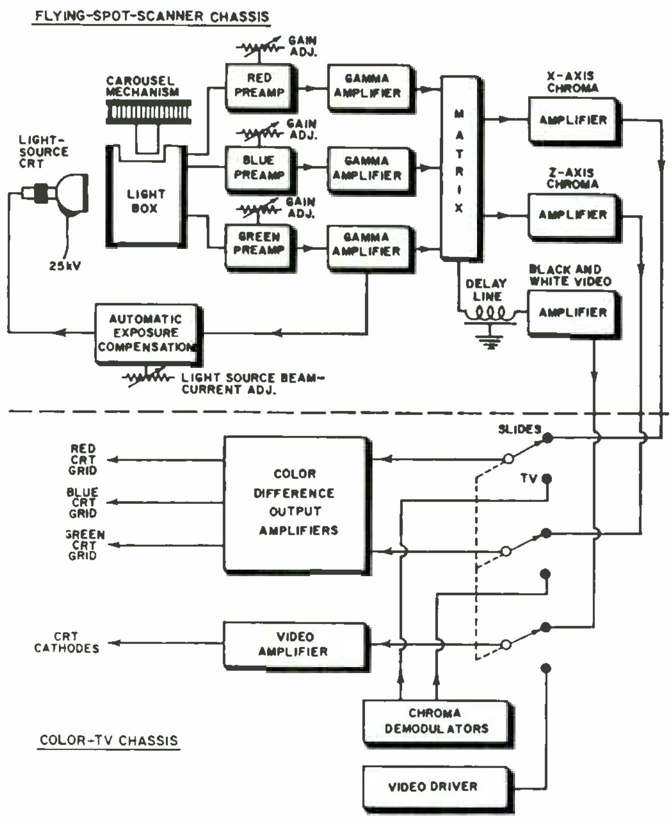


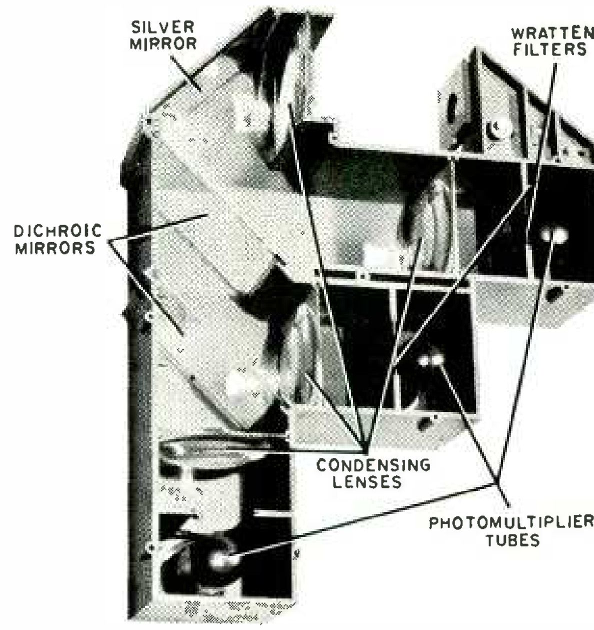
Fig. 2. Interconnections between scanner and TV section.

screen defects must be negligible. But, most important to the resolution of the system is a very short decay time of the phosphor light output. The moving spot must not leave a trail, or smeared pictures will result. This requirement is directly opposite to that of the tube which displays the picture. There, you want a longer decay time to reduce flicker and improve light output.

So, the phosphors used in this light-source CRT are very special. The tube was developed especially for this application by *Sylvania*.

The flying-spot scanner principle is as old as TV itself. Back in the early days of color, some TV studios used such scanners to show film. These scanners were very large, and cost about as much as a small house! The significant accomplishment here is the application of known principles to the development of a unit with the simplicity and price level of a consumer product.

The objective lens which focuses the raster on to the slide is 50 mm at $f/3.5$. This provides a sufficient depth of field to accommodate all cardboard-mounted slides, even



Optical portion of the flying-spot scanner (called the "light box") is shown here with its cover removed.

if they are warped or put in backward. Thus, the user needs no focus adjustment.

The cold light from the CRT will not bleach slides or cause them to "pop". And, the CRT will last much longer than a projection lamp.

The optical system is contained in a dust-sealed plastic box. The system includes four light-gathering lenses and two dichroic mirrors. These mirrors are made up of several molecular thin coatings, and selectively reflect or pass the various colors of light. One dichroic mirror reflects red light only, allowing the blue and green light to pass through. The other dichroic mirror reflects blue light only, allowing the green to pass through. Wratten-type filters adjacent to the red and blue photomultiplier tubes further purify the light presented to each of the electronic channels.

The optical parts simply drop into accurately located slots. There are no adjustments in the color-splitting "light-box."

Once converted to video by the photomultipier tubes, the signals are applied to solid-state circuitry which amplifies and *gamma*-corrects the picture. In such correction, we "stretch" the black region and compress the white region to correct for a tendency on the part of the color picture tube to compress the gray scale. This circuit is part of any color-TV camera. The d.c. component of the picture is preserved and/or restored throughout the system.

Connections to the Receiver

Most color-TV receivers are based on the color-difference system. *Y* or black-and-white information is presented to all three of the CRT cathodes and the color-difference information is presented to the CRT grids. Since the flying-spot scanner inherently generates primary red, green, and blue information, some conversion is necessary to be compatible with the normal color-TV circuitry. This conversion takes place in a matrix, which is a complex voltage divider, the derivation of which can be found in any comprehensive textbook on color-TV. Following the matrix, the *Y*, *X*, and *Z* signals are amplified for application to the color-TV output stages, as shown in the block diagram.

When showing slides, sync for the "borrowed" scan is provided by a local TV station, thus producing an interlaced picture.

The "B+" voltage that is required for the video circuits that are employed are derived from the TV power transformer. A separate power supply is provided for the audio circuitry so that the unit may (*Continued on page* 72)

TECHNICIAN ENGINEERING IN BRITAIN

By E. A. BROMFIELD/ Sec'y, The Institution of Electrical and Electronics Technician Engineers

The importance of the non-degreed engineer is being recognized. A new organization, which already boasts almost 10,000 members, is setting up qualifications and giving status to this member of the engineering team.

FOR many years there has been an acute awareness within Britain's electrical and electronics industries that something should be done to positively identify, by appropriate designation and status, that wide band of engineering personnel which provides the bridge between professionally qualified degreed engineers and craftsmen.

The first positive action came with the publication in 1954 of a definition for the engineering technician by the Conference of Engineering Societies of Western Europe and the United States (EUSEC), and a subsequent report, "The Education and Training of Electrical Technician Engineers" by the Institution of Electrical Engineers. Chairman of the Committee producing this Report was Sir Willis Jackson, F.R.S. (now Lord Jackson of Burnley). Lord Jackson, speaking on technician engineering matters at the World Congress on Engineering Education in Chicago in June 1965, said that the EUSEC definition emphasized the dependence of the engineer upon the technician. He also said that it was consequently "useless to expand the provisions for degreed engineers without at the same time expanding the provisions for the army of technicians whose services will be called into being".

At this same conference United States comment on engineering technicians was forthcoming from W. W. Wiggins, Deputy Director, Peace Corps, Washington, D.C. He said that there was a lack of what had come to be called "middle level manpower". Despite wide publicity given to the demand for technicians, the U.S. had experienced only a limited response to invitations to young men to become technicians and, Mr. Wiggins said, he wondered whether this response was due to lack of a suitable education.

Accent on Status

Since 1965, however, a great deal has happened in Britain. Events have tended to indicate that lack of status rather than suitable education might well have been the "stumbling block" all along.

In the United Kingdom, "professional" engineers of fourteen separate or allied disciplines are now joined together within the Council of Engineering Institutions, and are entitled to use the protected description "Chartered Engineer". Chartered Engineers of the future will all be *degreed engineers.* The former route to membership in "professional" institutions by part-time study is rapidly closing, and soon will be impassable.

In view of this it has become necessary to provide a separate identity and status for those other senior engineers who, although not holding a degree, are nonetheless equally entitled, because of their qualifications, industrial training, and experience, to the description "engineer". These are needed in the ratio of some four to every one chartered engineer. To a large number of these men the designation "technician" is unacceptable, mainly for the reason that, in Britain at any rate, it is as indiscriminately applied as the generic term "engineer". Now, the growing acceptance of the title "Technician Engineer"—from the Continental concept of the *Ingénier Technicien*—by Government departments, educational establishments, industry, and the press—shows that this provides the long-sought-after compromise.

Role of Technician Engineers

In the United Kingdom today, the work of the technician engineer is clearly seen to complement that of the chartered engineer. The technician engineer has become a responsible engineer in his own right, with a status and career of his own.

Technician engineers are expert in the application of specific engineering techniques in all sectors of industry; in manufacture, operation, maintenance, development, and research. Technician engineers carry out a wide variety of technical, technical-commercial, and administrative activities within the electrical and electronic engineering industries, and they are also engaged in those other industries using electrical communications, power, and control.

Below the technician engineer there is the grade of *technician,* tending to require similar technical skills in a narrower field and to a generally lesser degree of abstraction, and to have less need for administrative ability. Then there is the grade of *service technician,* who is an individual trained in a particular technique.

Advent of IEETE and SERT

The marked need for a learned society/qualifying body for the well-trained and experienced non-university type of engineer led to the setting up, in February 1965, of The Institution of Electrical and Electronics Technician Engineers. Aided by the full encouragement of industry and the firm support of The Institution of Electrical Engineers, the IEETE already has gained nearly 10,000 members: the potential is estimated at anything between 80,000 and 100,000.

Status and qualifications apart, the purpose of IEETE is to make available to technician engineers all the advantages of a first-class learned society, and provide technical facilities and services of the "down-to-earth" kind. The Institution promotes conferences, discussion meetings, and lectures and arranges visits to places of technical interest. Programs of lectures are running in London and throughout the nine regions in which centers have been set up thus far.

As the opening lecturer in the (*Continued on page* 84)

The author directs the generation of IC applications information and customer applications assistance. He has had eleven years of solid-state design experience including specifications, design, and analysis of LIC and DIC devices for use in advanced molecular radar systems at Westinghouse Aerospace Division. He has been an applications engineer with another major IC manufacturer. He holds a BSEE degree from Milwaukee School of Engineering and has published several technical papers. He is a member of the IEEE and currently has a patent pending.

The Linear IC— Types, Technology, Techniques

By KEN BLAIR/Supervisory Engineer, IC Applications
Molecular Electronics Div., Westinghouse Electric Corp.

Present LIC's match and even exceed performance of discrete circuits. This, along with a price drop, is spurring their use in all types of electronic equipment. What are the various types available? How do they compare? What are their most important characteristics? And what do they offer new-equipment designers?

LINEAR integrated circuits are here to stay. A few years ago many designers would have disagreed vehemently with this statement. The concept of electronic subsystems built with anything other than a token number of LIC devices was considered impractical in view of both technological and economical shortcomings. At that time the LIC had performance characteristics considerably below and costs considerably above conventional discrete component designs. Moreover, the fast pace set in the initial advance of digital integrated circuit technology was not matched in linear development.

Since those "prehistoric" times the performance and cost differentials between the LIC and discrete designs have narrowed rapidly. In many design areas present LIC devices match and even exceed the performance characteristics of discrete devices. The rapid drop in price has also kept them competitive with their discrete counterparts. These recent advances can be taken by designers as a barometer of things to come in LIC devices. Operating characteristics will advance and prices will continue to fall so that the circuit designer will be under increasing pressure to become familiar with LIC devices. Ultimately, if not now, he will be required to defend his discrete component design against the benefits offered by LIC devices.

Definition & Types

The term "integrated circuit" is used to describe a group of electronic elements connected together by a variety of circuit assembly techniques to perform a given electronic function. *(The IEEE Standard definition of an integrated circuit is "a combination of interconnected circuit elements inseparably associated on or within a continuous substrate."—Editor)* A linear integrated circuit is this group of components assembled to operate in a linear mode to perform signal amplification, processing, timing, and control. There is, at best, only a fine line of distinction between the LIC and the digital IC in some specialized areas.

There are two basic processing techniques used in the fabrication of LIC devices. The semiconductor technique, which is an extension of transistor technology, diffuses impurities into a block of silicon to form active and passive elements. The film technique deposits material on a common substrate to form passive components. Such films range in thickness from a few angstroms to 1 mil. Currently both of these techniques are used to make LIC devices.

In the monolithic LIC all circuit elements, both active and passive, are selectively diffused into a single-crystal block of silicon. The individual parts of the monolithic LIC are not separable from the complete circuit and are simultaneously interconnected by the deposition of metallic conducting paths on the surface of the monolithic block.

The hybrid LIC is a device in which separate component parts are mounted on a common substrate and interconnected by means of metalization or wire bonds. The hybrid LIC can resemble the conventional discrete component circuit except that the individual parts consist of passivated, diffused, or film components and the complete circuit is highly miniaturized. A hybrid device may contain one or more monolithic devices. *(A complete article on hybrid IC's appears further on in this Special Section.—Editor)*

One distinct advantage of the monolithic LIC is that a large number of individual circuits can be processed on one large wafer of silicon and thus is ideal for large volume production. The labor and material costs are kept at a lower level than with other techniques, provided the devices are produced in sufficient quantities at reasonable yields. Other advantages of the monolithic device are seen in terms of improved matching and temperature tracking of characteristics and better reliability. The matching and temperature characteristics are benefits of the close proximity of device elements and the fact that they are subjected to identical diffusion profiles.

Life is not completely rosy for the present-day mono-

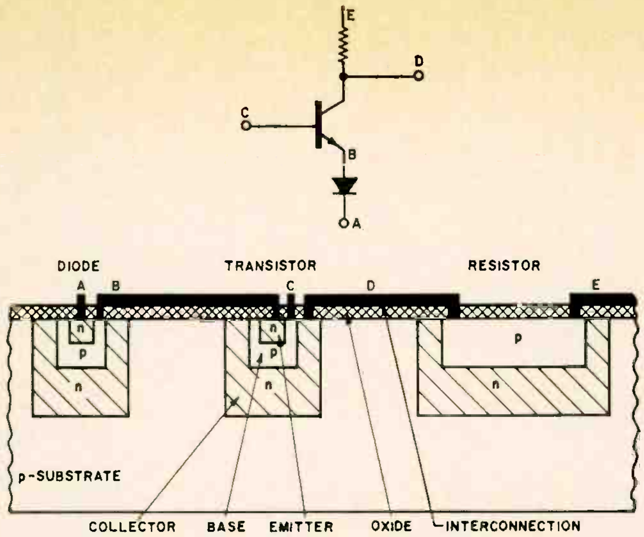


Fig. 1. Cross-section display of portion of typical monolithic LIC containing base-emitter diode, n-p-n transistor, resistor.

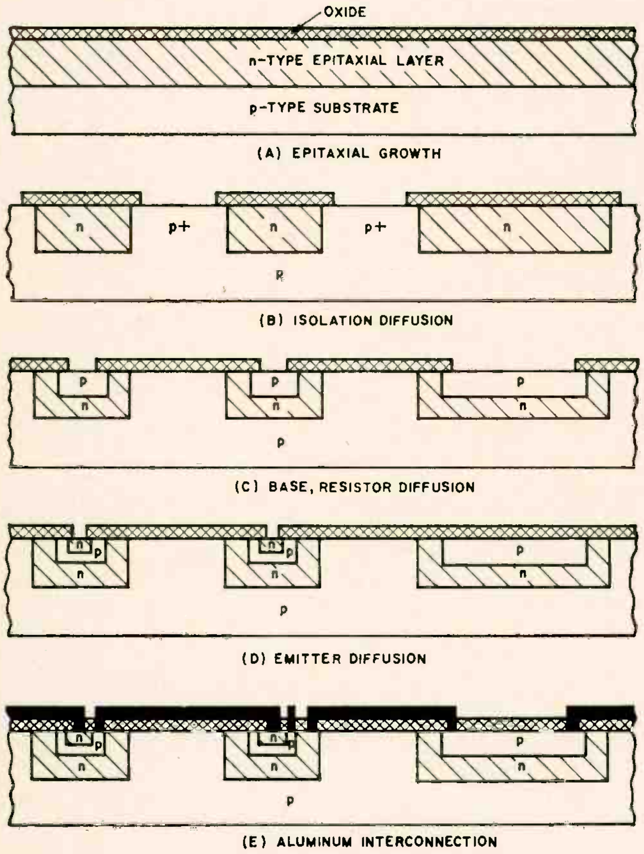


Fig. 2. Processing steps used to fabricate Fig. 1 circuit.

lithic LIC. There are still several disadvantages of concern to the designer. Because of parasitic capacitances and design compromises, the gain-bandwidth product is lower than with discrete circuits. High-voltage capability is lacking and resistor tolerances are often wider than designers would like. In some instances it is necessary to complement the monolithic LIC with discrete devices to achieve higher power and voltage capability. Resistor tolerances are minimized through use of negative feedback to place device dependence upon the excellent resistance ratios obtainable in monolithic LIC devices.

The simultaneous processing and identical environmental conditions of all elements within the monolithic structure and the greatly reduced number of interconnections all contribute to improved reliability over discrete designs. The figure generally quoted these days is 0.01%/1000 hours.

The growth figures for LIC devices for 1966 and 1967 have been somewhat overwhelming to say the least. A variety of device types coupled with a dramatic drop of about 50% in LIC prices have spurred the sale of LIC devices. The largest market is still military which is estimated at $27 million. The industrial and consumer LIC markets, which only recently have begun to rise because of competitive prices of LIC devices with respect to discretes, are estimated at $16 million and $3 million, respectively. This adds up to a total market of about $46 million in factory sales. *(This compares to a total market in 1967 of about $182 million for digital IC's—Editor)* It is estimated that the total market for LIC's in 1968 will be around $72 million.

The Processing Technology

A monolithic LIC usually contains both active and passive elements formed within a single chip of silicon and interconnected on the surface of the chip. The fabrication of monolithic devices is thus dependent upon the ability to selectively define and produce active and passive regions in the chip. A cross-sectional view of a portion of a typical monolithic chip and the circuit it represents are shown in Fig. 1. This illustration shows the common four-layer epitaxial structure in use and how the elements are electrically isolated with reverse-biased junctions.

The basic processing steps for producing the four-layer epitaxial LIC structure are illustrated sequentially in Fig. 2. The process combines a number of photoresist and diffusion steps in conjunction with the characteristic property of silicon oxide to resist diffusion. There are essentially two variables to be controlled in the diffusion operation. Accurate control of junction depth and impurity levels deposited permit production of devices with good yields and predictable characteristics.

The processing of the LIC begins with the growth of an *n*-type epitaxial layer on top of a *p*-type substrate (A). In this technique all elements are formed in the epitaxial layer. During growth of the epitaxial layer a protective layer of silicon oxide is formed on top of the device. This oxide is essentially impervious to the diffusion of impurities. By selectively opening windows in the oxide, impurities can be introduced to selected areas of the chip to form essential parts of the circuit. After opening up windows in the oxide, the next step is the formation of isolated islands in the *n*-type region. This is done by diffusing a heavy concentration of *p*-type impurities through the epitaxial layer until the *p*-type substrate is encountered (B). The illustrations indicate that the diffusion takes place in a vertical direction only. Actually the diffusion also progresses laterally so that the edges of any *p-n* junctions lie under the oxide. This prevents contamination of the sensitive junction and ultimate deterioration of device characteristics. In this manner, device stability and reliability are enhanced.

Another oxide layer is now grown and windows opened to permit formation of the transistor base and the resistor with a *p*-type diffusion (C). Note that the resistor is made up of the resistance of the *p*-type diffused region. The next step is the removal of a portion of the regrown oxide to permit the *n*-type emitter region to be formed (D). A final oxide layer is then opened up to allow interconnections to be made between elements. A deposition of aluminum (E) to form the interconnection pattern completes the basic device fabrication. A typical monolithic LIC chip is shown mounted in a TO-5 package in Fig. 3.

Transistors & Diodes

Because of the relatively small size of active devices (transistors and diodes) on the monolithic LIC chip, it is more economical to fabricate active elements than passive. This is in direct opposition to the economics of discrete-component design. In the LIC device, resistors and capacitors require large amount of chip area, and area on a chip is quite expensive. The smaller the chip the better the yield and the lower the cost. This is one reason why transistors and diodes are used so extensively in LIC devices.

The monolithic transistor requires fewer design compromises during processing than any other elements in the LIC. This is reasonable because the process used to produce the monolithic transistor was developed for discrete devices. A major reason for using a large number of active devices in the LIC is that the matching of element characteristics is excellent. The devices are in close proximity and tend to have identical diffusion profiles, hence, are more readily matched than discrete devices. The elements also have matched temperature coefficients. Much less total circuit resistance and generally no coupling capacitors are required when using the matched characteristics to establish operating levels.

Table 1 lists the degree of matching that can be expected in monolithic active devices. For the most part, monolithic diodes are simply transistors where connections are made to base-emitter or collector-base diodes. Thus, they also exhibit identical characteristics to those of the transistor junctions. Discrete transistors and diodes would both require extensive hand selection to obtain identical matched characteristics.

There are also other important differences with monolithic transistors that tend to limit LIC characteristics. The monolithic transistor has higher collector series resistance. Contact to the collector must be made at the top of the structure since the substrate is of oppositely doped material than the collector. This increases the collector series resistance which, in turn, produces higher saturation voltages and second-order effects at higher frequencies. One technique used to reduce collector series resistance is to diffuse a low resistivity region in parallel with the collector series resistance.

A second difference between monolithic and discrete transistors is parasitic capacitance. In the monolithic device the substrate forms a *p-n* junction with the collector region. This junction is reverse-biased to isolate the transistor from other elements in the device. The capacitance of this junction can degrade performance at higher frequencies unless lower impedance levels are employed.

In 1964 *Westinghouse* introduced the lateral *p-n-p* transistor to LIC devices. Prior to that time *p-n-p* transistors required extra processing steps to achieve a device with good characteristics. The lateral *p-n-p*, illustrated in Fig. 4A, uses the *n*-type epitaxial region as the base and two *p*-type regions formed during the normal base-resistor diffusion as collector and emitter terminals. In this configuration lateral rather than vertical transistor action takes place. There are parasitic effects associated with this device that reduce the current gain to low values. Fig. 4B illustrates a technique used to improve the current gain without requiring extra process steps. This composite transistor has an effective current gain that is equal to the product of the individual current gains.

The MOSFET, which at one time exhibited great promise, is generally not seriously considered for present LIC devices. The MOSFET is basically a surface-operated device. Because of a high surface sensitivity, processing techniques must be held under rigid control. It takes very little to contaminate the oxide to alter MOSFET characteristics. Thus most MOSFET devices are presently relegated to use in digital IC circuits where only "on-off" characteristics are of concern. In this area, threshold instability is not a serious problem.

The junction FET is better suited for LIC processes but it also has its problems. It is difficult to combine the FET and bipolar devices without compromising some characteristics. The over-all characteristics of the two devices generally require different voltage and current levels. It is also more difficult to match the characteristics of FET devices as required in differential amplifiers.

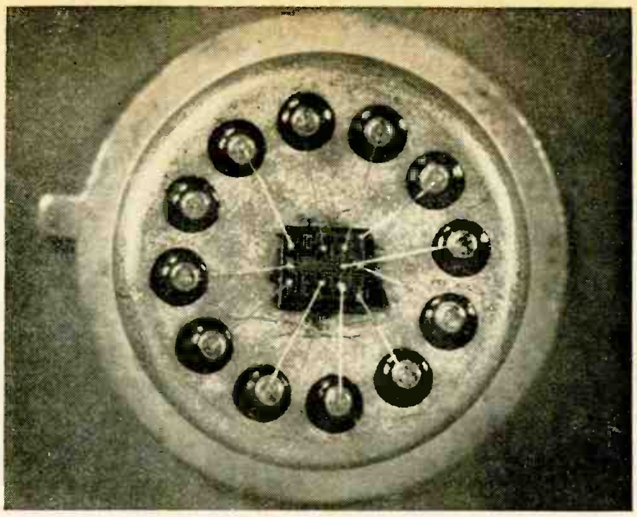


Fig. 3. A monolithic LIC amplifier chip in a 12-lead TO-5 package. Device contains 6 n-p-n transistors, 15 resistors totaling 316,000 ohms, and 2 50-pF metal-oxide capacitors.

Resistors, Capacitors & Inductors

The characteristics of passive elements in the monolithic LIC are much more limiting than those of the active elements. Monolithic resistors and capacitors have a narrow range of component values and temperature characteristics. Passive elements are also relatively large and often difficult to control to close tolerances. For these reasons use of passive components is held to a minimum where possible, or LIC designs are oriented to use matching characteristics rather than tolerances. Passive elements can often determine the ultimate cost of the LIC.

Monolithic resistors are generally formed during the *p*-type base diffusion step. The resistor characteristics, for the most part, are governed by required transistor characteristics since relatively few design compromises are possible with the transistor. Monolithic resistors are characterized in terms of sheet resistance with units of ohms per square. No matter how large or small the square involved, its resistance is determined by this characteristic. If, for example, the sheet resistance is 200 ohms per square (a typical value in LIC devices) a 1000-ohm resistor is fabricated by connecting five squares in series and making contact to the ends. It makes no great difference whether the squares are 0.5 mil or 2 mils on a side. Each square contains 200 ohms of resistance and a series of five is required to form a 1000-ohm resistor in the LIC.

Because of space economy consideration, it is not always possible to add squares in a straight line. Resistors often assume odd shapes to fit within an available area. The wider the resistor the longer it must be for a given value. This, then, is one significant limitation of monolithic resistors. The narrower a resistor is made, to reduce the ultimate length, the more difficult it becomes to maintain a given tolerance. From a percentage standpoint, variations in resistor widths due to chemical etching deviations are more severe with a narrow resistor. Sheet resistance is another variable to be considered.

It is reasonable to expect a 20% tolerance for a diffused resistor of 1-mil width and 10% tolerance for a 2-mil width. It is, therefore, preferable to design for maximum width where tolerances are critical. However, maximum widths will produce longer geometries. It is thus essential from a space-saving point that the widest possible tolerances be used. To permit large resistor tolerances without seriously degrading circuit performance requires ingenuity.

Characteristic	Symbol	Absolute Tolerance	Match of Elements in Close Proximity
Transistors			
Current gain	h_{FE}	±30%	±10%
Current gain TC	$\Delta h_{FE}/\Delta T$	0.5%/°C	0.05%/°C
Base-emitter voltage	V_{BE}	±5%	±2 mV
Base-emitter voltage TC	$\Delta V_{BE}/\Delta T$	−2mV/°C	±5μV/°C
Resistors			
Diffused resistor	R	±20%	±3%
Diffused resistor TC	$\Delta R/\Delta T$	0.2%/°C	0.01%/°C
Capacitors			
Diffused capacitor	C_J	±25%	±5%
Metal-oxide capacitor	C_{MOS}	±20%	±5%

Table 1. Tolerances of characteristics of monolithic elements.

The technique used is to design the LIC so that performance is governed by resistor ratios. The resistors on a given chip have identical characteristics and, while absolute tolerances approach 20%, the resistor ratios are better than 5%.

The importance of using resistor ratios in the design of LIC devices is paramount when taking temperature characteristics into account. The temperature coefficient of a 200-ohm-per-square monolithic resistor is typically 0.2%/°C. Fortunately, resistance ratio and tracking of temperature coefficients go hand in hand. If resistor ratios are used to establish operating levels, the levels will be stable over temperature because the temperature coefficients of the resistors are the same.

Two basic types of capacitors are available on the monolithic LIC. One is a junction capacitor. This type is formed by using a reverse-biased diode junction on the chip. The capacitance of this type is typically 0.2 pF/mil^2 of area and is highly voltage dependent.

A second type is the metal-oxide capacitor. This type uses the dielectric property of the protective layer of silicon oxide on the surface of the chip. One plate of the capacitor is formed by depositing aluminum on top of oxide during the interconnection process step. The other plate is the heavily doped *n*-type generally used for the emitter of the monolithic transistor. The capacitance of this capacitor is typically 0.4 pF/mil^2 of area. Although this type is very stable and voltage independent, large areas are needed to establish medium capacitance levels.

In many instances capacitors are designed out of LIC devices for this reason. This is also why the operational amplifier configuration is widely used in LIC devices. The input/output terminals normally operate at ground potential and the device does not require coupling capacitors.

It is possible to make inductors in LIC devices by depositing patterns of conductors in various geometric designs. The resultant characteristics render them all but useless, however. Considerable effort has been spent in this area but thus far the "*Q*" of such inductive type elements is extremely low.

Amplifier Circuits Available

Differential/Operational Amplifier: Probably the closest thing to a standard LIC device is the differential/operational amplifier. The versatility of these devices is practically unlimited. They can be used in linear modes as d.c., video and sense amplifiers, buffers, low-level detectors, tuned amplifiers, integrators, and summing amplifiers. Nonlinear operation includes use as comparators, astable multivibrators, and precision monostable devices. In many instances the differential-amplifier configuration is used as a basic building block in the design of power amplifiers, high-frequency amplifiers, and voltage regulators. *(For a complete discussion of this type of circuit refer to the article on operational amplifiers in this Special Section.—Editor)*

R.f./I.f. Amplifiers: The high-frequency capability of LIC devices has improved a great deal. A few years ago hybrid construction was needed to reach the higher frequencies. There are several reasons why monolithic devices are now capable of operation into the 250-MHz region. Better processing techniques have evolved. Resolution of geometries on the chip have improved considerably. Better resolution permits reduction of device geometry. Reduced dimensions result in smaller collector-base and collector-substrate capacitance and improved cut-off frequencies. Improvements in this area permit higher impedance levels to be used and reduce device power dissipation. A process called dielectric isolation is also beginning to help extend high-frequency capabilities. This technique uses oxide isolation between elements on the chip rather than the reverse-biased junction. In this technique the parasitic capacitance is very low and often the breakdown voltage of the LIC is improved.

Often the circuit designer will recognize the differential amplifier configuration or perhaps a modification of it in r.f./i.f. LIC devices. The basic configuration is well suited to high-frequency operations and with slight modification becomes a common-emitter/common-base amplifier exhibiting good frequency response. The basic configuration is also suitable for a.g.c. control. *(Further details on r.f. and i.f. LIC's are given in another article in this Special Section.—Editor)*

Power/Audio Amplifiers: The power-handling capabilities of monolithic LIC devices are also showing marked improvement. Power limitations are governed by the efficiency of the heat removal from the device. Properly applied heatsinks permit operation at higher dissipations. A reduction in the thermal resistance between the junctions and case of the LIC will improve power transfer. One technique is to provide a package with a built-in heatsink. The monolithic chip is placed on a metal pad in the package. The pad extends out the ends of the package and provides a low thermal resistance to ground. Another technique to improve power-handling capability is to use class-B operation in the output stages of the device. In this manner quiescent power is held at low levels until an input signal is applied. In this configuration power output can be increased without raising dissipations. High-efficiency operation is also achieved.

In power devices the differential amplifier configuration often reappears. Combining the low offset voltage of the monolithic differential amplifier in a feedback loop with a class-B output yields efficient designs. Feedback will zero the output and also reduce crossover distortion to acceptable levels. *(For additional information on audio LIC's, see the article on this topic in this Special Section.—Editor)*

Going from Discrete to LIC

When contemplating the use of LIC devices for the first time, several questions immediately confront the engineer. What kinds of circuits are most adaptable to LIC design? How should the design proceed?

Present-day LIC's are still primarily small-signal, low-power devices. This was the area where the demand was the greatest, and it was only natural that this segment of the market was pursued. Included in this area would be the frequency spectrum from d.c. to 250 MHz, power levels up to 2 watts, and voltage and current levels up to 50 volts and 1 A, respectively. In these areas, virtually any circuit function that can be built with discrete components can be integrated. The LIC, however, may be radically different schematically from the discrete version.

The first step a designer should take when thinking about replacing discrete designs with LIC devices is to establish specifications and requirements. Failure to complete this step adequately holds the same penalties with LIC devices as with discretes: time and dollars are wasted. Then the available products can be reviewed to determine if present LIC devices are capable of meeting the requirement. The versatility of many commercial LIC devices, especially operational amplifiers, is so extensive that often an existing product can be used. There is always an abundance of literature available from the manufacturer and in technical magazines to make this a relatively simple task. Often LIC devices can be used with externally connected discrete components to perform the given function.

If the designer has determined that existing devices do not meet his requirements, there is still one alternative before going to a new and distinctive LIC design. Perhaps an existing LIC can be modified slightly or specified in a different manner so that the required function can be obtained. In most instances the price will be somewhat higher depending upon required masking, process changes, or yields, but certainly this method should be considered.

The next approach is consideration of a separate and distinct LIC design to the customer's specification. At this point the circuit designer should consult LIC manufacturers with respect to required specifications. To achieve optimum transfer of information the designer should work directly with the device designers. The circuit designer knows the characteristics required. The device designer knows the features and compromises required of the LIC.

It is often beneficial if a discrete version has been built to form a basis for discussion and to show feasibility. Often a discrete component breadboard alone is sufficient to determine adaptability to specifications. In areas where parasitics are of concern, a breadboard built with a device such as the *Westinghouse* Insta-Circuit is often invaluable. This circuit, shown in Fig. 5, contains enough transistors, diodes, zener diodes, and resistors, all with associated parasitics and limitations, to make a meaningful breadboard design. *(Other manufacturers also have array devices of this type available to the designer.—Editor)*

Important Specifications & Reliability

The specifications that the engineer should be concerned with are as many and as varied as there are designs. Naturally the important specifications are those relating to system design requirements. Maximum device ratings such as power, voltage, and current must be observed to insure reliable operation. Environment must be considered.

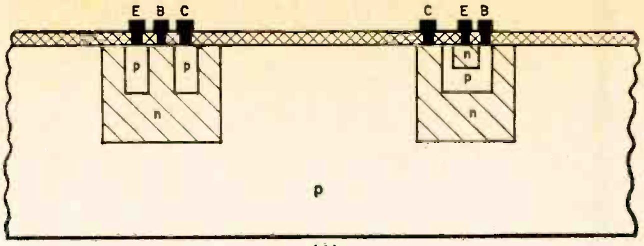
Both commercial and military LIC devices are available. The military devices are capable of operation over a much wider temperature range and under more adverse conditions of humidity than commercial devices. The military devices, however, cost more due to lower yields.

The package should also be carefully considered. Present LIC devices come in a number of packages including TO-5 cans, flat packages, and the dual in-line package.

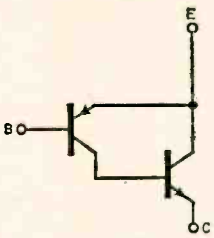
Reliability information on LIC's is mainly extrapolated from that available on digital IC devices. A low failure rate and the fact that major emphasis in the military and space agencies has been in the digital area have resulted in less reliability information on the newer LIC's.

Several years are required in order to accumulate sufficient data to calculate meaningful failure rates. However, by that time the fabrication techniques have improved and the failure-rate information becomes obsolete. The figure most commonly used at present is 0.01%/1000 hours. This means one failure for every 10 million hours of operation.

Future activity in the LIC field will continue to be fast and furious. Concentrated activity will produce a number of new developments that will have considerable effect on the LIC designer. This effort will be both in the monolithic and hybrid areas. Custom devices or those designed for specific functions will prevail rather than general-purpose types.



(A)



(B)

Fig. 4. (A) Lateral p-n-p and vertical n-p-n transistors. Both are formed simultaneously with no extra processing steps. The emitter and collector of the p-n-p are formed during base diffusion of the n-p-n. (B) Composite p-n-p transistor formed from lateral p-n-p and vertical n-p-n. The low current gain of the p-n-p is enhanced by the high current gain of the n-p-n.

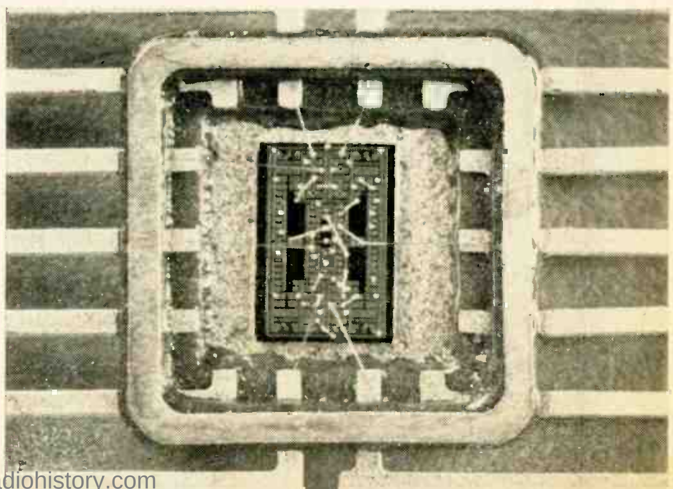
New developments and technological improvements will contribute to a continuing decline in LIC prices. Perhaps the decline won't be as drastic as in the last few years but it will be substantial. A number of high-volume users still haven't chosen to use LIC's. The present price is not considered at a level to be competitive enough with discrete devices to warrant altering present discrete designs. Lower cost rather than performance, size, or reliability must be the final consideration. Increases in volume sales in these areas will, as would be expected, give impetus to still lower prices.

The total IC market in 1973 is estimated to be around $865 million. Of this total, LIC devices will probably account for $240 million. This, in turn, will probably be broken down into $90 million for military, $50 million for industrial, and $100 million for consumer.

Declining LIC prices will continue to cut into the market for discrete devices but this will not render them obsolete. The LIC is still limited to certain specific areas in the market.

The engineer and technician must become familiar with LIC devices, including their fabrication, assembly, and use. If designs are to be optimized and subsystem troubleshooting time reduced, there is no substitute for knowledge and experience. LIC devices are here to stay, and the more the engineer knows about them, the better. ▲

Fig. 5. This monolithic IC "breadboard" consists of an array of transistors, diodes, zeners, and resistors that can be interconnected many ways to show the feasibility of a design.



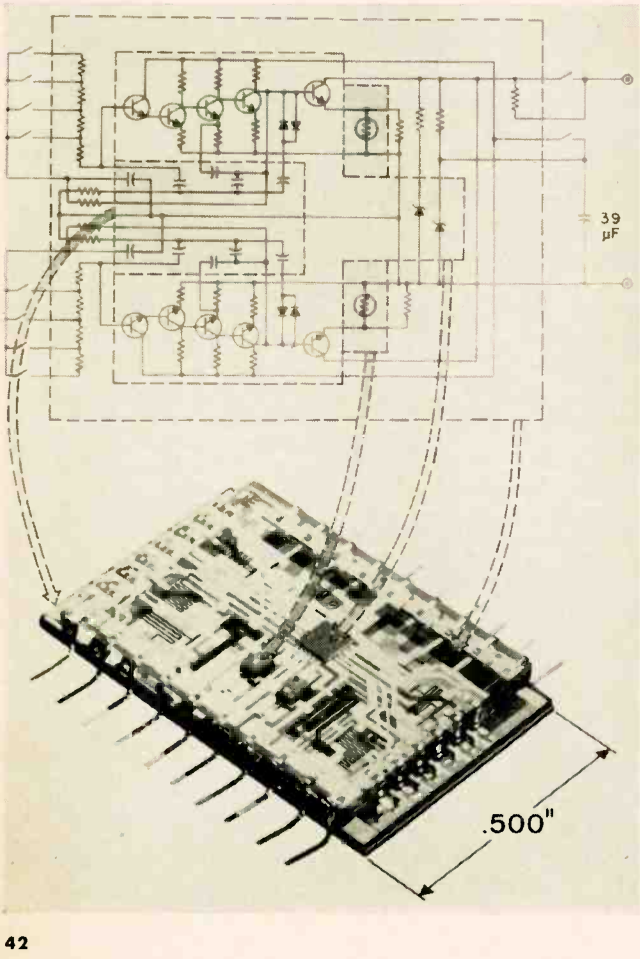
The author joined the company as a design engineer upon his graduation from Wesleyan University in 1958, after receiving his B.A. degree in physics. He received his M.S. degree in physics from Williams College in 1962. He is the author of more than a dozen technical papers on hybrid circuits and is the holder of 3 United States Letters Patents.

Hybrid Linear Integrated Circuits

By DARNALL BURKS / Department Head
Hybrid Circuit Development, Sprague Electric Co.

Using thin- and thick-film techniques along with monolithic elements, hybrid has higher value and more accurate passive components to complement the monolithic's active components.

The first application of IC technology to the telephone set is this hybrid tone generator for Touch-Tone push-button dialing. All transistors, diodes, and amplifier resistors are contained within the monolithic silicon chip about 1/16-in square at the center of the IC. Gold-tape leads interconnect the film resistor and capacitor substrates, which comprise the passive network for controlling calling frequencies.



THE Institute of Electrical and Electronics Engineers defines *monolithic integrated circuit* elements as those that are formed on or within a semiconductor substrate such as silicon. *Film integrated circuit* elements, on the other hand, are formed on an insulating substrate such as a ceramic. *Hybrid integrated circuits* combine film integrated circuits with monolithic IC's and discrete elements.

As applied to linear integrated circuits, hybrid technology can be used with *any* semiconductor or passive circuit that can be made in discrete component form and, in many cases, with improved performance. The monolithic technology restricts application to circuits of lower power and speed and less precise components. Where the monolithic approach can be used in large volume, batch processing using silicon planar technology is the least expensive method of fabrication.

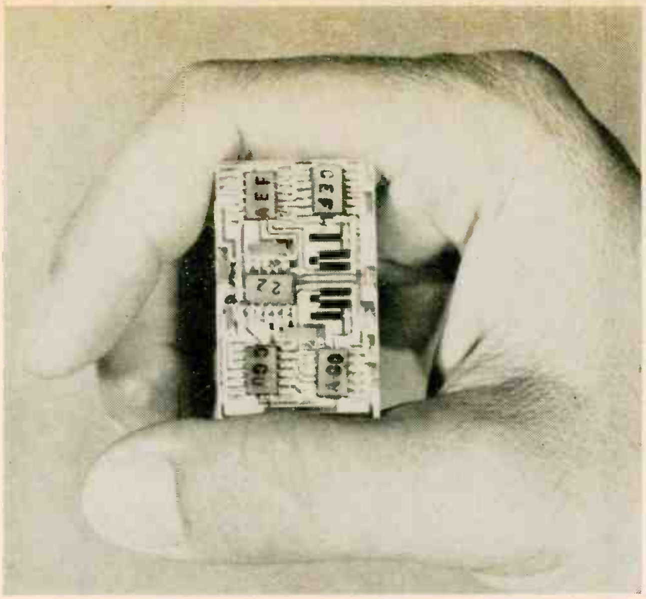
A discussion of the advantages and disadvantages of monolithic and hybrid integrated circuits can be misleading because it implies that these are competitive and mutually exclusive techniques. In fact, monolithic and hybrid approaches complement one another. The monolithic approach is less expensive for large quantities. The hybrid is being used in a wide range of applications that are either too exacting or too low in volume for monolithics to be economically feasible. Furthermore, hybrids are being used increasingly as embedding networks for monolithics. For example, monolithic operational amplifiers often require various terminating or feedback networks, usually accurate resistors and capacitors, not easily attainable in monolithic form. Hybrid LIC's are a natural for such use—the monolithic circuit and its embedding network can be packaged together or separately as desired.

Hybrid linear integrated circuits are now being used in great variety and numbers. At the beginning of 1968 there were reportedly more than 300 thick-film hybrid facilities in the U. S. In 1967 the monolithic integrated circuit market was about 46 million dollars. The hybrid LIC market is not so easily analyzed because the captive (or in-house) segment is a major part of the total. While estimates vary

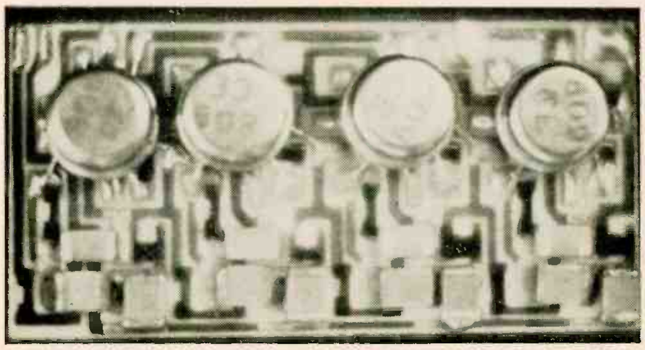
ADVANTAGES	MONOLITHIC	HYBRID: THICK FILM	HYBRID: THIN FILM
1	Highest reliability, MIL-S-750	High reliability	High reliability
2	Lowest cost (in volume)	Low cost (even in low volume)	
3	High production (by batch process)	High production (by mechanization)	High production (automation)
4	Highest density (photo-masking)		
5	Standardization (batch process)		
6	Standard packaging		
7		Wide choice of materials	Wide choice of materials
8		Wide choice of components & component values	
9		Fair to good component linearity & TC	Best component linearity & TC
10		High component precision through trimming	
11		May be operationally adjusted to circuit parameters	
12		High-power capability	
13		Multilayer interconnections	
14		High-frequency capability	Highest frequency capability
15		Highest noise immunity	Highest noise immunity

DISADVANTAGES	MONOLITHIC	HYBRID: THICK FILM	HYBRID: THIN FILM
1		Reliability not as well established. Test specifications not standardized.	
2	Highest design and start-up costs		Highest cost
3			Most difficult to mass produce
4		Lowest density (printing)	
5		Circuit types, materials, and processes not standardized	
6			Little or no package standardization
7	Silicon technology only		
8	Restricted choice of components, values, and component mix		Lower sheet resistivities
9	Highly non-linear characteristics, high TC		
10	Poorest component tolerances. Batch process does not allow individual component adjust.		
11	No operational adjustment		
12	Low power capability		
13	Multilayer interconnections difficult		Multilayer interconnections difficult
14	Limited frequency capability		
15	Lowest noise immunity		

Table 1. Comparison of linear integrated circuit types.



This hybrid circuit is a complefe 455-kHz i.f. amplifier.



Four-channel active filter with monolithic and film elements.

widely, the total hybrid LIC market was probably well in excess of that for monolithics while the non-captive portion was about one-half that of monolithics.

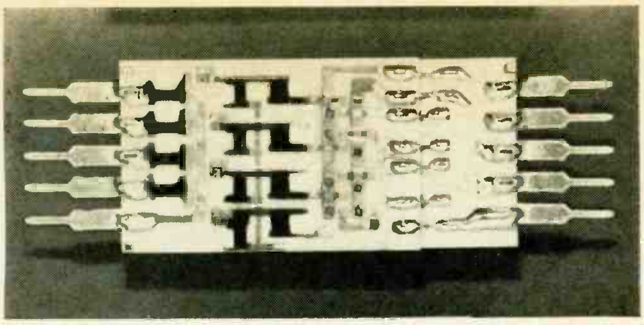
Types of Hybrids

Hybrid integrated circuits employ thin-film and thick-film techniques. The thin-film circuit utilizes vacuum-deposited films on an insulated substrate. The films may be deposited by evaporation, sputtering, or chemical vapor deposition and have a thickness measured in angstroms (10Å-10,000 Å being a common range).

Thick-film circuits are constructed by printing patterns on an insulating substrate and curing these in a furnace. The most common deposition process is screen printing,

Table 2. Characteristics of hybrid linear integrated circuits as compared with monolithic LIC's.

COMPONENT VARIETY	HYBRID	MONOLITHIC
High-value resistors	50 MΩmax. (up to 1 MΩ/square)	20 kΩ max.
High-value capacitors	Screened thin-film, 50,000 pF max. Discrete, 100 μF max.	300 pF max.
Low-resistance conductors	10 MΩ/square	1-10 Ω/square
Inductors and transformers	Yes	No
Distributed components (delay lines, stripline)	Yes	Limited
Semiconductors	Any type	Planar diffused silicon only (junction or MOS)
Semiconductor mix	Any	Limited
COMPONENT PRECISION		
Resistor tolerance	0.01%	±20% absolute, ±3% ratio
Capacitor tolerance	±1%	±20%
Operational adjustment	Yes	No
Temp. Coeff. of Res. (TCR)	±50 ppm/°C thin film ±200 ppm/°C thick film	±500 to 2000 ppm/°C
COMPONENT PRECISION (continued)		
Resistor tracking	10 ppm	10 ppm
Temp. Coeff. of Cap. (TCC)	NPO (±30 ppm/°C)	<±100 ppm/°C
Temp. compensated RC's	Yes	No
Discrete components	Matched, if necessary	
CIRCUIT FLEXIBILITY		
Packaging	Wide variety	Standardized
Power dissipation	Up to 100 watts	Approx. 1 watt (single chip)
Microwave circuits	Stripline to 30-50 MHz	Up to 50-250 MHz
High voltage	1000 V (limited by semiconductors)	40 volts
A.C. line operation	Yes	No
Noise immunity	As good as discrete circuits	Limited
Medium- and large-scale integration	Embedding networks for monolithic	In development
Volume	Low set-up costs, low volume	High set-up costs, high volume



This is a hybrid digital-to-analog converter circuit using thin-film precision resistor ladder network, thick-film terminating network, and monolithic switch and buffer amplifier.

although decal transfer, stencils, and offset printing are sometimes used. Firing is usually in air at 1000° to 2000°F.

The terms "thick-film" and "thin-film" are misleading, as some thick films are thinner than many vacuum-deposited thin films. For example, screened and fired precious metal film resistors can have film thicknesses of 100Å or less and range up to several mils (10^6 Å) in thickness. (Note that 1 mil equals 254,000 Å)

The advantages and disadvantages of thick-film and thin-film hybrid LIC's are listed in Table 1 and are compared to monolithic LIC's. In general, thin films provide the most linear and controlled component parameters. A good example is the sputtered-tantalum network tone generator for Touch-Tone® telephones. This network contains precision thin-film *RC* networks. Thick films are less expensive but generally have more non-linear characteristics than thin films. Recent developments have improved the properties of thick-film components to within striking distance of thin films. Both films have high, proven reliability.

Reasons for Hybrids

There are many reasons why a hybrid LIC may be preferred over a monolithic. The most important are listed in Table 2 along with comparative specifications. These reasons may be divided into three main categories: component variety, component precision, and circuit flexibility.

The silicon planar process imposes certain restrictions on what component and component mixes may be formed in a monolithic IC. The hybrid IC can utilize any component in film or discrete form up to and including discrete monolithic integrated circuit chips.

Similarly, the planar process has component precision limitations. In spite of great monolithic improvements, the attainable tolerance of film components is about a hundred times better. Likewise, discrete components may be tested and matched before assembly. Finally, film components may be operationally adjusted to a circuit performance parameter such as tuning a notch frequency or roll-off characteristic. For example, in the push-button telephone tone generator, the frequency is adjusted to ±0.1% and the notch depth to ±0.5 dB. In addition to initial component precision, film component stability is far better than for monolithics.

Circuit flexibility is another reason for hybrids. Hybrids may be used for microwave circuitry, for low noise or high power applications, and for large- or medium-scale integration. Hybrid packaging may take a variety of forms to suit the occasion. Low set-up and design costs make hybrids desirable for small quantity requirements (say under 30,000 units). Finally, hybrids are often useful as breadboard and preproduction designs, forming engineering prototypes for monolithic IC's. ▲

IC IGNORES TEMPERATURE CHANGES

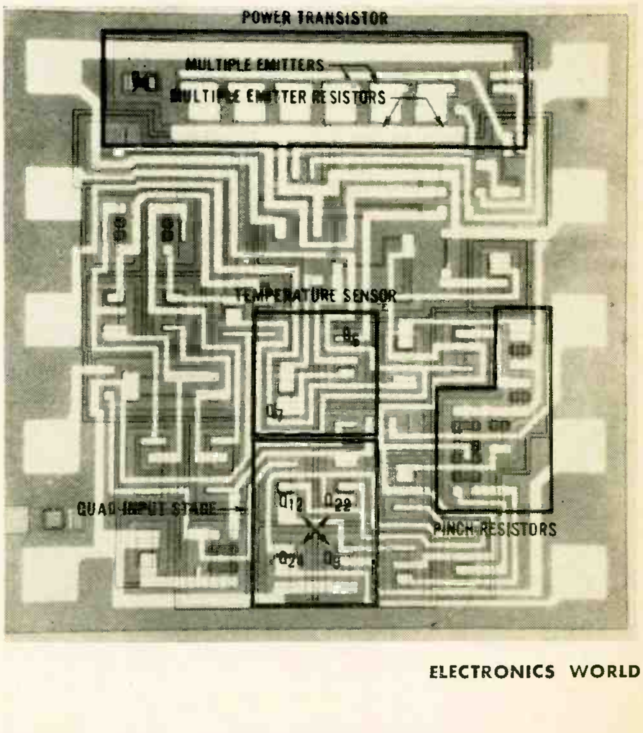
ENGINEERS interested in developing high-gain operational amplifiers with very low current and voltage drifts, can now use a new solid-state device developed by *Fairchild Semiconductor*. Called the μA727, it's a temperature-controlled differential preamplifier which has 24 active elements and an input impedance of 300 megohms over the −55° to +125°C temperature range. The device's asymmetrical input stages have two-dimensional or "quadrature" cancellation of thermal gradients. The chief applications for the device are in analog computer amplifiers, integrators, solid-state microvolt meters, and instrumentation amplifiers for low-level transducers.

The new monolithic circuit is actually a second-generation device; it was developed from first-generation units such as the μA702, μA703, μA709, and μA710 which did not meet many of the user's requirements. The new IC's main attraction is that it is tailor-made to the user's needs.

The μA727 is complex in construction. The asymmetrical input stages together with an on-chip regulator circuit, which maintains the die at a constant temperature independent of ambient temperature variations, result in an offset voltage drift of only 0.3 microvolt per degree centigrade. Offset current drifts are correspondingly low—only 2 picoamps per degree. Current "hogging" is prevented by diffusing multiple emitter resistors on the chip. The resistors work with the 1.5-watt power transistor in the regulator. This provides fast thermal response and reduces temperature gradients. It's the first IC of its type to employ such a temperature-control technique.

Fairchild also uses new processing schemes to construct the device. The result is high differential and common-mode input impedances (300 megohms and 2000 megohms, respectively). The new techniques also improve the second-generation devices by reducing the input noise to 3 microvolts r.m.s., lowering the input offset current to 2 nanoamperes, and the long-term drift to 5 microvolts per week.

The μA727 can be used to create "special-purpose" LIC's. For example, it can be used with a μA710 to make a high-impedance precision comparator in a digital voltmeter; with a 3701 multiplex switch, it will make a precision multiplex sample and hold circuit. It can also be used as a replacement for chopper-stabilized amplifiers. ▲



The author is responsible for the application engineering work on RCA's LIC product line. His group designs and builds systems using LIC's and prepares commercial data sheets and application notes describing their use. He has been active in the application of semiconductor devices since joining RCA in 1957. He holds three patents on circuits for communications and audio service and has written technical papers and applications notes in both areas.

IC R.F. and I.F. Amplifiers

By H. M. KLEINMAN / Engineering Leader, Linear Integrated Circuits Section
RCA Electronic Components

In order to select the proper integrated circuit for r.f. and i.f. use, a knowledge of the most important characteristics of the available types is required, as covered in this article.

LINEAR integrated circuits for r.f. and i.f. amplifier applications have captured the attention of the communications industry. At the end of 1967, a total of 39 integrated circuits specifically designed for such service had been announced. Their use in military and commercial equipment, especially in FM and TV receivers, has ranked this group of devices as the second largest seller, next to operational amplifiers. EIA figures for 1967 showed that 20 percent of the linear integrated circuits sold were classified as r.f. or i.f. amplifiers.

Although integrated circuits have demonstrated good performance and high reliability for r.f. and i.f. amplifier applications, their high cost has been a major deterrent to their use in the consumer-equipment field. Prices are coming down, and use has been increasing steadily.

To provide low-cost integrated circuits for this large market, the manufacturer uses two basic design approaches. One approach involves the manufacture of relatively simple, single-function, multi-purpose circuits. Economy is based on the extreme versatility of the circuit. The *RCA*-CA3005 differential amplifier, for example, can be used in a communications receiver as one of the following stages: an r.f. amplifier, mixer, oscillator, autodyne converter, i.f. stage with a.g.c., limiter, or detector. In a transmitter, this same circuit may be used as a low-power oscillator, a frequency doubler, or a balanced modulator. In a television receiver, this same differential amplifier may also be used as a video amplifier. For the integrated-circuit manufacturer, this flexibility results in lower production costs because of the larger volume of circuits that can be produced at a given time. For the equipment manufacturer who uses such circuits, this flexibility means that only a few basic types need be purchased and stocked.

The other, more economical, approach toward low-cost IC's involves the manufacture of highly complex special-purpose multiple-function integrated circuits which, although less flexible than the single-function type, derive their low cost from the number of functions they can perform simultaneously. The *RCA*-CA3042, for example, is specifically designed to perform the complete sound-i.f. function in a conventional television receiver. The power-supply regulator, i.f. amplifier, FM detector, and audio driver are included in this circuit.

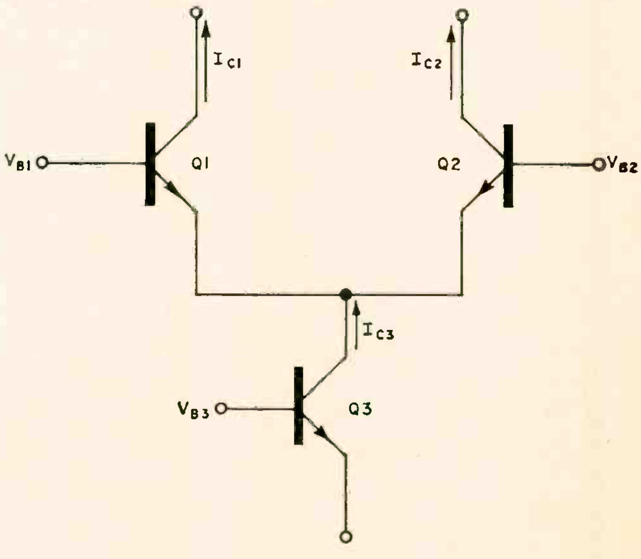
Both single-function and multiple-function circuits generally incorporate a differential amplifier as their basic configuration. In single-function multiple-purpose circuits, the differential amplifier provides extreme versatility for use in a large number of r.f. and i.f. applications. In the more complex multiple-function circuits, the differential amplifier provides sufficient gain per stage, good signal-handling capability, and a minimum of feedback capacitance.

Differential Amplifier, Universal IC

Fig. 1 shows the basic differential-amplifier circuit. Transistors *Q1* and *Q2* form the differential pair; *Q3* is referred to as the constant-current sink. By adjusting the base supply voltage V_{B3}, current through *Q3* (I_{C3}), and therefore the total operating current of the circuit, is established. The voltages applied to the bases of *Q1* and *Q2* then determine the proportion of the total collector current flowing through *Q1* and *Q2*. If *Q1* and *Q2* are well-matched during fabrication, and the voltages applied to their bases are equal, the corresponding collector currents (I_{C1} and I_{C2}) are also equal.

The versatility of the simple single-function differential amplifier for high-frequency communications applications is achieved by eliminating the load resistors. Diffused load resistors restrict the bandwidth of the amplifier. For maximum gain, such resistors should have high resistance values. A large-value load resistor, however, requires a very large chip area which, in turn, results in an appreciable distributed capacitance that limits the cut-off frequency of the device. The distributed capacitance results because, in the fabrication process, the diffused resistor must be isolated from the grounded silicon substrate by back-biased diodes. These back-biased diodes act as capacitors

Fig. 1. Basic differential amplifier showing electron flow.



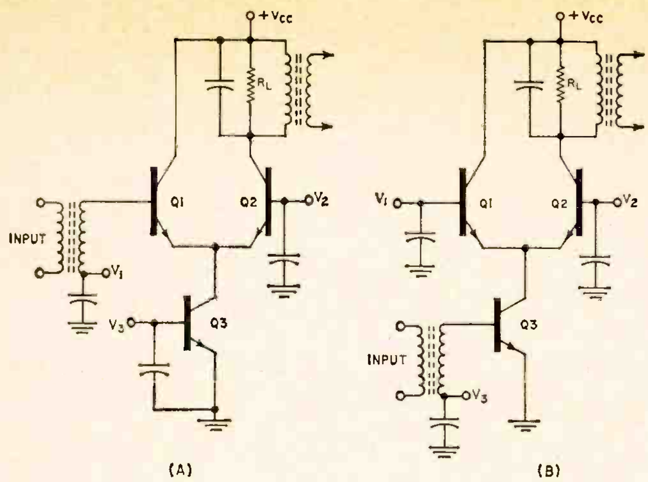


Fig. 2. (A) Differential and (B) cascode operating modes

Freq. (MHz)	R_{in} Ω	C_{in} (pF)	R_{out} (kΩ)	C_{out} (pF)	G_m (mmhos)	C_{FB} (pF)
DIFFERENTIAL OPERATION						
1	2500	16	100	4.0	20	0.03
10	1800	13	40	4.0	20	0.03
40	670	10.5	2.8	7.6	18.6	0.04
CASCODE OPERATION						
1	500	42	1670	3.0	78	0.001
10	500	42	1670	3.0	77	0.001
40	180	22	600	3.0	58	0.01

Table 1. Comparison of characteristics of the CA3005 integrated circuit employed in differential and cascode modes.

which shunt the load resistor at the higher frequencies.

The designer's answer for complete flexibility of the differential amplifier is to eliminate the diffused load resistors and use r.f. or i.f. transformer coupling. In the case of complex multi-function integrated circuits, the designer uses very low values of load resistors to provide a number of low-gain stages that add up to a high-gain amplifier. For example, one circuit uses three low-voltage-gain stages that provide a total of 70 dB of gain at low frequencies.

Flexibility of the differential amplifier also results from the various ways in which the circuit can be connected. Fig. 2A shows the *differential* mode of operation. The signal is applied to the base of $Q1$ and the load is connected to the collector terminal of $Q2$. The base circuits of transistors $Q2$ and $Q3$ are at a.c. ground. Because the output impedance of the grounded-base transistor $Q3$ is high, all of the emitter current in $Q1$ flows into the emitter of $Q2$. The result is a common-collector amplifier driving a common-base amplifier. Although the transconductance (C_m) of the integrated circuit is only one-fourth that of a single transistor drawing the same operating current, the output impedance may be higher, thus compensating for the lower G_m to provide comparable circuit gain.

Fig. 2B shows the *cascode* mode of operation. The signal is inserted at the base of $Q3$, and the load is connected at the collector of $Q2$. The bias on $Q1$ and $Q2$ is such that $Q1$ is cut off; *i.e.*, the collector current of $Q1$ is zero. Therefore, the circuit is essentially a common-emitter amplifier driving a common-base amplifier.

Table 1 shows some of the electrical characteristics of the *RCA*-CA3005 operated in both the differential and the cascode modes. The differential amplifier provides very low values of feedback capacitance (C_{FB}) as compared with a single transistor of equal transconductance. In the differential mode, the feedback capacitance is 150 times less than that obtained from a single transistor at frequencies up to 10 MHz. The cascode mode shows even better isolation (lower C_{FB}), with feedback capacitance reduced by more than 1000 times compared to a single-transistor circuit.

Signal-handling capability of an active device is measured by means of the a.g.c. characteristic. This curve shows the level of interfering signal required to obtain 3 percent cross-modulation of a desired signal at various levels of gain reduction produced by the a.g.c. signal.

The signal-handling capability of the differential amplifier is approximately equivalent to that obtained from a single bipolar transistor. The presence of interfering signals from 10 to 30 millivolts produces objectionable cross-modulation over most of the a.g.c. range. At present, the best cross-modulation performance is obtained from a dual-gate MOS field-effect transistor which may result in a ten-fold improvement in the cross-modulation performance.

Reliability

Reliability is an important reason for using an integrated circuit in place of a discrete-component circuit. Reliability can be roughly measured by counting the number of solder connections in the circuit. Because a solder connection is a possible point of failure, more solder points make it more likely that the circuit will fail. When an integrated circuit is used to replace a number of functions in a discrete-component circuit, the interconnections between these functions are made on the chip and not on the printed-circuit board. Therefore, the total number of solder connections is reduced.

Reliability is also measured by system performance under extreme changes in temperature. For military and space applications, the normal operating-temperature range specified is from −55 to 125° C. The designer of a discrete-component circuit maintains the required gain in this temperature range by incorporating special compensating devices such as diodes and positive- and negative-coefficient resistors. These components add to the total number in the system and thus increase the failure probability. The user of integrated circuits, however, can select a single device that includes all of the necessary compensating devices for constant gain over the temperature range. Fig. 3 shows gain as a function of operating temperature for the *RCA*-CA3002 i.f. amplifier. This circuit provides 27 ±0.5 dB of gain at 1 MHz over the entire military-temperature range.

In military and industrial applications, reliability is also measured by the period of time the equipment is inoperative as a result of component failure. The concentration of functions in a few integrated circuits instead of in a large number of separate components decreases the time required for diagnosis and replacement of the defective component and decreases equipment "down" time.

Single Function Circuit Applications

The simple differential amplifier driven by a constant-current transistor represents the optimum circuit configuration for a *limiter*. A notable feature of this configuration is that the collector saturation region of either $Q1$ or $Q2$ can be avoided because the peak-to-peak current swing measured at the output is controlled by the current level set by $Q3$.

Fig. 3. Variation in gain with temperature of IC i.f. amplifier.

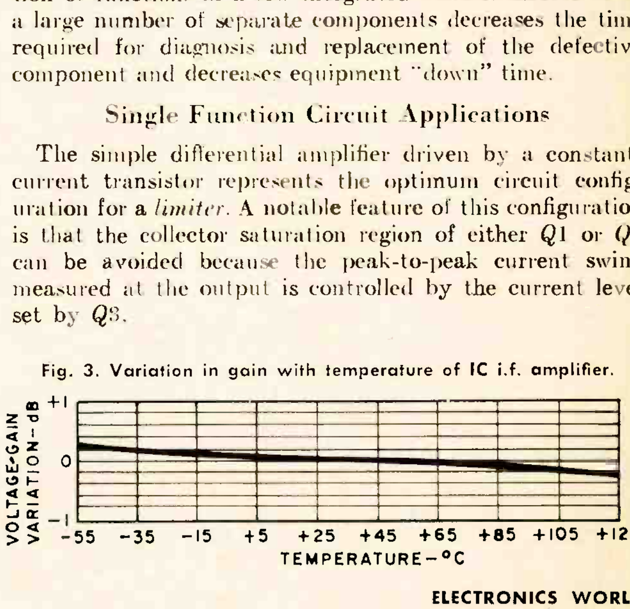


Fig. 4 shows the portion of the current I_{C3} flowing in either of the differential transistors as a function of the differential input voltage. When the peak-to-peak current swing has been accurately measured, a load resistance is selected to assure that the collector voltage of $Q2$ never becomes less than the base voltage. Under this restricted current swing, the output resistance and capacitance of the limiter circuit are maintained reasonably constant and the tuning characteristics of the load are not degraded.

Fig. 5 shows the differential amplifier as a typical *mixer*. The oscillator signal is connected to the base of $Q3$ and the r.f. signal is applied to the differential pair. (Either a single-ended or a balanced drive may be used.) The center-tapped load provides cancellation of the common-mode oscillator signal so that none appears in the subsequent i.f. amplifier. A resistor (R_E) is included in the emitter circuit of $Q3$ to improve the circuit linearity with respect to the oscillator signal. The more nearly sinusoidal the oscillator current in $Q3$, the better the mixer rejects spurious responses. When a balanced r.f. input is used, spurious responses are further reduced because the even harmonics of the r.f. signals are cancelled. Although the spurious-response performance of the mixer improves as the oscillator voltage is decreased, the conversion gain also decreases.

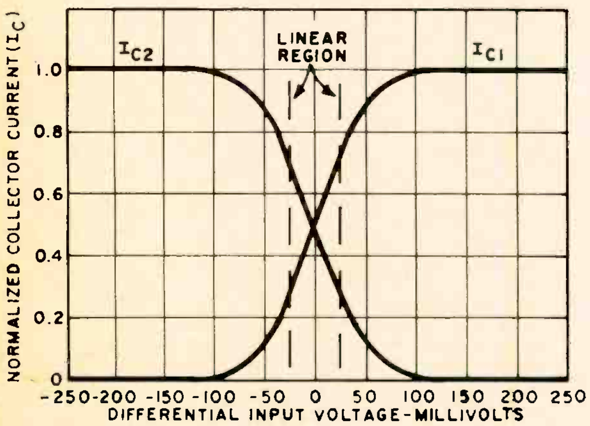


Fig. 4. Transfer characteristic of IC limiter circuit.

If $Q1$ and $Q2$ are closely matched, cancellation of the oscillator signal is nearly complete and this circuit may also be used as a *balanced modulator*. The modulating signal is applied to the differential pair, and the carrier signal is applied to the base of $Q3$.

Fig. 6 shows the differential amplifier as an *autodyne converter*. Again, the oscillator signal is connected to the base of $Q3$, and the r.f. signal is applied to the differential pair. Because all of the current in the collector of $Q3$ flows to the power supply V_{CC}, the current flowing in the oscillator tuned circuit is independent of the r.f. signal. As a result, the oscillator is not susceptible to pulling or blocking, which are typical problems associated with conventional single-transistor autodyne converters.

Multiple Function Circuit Applications

Although the simple single-function differential amplifier finds wide application as an r.f. or an i.f. amplifier stage, it is more economical to manufacture a more complex integrated circuit that functions as a complete system. Fig. 7 is the schematic diagram of the *RCA*-CA3023 wide-band amplifier. This circuit is specifically designed as a multi-stage i.f. amplifier and is capable of providing between 50 and 60 dB of gain at frequencies to 10 MHz.

The circuit contains two voltage amplifiers, $Q1$ and $Q4$. The emitter follower $Q3$ provides both impedance matching and level shifting between $Q1$ and $Q4$. The emitter follower $Q6$ provides a low-impedance output. Diode $D1$ provides bias stabilization. Internal d.c. feedback is also included. Automatic gain control is provided by $Q2$ and $Q5$. When pin 2 is connected to the "V+" voltage, these transistors are in saturation. As a result, the emitter circuits of $Q1$ and $Q4$ contain a very low resistance and their gain is maximum. When automatic gain control is applied to reduce the voltage at pin 2, the transistors come out of saturation, present a higher impedance emitter circuit to $Q1$ and $Q4$, and thus decrease their gain. For gain reduction greater than 35 dB, the circuit has better signal-handling capacity than the dual-gate MOSFET.

Fig. 8 shows the *RCA*-CA3041 integrated circuit used to perform the sound-i.f. function in a conventional tele-

Fig. 5. Differential amplifier employed as mixer.

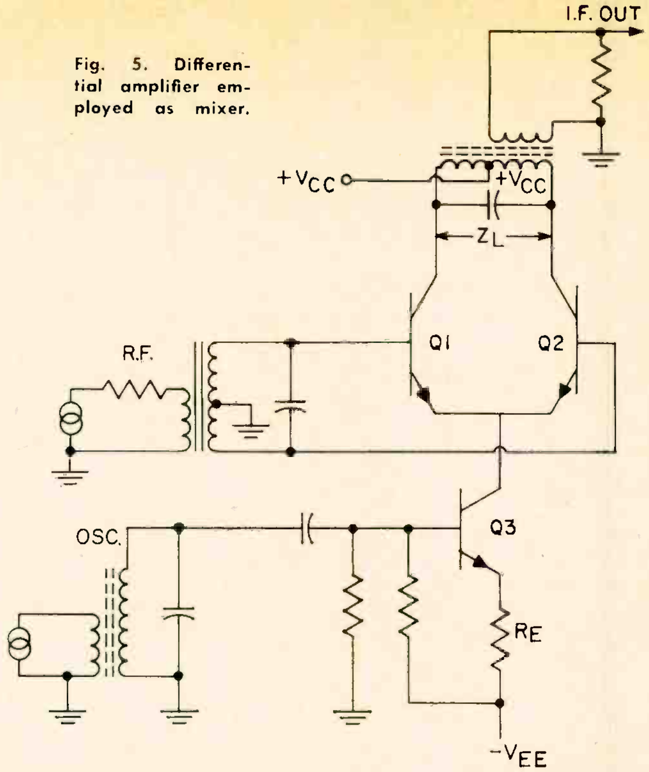
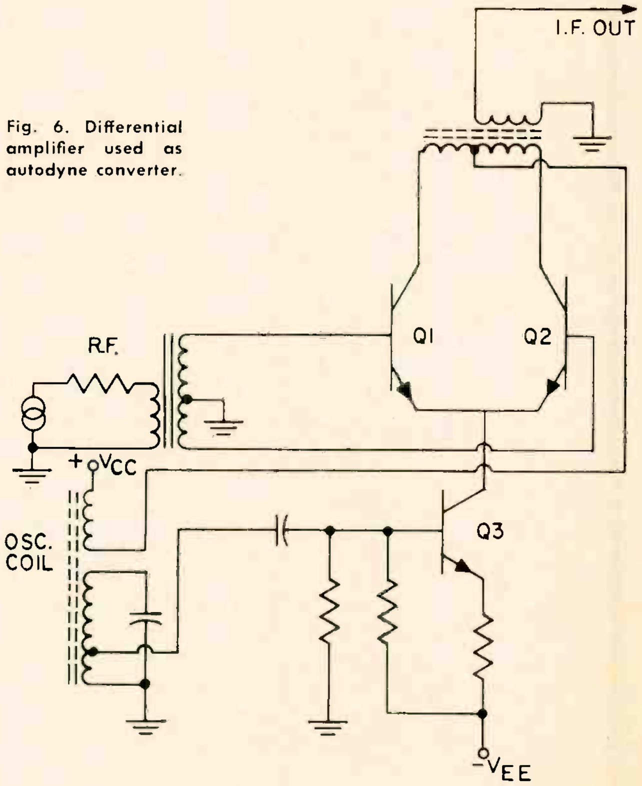


Fig. 6. Differential amplifier used as autodyne converter.



vision receiver. Designed to operate from the sound takeoff at the first video detector, this circuit provides full limiting for input signals above 200 microvolts r.m.s. The circuit can be connected directly to a conventional power amplifier tube such as the 6AQ5.

Proper Selection and Precautions

Selection of the proper integrated circuit for a particular r.f. or i.f. application is based on several important considerations: the size of the production run, the performance level required, the flexibility of the IC, and the expected life of the design in which it is used. A highly flexible circuit has the advantage of requiring fewer different parts to be stocked. When flexibility is not considered important, the designer should look to the more complex, multiple-function circuits. Even when all the functions of a particular integrated circuit are not required, these circuits may still be more economical than a relatively simple type because of the price competition in this area. At $1.75, in quantities from 11 to 100, the *RCA*-CA3041 provides an economical 70-dB amplifier-limiter; in addition, a pair of matched diodes and an audio amplifier are included.

Although good layout techniques are important for the proper operation of any high-frequency circuit, they are especially important when integrated circuits are used. The maximum stable or usable gain (MUG) is an inverse function of the feedback capacitance C_{FB}, as follows: $MUG \approx 1/2\pi f C_{FB}$. Therefore, special care must be exercised to minimize the capacitive feedback between input and output circuits. In the circuit of Fig. 8, for example, the load resistance is 1000 ohms, transconductance is 2300 μmhos, and the maximum usable gain for 65 dB of gain is 3×10^6. By transposition of the above equation to solve for C_{FB}, the maximum allowable feedback capacitance in this circuit is found to be less than 0.01 picofarad.

Because of this restriction in capacitive feedback, sockets should not be used at r.f. frequencies above a few megahertz. If a socket must be used, however, a hole should be drilled parallel to the axis of the socket and a grounding screw inserted to minimize the capacitance. A good method with a dual in-line socket is to split the socket and insert a thin metal grounding shim down the spine.

Lead inductance must also be minimized when integrated circuits are used. A common impedance of 1 ohm shared by the input and output circuits can cause oscillation with this circuit; an impedance of only 0.25 ohm can make tuning of the circuit very difficult.

Although some precautions are required in laying out this circuit, a compact layout with no special shields or ground planes can be employed.

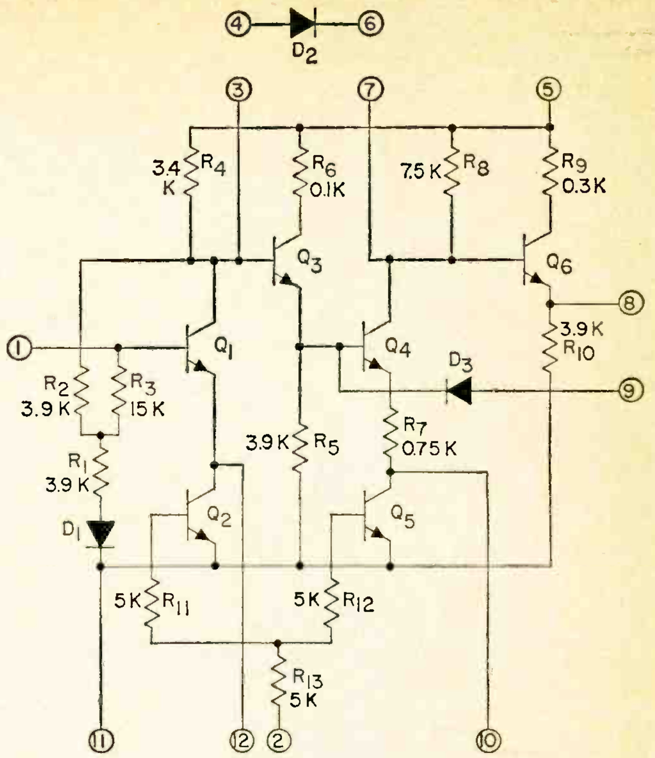


Fig. 7. Schematic of the CA3023 wide-band i.f. amplifier.

However, ways of handling and supporting the structure during and after fabrication are the main problems associated with this method. One solution may be the use of a plastic film, such as Teflon, as a base on which the integrated-circuit chips are mounted. The film can support the chips during etching and contain the external connections.

The fabrication of MOS transistors and bipolar transistors on the same chip is also expected to result in superior cross-modulation performance and overload capability for r.f. amplifier applications.

Performance is also expected to improve with the advent of new circuit configurations. One present development is a 3-stage, all-transistor IC that provides 43-dB of gain with a 3-dB bandwidth of 400 MHz and gain stability of ±0.3 dB over the entire military temperature range.

For the present, integrated circuit manufacturers will continue to provide relatively simple multi-function circuits with increasing levels of performance. The trend for the future is toward highly complex special-purpose circuits for large-volume manufacture. As performance and demand increase, the price will continue to decrease. ▲

Recent and Future Developments

The demand for low-cost IC's for r.f. and i.f. applications will increase as performance improves. Some techniques recently developed are providing substantial increases in gain and bandwidth. The technique of dielectric isolation, for example, uses silicon dioxide layers instead of conventional *p-n* junctions to separate components of the circuit. However, at present, yields of IC's using this technique are low and cost is high.

Beam-lead technology is another technique that promises improvement in high-frequency performance. This method involves the use of heavy lead connections between components so that the substrate can be etched away to leave the components isolated by air.

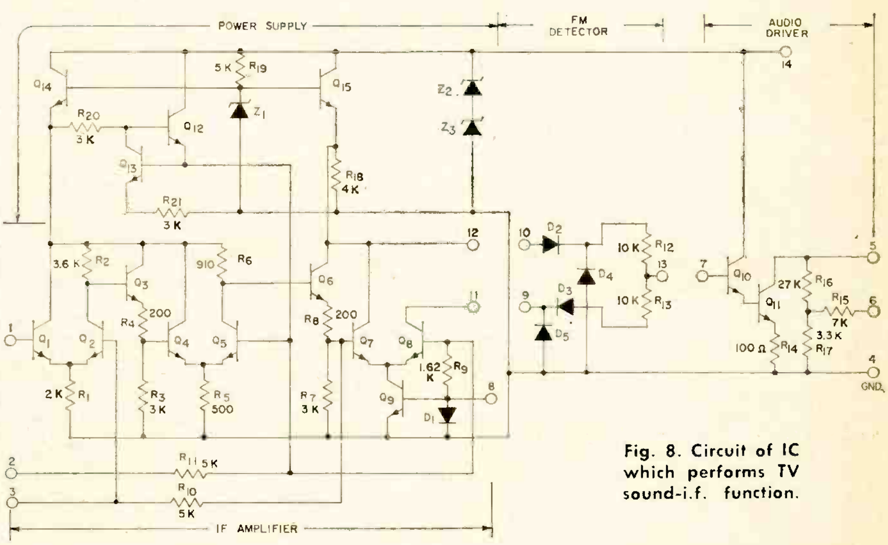


Fig. 8. Circuit of IC which performs TV sound-i.f. function.

The author, in his present position, is concerned with all small-signal discrete-component and linear integrated circuit applications up to 100 MHz. He holds a BSE in Electrical Engineering (1964) from Arizona State University and expects to receive his MSE degree from ASU in June 1968.

Monolithic Operational Amplifiers

By BRENT WELLING/ Manager, Signal Processing Applications
Motorola Semiconductor Products Inc.

One of the most important and versatile LIC, the op amp is saving expensive design and development time. Operating principles, important parameters, and applications are given.

THE past few years have seen a marked increase in interest in the operational amplifier. This interest has come now after many years in which few engineers used or thought about op amps except for specialized uses, such as analog computers and servo controls.

The rise in interest is due to the recent availability of high-performance monolithic integrated circuit op amps at very low prices. Some operational amplifiers are now so inexpensive that they can be used in hundreds of applications no one would have considered before. With this dramatic drop in prices, designers have discovered the convenience of using op amps to simplify their work and save expensive design and development time.

An operational amplifier is a high-gain, direct-coupled amplifier designed to be used with heavy external negative feedback. This feedback is so great that it almost completely determines the characteristics of the amplifier, making it convenient for the user of an op amp to obtain the characteristics he wishes by choosing the proper feedback network.

The name "operational amplifier" is a rather misleading designation. It comes from the original use of such amplifiers; they performed mathematical operations such as addition, subtraction, multiplication, integration, averaging, and scaling in analog computers.

The greatest application of monolithic operational amplifiers is as easy-to-use amplifiers rather than as function generators or other specialized uses. The op amp is a very convenient, easily controllable block of gain. A designer need only choose two resistors to get any reasonable value of amplification where he needs it, without spending expensive design time developing an amplifier. Op amps are used as linear amplifiers in this way in servo and process controls, signal conditioners and filters, input amplifiers, analog instruments and impedance transformers, and voltage and current regulators.

They are also used to perform the mathematical operations mentioned before and other types of non-linear analog aplications, such as analog-to-digital converters, digital-to-analog converters, nonlinear function generators, logarithmic and exponential amplifiers and voltage comparators, and specialized rectifiers.

Operational amplifiers using discrete components have been available for many years, but only at high cost. This has made their use practical only for a few specialized applications. The average designer could not use operational amplifiers costing $50 to $200 each in equipment. Monolithic operational amplifiers, on the other hand, are very inexpensive and are practical for many applications. Thanks to IC's, op amps have evolved from specialized to general-purpose components.

Monolithic operational amplifiers have two advantages: small size (and weight) and low cost. These advantages have opened hundreds of new applications. Discrete-component and hybrid op amps can now offer better specialized performance for some applications since they can incorporate high-voltage transistors, better *p-n-p* and *n-p-n* complements, field-effect transistors, and resistors with better properties. But these excellent properties are not necessary in many uses, while a low price is.

Differential Amplifier

The basic building block that is employed in the design of an integrated-circuit operational amplifier is the *differential amplifier* (Fig. 1A). This circuit is excellent for use in monolithic op amps because it is a stable circuit well adapted to d.c. coupling. Hence, capacitors need not be used within the IC. It provides excellent tracking and gain linearity with temperature changes, since both transistors can readily be made to have nearly identical characteristics. Gain in a differential amplifier is dependent on resistance ratios rather than on absolute values of close-tolerance resistors, which are difficult to control in IC manufacture.

The most significant aspect of the differential amplifier is its versatility. If a signal is applied differentially between the bases, so that one base goes positive while the other goes negative with respect to the emitters, current will rise in one transistor and fall in the other. This will cause a large voltage difference between the collectors. However, if a signal is applied to both the inputs in-phase (a common-mode signal), the collector voltages will be in-phase and the voltage across the differential output terminals will be zero. This feature yields a high degree of interference rejection since interference signals are largely common mode.

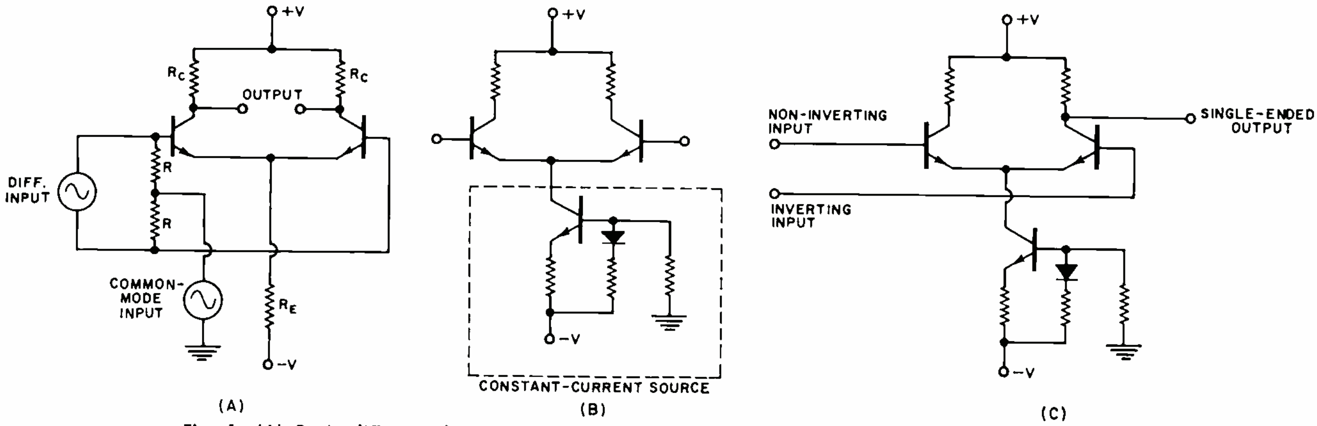


Fig. 1. (A) Basic differential amplifier. (B) Use of constant-current source. (C) Single-ended operation.

However, many applications require single-ended output from a differential pair. Even in this case, there is substantially less amplification of common-mode signals. This is due to the degeneration across the common-emitter resistor. With a common-mode signal, current increases in both transistors causing the voltage drop across the emitter resistor to rise. This reduces amplification and leads to low gain. With differential input, on the other hand, the current through the resistor remains relatively constant as the differential amplifier transistor currents seesaw.

A high value of resistance is necessary for best rejection of common-mode signals with this circuit, but high-value resistors are difficult to manufacture monolithically. Instead, a constant-current source consisting of a transistor, a diode, and a few low-value resistors are normally used (Fig. 1B). This holds the total current through the transistors constant, providing even better common-mode rejection than with a high-value emitter resistor and also reduces the need for excessively high power-supply voltage.

The differential amplifier has a choice of inputs and outputs. The output and input can either be balanced differential or single-ended. In single-ended use, the input signal can be applied between either base and ground (Fig. 1C) If an a.c. signal is applied to the inverting input, the single-ended output will be 180° out-of-phase. The single-ended output will be in-phase with the non-inverting input because the two transistors are in a common-collector, common-base cascode arrangement.

Operational-Amplifier Configuration

Monolithic operational amplifiers generally follow the block diagram shown in Fig. 2. The input stage is a differential amplifier with emitter current supplied by a constant-current source. This stage usually has the highest gain. Consequently, the collectors of the input stage are normally made available at external pins for frequency compensation.

An ideal operational amplifier would exhibit an infinite input impedance. Unfortunately, this is impossible to obtain. However, impedance levels of several hundred kilohms or more can be realized with a monolithic operational amplifier. A circuit often used to get this high impedance is the Darlington-configuration amplifier shown in Fig. 3A. The input resistance of the pair of transistors is equal to the input resistance of $Q2$ multiplied by the *beta* of $Q1$. This high impedance is gained at the expense of bandwidth.

The intermediate stage (Fig. 2) provides some amplification; more important, though, it buffers the input amplifier from the output. This stage does not require a constant-current source for emitter current because the common-mode rejection of an operational amplifier is determined primarily by the performance of the input stage.

The output of operational amplifiers is usually single-ended rather than differential. However, the single-ended output from the intermediate stage is at a quiescent d.c. level above or below ground. This level must be translated by a d.c. level shifter so that the quiescent d.c. output voltage will be at zero, preventing any undesired d.c. current in the load.

The output stage in most operational amplifiers employs a class-AB amplifier with single-ended input and output. Temperature compensation and negative feedback complicate the circuit slightly, but lead to excellent performance.

Most operational amplifiers are designed for use with split supply operation, that is, using equal positive and negative voltages with respect to ground. This simplifies offset problems (obtaining zero ouput voltage with no input) and keeps unwanted direct current out of the load. It also leads to simple biasing of the input stage. An op amp can be used with a single supply for many a.c. applications if necessary.

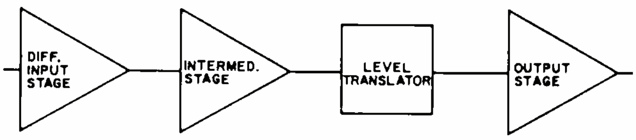
The plot of gain and phase shift from non-inverting input to output for a properly compensated op amp is shown in Fig. 3B. The phase shift must be less than 180° at frequencies where the amplifier has gain greater than one or it will oscillate. There is little or no phase shift for the low-frequency, constant-gain portion of the response. At the corner frequency, there is approximately 45° phase shift. At the higher frequencies, greater shift occurs. This is due to stray capacitance and lead inductance. At frequencies above the unity-gain crossover, phase shift may exceed 180°, but the amplifier cannot oscillate at these frequencies because of the lack of amplification.

Terminals are provided on most monolithic op amps to connect proper frequency-compensation circuitry. This compensation is necessary for stable operation and good high-frequency performance. Instructions for compensating an amplifier to meet different requirements are supplied on data sheets available from the manufacturer.

A High-Gain Operational Amplifier

The schematic of a high-performance, high-gain IC operational amplifier, Type MC1533, is shown in Fig. 4. This op amp has a typical open-loop gain of 60,000. Some other typical characteristics are low voltage drift with temperature change (±5 μV/°C), large output-voltage swing (up to ±13 V with a ±15-V supply), low output impedance (100Ω), high input impedance (1 MΩ), high common-mode rejection (100 dB), and low input-offset current

Fig. 2. Block diagram of an IC operational amplifier.



(30 nA). Cost for the inexpensive, limited-temperature range, plastic-encapsulated version, the MC1433P, is \$6 in quantities of 100.

This amplifier follows the block diagram of Fig. 2. The input stage uses Darlington differential amplifiers (*Q*1, *Q*2 and *Q*3, *Q*4) for high input impedance. Separate current sources are used for input transistors *Q*1 and *Q*4 instead of a single current source for the whole stage. This provides constant collector currents to *Q*1 and *Q*4; hence, the Darlington characteristics are independent of *beta*.

Temperature compensation of the input stage is accomplished by feedback from the second stage through the 28,000-ohm emitter resistor. If current in the first stage increases due to temperature rise, the voltage across the 8500-ohm resistor at the base of *Q*7 drops, reducing the current and stabilizing the amplifier. This action is known as common-mode feedback.

*Q*10 is a low-gain lateral *p-n-p* transistor which drives emitter-follower *Q*11. *Q*10 and *Q*11 shift the quiescent d.c. level applied to driver *Q*12 to almost zero. Negative feedback is applied to these stages from the output to reduce crossover distortion.

Q12 is the driver for the complementary-symmetry output stage. The output transistors are biased class-AB for efficiency and low distortion. Bias is supplied by the voltage drop across *D*2 and *D*3, which provides a small quiescent forward current to these transistors.

Temperature compensation to transistor *Q*10 is provided by diode *D*1. This diode has little effect on the performance of *Q*9 since it simply provides a voltage drop that decreases slightly with increasing temperature, but it is also in the highly voltage-sensitive base-emitter circuit of *Q*10. Thus *D*1 compensates for any temperature variations in the V_{BE} of *Q*10.

Two unusual features of this op amp are a choice of the amount of amplification and an input-offset-adjust terminal. The amplifier is in the high-gain stage if pin 7 is tied to "V+". Leaving pin 7 open reduces the gain to about half (6-dB loss) due to emitter degeneration in *Q*10. Input offset of the amplifier can be adjusted to zero by varying the voltage between pin 8 and "V+".

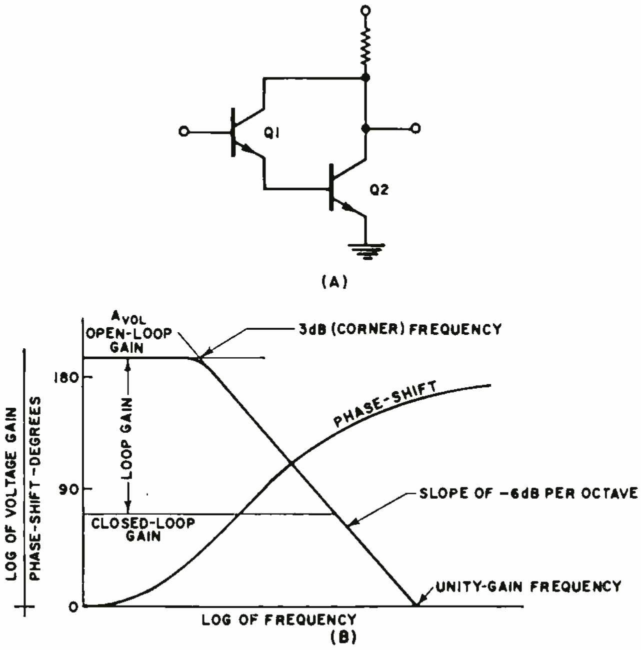


Fig. 3. (A) Darlington amplifier. (B) Gain and phase shift.

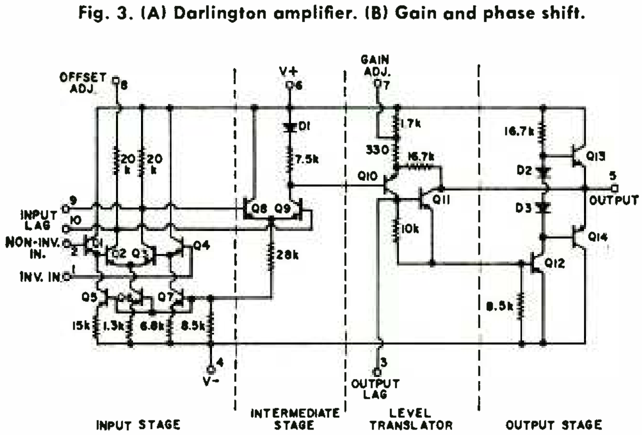


Fig. 4. Schematic of a high-gain IC operational amplifier. Compensation circuits are connected to the lag terminals.

Operational Amplifier Applications

The functional symbol used for an operational amplifier is shown in Fig. 5A. It has three terminals; the output, an inverting input, and a non-inverting input. A good operational amplifier has very high input impedance, very high amplification (open-loop gain), wide bandwidth, very low output impedance and low offset (d.c. output with no input). An amplifier with these characteristics might seem to be of limited use in common amplifier circuits since even a very small input signal would saturate it, causing the amplifier to act more as a switch than an amplifier. However, the operational amplifier is almost always used with heavy negative feedback that modifies its performance and results in the characteristics that have made op amps so popular.

The Inverting Amplifier: The basic amplifier configuration is the inverting amplifier shown in Fig. 5B. Very little current flows into input terminal A (the inverting input) because of the very high input impedance of the op amp. This means that there is almost no voltage drop across the input terminals, so terminal A is virtually at zero potential (0 V). This fact is very useful in analyzing op-amp circuits.

The voltage amplification of an inverting amplifier using an operational amplifier with very high open-loop gain is equal to $-R_F/R_I$. Thus, almost any desired value of amplification can be obtained through proper choice of the feedback-resistor ratio. This circuit can provide a gain of less than unity.

The input impedance of an inverting amplifier is approximately equal to R_I. This resistor is usually not more than 100,000 ohms in practical circuits.

Non-Inverting Amplifier: Another popular operational amplifier configuration is the non-inverting amplifier shown in Fig. 5C. In this circuit, a positive input gives a positive output. Amplification of this circuit, which is equal to $(R_I + R_F)/R_I$ or $1 + (R_F/R_I)$, can be any value greater than one. This circuit is very useful where a very high input impedance is needed. Since almost no current flows into the input terminal, the impedance is often 10 to 500 MΩ. This circuit is also excellent as a buffer since it does not invert the input. Neither input terminal of the op amp can be grounded in this amplifier.

A special case of the non-inverting amplifier is the one in which R_I is infinite (in other words, an open circuit) and R_F is any finite value including zero. This circuit is called a voltage follower and is shown in Fig. 5D. The voltage follower has unity gain, very high input impedance, low output impedance, and no phase shift at low frequencies, making it an ideal buffer.

Differential-Input Amplifier: Fig. 5E shows an operational amplifier arranged for differential input (subtraction). The output is directly proportional to the differential input voltage: $V_O/V_I = (R_F/R_I)(V_{IB} - V_{IA})$. The input is left floating above ground.

Operational amplifiers are very versatile. No article could do more than merely hint at the vast number of applications for which they can be used. By outboarding

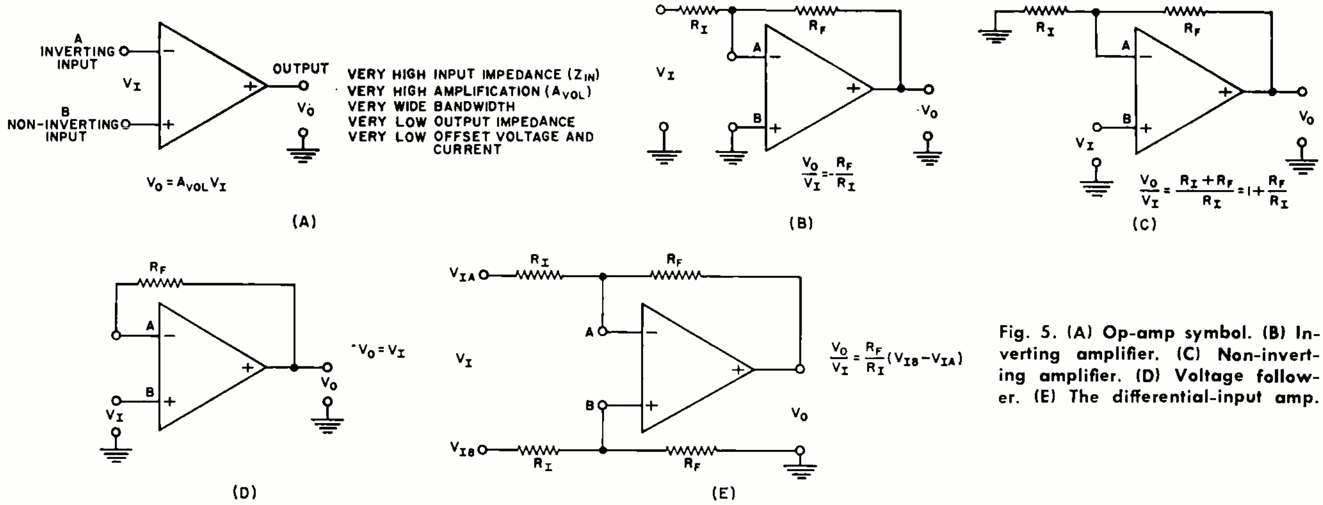


Fig. 5. (A) Op-amp symbol. (B) Inverting amplifier. (C) Non-inverting amplifier. (D) Voltage follower. (E) The differential-input amp.

RC components to the various terminals of IC op amps, it is possible to produce wide-band audio or r.f. amplifiers, oscillators and filters, adders and subtractors, integrators and logarithmic amplifiers, voltage regulators, and many other circuits. The manufacturers of op amps have available a large number of application notes showing just what interconnections are required for their products and what values of external *RC* components must be used for these applications.

Gain: The open-loop amplification or gain, A_{VOL}, of an operational amplifier is the ratio of output voltage to input voltage without feedback. This ratio can be expressed as a simple ratio or as a logarithmic ratio in decibels. An "ideal" operational amplifier would have infinite gain; practical IC op amps have open-loop voltage gains between 3000 (70 dB) and 100,000 (100 dB).

Closed-loop gain is the ratio of output voltage to input voltage with feedback. The difference in decibels (or ratio) between open-loop and closed-loop amplification is called loop gain. This loop gain can be thought of as the sacrifice in gain due to feedback. However, as is true in any amplifier, this feedback provides a number of advantages, particularly a decrease in sensitivity to changes in open-loop parameters, better stability, improved gain accuracy, higher input impedance, and lower output impedance. It is easy to see that the greater the open-loop gain available, the more loop gain can be used to increase stability and accuracy. Loop gain will not affect drift, noise, and offset. Because of the decreasing amplification of an op amp with increasing frequency, high open-loop gain is also valuable in providing amplification at high frequencies.

Impedance: The open-loop output impedance of an operational amplifier should be as low as possible. Practical op amps have typical open-loop output impedances between 20 to 2000Ω. Closed-loop output impedance is equal to the open-loop impedance divided by the loop gain. For example, the MC1533 op amp has a typical open-loop output impedance of 100Ω. If it is operated with a loop gain of 40 dB (100), the effective impedance is 100Ω/100 or 1Ω (plus, of course, the resistance in any leads between the feedback point and load). This would usually be insignificant compared to the feedback resistance, which is likely to be 10kΩ to 1 MΩ. Effective output impedance increases with frequency as a result of decreasing loop gain.

The open-loop input impedance of an operational amplifier should be high compared to any feedback resistors to avoid excessive shunting. Practical IC op amps have input impedances between 10 kΩ and 2 MΩ or even higher. The closed-loop input impedance in the inverting configuration is equal to the input resistor, and the closed-loop input impedance in the non-inverting configuration is equal to the open-loop input impedance multiplied by loop gain and may be hundreds or thousands of megohms. The primary effect of low open-loop input impedance is a reduction in loop gain and a consequent loss of accuracy.

Common-Mode Rejection: One of the advantages of the differential-amplifier configuration is its rejection of common-mode voltages. A voltage that appears at each input should be amplified equally, resulting in no differential output. In practice, however, no two amplifier stages will be perfectly matched, so that an operational amplifier is not completely immune to common-mode voltages. The ratio of the change in output voltage to the change in the input common-mode voltage producing it, divided by the open-loop gain is called the common-mode rejection ratio. The logarithmic ratio, which is called common-mode rejection (CM_{rej}) is usually used for this expression. CM_{rej} of 80 to 100 dB are typical for monolithic operational amplifiers. Common-mode rejection is not significant in the inverting configuration since one input is grounded.

Offset: The slight mismatch of components in any practical operational amplifier causes a small d.c. voltage to appear at the output even with no input. The voltage required at the input to balance the differential stages and produce no d.c. voltage output is called the input offset voltage V_{IO}. It can be considered a small voltage in series with one of the inputs. The input offset voltage is insignificant in some applications, but it can be balanced out if necessary by applying a slight bias to one of the inputs or to a special terminal provided. Unfortunately, the offset varies with temperature, making balancing adjustments useful only over a limited range. The input offset voltage for the MC1533 is typically 1 mV.

Input offset current, I_{IO}, like V_{IO}, is an indication of the matching of the differential stages. I_{IO} is the difference in input base bias current required by the differential inputs for equal emitter currents. Also like V_{IO}, I_{IO} should be as small as possible, particularly in precision applications. Typical I_{IO} for the MC1533 is 0.03 μA (30 nA).

Bandwidth: There are two significant frequencies in the response curve of a good operational amplifier, the frequency at which the gain has dropped 3 dB below the open-loop low-frequency value (3-dB bandwidth or corner frequency) and the open-loop unity-gain crossover frequency. Either can be considered as bandwidth, so specifications should be read carefully.

Last year, total U. S. linear integrated circuit factory sales were 7.4 million units valued at $45.7 million. Of this, 1.9 million units valued at $20.7 million were IC op amps. This represents 45% of the dollar sales and 26% of the number of units. Total linear IC sales are expected to rise to the $72 million this year and we expect the sales of op amps to rise rapidly as more designers discover the versatility of this important LIC. ▲

The author received his BSEE from City College of New York in 1962 and his MSEE from Rutgers University in 1965. Upon graduation he joined RCA as a specialized trainee, and was eventually assigned to the RCA Space Center, Astro-Electronics Division. Late in 1964 he transferred to Electronic Components where he is currently working in the Advanced Devices and Applications group. His present responsibilities include the area of integrated MOS linear arrays. He is co-author of two technical papers on integrated MOS digital arrays. He also holds one patent and has several more pending.

Large-Scale Integration of Linear IC's

By STANLEY KATZ/Engr., Linear Integrated Circuits Section
RCA Electronic Components

A complete transmitter or receiver on a chip is yet to come, but work now underway on LSI is bringing this goal closer.

PROBABLY the most dramatic trend in integrated-circuit technology is the fabrication of large electronic systems or functions on a single silicon chip. This concept is generally referred to as *large-scale integration* (LSI) or large-array technology, and much has been done on LSI for digital-circuit applications. The extension of LSI to linear-amplifier functions is expected to receive similar acceptance. An example of what large-scale linear integration (LSLI) can produce is a high-performance, highly reliable, low-cost communications receiver or transmitter complete on a single chip of silicon.

The advantages of large-scale integration are obvious. The fabrication of complex multi-stage circuits containing both active and passive elements on a single chip is much less expensive than the construction of individual discrete-component stages which must be hand-wired together. In the fabrication process many such complex circuits are processed simultaneously on one silicon wafer. The components for each circuit are first diffused into the silicon and then reliably interconnected. The wafer is then scribed into separate chips each containing a complex circuit that exhibits a high packing density.

Besides being smaller, more reliable, and less expensive to make, LSI circuits perform better than equivalent discrete-component circuits because both lead inductance and capacitance are minimized. In addition, because all components are on the same substrate, they exhibit better thermal tracking characteristics.

Limitations of LSLI

At present, the major obstacle to the development of large linear arrays is the low yield. From a statistical viewpoint, as the amount of components to be integrated increases, the over-all yield per chip decreases. One attempt to improve the yield involves use of what is called *discretionary wiring*. Instead of evaporating metal interconnections over the entire wafer, each individual circuit is first electrically tested and then a computer generates an interconnection pattern that avoids the defective units. The computer uses its "discretion" in selecting and wiring the individual circuits. To compensate for the number of defective circuits, more components than required by the system are diffused into the wafer. A major drawback of discretionary wiring is that every wafer requires a different complex metallization mask.

Another obstacle to the development of large-scale linear circuits is the present requirement for additional external components, *e.g.*, transformer, inductors, and relatively large capacitors. Because of the relatively large size of these components, sometimes little advantage is gained by reducing the space consumed by the remainder of the circuit. The additional components also increase the number of external connections required and therefore decrease the yield and increase the package requirements. For certain applications, the power-dissipation rating of the present package may also limit the size of the array. Much progress is being made, however, toward developing high-yield bonding techniques and packages capable of containing a large number of pins and dissipating greater amounts of heat.

Bipolar or MOS Arrays

In the relatively near future, large linear arrays will be fabricated by either of two processes. In the conventional diffused planar-epitaxial process used for present bipolar integrated circuits, a total of six masks, four diffusion steps, and the growth of an epitaxial layer is required. Components of the circuit are electrically isolated from one another by reverse-biased *p-n* junctions.

Metal-oxide semiconductor (MOS) technology is an alternate and more promising approach to large-scale linear integration. Because the integrated MOS field-effect transistor is much smaller than an integrated bipolar device, a tenfold increase in array packing density is achieved. Fabrication of this device involves only four masking operations and one diffusion. Because large isolation regions are eliminated, a minimum of silicon area is used. Other advantages of MOS transistors are that they exhibit extremely high input impedance, low distortion, and permit amplifier stages to be direct-coupled without level shifting. The MOS structure may also be used to form capacitors and large-value resistors with less chip space.

The expectation is that more complex linear functions will be performed by the MOS structures. For simpler structures, however, or those requiring higher transconductance per area, higher frequency response, and greater power-handling capability, bipolar structures will be used.

In present linear integrated circuits, a single layer or level of metallization provides the electrical connections for all components of the circuit. The metal is evaporated onto a layer of silicon dioxide which passivates the silicon surface and insulates the metal from the diffused components.

In large-scale linear integration, however, two or more layers of metallic conductors will be used, with a significant saving in silicon surface area. Crossover connections between layers will be isolated from one another by layers of insulating material. Although there are some difficulties associated with this multi-level process, several manufacturers have already reported the successful development of the technique. ▲

The author received his BSEE from Kansas State University in 1947. He joined General Electric that same year and was made responsible for the development and design of audio and test equipment. From 1956 to the present, he has been an application engineer for the Semiconductor Products Department. He is a member of Eta Kappa Nu, a senior member of the Institute of Electrical and Electronics Engineers, and the holder of two patents.

Audio-Frequency Integrated Circuits

By DWIGHT V. JONES / Semiconductor Products Dept., General Electric Co.

The audio IC, although the last to enter the marketplace, is now finding increased use in consumer electronic equipment as well as in military and aerospace products. Details on preamps, power amplifiers, and combination preamp-driver IC's are given, including information on what is available.

THREE different categories of IC audio amplifiers are available to the electronic circuit designer. These are preamplifiers, power amplifiers, and a combination preamp and driver. The latter group of components have low power output (less than 1 watt). Some of these monolithic circuits are available in plastic packages, while others are available only in metal packages. The metal-package audio IC's are used primarily in military, space, and low-volume industrial applications; while the lower cost plastic packages are used in consumer and high-volume industrial applications.

The interest in audio IC's is growing rapidly because of the increased reliability resulting from the use of fewer parts and lower over-all equipment manufacturing costs. The lower costs are the result of fewer components to purchase, inventory, and supply to the production line, in addition to the rapidly declining price of the IC's themselves.

Monolithic audio amplifiers began to appear in large numbers in 1967, and indications are that this growth will continue. Tables 1, 2, and 3 show representative examples of the available audio IC's; some of the IC characteristics are tabulated from their respective specification sheets. The bandwidth of most audio IC's is greater than 100 kHz and is usually limited by the external components used.

Of all the main types of linear IC's, (1) operational amplifiers, (2) i.f. and r.f. amplifiers, and (3) audio amplifiers, the third group was the last to enter the marketplace. The first audio IC's were used in hearing aids and in military and space equipment. The first consumer electronic use was in a 1-watt phonograph manufactured by *General Electric* and described by A.F. Petrie in the December, 1966 issue of ELECTRONICS WORLD.

Table 1. Some examples of monolithic integrated circuit audio preamplifiers and their characteristics.

	Manufacturer	Supply Voltage (Vmax)	Operating Temp. (°C)	Package Type	Package Diss. (mW)	Min. Gain (dB)	Equiv. Input Noise Volt.	Input Res. (kΩ)	Output Voltage (V)	
CA3036	RCA	10	—55 to 125	Metal (10 leads)	300	60 (current)		82		Dual Darlington
D16P	G-E	25	—65 to 120	Plastic TO-98 (3 leads)	320	76 (current)		650		Darlington
MC1302P	Motorola	16	0 to 75	Plastic (14 leads)	400	56 (voltage)	8 μV		1.7	Dual Preamp
PA230	G-E	10 to 14	—55 to 110	Plastic (8 leads)	800	72 (voltage)		35		
TAA310	Amperex	5 to 9.5	—20 to 75	Metal (10 leads)		90 (voltage)	4 dB NF		7.8	
WC183	Westinghouse	1.5 to 9	—55 to 75	Metal (10 leads)	100	84 (voltage)	3 μV	40		

Circuit Features and Applications

A monolithic IC amplifier design has an advantage over discrete circuits in utilizing thermal feedback to stabilize the voltage and quiescent current bias conditions. The small physical size of an IC, by its very nature, provides a close thermal coupling between circuit elements which cannot be matched using discrete transistors and biasing components mounted on a common heatsink. The reduced size of the small-signal IC transistor gives it a higher frequency capability than the usual discrete transistor used in audio and medium-frequency circuits. Therefore the IC circuit usually requires one or two external capacitors to attenuate the high-frequency response and compensate for phase shift.

Operational amplifiers have been used to perform audio preamp and driver functions, but the designs usually require both a plus and a minus power supply. IC's designed for audio to be used with a single power supply often employ an adapted form of the operational amplifier circuit.

The differential amplifier configuration is often used in audio monolithic circuits. This circuit is popular in IC's because of the matching of V_{BE} and h_{FE} that is inherent when two transistors with the same geometry are formed side by side on the same silicon chip. The emitters of the differential amplifier transistors should ideally be connected to a constant-current source so that the sum of the two transistor currents will always be constant. Then if the current in one side of a differential increases, the current in the other side will decrease by the same amount. Since a differential amplifier amplifies the difference between the two signals applied to the base of each transistor, an in-phase feedback signal is often applied to one side of the differential.

The Darlington transistor connection in monolithic form is a very simple preamp. Since the collectors are common with this IC structure, it does not usually require an isolating junction. The first two rows in Table 1 list some of the characteristics for two products of this type.

The input resistance can be increased by using an external emitter resistor (*R4*) as shown in Fig. 1. The bias network is also bootstrapped to increase the input resistance to 2.7 megohms at 50 Hz. This high input impedance is desirable for ceramic phonograph cartridges and microphones. The D16P4 has a minimum h_{FE} of 7000 at 2 mA collector current. *R5* and *C2* are in shunt with *R4* to increase the voltage amplification in the mid-range. With the *Astatic*-17 cartridge, this circuit provides an output frequency response from 40 to 12,000 Hz that is flat within ±2 dB from the *London* PS131 stereophonic frequency test record. The output reference level is 1.9 volts which is 10 dB below clipping and 80 dB above the unweighted noise level. The total harmonic distortion (for 1 and 15 kHz) is less than 0.2% at 1.9 volts output. The IM distortion (60 and 6000 Hz) at 1.9 volts is less than 1.5%. The input level for 1.9 volts is 350 mV.

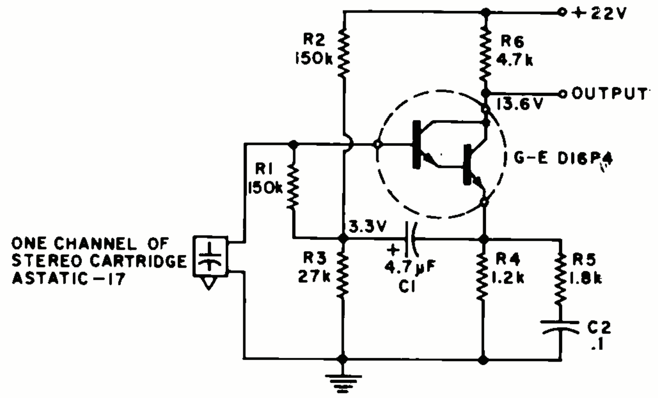


Fig. 1. Phono preamp using Darlington audio preamp IC.

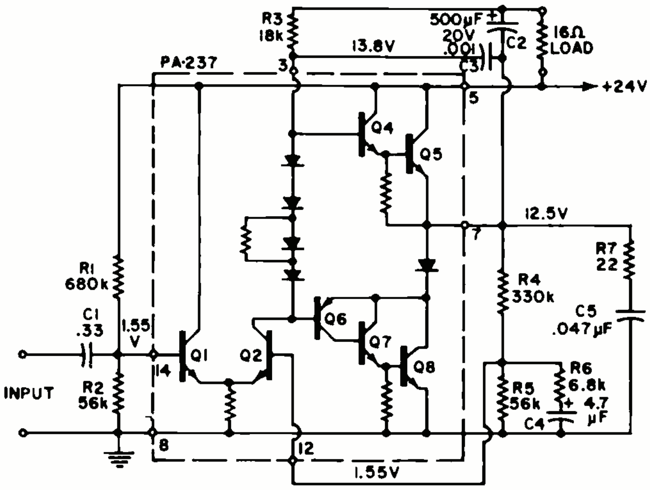


Fig. 2. A 2-watt audio power amplifier using audio IC. Components within the IC are shown here inside the dashed lines.

Power Amplifiers

The maximum power output of an IC depends on the circuit efficiency and the power dissipation capability of the IC. A monolithic power amplifier must provide a means for transferring the internally generated heat. The metal packaged IC's in Table 2 can be used with commercially available heatsinks designed for transistors with TO-5 type packages. *General Electric* has introduced a low-cost plastic package with a copper tab at one end which allows the heat to flow from the IC chip along the tab to the copper area on a printed-circuit board. The package would require the tab and leads to be bent at right angles for soldering in a printed-circuit board. The tab is connected to the substrate at the bottom of the monolithic chip and should be externally connected to circuit ground or the most negative potential.

Monolithic power-amplifier circuit designs use class AB push-pull outputs to attain good operating efficiency and performance. This type of output stage is usually used in discrete designs of higher power amplifiers. Class AB push-pull stages operate with a base-emitter bias near the conduction threshold of about 0.6 volt for silicon transistors. Operation would be class B without this forward bias which determines the quiescent current. Class AB operation reduces the crossover distortion that is present with class B, with a slight sacrifice in efficiency.

The highest power monolithic amplifier in Table 2 (the *G-E* type PA-237) has a quasi-complementary output circuit as shown in Fig 2. The monolithic circuit portion is shown within the dashed square with the external components shown outside the square. The quasi-complementary push-pull output circuit consists of *Q4*, *Q5*, *Q6*, *Q7*, and *Q8*. Three transistors (*Q6*, *Q7*, and *Q8*) are required for the composite *p-n-p* transistor since the h_{FE} of *Q6* is low (between 1 and 10 at 1 mA collector current). *Q6* and *Q7* are equivalent to a discrete *p-n-p* driver. This arrangement of push-pull composite transistors provides high current amplification so that *Q2* can operate at low currents (about 0.5 mA). This permits *R3* to be relatively large (18 k) so as to enhance the voltage amplification.

Q1 and *Q2* form a differential amplifier where *Q1* operates as an emitter-follower and drives *Q2* as a quasi-common-base stage. This circuit has no phase inversion of the signal from input to output except within the composite *p-n-p* transistor. The feedback signal applied to the base of *Q2* is in-phase as required with this connection of the differential amplifier.

The differential amplifier in Fig. 2 has voltage-source base bias which provides good bias stability against variations in h_{FE} for *Q1* and *Q2*. It also minimizes the effects of temperature. It is important that the d. c. bias voltage at lead 7 be stable if maximum power output at low distortion is to be maintained. The differential amplifier with d. c. feedback to the base of *Q2* provides this stability.

The diode string between the bases of *Q4* and *Q6* provides the necessary d. c. bias voltage for the quasi-complementary push-pull output to minimize distortion at low signal levels. The value of *R3* can be reduced to maintain 0.5 mA through the series diodes at lower supply voltage. The power output diode in series with *Q5* and *Q8* assists in the bias stabilization of this direct-coupled circuit and it also provides local a. c. feedback in the effective emitter of the composite *p-n-p* transistor. A treatise on the method is given in the book, "Transistor Audio Amplifiers," by D. V. Jones and R. F. Shea. (*John Wiley and Sons*, 1968).

The 16-ohm load is returned to the power supply, which is an a. c. ground, so that the load coupling capacitor can also serve to bootstrap resistor *R3*. This eliminates the need for a separate capacitor and resistor. This positive feedback increases the effective resistance of *R3* and thus increases the open-loop voltage amplification by 14 dB. The negative feedback with *R6* equal to 6800 ohms is 24 dB.

The 0.001-μF capacitor, *C3*, decreases the open-loop gain at the extreme high frequencies by decreasing the effective bootstrapping of *R3*. Without feedback (*i.e.*, $R6 = 0$) the frequency response is down 3 dB at 30 kHz. *C3* provides high-frequency stabilization when operating from a high-impedance signal source or with various output load conditions. Because of the high-frequency capability of the monolithic transistors, more precautions must be taken to prevent high-frequency oscillation than is the case with discrete amplifiers. *R7* and *C5* limit the increase of inductive load impedance and phase shift with frequency.

The distortion *versus* frequency and output power are shown in Fig. 3 for the monolithic 2-watt amplifier. These curves indicate good performance up to 2 watts peak with

Manufacturer		Supply Voltage (V)	Operating Temp. (°C)	Package Type	Package Diss. (W)	Gain (Voltage)	Input Res. (kΩ)	Output Res. (Ω)	Power Output (W)	Power Freq. Res. (kHz)	Load Res. (Ω)	Zero Signal Curr. Drain (mA)
MC1554G	Motorola	18	−55 to 125	Metal (10 leads)	1.68 (T_c = 50° C)	10X	10	0.2	1.0 @ 0.4% THD	270	16	11
PA-234	G-E	9 to 23	−55 to 125	Plastic (8 leads)	3.6 (T_c = 50° C)	8X	100	5.5	1.0 @ 3% THD	100	16 or 22	6
PA-237	G-E	9 to 27	−55 to 125	Plastic (8 leads)	2.25 (T_c = 30° C)	47X	40	0.85	2.0 @ 1% THD	100	16	4
WC334T	Westinghouse	4 to 30	0 to 85	Metal TO-78 (8 leads)		10X	400	0.3	1.0 @ 1% THD		16	

Table 2. Examples of monolithic integrated circuit audio power amplifiers along with their characteristics.

area of this heat fin should be chosen to maintain the package tab temperature within its rating under the worst-case operating conditions.

The input impedance of the PA-237 can be increased by boostrapping *R2* as shown in Fig. 4. Since the signal at both ends of *R2* is in-phase, this increases the effective impedance. The input impedance is increased to 100,000 ohms and this decreases the loading on a ceramic cartridge and improves the bass frequency response. The phono cartridge output level will determine the optimum resistance for *R8*. The circuit shown in Fig. 4 is designed for a nominal 0.7-volt output ceramic cartridge with a capacitance of 600 to 1000 pF. A minimum cartridge output of 0.5 volt will produce 2-watts power output. At this power, the total harmonic distortion at 1 kHz is typically between 1.5 and 2%. In normal operation, the volume control setting will decrease the cartridge loading compared to maximum output and increase the bass frequency response. The tone control at maximum treble cut attenuates a 10-kHz signal by 10 dB or more (depending on the volume setting) with respect to 1 kHz. A 1-kHz signal is changed by 1 dB or less at all tone control settings.

Just as with this example, many IC's can be adapted to various supply voltages, load impedances, and voltage gains. The IC user must remember to provide adequate heat-sinking as required to maintain the IC package temperature within its rating at all times. This dissipation *versus* temperature criterion is the same as that applying to discrete transistors. Because monolithic audio circuits have a much higher frequency capability than the usual discrete audio circuits, the user must take more care in the parts layout in order to avoid the possibility of producing any high-frequency oscillations. It is often advisable to locate the output power-supply electrolytic capacitor quite close to the IC in order to avoid inductance that is associated with long lead runs.

In the future we can expect to see many more product offerings that are designed to do a specific job at low cost where there is high volume usage. The power output capability of a monolithic power amplifier can readily be extended to 10 watts with a suitable package dissipation capability. Even higher power outputs will be practical as the industry increases its ability to fabricate higher voltage power IC's. The user cost of a 1-watt audio output IC is presently less than $1.00 in quantities of 100,000. It is expected that most high-volume-usage IC's will continue to decrease in price. ▲

	Manufacturer	Supply Voltage (V)	Operating Temp. (°C)	Package Type	Package Diss. (mW)	Gain (dB)	Input Noise Volt.	Resistance Input (Ω)	Resistance Output (Ω)	Power Output
CA3007	RCA	10 to 20	−55 to 125	Metal (12 leads)	300	22 P.S.		4,000	60	
CA3020	RCA	3 to 10	−55 to 125	Metal (12 leads)	600	58 P.S.	75 dB S/N	40,000		550 mW @ 10% THD
μA716C	Fairchild	10 to 27	0 to 70	Metal TO-99 (8 leads)	600	46 A_v	8 μV	11,000	1	150 mW @ 1% THD @ 100 kHz

Table 3. Examples of monolithic integrated circuit preamp-driver combinations and their characteristics.

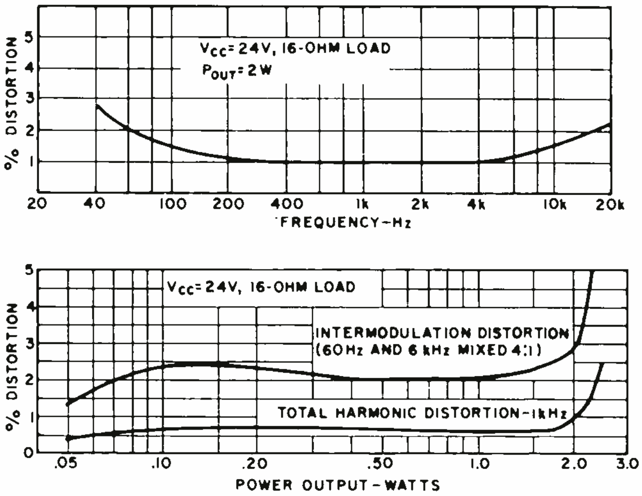


Fig. 3. Distortion vs frequency and power for Fig. 2 circuit.

clipping occurring at 2½ watts power output. The PA-237 has a typical operating efficiency of 53% and the circuit shown in Fig. 2 requires an input signal of 120 mV for a 2-watt output.

The integrated circuit in Fig. 2 is quite versatile since it can be biased to operate with supply voltages from 9 to 27 volts and the sensitivity can be increased or decreased by altering the feedback resistor, *R6*. Many combinations of supply voltage and load impedance are possible. The resistors shown outside the dashed square in Fig. 2 were not included in the monolithic circuit because they would increase the chip area and limit the versatility which the circuit has in its present form. Using an 18-volt supply, the load can be either 8 or 16 ohms for about 1.5 watts power output. With an 8-ohm load the efficiency drops to about 40% and the maximum operating temperature on the package tab is limited to 50° C for this power output. In addition to the copper area (circuit ground) on the printed-circuit board, a copper fin having a tab that is soldered to the tab of the PA-237 will provide an additional heatsink. The

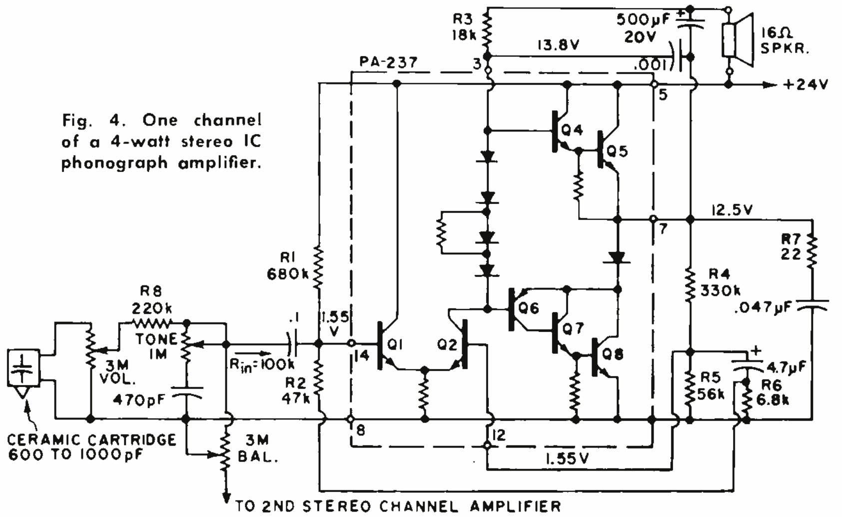


Fig. 4. One channel of a 4-watt stereo IC phonograph amplifier.

JOHN FRYE

The $46-billion U.S. health industry must make more and better use of electronics if it is to provide the care patients can afford.

THE COMPUTER AND THE CADUCEUS

IT WAS almost closing time at Mac's Service Shop, and the owner was glancing over the evening newspaper. From the scowl on his face, he was not liking what he read. "What's bugging you?" demanded Barney, the service technician. "You've been muttering in your beard ever since you picked up the paper."

"It's this story about the new addition proposed for the hospital."

"What's wrong with that? We certainly need more bed space. I visited a friend there last week, and they had him and several others out in the hall because there were no empty rooms."

"That's just the point. We need more bed space desperately, but a large percentage of the money is going to be spent on administrative offices and additional space for 'keeping the records required by Medicare,' quote and unquote."

"You don't believe it's necessary to keep these records?"

"Sure I believe that, but I also believe they should be kept by modern EDP equipment instead of in bulky filing cabinets. Such equipment provides greater accuracy, quicker retrieval, and a great reduction in space requirements. Right now 634 hospitals are using computers in some form, and this number is expected to rise to over 1300 by 1970. In this period the total number of hospitals in this country is expected to go from 7200 to 7800. To my way of thinking, it's almost criminal for any new hospital to be designed, built, or enlarged without a thorough investigation into how modern electronics can improve the operation and efficiency of the new facility. Yet, since hospital boards are frequently composed of people who know little of computers or medical electronics, I'm afraid many of those new hospitals will be built without even provision for basic patient monitoring equipment."

"You come on pretty strong about this."

"That's the way I feel. The health industry of this country—which is a whopping $46-billion-a-year industry—is in more serious trouble than the average healthy citizen realizes until he or some member of his family has a serious illness. Let me give you some facts and figures:

"Hospital charges in this country have jumped 31% nationwide in the past two years. In 1950 the average daily hospital room charge was $15; now it is nearing $50; and the Surgeon General himself estimates this may soar to $85 a day by 1970.

"Physicians fees have gone up 14% nationwide since 1965, and *Medical Economics Magazine* estimates the fee charged by the general practitioner has increased 25% since Medicare and Medicaid programs went into effect. The doctors blame increased paper work brought on by these programs for part of this increase."

"Why have hospital rates risen so sharply?"

"Hospital administrators say it is chiefly because of the increased cost of help. Since 1964 the average annual salary of nurses has increased about $2500. A few years ago, in spite of the three and four years of professional training required to become an R.N. or get a degree in nursing, nurses were paid no more than beginning stenographers. But in spite of this increase, the nation still needs at least 135,000 more trained nurses; so there's little likelihood the cost of nursing will turn downward. Furthermore, in 1965 hospital workers were brought under the Federal minimum wage and overtime laws. Previously, according to a Labor Department study made five years ago, hospital workers were one of the lowest paid occupational groups in the country. Now when you consider that labor costs comprise two-thirds of the total overhead of a hospital, it's not difficult to see how the sharp rise in nurse pay and in the pay of other hospital workers is bound to result in increased room rates."

"You talk about nurses being in short supply. Aren't doctors, too?"

"They are, but the picture is not quite so simple. Actually the present ratio of doctors to patients—one to 720—is just about what it was thirty years ago; but during that thirty years there has been a great increase in specialization and in the average number of visits each patient makes to his doctor. Moreover, more and more doctors are going into medical research jobs where the hours are regular and the work-week is short. It has been charged the government itself is largely responsible for this trend because of the $1.4 billion a year it spends on medical research with the consequent siphoning off of doctors. Anyway, the upshot of the whole thing is that the dwindling group of general practitioners are overworked and patients have a difficult time finding one who will take them on.

"The A.M.A. admitted in June of 1967 there was a serious and worsening shortage of doctors and called for an immediate and unprecedented increase in the intake of medical schools. This was an abrupt about-face from their previous attitude in which they expressed doubt there *was* a doctor shortage and used their power to accredit schools and to approve hospitals to limit sharply entry into their profession. Since the median net income for all American physicians rose from $16,017 in 1955 to $32,170 in 1966 and since one doctor out of seven now clears, after paying all office expenses and other costs, more than $50,000 a year, plenty of young men are eager to become doctors. Unlike in the nursing profession, there has been no lack of monetary incentive to account for the doctor shortage.

"It is a sad commentary on our ability to train doctors that during every recent year some 2500 graduates of foreign medical schools—almost a third of the total number of M.D. degrees conferred last year by American medical schools—started working in the U.S. Since a high proportion of these come from countries desperately in need of medical services, this drain is bitterly resented in low-income countries who believe the U.S. is rich enough to train its own doctors. But it will take years for this change in attitude of the A.M.A. to take effect. As a recent *Life* editorial put it: 'By 1980 the public will begin to appreciate the results of a 1967 A.M.A. decision that should have been made in 1947.'"

"Let's see if I follow you," Barney said, ticking off the points on his fingers: "Hospital beds, nurses, and doctors are all in short supply. The cost of these services is soaring and threatens to go far beyond the reach of the average person.

No immediate relief is in sight. You think electronics can help."

"You've been listening all right," Mac approved. "A protracted 'catastrophic illness,' such as that resulting from stroke or cancer, can destroy a fairly affluent family financially in spite of all the government and private insurance they can afford. Yet these two illnesses are the major killers. Heart and blood vessel deaths—and many of these were from strokes—exceeded one million in 1965, the last year for which figures are available. Cancer deaths were almost a third of this number.

"We simply *must* keep the cost of medical care, even for such cases, within reach of the average person. The only hope I see of doing this short of socialized medicine—a course still repugnant to most Americans—is to amplify the effectiveness of hospital workers, nurses, and doctors. In extolling our liberties, Dr. Milford O. Rouse, president of the A.M.A. for 1967, said, 'The American way of life can be described in one word: capitalism.' If that be true he should recognize this precept of capitalistic industry: the best way to reduce costs is to increase production."

"I get it!" Barney interrupted. "The modern way to increase production is through electronic automation. But maybe doctors believe human life is too precious to be entrusted to a robot."

"That won't hold water. The lives of our astronauts are almost entirely in the hands of computers. So, to a lesser extent, are the lives of airplane passengers, our fighting pilots, and workers in dangerous jobs in industry. These persons are safer with the 'human error' factor removed."

"Why does the medical profession seem to be reluctant to take advantage of electronics?"

"Probably the chief factor is a lack of communication. Doctors don't know what electronic equipment is available; engineers don't understand the needs of doctors. Physicians are ultra-conservative by training. They hesitate to try a new remedy, procedure, or device until it has been thoroughly tested, proved, and used successfully by other doctors. This is good up to a point, but it ceases to be a virtue if carried so far as to reject life- and time-saving equipment that has been thoroughly tested and proved trustworthy in other fields where performance requirements are just as stringent as those in medicine. Finally there is that hobglobin that more and more haunts modern doctors: the question of legal responsibility. If a patient is injured while a computer is administering an anesthetic, is the doctor responsible? Can the computer manufacturer be sued? Who is responsible for injury done a patient by a malfunctioning intensive care computer?"

"How does the electronics-in-medicine manufacturing field look financially?"

"Promising. Last year total sales in medical electronics totaled about $260-million, and they should hit $600-million in ten years. More than 500 companies in this country are now producing medical electronic equipment. Thirty companies engaged in the most promising market of patient monitoring are presently selling about $20-million worth of this equipment annually, and the market is said to have a growth potential of something like 50% annually for the forseeable future."

"What kind of work can a computer do in a hospital?"

"Finding some of the answers to that question has been the aim of a six-year joint effort conducted by *Bolt, Beranek, and Newman (BBN)*, a consulting development research organization at Cambridge, Mass., and the Massachusetts General Hospital (MGH) with financial support from the National Institutes of Health and the American Hospital Association. You see in a 1000-bed hospital, about 50,000 separate items of information are entered into the patients' records each day, or almost 20 million separate items a year. The technology for handling this information has remained virtually constant for the past 50 years and is mainly based on the pencil, the courier, the telephone, and on slips of paper.

"Some of the computerized programs tested at MGH by *BBN* aimed at reducing this time-consuming paper work involve compiling bed-utilization data and daily census lists, reporting laboratory-test results, organizing data within the chemistry lab, ordering and charting medications, automatically forecasting nursing staff requirements, and, of course, information storage and retrieval. I'll bring you some reports on their findings tomorrow, but right now I'll just mention Paul A. Castleman of *BBN* has concluded a computer for hospital use should be a hybrid (general/special purpose) time-sharing type to provide high reliability for handling routine EDP information and flexibility for including new applications as they occur to the staff without any mutual interference between the two programs."

"I know computers are being used to administer anesthetics, to perform—automatically—complicated blood chemistry analyses, to aid in diagnosing ailments—especially those involving the heart—and in monitoring intensive care patients. I have no doubt electronically oriented doctors and medically oriented engineers are already testing many new applications.

"I was just thinking," Barney said, "that the medical profession may have to change its emblem before long. One of the snakes of the caduceus may be replaced with a computer tape!" ▲

Look What's New

NEW HEATHKIT In-Circuit Transistor Tester

At last, a realistic price for in-circuit testing of transistors! The new Heathkit IT-18 Tester has the facilities you need and it costs a lot less. It measures DC Beta in-or-out-of-circuit in 2 ranges from 2 to 1000 (the spec. commonly used by mftrs. and schematics to determine transistor gain). It tests diodes in-or-out-of-circuit for forward and reverse current to indicate opens or shorts. Measures transistors out-of-circuit for ICEO and ICBO leakage on leakage current scale of 0 to 5,000 uA. Identifies NPN or PNP devices, anode and cathode of unmarked diodes; matches transistors of the same type or opposite types. Cannot damage device or circuit even if connected incorrectly. Big 4½" 200 uA meter. 10-turn calibrate control. Completely portable, powered by "D" cell (long battery life). Front panel socket for lower power devices. Attached 3' test leads. Rugged polypropylene case with attached cover. Build in 2 hours. 4 lbs.

NEW HEATHKIT 1-15 VDC Regulated Power Supply

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NEW HEATHKIT Crystal-Controlled Post Marker Gen.

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NEW HEATHKIT Low-Cost 5 MHz 3" 'Scope

Here is the wideband response, extra sensitivity and utility you need, all at low cost. The Heathkit IO-17 features vertical response of 5 Hz to 5 MHz; 30 mv Peak-to-Peak sensitivity; vertical gain control with pull-out X50 attenuator; front panel 1 volt Peak-to-Peak reference voltage; horizontal sweep from internal generator, 60 Hz line, or external source; wide range automatic sync; plastic graticle with 4 major vertical divisions & 6 major horizontal; front mounted controls; completely nickel-alloy shielded 3" CRT; solid-state high & low voltage power supplies for 115/230 VAC, 50-60 Hz; Zener diode regulators minimize trace bounce from line voltage variations; new professional Heath instrument styling with removable cabinet shells; beige & black color; just 9½" H. x 5½" W. x 14½" L.; circuit board construction, shipping wt. 17 lbs.

NEW HEATHKIT Solid-State Portable Volt-Ohm Meter

There's never been a better buy in meters. Solid-state circuit has FET input, 4 silicon transistors (2 used as diodes), and 1 silicon diode. 11 megohm input on DC, 1 megohm on AC. 4 DC volt ranges, 0-1000 v, with ±3% accuracy; 4 AC volt ranges, 0-1000 v. with ±5% accuracy. 4 resistance ranges, 10 ohms center scale x1, x100, x10K, x1M, measures from 0.1 ohm to 1000 megohms. 4½", 200 uA meter with multicolored scales. Operates on "C" cell and 8.4 v. mercury cell (not included). Housed in rugged black polypropylene case with molded-in cover and handle and plenty of space for the three built-in test leads. An extra jack is provided for connecting accessory probes to extend basic ranges. Controls include zero-adjust, ohms-adjust, DC polarity reversing switch, continuous rotation 12-position function switch. Easy-to-build circuit board construction completes in 3-4 hours. 4 lbs.

From Heath

NEW HEATHKIT AA-15 Deluxe Stereo Amplifier

For the man who already owns a fine stereo tuner, Heath now offers the famous amplifier section of the AR-15 receiver as a separate unit. The new AA-15 Stereo Amplifier has the same superb features: 150 watts Music Power; Ultra-Low Harmonic & IM Distortion (less than 0.5% at full output); Ultra-Wide Frequency Response (±1 dB, 8 to 40,000 Hz at 1 watt); Ultra-Wide Dynamic Range Preamp (98 dB); Tone-Flat Switch; Front Panel Input Level Controls; Transformerless Amplifier; Capacitor Coupled Outputs; Massive Power Supply; All-Silicon Transistor Circuit; Positive Circuit Protection; "Black Magic" Panel Lighting; new second system Remote Speaker Switch; 120/240 VAC. 26 lbs. *Walnut cabinet AE-18, $19.95.

NEW HEATHKIT AJ-15 Deluxe Stereo Tuner

For the man who already owns a fine stereo amplifier, and in response to many requests, Heath now offers the superb FM stereo tuner section of the renowned AR-15 receiver as a separate unit. The new AJ-15 FM Stereo Tuner has the exclusive design FET FM tuner for remarkable sensitivity, the exclusive Crystal Filters in the IF strip for perfect response curve and no alignment; Integrated Circuits in the IF for high gain, best limiting; elaborate Noise-Operated Squelch; Stereo-Threshold Switch; Stereo-Only Switch; Adjustable Multiplex Phase, two Tuning Meters; two variable output Stereo Phone jacks; one pair variable outputs plus two fixed outputs for amps., recorders, etc.; front panel mounted controls; "Black Magic" panel lighting; 120/240 VAC operation. 18 lbs. *Walnut cabinet AE-18, $19.95.

NEW HEATHKIT 2-Meter AM Amateur Transceiver

2-Meters at low cost. And the HW-17 Transceiver has 143.2 to 148.2 MHz extended coverage to include MARS, CAP, and Coast Guard Auxiliary operation. Output power of tube-type transmitter is 8 to 10 watts, AM. 4 crystal sockets plus VFO input. Relayless PTT operation. Double conversion solid-state superhet. Receiver has 1 uV sensitivity with prebuilt, aligned FET tuner, ANL, Squelch, "Spot" function, and lighted dial. Signal-strength/relative power-output meter. Battery saver switch for low current drain during receiving only. 15 transistor, 18 diode, 3 tube circuit on two boards builds in about 20 hours. Built-in 120/240 VAC, 50-60 Hz power supply and 3" x 5" speaker; low profile aluminum cabinet in Heath gray-green; ceramic mic. and gimbal mount included. 17 lbs. *Optional DC mobile supply, HWA-17-1, $24.95.

NEW HEATHKIT Home Protection System

Customize your own system with these new Heathkit units to guard the safety of your home and family. Warns of smoke, fire, intruders, freezing, cooling, thawing, pressure, water, almost any change you want to be warned about. Your house is already wired for this system, just plug units into AC outlets. Exclusive "loading" design of transmitters generates unusual signal which is detected by the Receiver/Alarm. Solid-state circuitry with fail-safe features warns if components of system have failed. Any number of units may be used in system. Receiver/Alarm has built-in 2800 Hz alarm and rechargeable battery to signal if power line fails (built-in charger keeps battery in peak condition). Receiver accepts external 117 VAC bells or horns. Smoke/Heat Detector-Transmitter senses smoke and 133°F. heat (extra heat sensors may be added to it). Utility Transmitter has several contacts to accept any type switch or thermostat to guard against any hazard except smoke. All units feature circuit board construction and each builds in 3-4 hours. All are small and finished in beige and brown velvet finish. Operating cost similar to that of electric clocks. Invest in safety now with this unique new low-cost Heathkit system.

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CIRCLE NO. 112 ON READER SERVICE CARD

Letter to a NEW TV SERVICE TECHNICIAN

Some straight talk that should go a long way to helping a newcomer shape a solid, successful service career.

Dear Jim,

Your letter was both a surprise and a pleasure. I am glad to hear that you are starting your own TV service business. And, naturally, I am flattered that you asked me for suggestions that might help you make a go of it.

Let's Get Personal

My first "hints" are personal, Jim. They include such seemingly minor things as neatness, cleanliness, and a pleasant disposition. At a shop I managed a few years ago, the technician with the highest call-back rate was a fellow who wore a dirty gray shirt and slacks to work every day, shaved only twice a week, and didn't hold with the personal cleanliness bit. Yet, put that same guy at a bench and he could turn out work just as good as anyone else's. When broad hints to shape up failed to make a dent, he lost his job—all because of his sloppy appearance.

Next to the personal impression you make on the customer, the way you treat him or her is extremely important. Remember that, given a choice among equally competent technicians, the customer will always pick the one with the nicest personality. If a customer's TV set has gone bad, he is in no mood to listen to some wise-mouth. When a customer storms and raves, he is often taking it out on the set rather than you—you have to remember that. Listening to a customer's gripes is part of your job.

Treat a customer like a VIP, because he *is* the most important person in your business life. Without him, your business doesn't stand a ghost of a chance of surviving.

Do the Job Right

The next "must" I have for you is: Do your job well. Nothing makes a customer unhappier than a job half done. When a job is half-finished, no matter how hard or how well you've worked, a customer won't like the set, won't like you, won't like the shop, and won't like what work you did do. Every time, do a *complete* job. Besides just fixing the trouble keep an eye out for impending troubles. Brush the dust out, wipe off the cabinet, clean the safety glass and the TV tube faceplate, and make those extra adjustments so that the picture looks exactly right. If you don't do the whole job the first time, the customer will expect you to come back later and finish your job at no extra charge. And he's absolutely right—you should.

That leads me to my next suggestion, Jim. If you are to do the job right, you'd better know what you're doing. You mentioned in your letter that you'd just finished a course from a correspondence school. If the school is well-known and reputable, the course you took is probably a good one. However, you'll have to know more.

You need experience. No graduate of any training course was ever a cracker-jack technician right away. Expect to sweat it out on some of the really tough ones until you've "served time." Apprentice programs exist because shop owners know that only experience will teach the techniques and short-cuts you need to get through those tough ones quickly and with confidence.

And—don't stop studying. Just because you've learned a certain amount about electronics, don't think that you know all there is to know about it. You don't. No one does. The only way you can ever become really topnotch is to expose yourself constantly to more and more electronics education. Take advanced courses. Attend distributor clinics. Read books and magazines. Go to seminars. "Experiment" on sets of your own—either your set at home or sets you take in trade-in. Once, years ago, when I was trying to polish up my newly gained skills in color-TV, I spent $200 of my hard-earned dough on a used color set. I took it home and I learned that set inside out. There wasn't anything in it I left untouched. Every color set I've run into since has been nothing worse than a variation on that first one. Those were some of the best dollars I ever spent on my electronics education.

Well, so much for you personally, Jim. On the business side, there are at least two things that will make you or break you. One is the prices you charge and the other is how carefully you keep track of your costs. Together, these make up my idea of *management.*

I knew a fellow not many years ago who lost more than $1000 a year for several years before he had any notion that he was losing money. He had a good bookkeeper, but he didn't know how to read financial statements. He knew what they said, but he didn't know what they meant; and once the story was spelled out for him, he didn't know what to do about it. If you want to be a success, study business management (a course, or even a book if that's all you can manage). And then, keep careful records. The time you spend keeping track of and controlling your business will net you more *profit* than the time you spend fixing sets. Don't ever forget that.

How Much to Charge

And that brings me to my final point, on how much you should charge. For some reason, this is one of the trickiest and least understood areas of the servicing business. There are more cockeyed notions about service pricing than about anything else in the business. And yet, the principle of intelligent pricing is simple.

You should always base your charges on three things: wages for your (or your technicians') time, *plus* your cost of doing business, *plus* a profit on your investment. If you leave out *any* of these things, you are only fooling yourself, and you'll end up like the guy I mentioned earlier: he eventually used up all his capital and went out of business, broke.

Somehow, quite a while ago, the idea got around the servicing fraternity that you should charge less and less when you wanted to get more and more business. *This just isn't so.* Absolutely not.

One very successful company, as an experiment a couple of years ago, began raising its service charges every six months. It had been charging $4.00 for a service call, and losing money on every one of them. Neither the owner nor his employees could be paid a decent wage. Today, this company has tripled its charge. Every service call nets a tidy profit, and the owner and employees are all very well paid—as well paid, in fact, as electricians, plumbers, and other skilled workers in their locality. What happened to the volume of customers? Not a thing. In fact, this year the shop had 8 percent more customers.

A word of caution, though. It was not the rise in the service-call charge that netted the increase in customers. It was the fact that this shop does a complete and thorough job on every set and does it with neat and competent technicians who know how to treat customers properly. The owner keeps complete records of all costs and manages his business carefully and competently.

I know you have the will and ambition to build yourself a solid career in electronics, Jim. To that, I'd like to add my own wish for just enough luck to help you over the rough spots.

Sincerely,
LARRY ALLEN

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(*Continued from page 22*)

gering 110 watts per channel at the clipping point (about 0.5% distortion). Hum and noise, referred to 10 watts, were −72 dB on the tuner input and −58 dB on the phono input, both well below published ratings. The RIAA equalization was within ±1 dB from 30 to 15,000 Hz.

The amplifier runs slightly warm and must be ventilated. It never faltered during our severe full-power measurements, although it became uncomfortably warm to the touch. There is no stereo headphone jack and no internal switching for remote speaker systems. No doubt the company engineers considered these to be in the "gadget" category.

Now that we have tested the amplifier in our laboratory and listened to it at length in our homes, we can report that the *AR* amplifier is an excellent unit—in fact it ranks among the very best available. Perhaps its most remarkable feature is its price—$225—which is less than any comparably rated amplifier and is actually less than some of the better kit-type amplifiers. The optional walnut cabinet is $15. ▲

Schober LSS-10A Speaker System

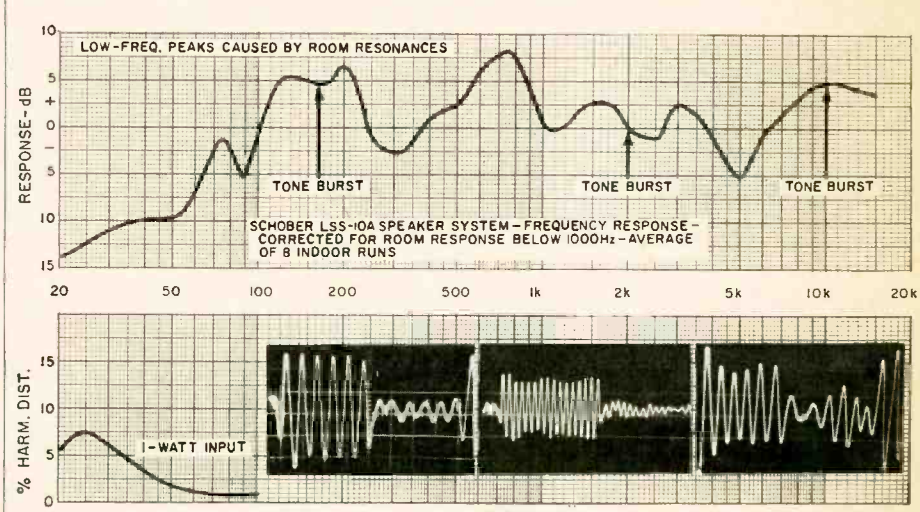
For copy of manufacturer's brochure, circle No. 35 on Reader Service Card.

THE name *Schober* is well-known to fanciers of electronic organs. For over twelve years, *Schober* has produced a line of electronic organ kits, ranging from a modest spinet to a two-manual recital organ comparable to a pipe organ in its playing facilities.

These organ kits do not include the amplifier or speaker system. In the March, 1965 issue we reported on the *Schober* TR-2 40-watt transistor amplifier, a husky unit designed for the rigors of organ reproduction. The Model LSS-10A speaker is the basic reproducer for this particular family of organs, although a larger model is also available.

The LSS-10A is a large, floor-standing system, measuring 24" wide x 16" deep x 34" high. It is supplied with the walnut-veneered cabinet fully assembled, but the purchaser must mount the speakers, install the internal padding and grille cloth, and wire the crossover network. The enclosure is a ducted-port bass-reflex design, with a single 12" woofer having a 3.4-pound magnet, and an 8" middle and high-frequency driver. The smaller unit is in an acoustically isolated compartment within the main enclosure. A small cutout in the speaker panel, normally covered by a plate, allows installation of an optional horn-type tweeter for extended high-frequency response, if this is desired.

The crossover frequency between the woofer and high-frequency driver is 250 Hz and the over-all frequency response of the system is rated at 32 to 12,000 Hz. This is more than adequate for organ applications, although it might



be considered somewhat lacking in the upper ranges for general high-fidelity music reproduction. It is for such applications that the optional tweeter is offered. The LSS-10A is relatively efficient, so that it is capable of delivering the highest levels required for home organ reproduction with the TR-2 amplifier as a driver.

We tested the speaker system in the same manner as we do all speaker systems. It was placed on the floor adjacent to an end wall of our test room and the multiple response curves were made with a total of eight microphone positions throughout the room. These were averaged to derive a single composite response curve. Harmonic distortion at low frequencies was measured with the microphones about one foot from the woofer, at a driving level of 1 watt (into an 8-ohm nominal load resistance). Tone-burst measurements were made with the microphone on the central axis of the system, sufficiently close to minimize the effects of room reflections.

The frequency response was within ±6.5 dB from 65 to 15,000 Hz. Below about 80 Hz, the response fell off at a gradual 6 dB octave rate. Low-frequency harmonic distortion was very low, reaching a maximum of only 8% at 24 Hz. At all frequencies above 33 Hz, the distortion was under 5% at a 1-watt drive level. The tone-burst response was fair, with some ringing at several frequencies but there was no severe breakup or generation of spurious frequencies.

Although the LSS-10A was designed primarily for reproduction of electronic organ music, we listened to it with ordinary music and speech program material of various kinds. Subjectively, it seemed to have a heavier bass than the response curve would suggest. The mid-range was somewhat subdued, and there was a slight accentuation of record hiss, as compared to several other compact speaker systems of similar or higher price. The system is much more efficient than any of the bookshelf speakers which we have used and can deliver an impressive sound level without straining. When reproducing organ music, it did a very fine job and was thoroughly musical and listenable on the general type of program material that we used.

The *Schober* LSS-10A, in kit form, is priced at $175. It is available with the cabinet sanded, but unfinished, for $165.50. The speakers and crossover components, less cabinet, can be had for $69.50, and the optional tweeter is $28. Speakers of the size and efficiency of this one generally cost far more. It can serve quite adequately for general hi-fi listening, and should be a potent performer when driven by an electronic organ. ▲

VR's for Camera Tubes

By CHARLES BRYANT/Electro-Visual Dept.
Fairchild Space & Defense Systems, Fairchild Camera and Instrument Corp.

Traditionally, voltage regulators in television camera systems have been expensive and ineffective. A new subminiature regulator used in closed-circuit television systems, combines reliability with low cost.

TELEVISION systems are being used by industry to observe the mixing of dangerous chemicals, monitor blast furnaces, act as guards and watchmen, and even bank tellers. In all of these applications, two qualities are paramount—the television camera must be reliable and the picture must be stable.

Today's industrial television cameras can produce sharp, well-focused images with 700 to 1000 line resolution. But unstable vidicon control voltages may cause the TV image to be fuzzy and indistinct. To assure stability, *Fairchild Camera and Instrument Corp.* has incorporated a subminiature voltage regulator in the outputs of all power supplies used with its industrial and military television cameras. The regulators, produced by *Signalite Inc.*, are an advanced development of the neon glow lamp. They are capable of regulating to within one volt over the rated current range (Fig. 1) and have very low temperature coefficients.

Stable Voltage, Stable Picture

As previously indicated, any variation in voltage on the control grid, the accelerating grid, the focusing grid, or the decelerator grid will result in an imperfect picture. For example, the electron beam which is scanning horizontally at frequencies of 15,750 Hz and at 60 Hz vertically, produces a signal voltage which is directly proportional to the amount of light incident on the light-sensitive layer of the signal electrode. If instability within the system causes the voltage to vary rather than the image on the signal electrode, the output will not be a true representation of the scene under observation.

Years ago when industrial television cameras had resolutions of about 350 lines, precise regulation was not important. In fact, many cameras had no provisions for voltage regulation. But as camera resolution improved, so did the requirements for regulation. Camera manufacturers began to use transistorized power supplies, regulated transformers, large gas tubes, and zener diodes for control.

The transistorized power supply was usually a complex d.c.-to-d.c. converter that required a great number of components. The regulating transformers (which controlled the camera's input voltage but left internally developed voltage variations untouched) were large and heavy and could not be used with portable television units. In addition to large size, the gas tube regulators did not have the quality of regulation needed by high-resolution TV cameras. All of these were expensive. Zener diodes were out because their temperature coefficients were too poor to make them useful. Consequently, development of the subminiature regulators meant that control devices which are reliable, low in cost, and small enough to meet miniaturization requirements were at last available.

Regulated Grid Potentials

In the television camera, the voltage on each of the vidicon's four grids is regulated separately (Fig. 2). Grid #1 is the beam control and operates at a voltage of 0 to

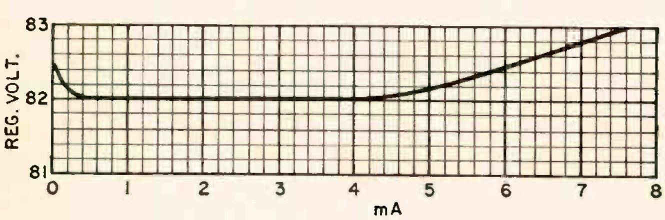


Fig. 1. Regulated voltage of the subminiature tube varies a maximum of one volt over the entire rated current range.

Fig. 2. Typical television camera system for industrial-type use.

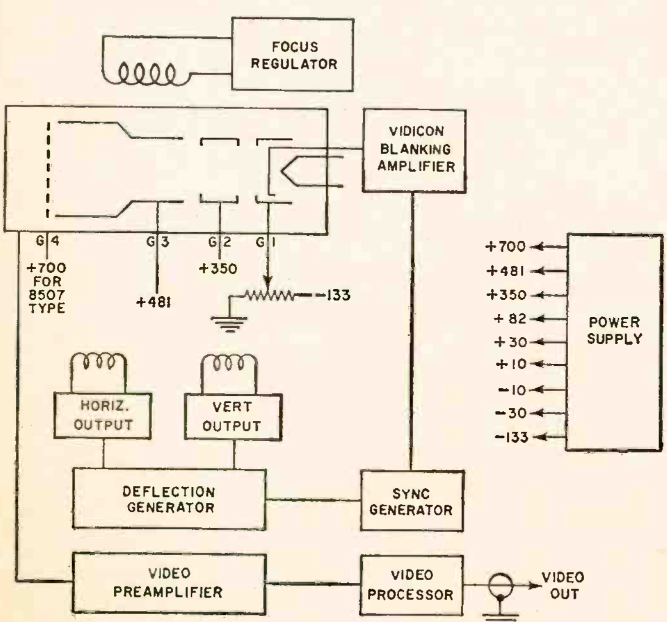
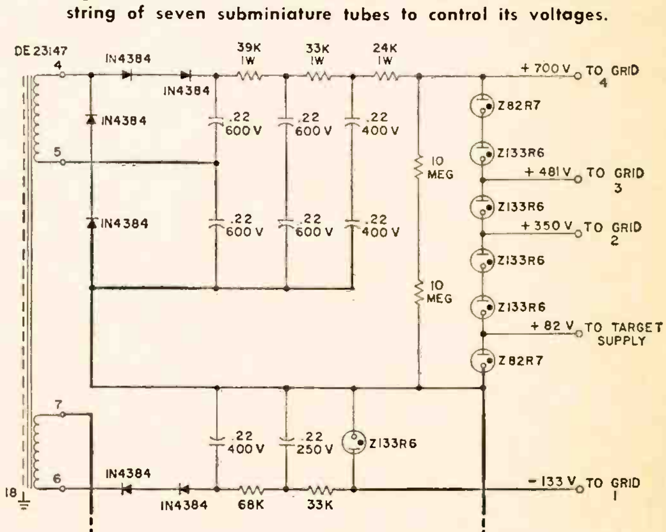


Fig. 3. Fairchild's TO950 industrial television camera uses string of seven subminiature tubes to control its voltages.



—133 volts. This grid controls the electron beam which scans the light-sensing layer of the signal electrode. If the voltage level changes in the negative direction, the picture will be lost completely; if the voltage becomes more positive, defocusing will occur and clarity will be lost in the center of the picture.

Grid #2 is the accelerator which operates at 350 volts. Grid #3 is the focusing electrode and Grid #4 is the decelerator. The decelerator is a fine mesh screen located adjacent to the photoconductive layer and is connected to Grid #3. Its purpose is to make the electron beam strike the target at right angles to the surface. In the Type 7735 vidicon, Grids #3 and #4 both operate at 481 volts.

The power supply for the *Fairchild* TC950 industrial television camera consists of a high-voltage power supply for the vidicon tube and a low-voltage power supply for the transistorized circuitry (Fig. 3).

The high-voltage section of this power supply consists of a secondary (Terminals 4 & 5) which feeds approximately 350 volts a.c. to a voltage doubler/rectifier system. The output of the voltage doubler is filtered by an *RC* network and fed to the string of subminiature voltage regulators.

The maximum voltage output of the power supply is +700 volts. This voltage is dropped through ZR82R7 and Z133R6 subminiature voltage regulators to the next tap at +481 volts. Voltage is then further reduced by the drop across one more Z133R6 to +350 volts. The final positive voltage tap, +82 volts, through another series arrangement, is obtained by the voltage drops across the next two Z133R6 regulators.

A half-wave rectifier in the vidicon grid power supply is regulated by a Z133R6 and supplies the —133 volts for the Grid #1 of the vidicon.

The +700 and +481 output voltage taps are regulated to ±0.7%. The +350 voltage output is less demanding; it is regulated to within ±1.1%. The +82-volt output is held at ±1.2% and the —133-volt potential is regulated to within ±1.3%. ▲

Table 1. Typical characteristics of three common voltage regulators.

Characteristics	Large Gas Tube Reg. (Type VR90)	Zener Diode 91 V, 1 W Low Tol.	Zener Diode 91 V, 1 W High Tol.	Submin. Gas Tube Regulator (Z91R2)
Regulation Tolerance	±3%	±20%	±5%	±1%
Approximate Temperature Coeff.	—15 mV/°C	135 mV/°C		—3.5 mV/°C
Approximate Size	ST12 tube	DO-7 to TO-3 can, or lug type to 1½" long by ½" d		T-2 Bulb 1⅟₁₆" long
Reliability (Life)	2000 hours	30,000 hours		30,000 hours
Stability	May exhibit jump characteristics	Excellent		Excellent
Voltage Range	3%	2%		1%
Current Range	5-40 mA	.25 to 7 mA		.25 to 7 mA
Shock & Vibration Tolerance	Must be isolated from vibration & shock	Good		Good
Installation	Socket	Solderable leads		Solderable leads
Mounting Position Restrictions	Must be upright in certain applications	None		None

Color-TV Set Shows Slides

(*Continued from page* 35)

be used independently for tape recording and playback.

In the tape unit, the slide-changing signal is a 60-Hz tone, derived from the power line, and recorded on the tape whenever the "slide-change" button is depressed during recording. On playback, this tone is sensed by a highly selective amplifier which operates a relay. A number of provisions guard against false triggering, including the use of a switch which senses the difference between home-made tapes which may have the synchronizing tone recorded on them, and prerecorded tape cartridges which, of course, do not.

Performance of the system exceeds NTSC standards. Resolution is about 40 percent greater than normal color-TV. The absence of the 3.58-MHz grain improves picture quality. Black-and-white slides can also be projected on the TV tube.

Controls & Adjustments

User controls on the scanner include contrast and color level. These controls can be used to enhance the quality of color slides, which of course is not possible with the conventional optical projector. Brightness is adjusted with the normal TV brightness control.

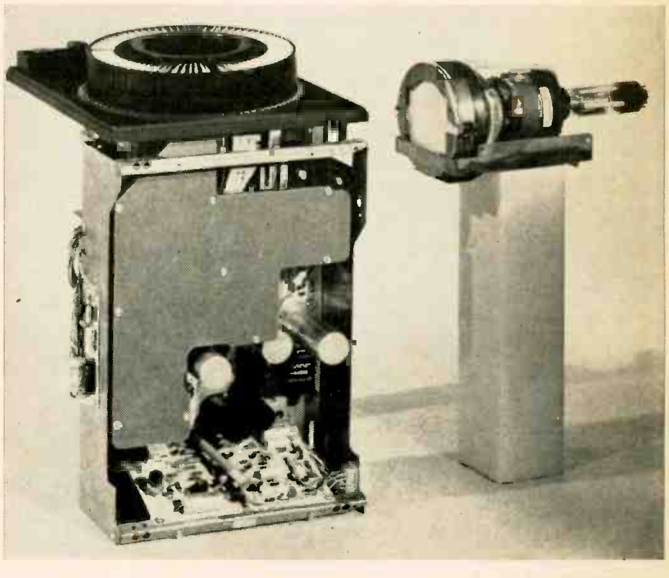
There is no tint or hue control associated with the slide scanner, nor is one necessary. Remember that this is a 3.58-MHz phase control to compensate for TV station and transmission errors. In this system, there is no 3.58-MHz subcarrier, no transmission errors, and no need for user adjustment.

Color balance is adjusted at the factory or by the service technician with a "white-window" slide (cardboard with a hole) and scope. The red, blue, and green photomultipliers are adjusted for equal output at specified test points.

The only other factory or service adjustments are: light-source CRT position (picture size), centering, optical focus, electrical focus, and light-source CRT beam current. There is also a sensitivity adjustment in the audio circuit which senses slide-change signals.

Most of the circuitry is accessible with the complete assembly mounted in the cabinet. The "window" slide, scope, and v.t.v.m. will track down just about any circuit malfunction. The chassis and optical system slip out easily and as a unit, as shown in the photo below. A schematic and service instructions are packed with each set. ▲

Flying-spot scanner chassis with slide-change mechanism mounted on top. The light-source CRT shown at right.



IC Preamplifier

(*Continued from page 29*)

dependence, so that feedback is greater at higher frequencies. This loop is responsible for the low-frequency boost that is produced.

Three capacitors at switch S1*A* produce a high-frequency rolloff. As frequency is increased, a smaller load is applied to the first transistor's collector circuit. In the microphone position, no bass boost is employed; the capacitor at switch S1*A* limits high-frequency response to about 30 kHz. (See Fig. 2.)

If higher gain is required for tape playback applications, the preamp gain can be increased by providing an additional capacitor to ground across part of the emitter resistance. A large capacitor is required because of the low emitter resistance levels, if the extra gain is to be useful at low frequencies. For example, a 125-μF capacitor can be used across a 560-ohm resistor, with a 180-ohm unbypassed series resistor.

This gain-boosting technique must be applied carefully for tape playback work. If head inductance exceeds 5 mH or so, input circuit loading will result in a strong treble rolloff.

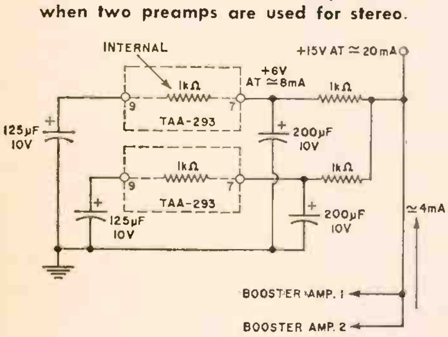
The rated output of the preamp is about 0.5-volt r.m.s. for a good overload ratio. If this is insufficient, then the booster amplifier of Fig. 3 should be used. This will produce a maximum output of about 4 volts r.m.s. into a 47,000-ohm or higher load.

Amperex's A104 transistor used in the booster may be replaced by any silicon *n-p-n* type with a *beta* over 150 or so. Almost any of the new small-signal silicon-planar transistors should be satisfactory.

For stereo operation, two TAA-293 preamplifiers (and booster amplifiers, if used) will be required. For maximum channel isolation it is suggested that separate decoupling be used to each system. This is shown in Fig. 4.

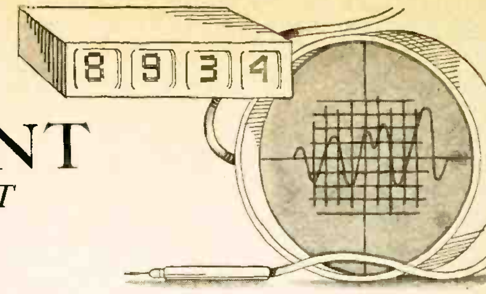
The applications suggested here for the TAA-293 integrated circuit are only typical. Due to the accessibility to the IC internal connections, a considerable latitude of design freedom is possible when this IC is used. ▲

Fig. 4. This decoupling system will prevent feedback and crosstalk problems when two preamps are used for stereo.



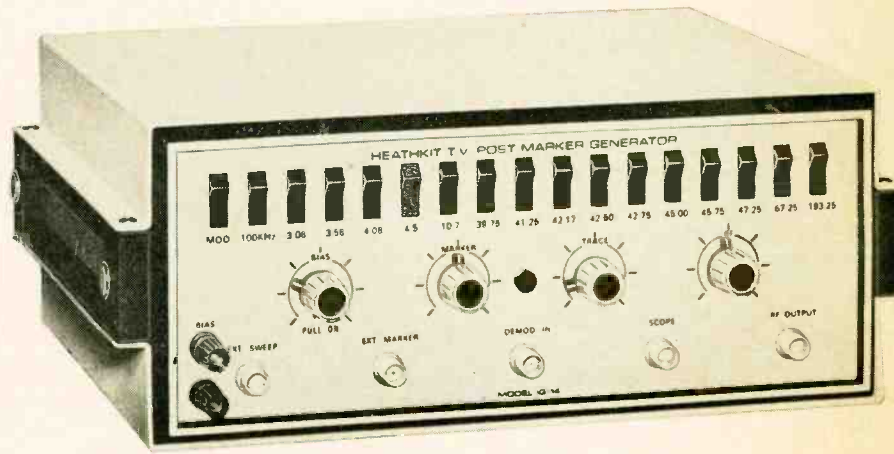
TEST EQUIPMENT

PRODUCT REPORT

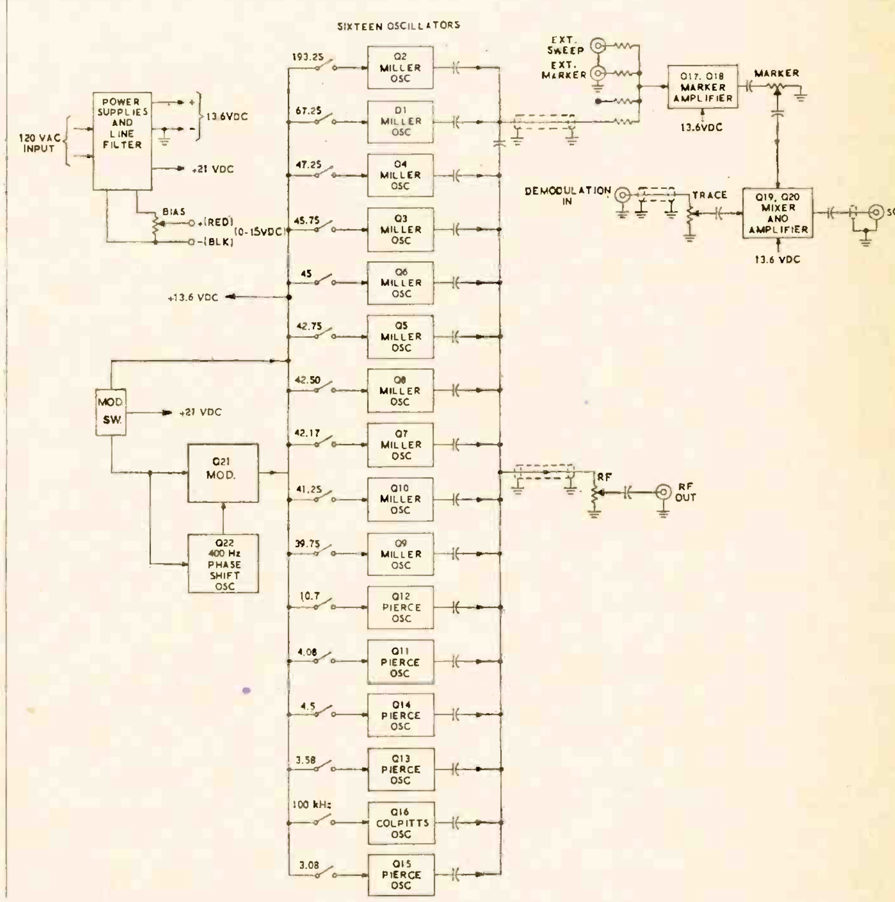


Heath Model IG-14 Marker Generator

For copy of manufacturer's brochure, circle No. 36 on Reader Service Card.



ANY technician who has ever sweep-aligned a TV or FM set knows the value of an accurate marker generator to indicate precise frequencies on the response curve produced by his sweep generator. A good many sweep generators have built-in facilities for marker generation, consisting of a rather simple variable-frequency r.f. generator. Some of these generators have a front-panel



socket to accommodate a single crystal, say at 10.7 MHz or at 4.5 MHz, in order to produce a highly accurate marker at that frequency. The new *Heath* Model IG-14 contains no less than 16 separate oscillators, 15 of them being highly precise crystal oscillators that operate within 0.005% or 0.01% of the indicated frequency.

This instrument is referred to as a "post marker generator" because the various markers are introduced *after* the tuned circuits that shape the response curve rather than before. In this way, the tuned circuits do not alter the shape and amplitudes of the markers as would be the case if the markers were applied to the tuned circuits. With the post-marker technique, it is possible to spot dips in the response curve where trap "suck-out" frequencies occur and to completely mark any curve regardless of its shape.

The Model IG-14 must be used in conjunction with a separate sweep generator which supplies it with a sample of its sweep signal in order to generate the "birdie" markers. A scope is, of course, also required in order to display the swept response-curve waveform. By using six of the crystal oscillators simultaneously, it is possible to show on a single TV i.f. response curve exact frequencies for the picture i.f. carrier, sound i.f. carrier, the maximum amplitude point, the −1.5 dB and −6 dB frequencies, and trap frequency. Adjacent-channel trap frequencies can also be marked by switching in additional oscillators. Frequencies available in the TV i.f. range are: 39.75, 41.25, 42.17, 42.50, 42.75, 45.00, 45.75, and 47.25 MHz. The chroma bandpass and sound i.f. curves can be marked with crystal oscillators at 3.08, 3.58, 4.08, and 4.5 MHz. The FM i.f. can be marked with a crystal oscillator at 10.7 MHz, while TV channels 4 and 10 pix carrier can be marked with crystal oscillators at 67.25 and 193.25 MHz. In addition, a 100-kHz *LC* oscillator, which can be adjusted to zero-beat with WWV, supplies closely spaced r.f. markers while a 400-Hz *RC* oscillator provides audio modulation.

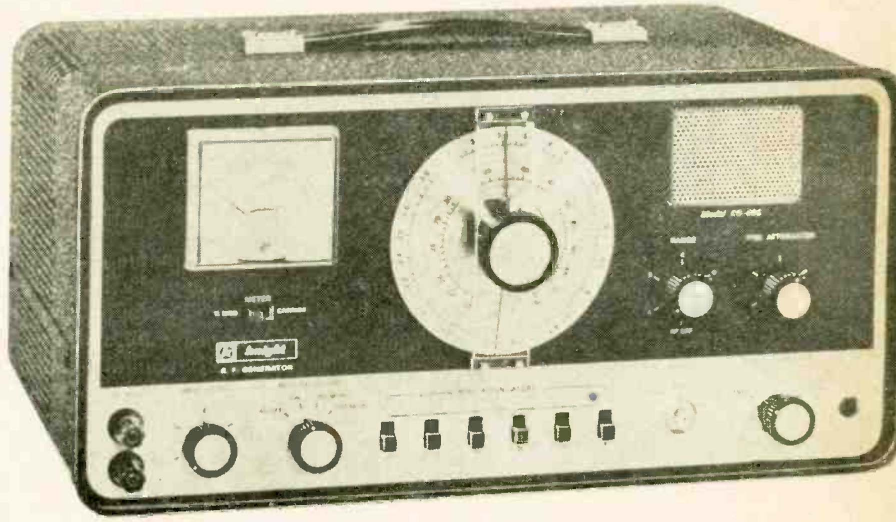
This compact solid-state, a.c.-line-operated generator uses 22 silicon transistors and 4 diodes to generate all the signals mentioned above. In addition, a built-in bias supply that can deliver an adjustable voltage of either polarity up to 15 to 18 volts (depending on load) is included. This is required during sweep alignment in order to bias the amplifier stages being aligned.

All the crystal oscillators in the kit we constructed were highly active and they operated over a wide range of collector tuning adjustment. By adjusting these circuits in the Miller crystal oscillators, it was possible not only to set the circuits to be stable and self-starting, but also to adjust the amplitudes of the outputs so as to make all markers the same size. The Pierce crystal oscillators used for the lower frequencies were, of course, not adjustable.

Construction of the kit was simple; all the oscillators are on one printed-circuit board while the remainder of the circuitry is on another. Once these boards are completed and the front-panel switches, controls, and coax connectors are wired up, the unit is ready to operate. Price of the IG-14 post marker generator kit is $99.95. ▲

Knight Model KG-686 R.F. Signal Generator

For copy of manufacturer's brochure, circle No. 37 on Reader Service Card.



THE Model KG-686 signal generator is another product in *Knight's* new line of solid-state test equipment in kit form. We have already covered a matching sweep generator in considerable detail in our January "Test Equipment Product Report." This r.f. signal generator also uses all silicon transistors for temperature stability and long-lived operation.

The generator covers a frequency range from 100 kHz to 54 MHz. This includes the television i.f. frequencies so the instrument can be used for trap alignment or for marking an i.f. response curve. Frequency accuracy is within 1.5 percent on all five bands while the built-in 100 kHz/1 MHz crystal calibrator (accuracy 0.05 percent) provides audio heterodyne beats—through built-in detector, amplifier, and speaker—that are close enough together so as to more accurately calibrate the dial reading of the generator. The switchable meter operates in conjunction with the six-switch step attenuator and fine attenuator to show r.f. carrier output or modulation level. Total capability of the shielded step attenuator is −96 dB while a calibrated output as low as −106 dB (0.5 microvolt) is obtainable. Careful chassis layout and the use of plenty of copper shielding assure that radiated leakage is kept to a minimum.

The generator uses a floating-type chassis-isolated oscillator, which also minimizes radiated leakage. There are tunable coils and trimmer capacitors on each band so that good frequency accuracy and close tracking can be produced.

The instrument uses ten transistors and six diodes, one of which is a zener for power-supply regulation. All wiring in the kit is point-to-point using a large number of widely spaced terminal strips for parts mounting and interconnections. Printed circuits are not used. Price of the kit, which is available from *Allied Radio*, is $95. ▲

Hewlett-Packard Model 220A Square-Wave Generator

For copy of manufacturer's brochure, circle No. 149 on Reader Service Card.

THE new *H-P* Model 220A provides a negative square-wave output with a pulse repetition rate of from 1 Hz to 10 MHz. The pulse repetition rate may be adjusted by a front-panel control, or it may be remotely varied by application of a d.c. voltage to a rear-panel connector. The generator may also be used as a gated source by applying a pulse to the connector.

The Model 220A is a high-quality, general-purpose test instrument that may be used for testing video or audio amplifier performance and in making phase shift, frequency response, or transient measurements. In computer, pulse code, telemetering applications, it provides a variable trigger source for switching purposes.

Frequency is selectable in seven decade ranges. A vernier selects the exact frequency desired. Source impedance is 50 ohms. This preserves the clean waveshape with its less than 15-nanosecond rise time, by absorbing reflections from impedance mismatches on the output cable. If the source impedance were not 50 ohms, reflections would be re-reflected, thus distorting the square wave form produced.

The generator uses all silicon transistors and diodes and operates from the 60-Hz power line. It measures only 5⅛″ wide by 3⁷⁄₁₆″ high by 11⅝″ deep. Price of the instrument is $195. ▲

EXECUTIVE RESERVES NEEDED

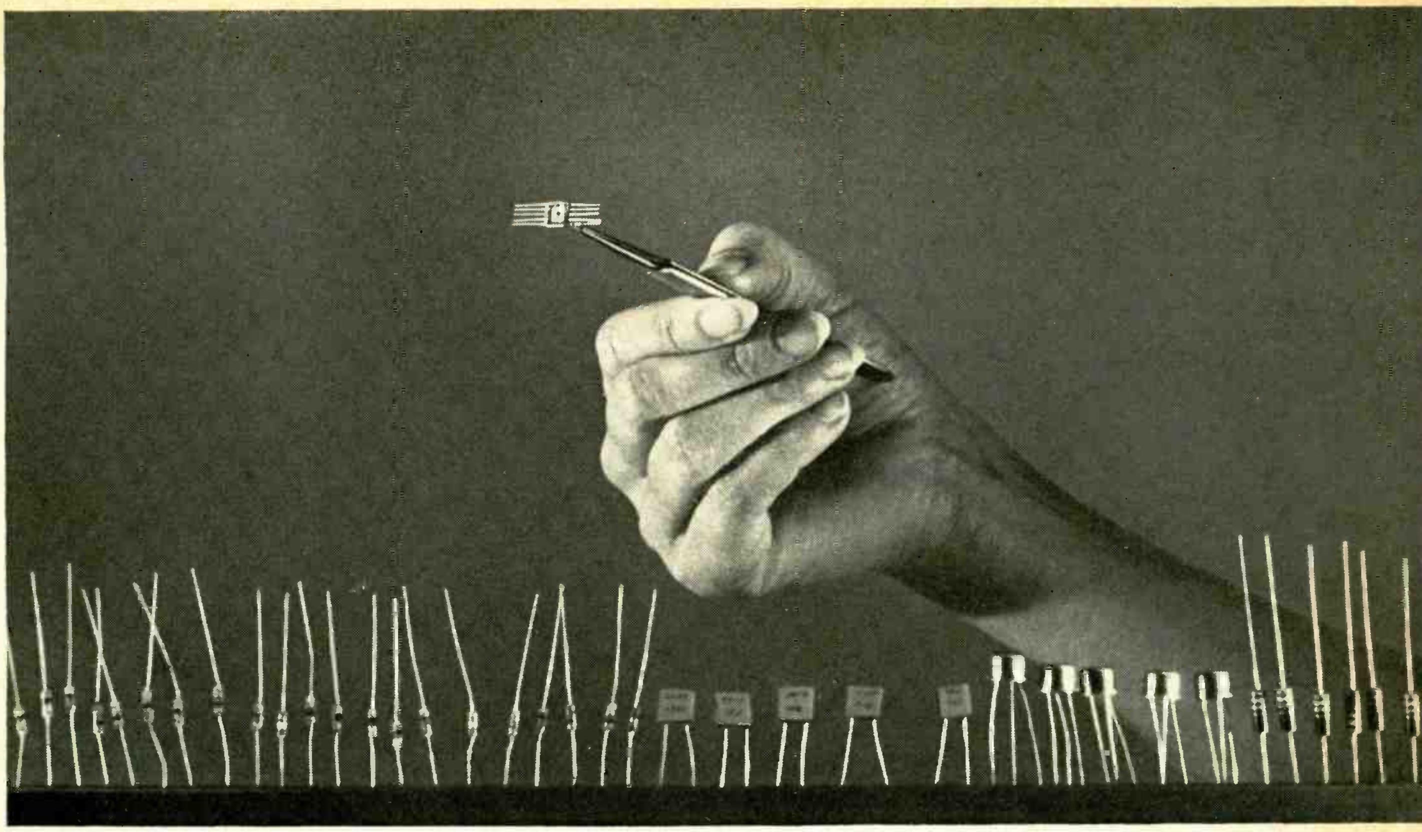
THE U.S. Department of Commerce has issued a call for executives to fill vacancies in the National Defense Executive Reserve, the civilian organization that helps the Government mobilize industry in times of national emergency. The need is especially acute in the scientific, photographic, and business equipment division of the corps.

The Division's prime functions are to help foster, promote, and develop business opportunities and direct industrial mobilization activity of the BDSA in the industrial areas covered. Executive Reserve candidates should be in the 35-55 age bracket and have executive experience in business administration, production procedures, and/or industrial distribution processes. Appointments are for three years and are renewable.

The BDSA industrial unit of the Executive Reserve has 1450 members at present. The Office of Emergency Planning has authorized an increase to 3000.

In past emergencies—three times in this century, the U.S. was forced to expand its civilian staff to meet military defense requirements. Each time nongovernmental sources were called upon for additional executive talent to fill important administrative positions. This proved to be a costly, time-consuming task, especially when such recruiting had to be done on an improvised basis. The Defense Production Act of 1950 was designed to eliminate such hit-and-miss recruiting by maintaining industrial mobilization capability. A 1955 amendment to the Act provided for the National Defense Executive Reserves.

The Business and Defense Services Administration has developed manpower requirements for specific skills needed to staff the Unit at national, regional, and field-office levels. To see if you qualify and for additional information on the Reserves, contact the Office of Industrial Mobilization (Code 520), BDSA, U.S. Department of Commerce, Washington, D. C. 20230, or any of the Department's field offices. ▲



50 functions in a single chip. *The functions of 50 separate transistors, diodes, resistors and capacitors can now be formed by the tiny dot in the center of the integrated circuit held by the tweezers.*

The "Chip"

...will it make or break your job future?

THE DEVELOPMENT OF INTEGRATED CIRCUITRY is the dawn of a new age of electronic miracles. It means that many of today's job skills soon will be no longer needed. At the same time it opens the door to thousands of exciting new job opportunities for technicians solidly grounded in electronics fundamentals. Read here what you need to know to cash in on the gigantic coming boom, and how you can learn it right at home.

TINY ELECTRONIC "CHIPS," each no bigger than the head of a pin, are bringing about a fantastic new Industrial Revolution. The time is near at hand when "chips" may save your life, balance your checkbook, and land a man on the moon.

Chips may also put you out of a job...or into a better one.

"One thing is certain," said *The New York Times* recently. Chips "will unalterably change our lives and the lives of our children probably far beyond recognition."

A single chip or miniature integrated circuit can perform the function of 20 transistors, 18 resistors, and 2 capacitors. Yet it is so small that a thimbleful can hold enough circuitry for a dozen computers or a thousand radios.

Miniature Miracles of Today and Tomorrow

Already, as a result, a two-way radio can now be fitted inside a signet ring. A complete hearing aid can be worn entirely inside the ear. There is a new desk-top computer, no bigger than a typewriter yet capable of 166,000 operations per second. And it is almost possible to put the entire circuitry of a color television set inside a man's wrist-watch case.

And this is only the beginning!

Soon kitchen computers may keep the housewife's refrigerator stocked, her menus planned, and her calories counted. Her vacuum cleaner may creep out at night and vacuum the floor all by itself.

Money may become obsolete. Instead you will simply carry an electronic charge account card. Your employer will credit your account after each week's work and merchants will charge each of your purchases against it.

When your telephone rings and nobody's home, your call will automatically be switched to the phone where you can be reached.

Doctors will be able to examine you internally by watching a TV screen while a pill-size camera passes through your digestive tract.

New Opportunities for Trained Men

What does all this mean to someone working in electronics who never went beyond high school? It means the opportunity of a lifetime—if you take advantage of it.

It's true that the "chip" may make a lot of manual skills no longer necessary.

But at the same time the booming sales of articles and equipment using integrated circuitry has created a tremendous demand for trained electronics personnel to help design, manufacture, test, operate, and service all these marvels.

There simply aren't enough college-trained engineers to go around. So men with a high school education who have mastered the fundamentals of electronics theory are being begged to accept really interesting, high-pay jobs as engineering aides, junior engineers, and field engineers.

How To Get The Training You Need

You can get the up-to-date training in electronics fundamentals that you need through a carefully chosen home study course. In fact, some authorities feel that a home study course is the best way. "By its very nature," stated one electronics publication recently, "home study develops your ability to analyze and extract information as well as to strengthen your sense of responsibility and initiative." These are qualities every employer is always looking for.

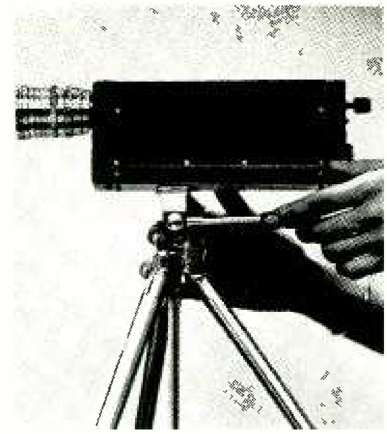
If you do decide to advance your career through spare-time study at home, it makes sense to pick an electronics school that specializes in the home study method. Electronics is complicated enough without trying to learn it from texts and lessons that were designed for the classroom instead of correspondence training.

The Cleveland Institute of Electronics has everything you're looking for. We teach only electronics—no other subjects. And our courses are designed especially for home study. We have spent over 30 years perfecting techniques that make learning electronics at home easy, even for those who previously had trouble studying.

Your instructor gives your assignments his undivided personal attention—it's like being the only student in his "class." He not only grades your work, he analyzes it. And he mails back his corrections and comments the same day he gets your lessons, so you read his notations while everything is still fresh in your mind.

Always Up-To-Date

Because of rapid developments in electronics, CIE courses are constantly being revised. Students receive the most recent revised material as they progress through their course. This year, for example, CIE students are receiving exclusive up-to-the-minute lessons in Microminiaturization, Logical Troubleshooting, Laser Theory and Application, Single Sideband Techniques, Pulse Theory and Application, and Boolean Algebra. For this reason CIE courses are invaluable not only to newcomers in Electronics but also for "old timers" who need a refresher course in current developments.



Tiny TV camera *for space and military use is one of the miracles of integrated circuitry. This one weighs 27 ounces, uses a one-inch vidicon camera tube, and requires only four watts of power.*

Praised by Students Who've Compared

Students who have taken other courses often comment on how much more they learn from CIE. Mark E. Newland of Santa Maria, California, recently wrote: "Of 11 different correspondence courses I've taken, CIE's was the best prepared, most interesting, and easiest to understand. I passed my 1st Class FCC exam after completing my course, and have increased my earnings $120 a month."

Get FCC License or Money Back

No matter what kind of job you want in electronics, you ought to have your Government FCC License. It's accepted everywhere as proof of your education in electronics. And no wonder—the Government licensing exam is tough. So tough, in fact, that without CIE training, two out of every three men who take the exam fail.

But better than 9 out of every 10 CIE-trained men who take the exam pass it.

This has made it possible to back our FCC License courses with this famous Warranty: you *must* pass your FCC exam upon completion of the course or your tuition is refunded in full.

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Want to know more? The postpaid reply card bound in here will bring you a free copy of our school catalog describing today's opportunities in electronics, our teaching methods, and our courses, together with our special booklet on how to get a commercial FCC License. If card has been removed, just send us your name and address.

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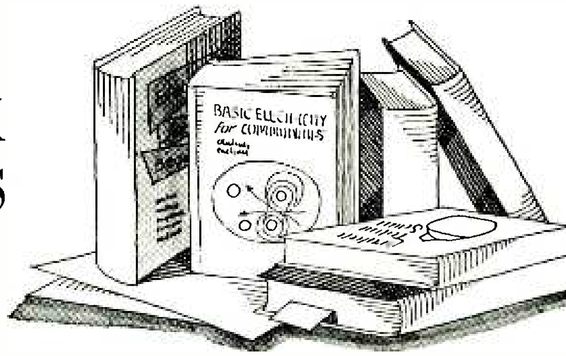
BOOK REVIEWS



"LASER TECHNOLOGY AND APPLICATIONS" edited by Samuel L. Marshall. Published by *McGraw-Hill Book Co.*, New York. 286 pages. Price $14.00.

Eleven authorities in the areas of lasers have contributed to this volume which is directed to engineers and physicists on a senior or first-year graduate level. Their dependence on mathematics is extremely heavy and persons without the requisite engineering background will find this text hard going.

But for those who do have the background, this is an extremely valuable contribution to the literature of lasers. Each contributor writes about his own speciality: Dr. C. Bowness of *Raytheon*, P.A. Cirincione of the U.S. Naval Training Device Center, Dr. C.G.B. Garrett, Dr. E.I. Gordon, and Dr. J.P. Gordon of *Bell Labs*; Dr. C.F. Luck, Jr., *Raytheon*; Dr. H.T. Minden, *Sperry Rand;* Dr. A. Paladino, *Raytheon*; T. Schultz, *TRG*; Dr. C.M. Stickley, Air Force Cambridge Research Labs; Dr. L.M. Vallese, *ITT-Federal*; and L. Waszak, *TRG*.

The text is divided into nine chapters covering an introduction to lasers, backgrounds in modern physics, elements of laser theory, solid-state lasers, semiconductor diode lasers, gas lasers, crystal and glass laser material synthesis, laser instrumentation, and applications of lasers.

* * *

"ELECTRICAL CHARACTERISTICS OF TRANSISTORS" by R. L. Pritchard. Published by *McGraw-Hill Book Company*, New York. 697 pages. Price $19.50.

This volume has been prepared as a "middle ground" text to fill the void between texts on semiconductor physics and transistor circuit applications. The author, now professor of electrical engineering at Stanford but formerly staff director of engineering at *Texas Instruments'* Semiconductor/Components Division, begins with a brief introduction in which the qualitative aspects of *p*- and *n*-type semiconductors and the various types of *p-n* junctions are covered and then goes on to discuss d.c. characteristics, low- and high-frequency a.c. characteristics. equivalent circuits, switching response, the linear-performance characteristics of gain, distortion, noise, and temperature variations.

The necessary basic fundamentals of semiconductor physics are covered briefly in the first chapter—in terms of classical physics where possible.

The other eight chapters cover the *p-n* junction diode; transistor static characteristics; low-frequency small-signal characteristics; high-frequency characteristics: alloy-like model; high-frequency a.c. characteristics—generalized switching characteristics; signal transmission properties; and thermal effects in transistors.

A bibliography of some thousand works by 800 authors is appended to the text and represents a veritable gold-mine of additional data on any or all of the topics discussed in the text.

* * *

"HANDBOOK OF SEMICONDUCTOR CIRCUITS". Published by *Tab Books*, Blue Ridge Summit, Pa. 17214. 448 pages. Price $7.95.

This is a hard-cover edition of a U.S. Government Printing Office publication entitled "Military Standardization Handbook, Selected Semiconductor Circuits" (MILHDBK-215).

It contains 124 examples of standard transistor circuits, complete with operational data, for amplifiers, oscillators, logic and switching circuits, power supplies, and various nonlinear circuits. Directed to engineers and technicians, each circuit description includes data concerning any unique design or operating feature, a complete schematic, and parts values. The text is lavishly illustrated.

* * *

"MEASURING METHODS AND DEVICES IN ELECTRONICS" by A.C.J. Beerens. Published by *Hayden Book Company, Inc.*, New York. 176 pages. Price $4.25. Soft cover.

This book has been translated from the Dutch and is one of a series of technical treatises published by *Philips of Eindhoven*. The technical level is such that both electronics engineers and technicians will find it useful.

The first part of the book deals with various types of measuring instruments —equipment for measuring current and voltage, the CRO and its accessories, signal generators, impedance measuring bridges, frequency meters, regulated power supplies—while the second part of the book covers various types of measuring methods.

There has long been a need for a book of this type and luckily this volume goes a long way towards meeting that need. Only a minimum amount of mathematics is required and the lavish use of illustrative material generally makes the information clear without too heavy reliance on mathematical derivations.

* * *

"UNDERSTANDING SILICON CONTROLLED RECTIFIERS" by Saul Heller. Published by *Hayden Book Company, Inc.*, New York. 130 pages. Price $3.50. Soft cover.

This handbook, written by an instructor at *Voorhees Technical Institute*, offers a concise treatment of the SCR which is designed to make this important component understandable to engineers, technicians, and students.

The illustrated text is divided into nine chapters dealing with semiconductor fundamentals; how the SCR works; triggering circuits; turn-off methods; the family of SCR's; static switches; phase-control switching; inverters, choppers, and cycloconverters; and factors affecting applications, characteristics, and ratings.

The author's approach is lucid, simple, and non-mathematical. Even persons without a background in semiconductor technology should be able to handle this text.

* * *

"FUNDAMENTALS OF ELECTRONIC COMPUTERS" by Matthew Mandl. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 337 pages. 101-page laboratory manual for use with text, soft bound.

This text covers both digital and analog computers and is designed as a medium-level book for those who have a basic knowledge of d.c. and a.c. electronic fundamentals, including solid-state circuits, and are ready to move up to the computer field.

The text is divided into twelve chapters and an appendix. After discussing the basic types, circuits, and signals, the author launches into computer arithmetic; logic gates and Boolean algebra; flip-flops, accumulators, and counters; special codes and notation; calculation circuits; storage systems and component logic; input and output devices; programming fundamentals; programming procedures; analog computer principles; and auxiliary analog devices. The material has been carefully presented so that each topic the student learns is of immediate application in the next topic under consideration.

The writing is clear, concise and any student with the requisite background should have no difficulty in handling this material. The companion lab experiment book is closely keyed to the text and offers practical experience in putting theory to work. The manual is based on the *Philco-Ford* Digital Computer Fundamentals Laboratory Unit which is being used in a number of schools and colleges. ▲

"PROGRAMMING" SLIDE RULE FOR RESONANCE PROBLEMS

By M.D. BERNARD, Jr.

ANY standard slide rule having *A*, *B*, and *CI* scales can be used to set up the resonant-frequency formula, and can even be "tuned" as if it were an actual resonant circuit. Not only is the method to be described quite rapid, but it also demonstrates that slide rules are simple analog computers whose "program" can be changed as described below. The point of resonance is fixed by the $1/2\pi$ factor in the resonance formula, which occurs at 1.592 on the *D* scale or squared at 2.53 on the *A* scale. Marks can be scribed at these points for resonant-frequency problems.

To "program" the rule, first turn it so that the side with the *A* and *B* scales is facing the user. Next, remove the slider from the rule, turn it over end-for-end, and reinsert it into the rule. The *B* scale will now be upside down while the *A* scale remains right side up. The *A* scale is used for inductance values ranging from 10 μH at the left end, through 100 μH at the middle, to 1000 μH at the right end. The *B* scale is used for capacitance ranging from 10 pF on the right, through 100 pF at the middle, to 1000 pF at the left. The *CI* scale is used for *frequency*, reading from 1 MHz at the left to 10 MHz at the right end. This scale may be on the back side of the *A* and *B* scales.

To "tune" the rule, given *L* and *C* values within these ranges, set the hairline to align these values with it. The frequency then appears on the *CI* scale at the resonant-frequency marks. For instance, suppose we have an inductance of 20 μH and a capacitance of 79 pF. We set the hairline on 20 μH (*A* scale) and move the slider until 79 pF (*B* scale) lines up with it. Then, holding the slider fixed, we move the hairline to the resonant-frequency marks. In line with the hairline, on the *CI* scale, is the resonant frequency of 4 MHz. Increasing capacitance to 365 pF (*B* scale) which is again lined up with 20 μH (*A* scale), shows up as 1.86 MHz on the frequency scale (*CI*) at the point of resonance. In short, we have "tuned" the rule by varying the capacitance.

To change ranges, we remove or add zeros. Suppose a zero is removed from the frequency scale; it then reads from 100 kHz to 1 MHz. This requires that a pair of zeros be added to the inductance and capacitance since the *A* and *B* scales are squared values. One zero can be added to each scale to make the pair, or two zeros can be added to either value alone. ▲

Technician Engineering

(*Continued from page 36*)

Institution's 1967/68 sessions, Dr. George E. Mueller, Associate Administrator for Manned Space Flight at NASA, visited London last October to deliver a paper on "The Future of Manned Space Flight". The Institution's Journal carries technical material of general interest, along with news of Institution activities.

There are four categories of IEETE membership: Graduates; Corporate Members (Member and Associate Member); Associates; and Students. Generally, the standard of technical education required of Graduates and Corporate Members is at the level of the Higher National Certificate in Electrical/Electronic Engineering. The prospectuses of a growing number of educational establishments list the IEETE qualifications among nationally recognized distinctions, and employers are beginning to specify them in their advertisements for senior technical staff appointments.

Formed at about the same time as the IEETE, the Society of Electronic and Radio Technicians (SERT) provides qualifications and technical lectures and services for technicians, mostly in the television and radio service engineering field.

What About the Future?

The wide-ranging discussions now taking place on the whole span of technician engineering pinpoints the concern of all toward securing an adequate force of the all-important "middle-level manpower". There is at least an awareness of the situation and a start is being made on building for the future.

The Government-based Haslegrave Committee is now considering evidence submitted by many technician engineering and other bodies on educational requirements; the report of the national Engineering Industry Training Board on the training of technician engineers will be published in the Autumn; and the Council of Engineering Institutions is now consulting informally with a large number of technician engineering interests as to the possibilites of establishing a national qualification and title and a CEI kind of organization for technician engineers and technicians.

One thing seems sure: now that engineering technicians in Britain's electrical and electronics industries are beginning to have recognizable status as qualified Technician Engineers with attractive career prospects, there is a much better chance of inducing young people to embark upon a technician engineering career than was the case in 1965. ▲

NEW PRODUCTS & LITERATURE

Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • HAM • COMMUNICATIONS

CLOCK OSCILLATOR

The new CO-231 clock oscillator provides a high-stability square-wave output to drive DTL or TTL logic. Measuring 1.5" x 1.5" x 0.5",

the module is designed for PC board mounting and operates from any voltage in the 5-32 V d.c. range.

Stability is ±0.0025% over the 0 to 70° C temperature range. The Model CO-231-2 provides stability of ±0.005% over the −55 to +105° C temperature range. While the oscillator is factory set to within 0.001% of the specified frequency, both mechanical frequency adjustment and voltage frequency control are optionally available for even more precise setting. Vectron

Circle No. 126 on Reader Service Card

QUICK CHARGE BATTERY

A new quick-charge nickel-cadmium battery cell, which can be charged at two rates—1 hour at 1 ampere or 3 hours at 0.4 ampere—is now available. The battery is self-sustaining and the quick-charge capability is built into the cell. Sonotone

Circle No. 1 on Reader Service Card

BLISTER-PACKAGED COMPONENTS

A new line of 53 different blister-packaged components, including many hard-to-find connectors used by experimenters, audiophiles, CBers, and hams, is now on the market.

Designed to be merchandised from rotating racks, these self-service displays include a broad spectrum of the firm's most popular microphone and electronic components. Each three-color pack carries complete assembly information and detailed step-by-step instructions on how the component should be assembled and used. Amphenol Distributor

Circle No. 2 on Reader Service Card

WIREWOUND TRIMMER

A flat, 3/8" square wirewound trimmer designed to meet the environmental requirements of MIL-R-27208, is now on the market as the Type 700. This RT-24 style unit features positive clutch action that insures against damage to contact wiper and drive mechanism.

The high-temperature, diallyl-phthalate case was especially designed to minimize the length of the moisture seal which is a potential trouble source in some models. The trimmer also has molded-in PC pin terminals.

The Type 700 is available over a resistance range of 10 to 50,000 ohms, ±5% tolerance. It is rated 3/4 watt at 85° C. Multi-wire silver brazed terminations minimize the possibility of shock or vibration damage. IRC

Circle No. 127 on Reader Service Card

300/75 OHM TV ANTENNAS

A new series of 300-ohm rooftop TV antennas that can be converted for use with 75-ohm Color-axial downleads has been developed.

Designated Paralog 300 Plus, the new antennas can be converted by means of a new snap-on transformer (Model STO-83) which is available separately. The new antennas feature high front-to-back ratios and sharper directivity to suppress ghosts, according to the company. Flat response of ±1 dB per channel provides optimum color fidelity. The new antenna comes in seven models for metropolitan to deep fringe areas. Jerrold

Circle No. 3 on Reader Service Card

MATV EQUIPMENT

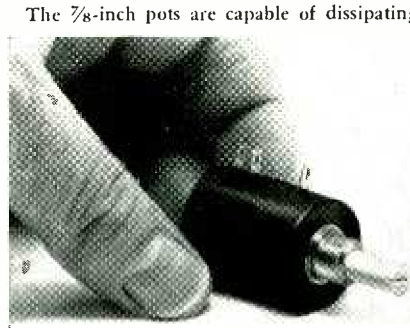
A new and complete line of v.h.f. and 82-channel MATV equipment which includes 200 items has recently been introduced. The line includes solid-state silicon transistor preamplifiers, amplifiers, and converters; passive networks; wall taps; and test equipment.

Complete catalogues covering specifications for each product, price lists, and systems planning forms are available on request. Finney

Circle No. 4 on Reader Service Card

COMMERCIAL POTS

A new line of 10-turn precision pots has just been introduced as the miniature 4100 Series. The 7/8-inch pots are capable of dissipating 2



watts at 40° C for 1000 hours and have a mechanical life of over 200,000 revolutions. Standard linearity is ±0.25% and the standard temperature coefficient of resistance over the operating range of −55 to +125° C is 70 ppm maximum. Units have a standard resistance range of 100 to 100,000 ohms. Amphenol Controls

Circle No. 128 on Reader Service Card

TRANSISTORIZED INVERTER

A compact, transistorized inverter which its makers claim provides 100% protection against

reversed polarity and features automatic overload protection is now available as the Model TI-250A.

Although the unit measures only 10" x 4 1/2" x 7 1/2" and weighs just 9 pounds, it produces 250 VA, 60 Hz, 117-volt a.c. from 12 volts d.c. It is designed to be used to power portable TV sets, radios, portable electric tools, CB equipment, p.a. systems, and many appliances.

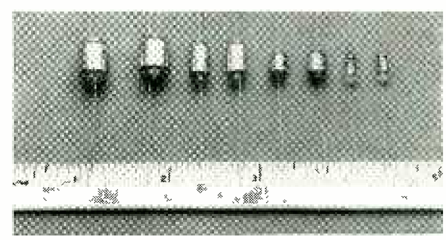
The instrument includes a "start" switch to permit rapid starting for motors, light bulbs, etc., and an indicator light to show battery condition, indicate shorts or overloads, and give a low-charge warning. A remote-control console, which duplicates the front-panel controls, is available for use with the inverter. It measures 2 1/8" x 4 1/8" x 2 1/8" and comes complete with an 8-foot cord. Electro Products

Circle No. 5 on Reader Service Card

SUBMINIATURE CAPACITORS

A new line of subminiature, polystyrene capacitors has just been introduced as the Type SC.

Designed for tight spaces, the new capacitors



offer excellent "Q" factor, high stability, and wide temperature range, according to their maker. The new units are available from 5 pF to 0.1 μF, and cover the voltage range from 25 to 630 volts. Standard tolerances are ±20%, ±10%, ±5%, ±2 1/2%, and ±1%—or 0.5 pF for the smaller units.

Dimensions of the new family of capacitors are as small as 0.1 inch diameter and 0.275 inch long, making them suitable for high-density packaging applications in industrial and consumer products. The outer foil of the capacitors completely encloses the inner foil and the entire assembly is encapsulated in a fused-polystyrene enclosure. Either axial or printed-circuit leads can be furnished, and special requirements such as coatings and precision standards can be met on request. Seacor

Circle No. 129 on Reader Service Card

TRANSIENT SUPPRESSOR

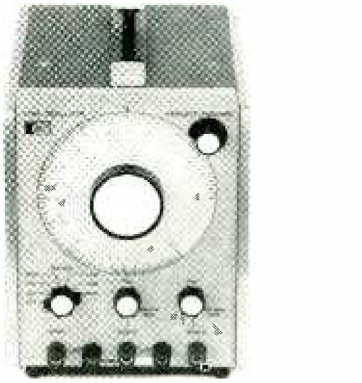
A solid-state transient suppressor that is capable of protecting electrical and electronic equipment from damage due to extreme voltage surges is now on the market. These devices are capable of providing as much as 20 kW of transient power suppression. Typical ratings are 36 and 200 volts; power capability as required. They are designed for continuous power dissipation in excess of 500 watts and can dissipate up to 20 kW under transient conditions. The units are small size and operate instantaneously. IRC

Circle No. 130 on Reader Service Card

SINE/SQUARE RC OSCILLATOR

A new solid-state oscillator which provides sine and square-wave functions from 4 Hz to 2 MHz in six continuously variable ranges with simultaneous outputs, is now available as the Model 209A.

Each output has its own attenuator, continuously adjustable over a 20 dB range. Output



voltage is at least 20 V p-p open circuit for square wave and at least 10 V r.m.s. open circuit for sine wave. Sine-wave distortion is less than 0.1%. Square waves are essentially transient-free with rise and fall time of less than 50 ns. Frequency calibration is better than ±3%.

A unique feature of this instrument is that it may be completely disassembled in two minutes for maintenance. A single epoxy glass printed-circuit board plugs into the output terminals on the one-piece molded plastic front panel, and requires only three wiring connections. All test points appear at the board's rear connector. The range switch connects to the circuit board through a "spider" mount which incorporates all interconnecting conductors. The entire unit is less than 7 inches high and weighs less than 7 pounds. Hewlett-Packard

Circle No. 6 on Reader Service Card

HIGH "Q" INDUCTORS

Two lines of temperature-stable, high-"Q" inductors designed for communications and military applications have been introduced as the PFL and PFM series.

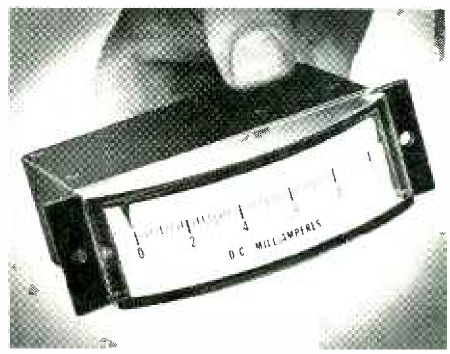
Manufactured to MIL-T-27 grade 4 or 5, type RX, the inductors are specially suited to printed-circuit board applications. The PFL series—available in 8 types—includes 329 individual inductors which cover the frequency spectrum of 10 Hz to 500 kHz with an inductance range of 1 mH to 30 H and a "Q" range of 300 to 700. The PFM series—offered in 7 types—has 309 individual inductors which cover the spectrum from 50 kHz to 2 MHz with an inductance range 15 μH to 100 mH and a "Q" range 100-700. Both types can be supplied with taps and/or separate windings. Freed Transformer

Circle No. 131 on Reader Service Card

EDGEWISE PANEL METERS

A new 3½" edgewise panel meter series that is designed to take up a minimum of instrument panel space yet provide the user with the performance of a conventional 3½" meter is now on the market.

The 320-E series features the company's self-shielded movement which allows meter stacking for maximum instrumentation in a minimum amount of space. Each unit is equipped with an anti-parallax black arrowhead-type pointer to minimize reading error.



The series can be provided as a d.c. voltmeter, millivoltmeter, ammeter, d.c. milliammeter, and d.c. microammeter with appropriate scales. The AC, Model 330-E is available in voltmeter, ammeter, and milliammeter versions while the RF, Model 340-E comes in ammeter and milliammeter types. Triplett

Circle No. 7 on Reader Service Card

POWER SUPPLY

The new Model 2020 power supply combines the functions of a precision calibrator and a laboratory power supply at a fraction of the cost of equivalent instrumentation, according to its maker.

Output range of the Model 2020 is 0-20 volts d.c. at 0-2 A with a calibration accuracy of 0.1% +100 μV of the output voltage. Front-panel dual concentric dials and a vernier potentiometer provide digital readout to four places with a continuously adjustable fifth place. A toggle switch in the 10-20 volt range provides an effective sixth place readout. The resolution of the vernier control is better than 10 μV.

The unit features a self-indicating output current limit control, remote programming, and remote sensing. Power Designs

Circle No. 8 on Reader Service Card

ELECTRONIC IGNITION SYSTEMS

A solid-state ignition system for 12-volt cars (and boats) is now available as an inexpensive, easy-to-assemble kit.

The "Knight-Kit" KG-372 capacitive discharge ignition system uses SCR switching to provide many times the energy of conventional systems, according to the company. With the system, the company claims a 20% increase in gasoline mileage, 3 to 10 times longer sparkplug life, instant starts in all weather, and a 60-80% reduction in ignition maintenance.

The system will operate from positive- or negative-ground 12-volt batteries, generator, or alternator. Triggering is handled by ignition

points or other suitable source. The system can be installed in about 10 minutes with no rewiring or removal of the original system required. Allied Radio

Circle No. 9 on Reader Service Card

U.H.F. ADD-ON ANTENNA KITS

To meet the demand created by new u.h.f. stations going on the air, three new u.h.f. antenna Add-On kits have just been introduced.

Each of the three kits contains a u.h.f. antenna, a u.h.f./v.h.f. antenna coupler to combine the two antennas into the existing downlead, two lengths of twinlead cut to correct length and with connectors attached, two snap-on stand-off insulators, an indoor u.h.f./v.h.f./FM adapter, and easy-to-follow installation instructions. The Model CR-5AK kit uses a 13-element corner reflector, the J-1AK kit uses a 7-element u.h.f. yagi, while the J-3AK kit uses a 20-element u.h.f. yagi. Gavin Instruments

Circle No. 10 on Reader Service Card

HI-FI—AUDIO PRODUCTS

PORTABLE CASSETTE RECORDER

A mono cassette tape recorder for portable applications has been introduced as the Model 210. The unit comes complete with a dynamic remote-control microphone, leather-type carrying case, shoulder strap with pad, accessory pouch, recording patchcord with insulated alligator clips, dynamic earphone, a one-hour blank cassette, and a transistorized filtered a.c. adapter.

The unit includes automatic record level con-

trol, a pop-up cassette ejector, record level meter and battery condition indicator, and a large speaker. The Model 210 will handle all size Philips-type cassettes. Concertone

Circle No. 11 on Reader Service Card

SPEAKER SYSTEM

The CS-88 three-way bookshelf speaker has five speakers: a 12" woofer, a mid-range, and three tweeters. The specially designed woofer has an exceptionally thick cone to provide mechanical strength and avoid breakup at high-level outputs while the edges are specially processed for high compliance. The woofer is designed to deliver sound reproduction down to 25 Hz. Damping has been designed so that there is virtually no distortion even at high signal levels, according to the company. The mid-range is a 5-inch unit while the tweeters include two cone-type and one exponential horn.

The walnut cabinet is of infinite-baffle design and has a lattice wood grille. The enclosure is compact enough to be placed on a bookshelf and can be used in vertical or horizontal positions.

Crossovers are at 800 and 4000 Hz. Response is virtually flat from 25 to 20,000 Hz, according to the company. There are separate tone controls for high and mid-range frequencies, with each control having three positions: normal, increase, and decrease. Pioneer

Circle No. 12 on Reader Service Card

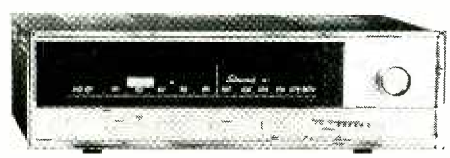
SOLID-STATE STEREO RECEIVER

The Model 36-220 is a compact, solid-state, AM-FM-stereo receiver featuring slide-rule tuning, a.f.c., stereo indicator, and provision for including a record changer, auxiliary input, and headphones. The receiver is housed in a walnut finished wood cabinet with illuminated brushed aluminum panel. Matching speakers housed in oiled walnut cabinets are available as Model 67-010. Claricon

Circle No. 13 on Reader Service Card

FM TUNER

The Model S-3300 FM stereo tuner incorporates silicon monolithic microcircuits in its i.f. preamplifier and in the new FM limiter/detector section. According to the company, FM distortion is reduced to 0.15% at 100% modulation. The



design also offers improved noise rejection and better reception under difficult multipath FM signal conditions.

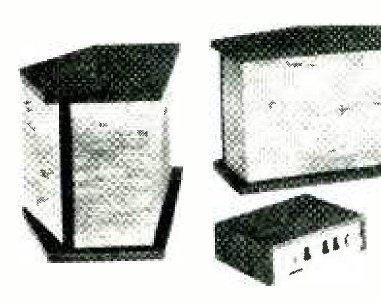
FET's are used in both the r.f. and mixer stages to suppress spurious responses in strong signal areas. Performance specifications are 1.8 μV (IHF) FM sensitivity, 2 dB capture ratio, 55 dB AM rejection, and −95 dB FM crossmodulation rejection. The tuner also features noise-threshold-gated automatic FM-stereo/mono switching, a d'Arsonval zero-center tuning meter, interchannel hush, and a stereo-noise filter which does not affect frequency response. Sherwood

Circle No. 14 on Reader Service Card

STEREO SPEAKER SYSTEM

A new speaker system, Model 901, offers a number of performance features which are unique. The speaker radiates 11% of sound directly and 89% indirectly by reflection at optimum angles from the rear wall to simulate the spatial characteristics and the fullness of sound in a concert hall.

A solid-state active equalizer is supplied, containing over 100 components to precisely control the frequency response over the entire audible range. Front-panel controls enable the listener to exercise his options in compensating for recording techniques and room characteristics. Nine specially designed, high-compliance, long-excursion speakers are acoustically coupled to render individual resonances inaudible and preserve the natural sound of the musical instruments. The stereo channels are acoustically balanced. Each speaker measures 12¾" high x 20 9/16" wide x



12⅞" deep. The units are marketed in pairs with the active equalizer. Bose

Circle No. 15 on Reader Service Card

ORCHESTRA BELLS

A new deluxe orchestra bell that is designed to be operated from any organ keyboard through additional key contacts is on the market. The thirty tuned bars range from G above middle C to top C and add sparkle and rhythm to all kinds of music, according to their maker.

The 12½" x 26½" x 5" oiled-walnut case can be located up to 20 feet from the console. All necessary cable, contacts, and installation instructions are included. Artisan Organs

Circle No. 16 on Reader Service Card

NEW CASSETTE TAPE

A new slow-speed, low-noise, audio-range magnetic tape has just been developed for the cassette market. According to the company, the tape has an extended frequency response and dynamic range and an excellent signal-to-noise ratio.

The tape is being supplied to a number of the major tape duplicators and will be offered on the consumer market under the firm's American brand label. Greentree

Circle No. 17 on Reader Service Card

FM-STEREO RECEIVER SYSTEM

The Model STA-12 AM-FM stereo receiver has two acoustically matched bookshelf speakers for full stereo listening facilities. Input jacks have been provided for easy hook up to a record/play stereo deck or an accessory record changer.

The electronics is all solid-state and includes a large antenna and a professionally tuned circuit for excellent reception in fringe areas, according to the company. Special features include an exclusive stereo indicator system for pinpoint tuning accuracy; automatic frequency control lock-in tuning; stereo balance, treble, and bass tone controls; and a five-position mode selector for AM, FM, FM-stereo, phono, or tape. Response is 40-18,000 Hz with stereo reception better than 25 dB at 1 kHz. Power output is 10 watts and sensitivity is better than 40 microvolts.

The system is housed in dark grained teak cabinet measuring 14⅞" wide x 4¾" high x 10⅜" deep. The two matching speakers that are supplied each measure 7⅜" x 9½" x 4⅝" deep. Concord

Circle No. 18 on Reader Service Card

SPEAKER SYSTEMS

Five new fine-furniture speaker systems have just been introduced to meet the requirements of a wide range of hi-fi installations.

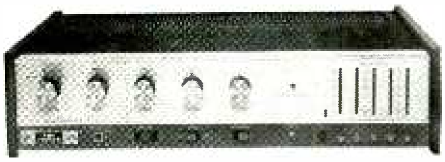
The TF-3B system incorporates four speakers in a 3-way bookshelf enclosure and covers the frequency range 25-20,000 Hz. Power rating is 25 watts. The slim-line TF-4A has five speakers in a 4-way system housed in a cabinet only 8¾" deep. Frequency and power ratings are the same as the TF-3B. The PR-200A is a 3-way, three-speaker bookshelf system with a power rating of 35 watts and a frequency range of 25-20,000 Hz. The PR-300A is a high-boy/low-boy system which offers three speakers in a 3-way system to cover the range of 20-20,000 Hz. The custom console, PR-400A, is a three-speaker, 3-way system covering 20-20,000 Hz with crossovers at 1000 and 5000 Hz. Power rating is 40 watts. Jensen

Circle No. 19 on Reader Service Card

LOW-COST FM-STEREO RECEIVER

The 160-T FM-stereo receiver features the company's exclusive Tune-O-Matic push button tuning with five separate FM dials, incorporates advanced solid-state circuitry, and has full complement of controls and switches for tape and phono.

The 40-watt receiver permits each of the five FM dials to be preset to a favorite FM station and thereafter it can be selected instantly at the press of a button. Diode tuning, coupled with a.f.c., electronically locks in the desired station. The company's exclusive "Stereo Beacon" auto-



matically signals the presence of stereo, switches to the stereo mode, and back again to mono. Fisher

Circle No. 20 on Reader Service Card

TAPE CASSETTE

A new tape cassette that delivers a full 90 minutes of recording and playback time is now available as the C-90. Released in response to customer demand for longer recording and playback time in their Sony cassette recorders, the C-90 offers 30 more minutes of recording/playback time than the previously announced C-60. Superscope

Circle No. 21 on Reader Service Card

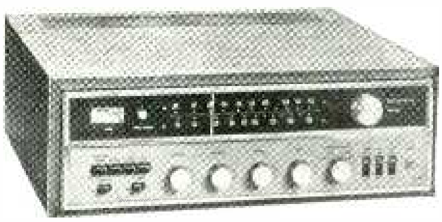
120-WATT STEREO RECEIVER

The RX200 AM-FM-stereo receiver has a rated output of 120 watts (IHF) at 4 ohms. The unit features all-silicon, solid-state design; push-button selector switches; flywheel tuning; FET's; illuminated AM-FM tuning meter; and automatic "Stereo-Minder" signaling and switching.

Frequency response is broad and flat, ranging from 10 to 35,000 Hz, ±1 dB. Harmonic distortion is 0.8% at full output. At 100 watts or below, harmonic distortion is less than 0.2% and IM distortion is less than 0.3%.

The power amplifier section couples directly to loudspeakers for reduced low-frequency phase shift, improved stability, and solid bass response. The receiver is short-circuit-proof and retains its published specifications even when operated into a 2-ohm load. Bogen

Circle No. 22 on Reader Service Card



LOUDSPEAKER SYSTEM

The new "Brookfield" speaker system is an acoustic suspension bookshelf type which incorporates a high-flux dome tweeter which responds to frequencies beyond 20,000 Hz, but can still work effectively down to 1000 Hz; a specially designed 5¼" driver which works in conjunction with the tweeter and has extended performance down to the upper bass region; and a 10" bass speaker which will handle frequencies down to 30 Hz.

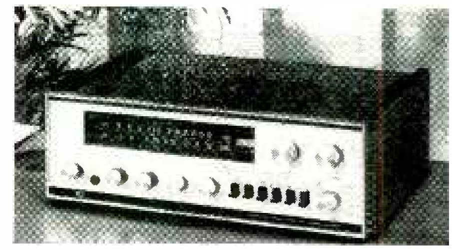
Over-all response is 30-20,000 Hz ±3 dB in an average listening room. Power requirements are 10 watts minimum, 60 watts maximum. The system is housed in a cabinet 25" high x 14½" wide x 11⅞" deep. A three-position treble switch is included on the rear panel for matching to room acoustics. The grille cloth frame is removable so that the grille cloth can be changed to match room decor. ADC

Circle No. 23 on Reader Service Card

AM-FM-STEREO RECEIVER

The SX-1500T AM-FM-stereo receiver is rated at 170 watts, has an FET front-end and four IC's in the i.f. section. FM sensitivity is 1.7 μV (IHF), capture ratio is 1 dB at 98 MHz, and over-all frequency response is 20-70,000 Hz ±1 dB. Signal-to-noise ratio is 65 dB (IHF) and harmonic distortion is measured at less than 0.1% (at 1000 Hz at 30 watts, and into an 8-ohm load.)

A tuning meter indicates maximum signal



strength, an automatic stereo indicator shows when FM-stereo programs are being received, and a headphone jack is provided. The front panel is brushed gold with a dark background and lighted slide-rule markings. Pioneer

Circle No. 24 on Reader Service Card

CB-HAM-COMMUNICATIONS

HAND-HELD RADIOTELEPHONE

The DP15 is a waterproof, hand-held, two-way radiotelephone which weighs only 30 ounces, including its rechargeable battery. It is fully compatible with all FM land mobile and marine radio systems. The unit contains a fully solid-state transmitter and receiver and has been type accepted under FCC rules Parts 21, 81, 91, and 93 for industrial transportation, public safety, and common carrier use.

The unit is available in various models for operation on one to five channels and in the 30-50 MHz and 132-174 MHz bands, employing narrow-band or wide-band FM. Transmitter power output is 2.2 watts, receiver sensitivity is better than 0.35 μV for 12 dB SINAD and adjacent-channel selectivity is better than −80 dB for 20 dB quieting. Kaar

Circle No. 25 on Reader Service Card

FM TWO-WAY RADIOS

A new FM two-way radio has been announced. It incorporates a unique building-block approach to transceiver design since the basic 7-watt radio can be adapted to mobile or base-station use or boosted in power to 60 watts, thus providing a complete line of transceivers.

In addition, the basic transceiver is transistorized, throughout and measures only 2½" high x 8" wide x 11" deep and weighs 8 pounds. The unit operates in the 150-174 MHz service and is designed for Public Safety as well as Business and Special Industrial frequencies. It is completely compatible with existing FM systems, including tone squelch, and requires no modification if used in conjunction with other transceivers.

Bulletin 450028 which provides complete information on this new line is available on request. E. F. Johnson

Circle No. 26 on Reader Service Card

DUAL-OPERATION CB UNIT

The Model A-2567 two-way radio for Citizens Band service features built-in solid-state power supplies for both 12-volt d.c. mobile and 117-volt a.c. base-station use. A frequency synthesis circuit permits crystal-controlled transmit and receive operation of all 23 channels. Is is only necessary to turn the selector knob to any desired channel. Illuminated numerals show the channel in use. All crystals are included.

The 5-watt transmitter offers 100% modulation. A switchable range-expander boosts talk power to increase transmitter range. The pi-network output matches any CB antenna. A special s.w.r. bridge cricuit permits measurement of s.w.r. for optimum antenna tuning.

The transceiver measures 7½" high x 13⅜" wide x 5½" deep. It comes with all crystals, a.c. and d.c. power cords, noise-cancelling push-to-talk mike with coiled cord, and universal mobile mounting clips. Allied Radio

Circle No. 27 on Reader Service Card

23-CHANNEL TRANSCEIVER

The new "Royale" 23-channel CB transceiver features a new Clevite computer-designed hybrid ceramic filter which provides excellent selectivity and high stopband rejection, according to the company.

The transceiver has hand-wired, hand-soldered circuitry, tubes instead of transistors (including a nuvistor), and a large chassis to dissipate the heat generated in the overpowered transformer.

The unit incorporates an exclusive range expand/speech compressor and a modulation sampler which boosts or cuts the signal to the proper audio level. Also featured are a standby switch, p.a. system, triple-duty meter, variable noise limiter, tone control, squelch control, receive and transmit indicators, noise-cancelling microphone, and built-in 12-volt transistorized power supply for mobile operation. Courier

Circle No. 28 on Reader Service Card

MANUFACTURERS' LITERATURE

TOOLS FOR ELECTRONICS

Catalogue No. 150 pictures and describes an extensive line of precision tools for electronics, telephone, and communications uses. Over 500 spring adjusters, gages, burnishers, and miscellaneous precision hand tools are listed. Details are also included on the firm's custom facilities for producing hand tools to a manufacturer's requirements. Jonard

Circle No. 132 on Reader Service Card

HYBRID IC's

A 4-page brochure entitled "A Designer's Guide to Hybrid Microciruits" has been published containing a comparison between hybrid and monolithic IC's, a description of the techniques used to translate a customer's circuit requirements into a breadboard, a description of production processes and controls, and helpful hints on designing and ordering hybrid IC's. Crystalonics

Circle No. 133 on Reader Service Card

FILTER DESIGN MANUAL

A 12-page filter design manual which provides important engineering data and an in-depth description of many of the low-, high-, and band-pass filters used in the electronics industry, is now available for distribution.

In easy-to-read two-page spreads, the booklet illustrates typical filters and includes feasibility curves which permit the designer to quickly locate the best design for his particular requirements. In addition, normalized frequency-attenuation curves are presented for both single-section and double-section filters. Nytronics Burnell

Circle No. 134 on Reader Service Card

ZENER DIODE DATA

A comparison guide to assist the circuit designer in the selection of zener diodes and temperature-compensated reference elements is now being offered without charge.

All major series of EIA-registered zener diodes are listed by power dissipation and zener voltage. In addition, test current, zener impedance, zener voltage tolerance, and package dimensions are given for each zener. All major series of EIA-registered temperature-compensated reference elements are listed by zener voltage and/or power dissipation.

This information is contained in a convenient four-page foldout that is punched to fit a three-ring binder. Semcor

Circle No. 135 on Reader Service Card

COMPONENT SELECTOR

A completely revised and updated 1968-69 edition of the company's Component Selector is now available. It describes and catalogues the entire product line including capacitors, filters, and relays. Every standard stock item listed in the catalogue is available from the firm's industrial distributors.

The 120-page book includes application charts, type selector charts, and standard rating tables arranged to guide the designer/purchaser to easy selection of the proper device and rating. Cornell-Dubilier

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SWITCH CATALOGUE

A 28-page switch catalogue, #E, providing descriptions, specifications, and illustrations of toggle, slide, push, rotary, trigger, and tippette switches for appliance, aircraft, automotive, electronics, marine, military, motor control, and special applications is now available.

In addition to electrical specifications for each type, the switch is illustrated and its dimensions presented to facilitate selection. Carling

Circle No. 136 on Reader Service Card

INDICATOR LIGHT HANDBOOK

A new 32-page catalogue of indicator lights, compiled in the form of an engineering handbook, is now available as Catalogue L-68.

The publication features photographs, line drawings, and detailed specifications on over 60 different indicator lights, ranging in size from 1" diameter heavy-duty types to microminiature neon EMI-suppressed designs. A lamp selection guide contains information necessary for finding the right indicator assembly for any application. Marco-Oak

Circle No. 137 on Reader Service Card

RFI FILTERS

A complete line of filters and components for suppressing radio frequency interference is pictured and described in a new 24-page catalogue, No. P-68. Included are performance curves and complete engineering and mechanical specs. Hundreds of different power-line filters, communications and signal-line filters, and filtered, shielded circuit breakers used in military, aerospace, testing and research laboratories, and hospitals are covered. Filtron

Circle No. 138 on Reader Service Card

AUDIO CONNECTOR LINE

Catalogue #C502a describing a broad and complete line of audio connectors is now available. Included are specifications, detailed drawings, and application hints for single-and multiple-conductor connectors, microphone connectors, miniature and slim-line connectors as well as a.c. receptacles and phone jacks. Switchcraft

Circle No. 30 on Reader Service Card

TEST EQUIPMENT CATALOGUE

Insulation test equipment, electronic test and measuring instruments, high-voltage power supplies, and automatic component testers are comprehensively covered in a new 40-page catalogue, No. 31. Technical data, complete specifications, and photographs are supplied on a wide range of electrical/electronic test equipment in the company's line. Beckman Instruments

Circle No. 139 on Reader Service Card

INTEGRATED CIRCUIT DATA

Engineering Bulletin No. 25700A contains complete information on the SE8000 and NE-8000 Series of high-speed, low-power DTL/TTL integrated-circuits. The 44-page publication contains schematic diagrams for each series, plus complete electrical characteristics in tabular form for easy interpretation. Performance curves are supplied in the areas of pair delay, turn-on and turn-off delays, switching and holding levels, and toggle rates. Sprague

Circle No. 140 on Reader Service Card

TEST INSTRUMENTS

A new 12-page, two-color catalogue, fully illustrated and detailed with electrical and mechanical characteristics of the newest and most popular portable electrical and electronic test instruments in the company's line, is now available.

Catalogue 52-T describes an extensive v.o.m. line, ranging from a hand-held unit to a high-impedance instrument with FET amplification. A handy and comprehensive v.o.m. comparison chart is also included to aid in selection of the correct instrument for the job. Triplett

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TRANSISTOR CATALOGUE

A 40-page, 3-color condensed catalogue covering the company's line of silicon and germanium small-signal and power transistors for use in military, industrial, and commercial applications is now available for distribution.

Each family of transistors is presented in a separate section and includes typical h_{FE}, $V_{BE(sat)}$, and $V_{CE(sat)}$ curves, along with specification charts, outline dimension drawings, and actual size photos of the standard cases. Brief suggested application uses are included throughout the catalogue. Solitron

Circle No. 141 on Reader Service Card

INDUSTRIAL LAMP CATALOGUE

A new condensed catalogue containing detailed descriptions of popular lamp types for industrial applications is now available as #CMD-2.

Included in the catalogue is information relating to standard industrial lamps, miniature, thin line, and line filament lamps, neon glow lamps, and telephone slide lamps. All lamps are listed in numerical order to facilitate locating a specific lamp type. Each listing indicates design voltage, current, mean spherical candlepower, base type, bulb type, filament type, average life, maximum diameter, and length. Chicago Miniature Lamp

Circle No. 32 on Reader Service Card

SOLID-STATE POWER SUPPLIES

A 4-page data sheet which describes the current line of solid-state power supplies has been issued. The new publication includes descriptive material on militarized modular supplies, wide-range modules, inverters and frequency changers, solid-state a. c. regulators, over-voltage protectors, laboratory supplies, and other types of units. Catalogue 150A will be forwarded on request. Electronic Research

Circle No. 142 on Reader Service Card

MUSICAL-INSTRUMENT SPEAKERS

A six-page data sheet covering the power capacity of the firm's musical instrument loudspeakers is now available. In layman's language and in considerable detail, the booklet explains various important points involved in selecting and choosing a speaker for instrument applications. Four of the firm's speakers designed specifically for such applications are pictured and described briefly. JBL

Circle No. 33 on Reader Service Card

DATA FOR DESIGNERS

A new technical reference tool addressed to consumer/industrial/military designers who need comprehensive information about using silicon power transistors in switch and amplifier designs is now available.

The more-than-120-page, 65-circuit edition is one of a new series of publications which are intended to save the engineer designing time. It is highlighted by easy-to-understand "how to do it" topics such as using direct coupling to eliminate amplifier transformers, outguessing the effects of damaging secondary breakdown transients, square waveforms and intermittent pulses, etc. Motorola Semiconductor

Circle No. 143 on Reader Service Card

HEAT-SINK CATALOGUE

A new 4-page data sheet has been issued showing 24 different low-cost semiconductor heat sinks. Included in the publication are dissipation data, dimensions, and weight of all models, including eight new types. All of the models illustrated and described are available for off-the-shelf delivery. Accel

Circle No. 144 on Reader Service Card

ELECTRONIC COMPONENTS

A 25-page, short-form catalogue listing an extensive line of electronic components is now available on request. The book covers such major product categories as jacks, plugs, switches, connectors, indicating devices, and audio accessories.

The information indicated is condensed and the electronic components illustrated and described are items available for immediate delivery from the firm's industrial distributors.

The catalogue includes numerous electronic components for application with analog and digital computers, analyzers, transmitters, receivers, intercoms, numerical control, ground support systems, scientific instruments, home entertainment systems, and various home appliances. Switchcraft

Circle No. 145 on Reader Service Card

ELECTROMECHANICAL COMPONENTS

A new, fully illustrated catalogue of electromechanical components and equipment has just been published and is now available for distribution.

The 100-page catalogue lists components of all major manufacturers and features such items as accelerometers, counters, meters, motors, precision pots, selsyns, servomotors, test equipment, and timers. Special complete sections are devoted to relays, pressure transducers, and gyros.

Illustrated with photos, diagrams, and drawings, the catalogue will be forwarded on request. American Relays

Circle No. 146 on Reader Service Card

ALUMINUM TRANSMISSION LINE

A comprehensive catalogue describing bare aluminum transmission conductor, said to be one of the most complete publications of its kind in the electrical power utility industry, has been issued.

Physical properties and electrical characteristics covering four major types of bare aluminum transmission conductor are offered in the catalogue as well as a section containing packaging information. The directory includes photos illustrating wire drawing, cable stranding, product application, manufacturing, and inspection procedures. General Cable

Circle No. 147 on Reader Service Card

POTS AND RESISTORS

A new 32-page illustrated catalogue of potentiometers, field-assembled controls, power rheostats, and resistors is now available for distribution

This full-line catalogue includes photographs, engineering drawings, and descriptions of field-assembled controls, sound-system attenuators, theater-speaker controls, precision decade boxes, shafts, bushings, rotary selector switches, and high-voltage couplers. Complete technical specifications and dimensional information are included.

A special section describing military-qualified pots, including a complete listing of off-the-shelf types as well as ordering information for these, is also provided. Clarostat

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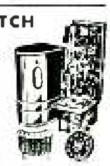

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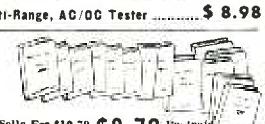

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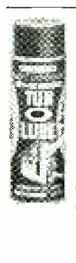

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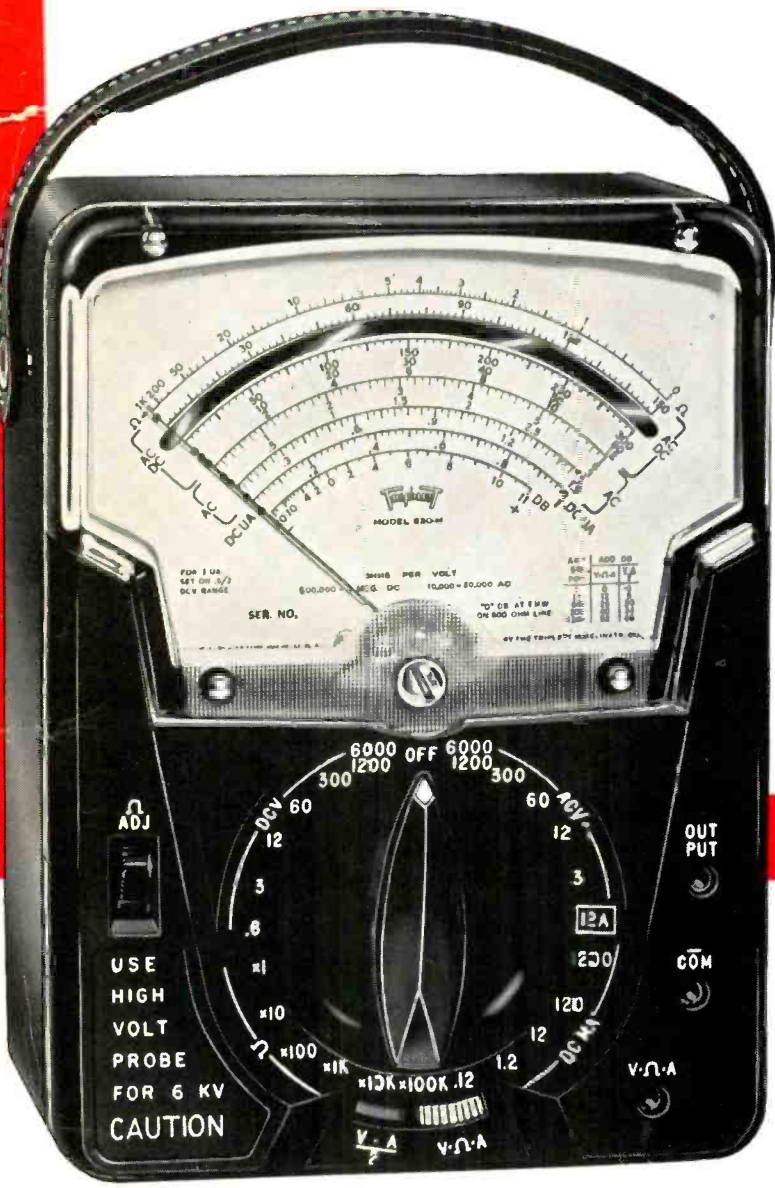

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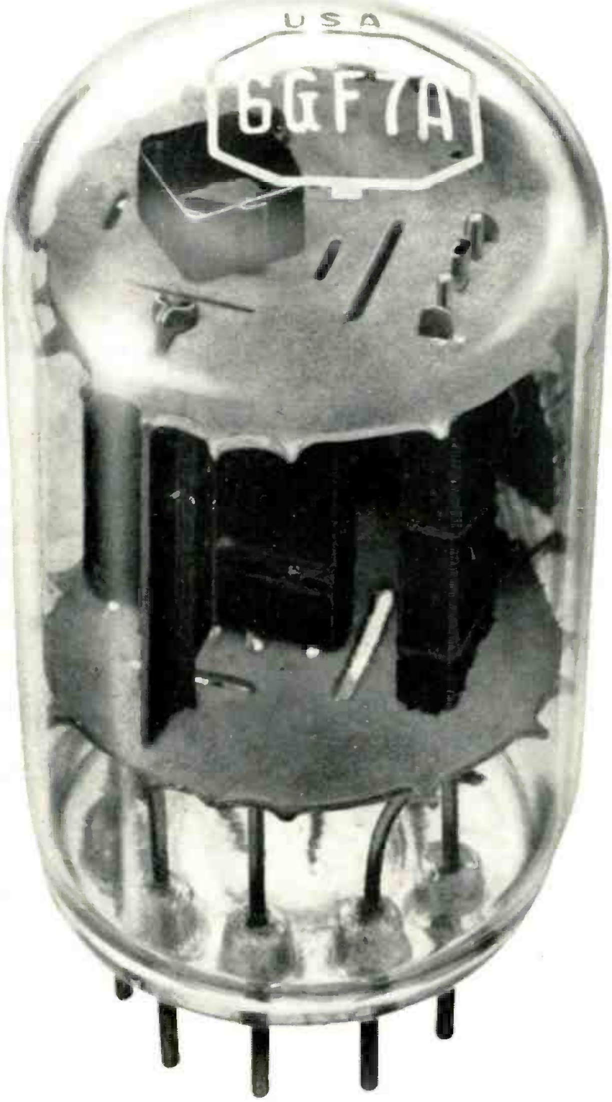

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