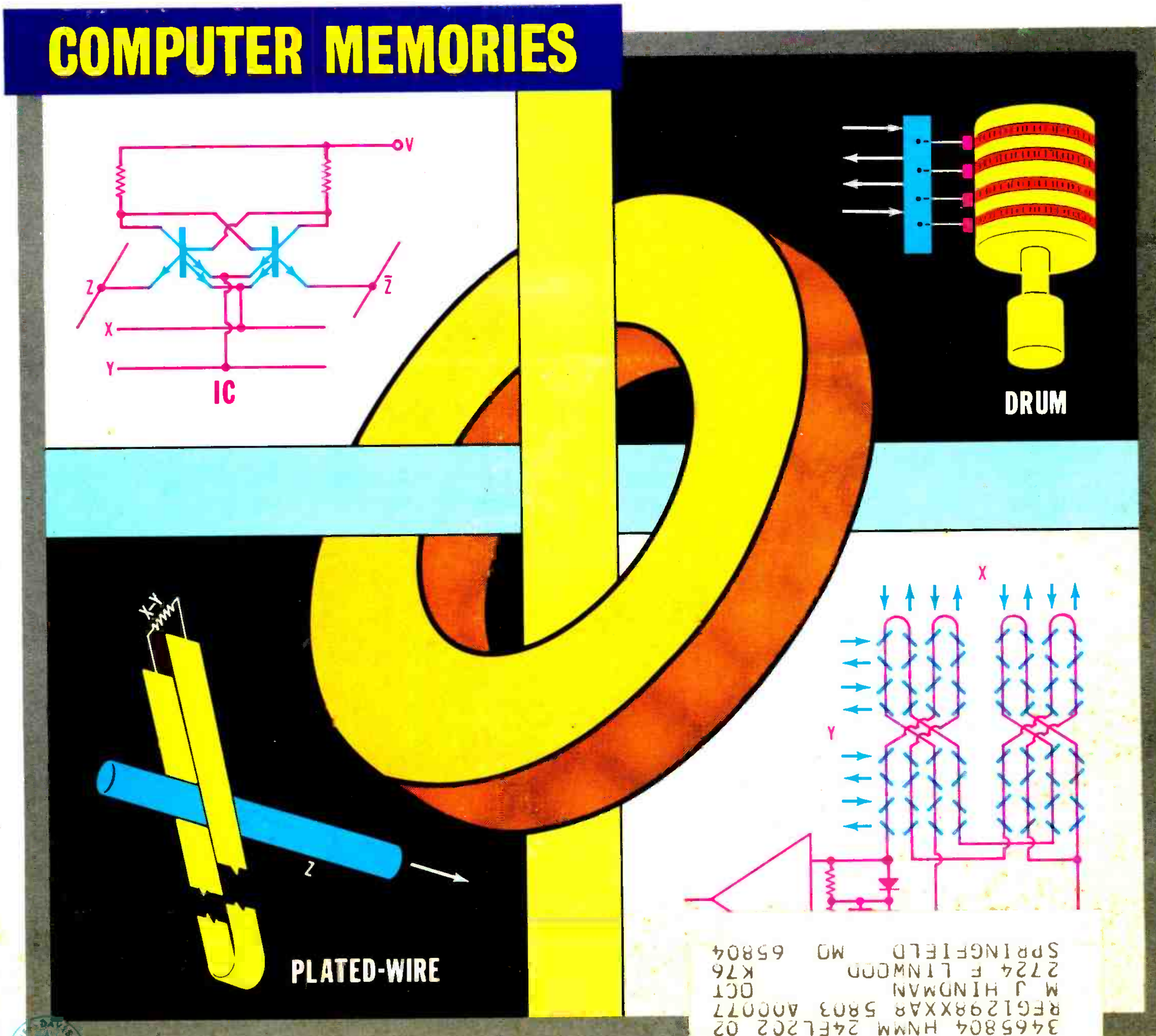
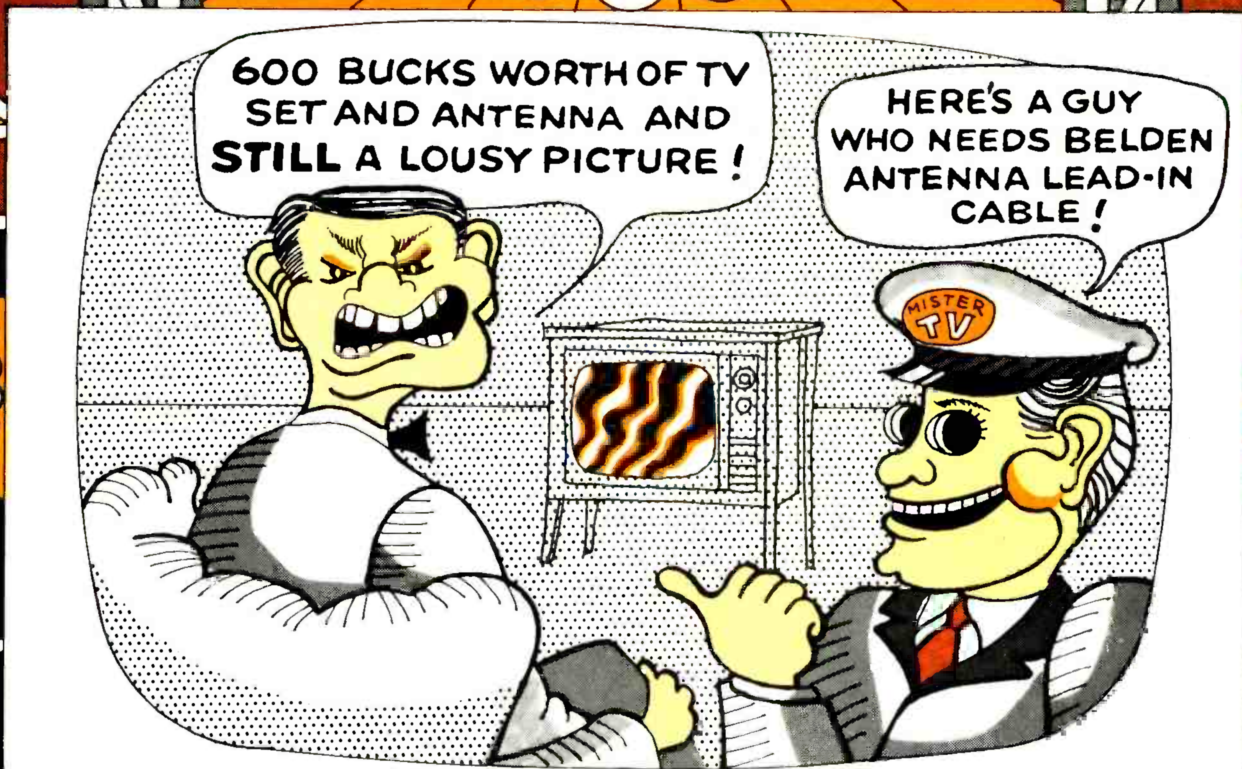
Electronics World

OCTOBER, 1970
60 CENTS

SPECIAL ISSUE

DIGITAL VOICE COMMUNICATIONS
ADD EXTRA CHANNEL FOR IMPROVED HI-FI
GRAPHIC COMPUTER TERMINALS





Color or UHF set perfect? Antenna perfect? Then obviously there's a missing link. Check that antenna lead-in cable. Old, worn-out, weather-beaten cable, or the ordinary flat ribbon kind designed for black and white VHF, causes more fuzzy, distorted pictures than you can count. It's your opportunity to upgrade these customers to a cable matched to their particular signal reception situations. One of Belden's Big Four—the link to perfect reception.

FOR CONGESTED AREAS...

8290 SHIELDED PERMOHM®

In congested, in-city areas, stray electrical interference and noise are at their worst. For perfect, all-82 channel reception—color or B/W—replace old cable with Belden's 8290 Shielded Permohm. Its aluminum Beldfoil® shielding prevents pickup of ghost signals and electrical noise by the lead-in. Weather-proof and water-proof. You can tape it right to the mast. Or install it underground, in conduits—even in rain gutters.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100' mc	db	Standard Package Lengths in ft.
22 (7 x 30)	Brown	.305 x .515	69.8%	7.8	57	1.7	50', 75', 100' coils have terminals attached.
					85	2.1	
					177	3.2	
Copperweld, 2 conductors, orange polyethylene insulation and web between conductors, cellular polyethylene oval insulation, Beldfoil shield, stranded tinned drain wire, polyethylene jacket.					213	3.5	Available in counter dispenser.
					473	5.4	
					671	6.6	
					887	7.7	250', 500' spool.

FOR FRINGE AREAS...

8285 PERMOHM®

Antenna cable in uncongested or fringe areas picks up little electrical interference. But does get a lot of weathering, which degrades an already weak signal. These customers need encapsulated cable. Belden 8285 Permohm. Its special polyethylene jacket protects the energy field, regardless of weather conditions. It delivers the strongest signal of any unshielded twin lead under adverse conditions. Requires no matching transformers and connectors. For all 82 channels, color or B/W.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100′ mc	db	Standard Package Lengths in ft.
22 (7 x 30)	Brown	.255 x .468	73.3%	5.3	100 300 500 700 900	1.4 2.8 3.8 4.8 5.6	50′, 75′, 100′ coils have terminals attached. Available in counter dispenser. 250′, 500′ coils and 1000′ spool.

Copperweld, 2 conductors parallel, orange polyethylene insulation and web between conductors, cellular polyethylene oval jacket.

FOR LOCAL BLACK AND WHITE...

8275 CELLULINE®

Cracked, corroded, weathered cable, full of dirt and moisture, loses signal strength; prevents any TV set from delivering a quality picture. Upgrade B/W VHF and local UHF customers to Belden 8275 Celluline. Performance is improved because all possible moisture between conductors has been eliminated. Abrasion-resistant and weather-resistant for a long, long service life. And, it requires no end sealing.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100′ mc	db	Standard Package Lengths in ft.
20 (7 x 28)	Brown	.300 x .400	80%	4.6	100 200 300 400 500 700 900	1.05 1.64 2.12 2.5 2.98 3.62 4.3	50′, 75′, 100′ coils in counter dispenser. 250′, 500′, 1000′ spools.

Bare copperweld; 2 conductors parallel, polyethylene jacket with inert gas filled unicellular polyethylene core.

FOR MATV AND CATV...

8228 DUOFOIL® COAX

Got an apartment or townhouse complex in your area? Motels or hotels? Or is CATV coming? Use Belden's new 75 ohm coaxial cable—8228 Duofoil. Shielding is 100%—sweep tested 100%. Spiral wrapped drain wires provide long flex life. Small diameter saves space in conduit installations. Use Duofoil for all coaxial color and B/W VHF, UHF and CATV applications.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100′ mc	db	Standard Package Lengths in ft.
18 Solid, Bare	Black	.242	78%	17.3	50 100 200 300 400 500 600 700 800 900	1.5 2.1 3.1 3.8 4.5 5.0 5.5 6.0 6.5 6.9	100′, 500′, 1000′ spools.

Don't forget to ask them what else needs fixing.

See your local Belden distributor for full details or to order. For a free copy of the recent reprint article, "Electronic Cable," write: Belden Corporation, P.O. Box 5070-A, Chicago, Illinois 60680.

BELDEN

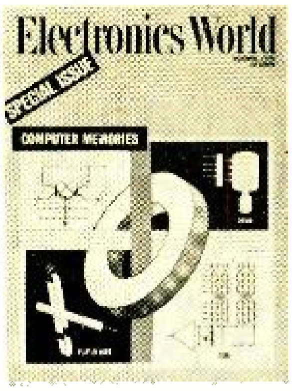
8-6-8A

CIRCLE NO. 145 ON READER SERVICE CARD

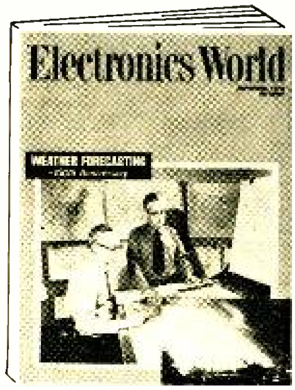
Electronics World

OCTOBER 1970 VOL. 84 NO. 4

CONTENTS



THIS MONTH'S COVER symbolizes our Special Section on "Computer Memories." At the center is the ferrite core which dominates memory usage today. Future core memories will use only two wires threading each core, so this is what we have shown. A simplified circuit of a core memory is at the lower right. Other leading contenders for the main-memory market, the integrated-circuit (IC) and plated-wire types, are symbolized. In addition, the important electromechanical storage device, the magnetic-drum type, is illustrated at top right. For details on these and other computer memories, refer to our Special Section.



Coming Next Month

WHAT'S THE WEATHER GOING TO BE?	People have been asking this question for centuries and—for the past one hundred years—the U.S. Weather Bureau has been providing the answers. In its Centennial Year, the Bureau uses some highly sophisticated equipment to keep track of the weather but still relies heavily on the expertise of its Weather Forecasters.
MARINE ELECTRONICS: A VOCATIONAL PROFILE	Technicians with a good basic electronics background and a desire for a challenging job should investigate the field of marine electronics. Although the educational and technical requirements are exacting, the rewards can be worthwhile for a top-notch man.
A 4-CHANNEL POWER AMPLIFIER	Design details on a circuit for use with multi-speaker systems which provides two low- and two high-power channels. It can also be used as an electronic crossover for a pair of two-way systems.
WHAT SHOULD YOU PAY FOR A PHONO CARTRIDGE?	Is price alone a good criterion for determining how well a phono cartridge will perform? Julian Hirsch concludes that, although the differences are slight, the higher priced cartridges do offer extended, smoother high frequencies and will track at higher velocities and lower stylus forces. He then demonstrates his conclusions by presenting test results on Shure's entire line of cartridges.

All these and many more interesting and informative articles will be yours in the ***November*** *issue of ELECTRONICS WORLD . . . on sale* ***October 20th.***

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LETTERS

ENGINEERING CRISIS

To the Editors:

In reference to a paragraph entitled "Engineering Crisis" that appeared in the News Highlights section of your May, 1970 issue, you stated that the number of engineers being produced in this country is decreasing due, in part, to "youth's zealous interest in society's social and environmental problems."

Now let's be honest about it. Could it not be that there are fewer engineers being produced because of negative feedback? I have been an engineer for several years now and have met and worked with many engineers. From my experience, it appears that engineers are dissatisfied, and becoming more so as time goes on. After all, with many plumbers, carpenters, and factory workers earning $15,000 to $20,000 per year for a forty-hour week, why should anyone enter a demanding profession like engineering, where he *may* earn $20,000 per year after hard study and many years' experience?

What has happened is that engineers are becoming less rewarded for their value to society, while other workers are being rewarded more. What we need, therefore, is fewer engineers, not more. Then maybe someone will realize what is happening.

E. E.
Chicago, Ill.

To the Editors:

You are correct when you say there is an "engineering crisis" (News Highlights, May, 1970). But the crisis is not in the present or potential shortage of engineers, but in the actual present and future shortage of true engineering jobs.

If industry would have engineers do real engineering work, give them professional recognition, and the pay to go with it, then you would not find a dearth of engineering students. As it is now, the average defense contractor hires an engineering college graduate, gives him work that any technical high school graduate can do, and after ten to fifteen years lays him off ("technical obsolescence" it is called) then hires a new engineering graduate, at less pay than the other man was getting. It does not take too long before the older engineer is over middle age and not able to get engineering work.

It does not take too long before potential engineering students get the word and realize engineering is not the profession that you, the IEEE, ASME, and others would like them to believe it is.

EDWARD BREITT
Placentia, Cal.

* * *

MORE WEATHER BROADCASTS

To the Editors:

Your answer to Reader Steiner in a recent Letters column concerning the widespread U. S. Weather Bureau broadcasts on 162.55 MHz was informative, but you should also have told weather buffs about another weather broadcast as well. Readers without v.h.f. receivers but with short-wave sets can pick up New York Radio's International Flight Service weather broadcasts which are transmitted for international aircraft flights. These broadcasts are sent out simultaneously on 3001, 5559, 8828, and 13.264 MHz at 15 minutes and 45 minutes past every hour. The five-minute broadcasts give weather conditions at a number of East Coast airports from Boston to Washington, D. C.

WILLIAM DONNER
New Hope, Pa.

Thanks to Reader Donner for this information on additional weather broadcasts. Incidentally, just as soon as New York Radio ends its transmissions, Radio Gander comes on the same frequencies to give weather for airports in Newfoundland, Nova Scotia, southern Canada, and a couple of midwestern U. S. cities. The last time we heard these broadcasts they were on from 20 to 30 and from 50 to 60 minutes past every hour.—Editors

* * *

MURPHY'S LAW

To the Editors:

My employers recently hired a new man. This man, a young technical-school graduate, ran up against Murphy's Law his first day at work. This young man had never heard of Murphy's Law which, as I am sure you know, in its most basic, familiar form states, "If anything can go wrong, it will."

I feel that the young people of today should be forewarned about some of the applications of this law to all fields of science and engineering.

For example, in mathematics, a decimal will always be misplaced; and in any miscalculation, the fault will never be placed if more than one person is involved.

In general engineering, all warranty and guarantee clauses become void upon payment of invoice: and the less important a design change appears, the further its influence will extend.

In prototype and production, any wire cut to length will be too short; a dropped tool will land where it will do the most damage; and interchangeable parts won't.

GENE M. PRESSON
Raleigh, N. C.

* * *

SONIC HOLOGRAPHY'S GABOR

To the Editors:

Noting the article "Sonic Holography" in your June, 1970 issue—Dennis Gabor is not a British scientist. He may have lived in England, but he is a Hungarian scientist.

STEPHEN MARKUS
Markus Radio & TV
Indianapolis, Ind.

Although Gabor was born in Hungary and did early work in Germany, he spent most of his life (since 1933) working and teaching in England. More recently, he spends some time each year in the U. S. as a staff scientist with CBS Labs. *—Editors*

* * *

ELECTRONIC VIDEO RECORDING

To the Editors:

We noted with interest your item on the new *CBS* color playback EVR (electronic video recording) unit, which is being made by *Motorola* to sell for $795. A photo of the player appeared in your July feature "Recent Developments in Electronics" on page 27. The item indicated that the major market was expected to be in schools, businesses, and institutions rather than in the home.

I just don't see the advantage of such a unit for school use. Most schools have motion-picture equipment, large screens, and a big library of excellent films. Why should a school go to the expense of purchasing this additional equipment, especially since there is such a limited program library and the pictures are displayed on small-screen TV sets, many of which are not kept in the best of repair even if a school does have them.

ALAN SIMON
Valley Stream, N. Y.

Reader Simon makes a number of valid points in his letter. On the other hand, some teachers feel that the learning process via TV is somewhat better with a generation of TV watchers. As with any new system, the programming is very important and there are a number of producers of programs for the new EVR player, including The New York Times. *An advantage of the player is that it can show pictures on a large number of interconnected TV sets at various locations within a school.—Editors* ▲

You get more for your money from NRI

—more value, more solid experience so essential to careers in Electronics. NRI's pioneering "discovery" method is the result of more than half a century of simplifying, organizing, dramatizing subject matter. In each of NRI's major courses you learn by doing. You demonstrate theory you read in "bite-size" texts programmed with NRI designed-for-learning professional lab equipment. Electronics comes alive in a unique, fascinating way. You'll take pleasure in evidence you can feel and touch of increasing skills in Electronics, as you introduce defects into circuits you build, perform experiments, discover the "why" of circuitry and equipment operation.

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NRI Has Trained More Men for Electronics Than Any Other School

—By actual count, the number of individuals who have enrolled for Electronics with NRI could easily populate a city the size of New Orleans or Indianapolis. Over three-quarters of a million have enrolled with NRI since 1914. How well NRI training has proved its value is evident from the thousands of letters we receive from graduates. Letters like those excerpted below. Take the first step to a rewarding new career today. Mail the postage-free card. No obligation. No salesman will call. NATIONAL RADIO INSTITUTE, Electronics Division, Washington, D.C. 20016.

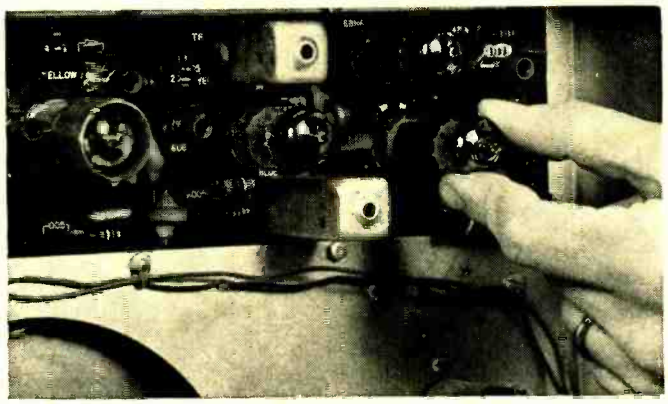
L. V. Lynch, Louisville, Ky., was a factory worker with American Tobacco Co., now he's an Electronics Technician with the same firm. "I don't see how the NRI way of teaching could be improved."

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."

APPROVED UNDER NEW GI BILL. If you served since January 31, 1955, or are in service, check GI line on postage-free card.

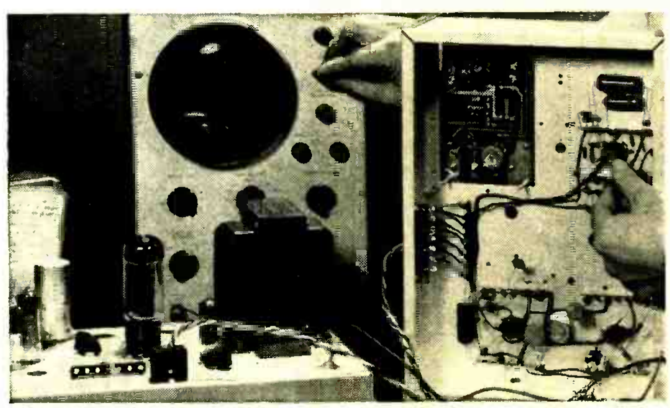


COLOR TV CIRCUITRY COMES ALIVE

as you build, stage-by-stage, the only custom Color-TV engineered for training. You grasp a professional understanding of all color circuits through logical demonstrations never before presented. The TV-Radio Servicing course includes your choice of black and white or color training equipment.

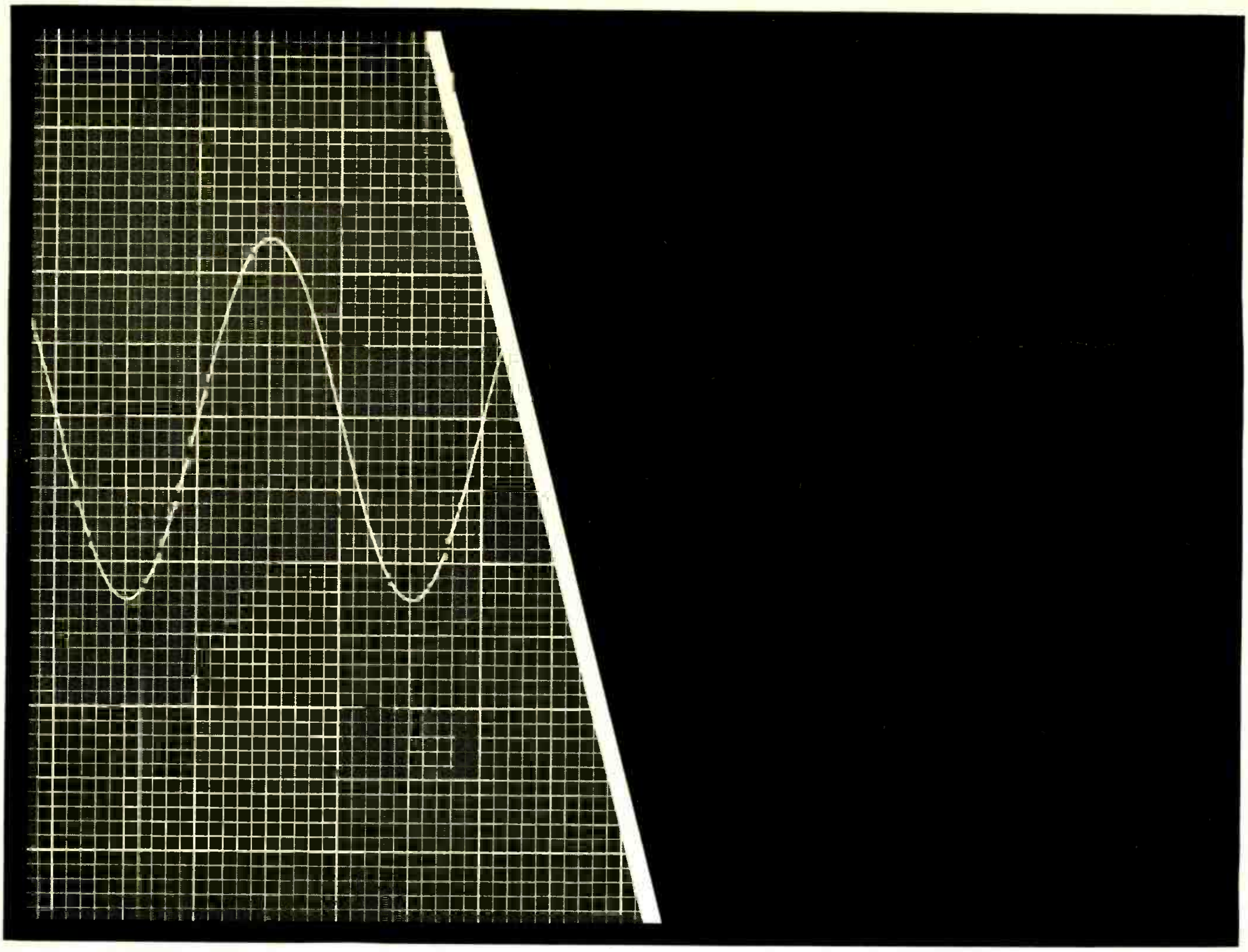
COMMUNICATIONS EXPERIENCE

comparable to many months on the job is yours as you build and use a VTVM with solid-state power supply, perform experiments on transmission line and antenna systems and build and work with an operating, phone-cw, 30-watt transmitter suitable for use on the 80-meter amateur band. Again, no other home-study school offers this equipment. You pass your FCC exams—or get your money back.

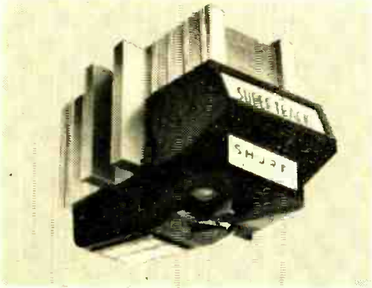


COMPETENT TECHNICAL ABILITY

can be instantly demonstrated by you on completing the NRI course in Industrial Electronics. As you learn, you actually build and use your own motor control circuits, telemetering devices and even digital computer circuits which you program to solve simple problems. All major NRI courses include use of transistors, solid-state devices, printed circuits.



Finally! A visually perfect sine wave!



The sine wave above was generated by Shure's design computer—it looks like the sine wave that was generated by the *Shure V-15 Type II Improved* Super Track Cartridge in the Hirsch-Houck testing laboratories . . . "the first cartridge we have tested to have done so," according to their published report. This perfect sine wave was generated during the playing of the heavy bass bands on the Cook Series 60 test record at ¾ gram, and the 30 cm/sec 1,000 Hz band of the Fairchild 101 test record at 1 gram. They were impressed, and we were pleased. And we'll be pleased to send you the full Hirsch-Houck Report on the "trackability champion." Shure Brothers Inc., 222 Hartrey Ave., Evanston, Ill. 60204.

SHURE

CIRCLE NO. 108 ON READER SERVICE CARD

HI-FI PRODUCT REPORT

EW LAB TESTED

by Hirsch-Houck Labs

E-V "Landmark 100" Stereo Compact
Heath AR-29 AM/Stereo-FM Receiver

Electro-Voice "Landmark 100" Stereo Compact
For copy of manufacturer's brochure, circle No. 1 on Reader Service Card.

THE *E-V* "Landmark 100" is a compact music system with several unusual design features. Perhaps the most interesting of these is the use of motional feedback from the loudspeakers around the amplifiers, to flatten the acoustic frequency response curve of the speakers, improve their transient response, and lower their distortion.

Loudspeakers included in an amplifier feedback loop are not new, but few of the systems we have seen over the years have really performed as they should. *Electro-Voice* has not released any schematic or other details of the system employed, but our tests do confirm that this system works, and works well.

Because the speakers are electrically integrated with the amplifier circuits, it is not practical to make amplifier response, power, and distortion measurements in the conventional manner. The manufacturer does publish amplifier specifications, principally to indicate the type of performance built into the system as compared to conventional music systems. The power rating is 20 watts per channel, with both channels driven on a continuous basis, or 80 watts total IHF music power. The distortion is stated to be less than 0.15% at 1000 Hz, with full output.

Externally, the most obvious distinction between this and other compact systems is in its speakers. They are essentially 10" cubes, with slices cut off three of their surfaces. Within each cube (which weighs 10½ pounds) are four speakers, mounted at various angles. Three of these are full-range 4½" units with long-throw voice coils. In addition, a 2¼" tweeter, connected *via* a capacitor, is mounted at the upper corner of one of the rear surfaces. One of the larger speakers faces forward, while the others bounce their sound off the walls.

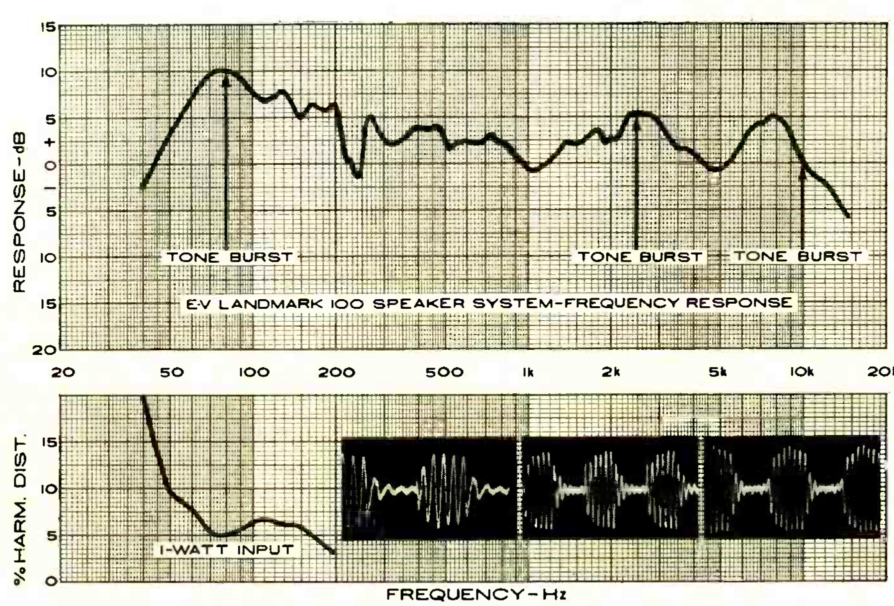
The FM tuner is relatively sophisticated for a compact system, featuring an FET front end, IC's in the i.f. and multiplex sections, and ceramic i.f. filters. There is automatic stereo/mono switching, a stereo indicating light, and a zero-center tuning meter. There is an AM tuner as well, which sounded very good as AM tuners go, certainly comparable to the better AM/FM receivers we have used.

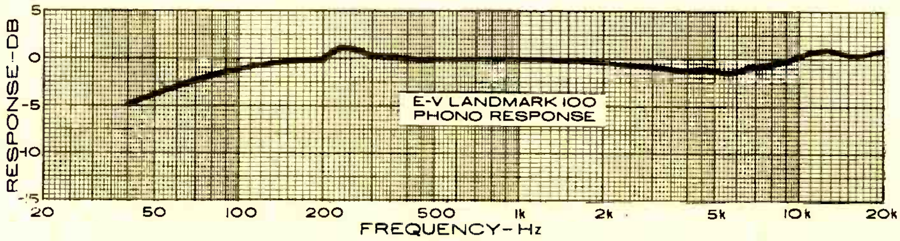
The operating controls are straightforward and uncomplicated. The unit has the usual bass and treble tone controls, volume and balance controls, and tuning knob. A row of five push-buttons control power, tape monitoring, loudness compensation, and mono/stereo operation. A headphone jack completes the front-panel lineup. In the rear are the five-pin sockets into which the special speaker cables plug, tape recorder connection and auxiliary inputs, and speaker protective fuses. There is a line fuse, within the unit, that will not blow unless something is seriously wrong, in which case the unit will require servicing. For that reason, it is not accessible to the user. There are no a.c. convenience outlets.

In our laboratory measurements of the FM tuner, made at the tape outputs, it proved to be an excellent performer. The IHF usable sensitivity was 1.9 μV, exactly as rated, and the distortion was 0.53% at 100% modulation (rated at 0.5%). The stereo separation, rated at 30 dB for middle frequencies, was somewhat better than the average good tuner we have tested. It exceeded 35 dB from 500 to 2500 Hz and 20 dB from 30-12,500 Hz. The FM frequency response was very flat, within ±0.5 dB from 30 to 15,000 Hz.

The record player is an inexpensive *Garrard* four-speed changer, equipped with a special magnetic cartridge set up to track at 3 grams. The changer does not have anti-skating (as far as we cou'd see) and lacks a balanced arm and any type of cueing device. However, the cartridge provided some pleasant surprises. Its frequency response, including that of the preamplifier, was within ±3 dB from 40 to 20,000 Hz. The channel separation was at least 20 dB over most of the audible frequency range.

Although the cartridge does not have a particularly high compliance, as evidenced by its 3-gram tracking force and the fact that it could not track the high-velocity 30-Hz bands of the *Cook* Series 60 record, it proved to have exceptional tracking ability at middle frequencies. At 1000 Hz, the 30 cm/s tones of the





Fairchild 101 record were played without significant waveform distortion—something few, if any cartridges in our experience have been able to do. IM measurements with the *RCA* 12-5-39 record showed satisfactory tracking up to about 15 cm/s with increasing distortion at higher velocities.

The *Shure* "Audio Obstacle Course" record confirmed the generally good tracking ability of this cartridge. Except for high levels of bells, cymbals, and harpsichord, it had no difficulty. Overall, its "trackability" score was just behind the top-priced cartridges, which are the only ones we have found to be able to negotiate the difficult passages of this record with no more than mild mistracking.

To test the speakers, we supplied a constant amplitude signal to the amplifier Aux input, and drove only one speaker. We had no way of knowing what power level was driving the speaker (it is electrically inaccessible), but set it up so that the acoustic output was similar to what we use with most speakers. Above 300 Hz, we obtained a relatively flat, smooth response curve, within ±3 dB from 300 to 10,500 Hz. The output fell off smoothly above 9 kHz, at a rate of about 12 dB/octave. It is likely that the extreme high-frequency response of this speaker would be strongly affected by the type of wall used for reflection. In our case this was a ordinary wallboard surface.

Below 300 Hz, we compared the response of the Landmark 100 to that of a calibrated reference speaker. Using the difference between the two, we were able to plot the response of the Landmark speaker as though it were not influenced by room resonances. To our surprise, it had a rising response below 200 Hz, reaching a maximum at 80 Hz. It dropped off rapidly below 70 Hz, although here again the placement of the speakers in the room would alter this low-frequency response considerably. The low-frequency distortion was fairly constant down to 70 Hz, increasing somewhat at 50 Hz and then rapidly below that frequency.

The tone-burst response of the speaker was excellent at all frequencies. Subjectively, we confirmed that the speakers can put out a very solid, clean bass in the 50 to 60 Hz region and that the output is smooth and audible at least to 15 kHz, which is about as high as we can hear.

(*Editor's Note: With respect to the low frequencies, the manufacturer has set up the motional feedback and power contouring to maintain constant total acoustic output down to about 55 Hz. Below this there is an 18 dB octave cut in the feedback circuit to conserve power and avoid rumble problems.*)

The Landmark 100 would seem, from these measurements, to be a good high-fidelity system, even judged by component standards. It has the unique advantage that the speakers can be placed almost anywhere, and oriented in many ways to obtain the desired special characteristics. Some people do not care for reflected-sound speakers; we happen to like them, and find that they impart a spaciousness that adds to our enjoyment.

In listening, the system has a uniquely clean and well-dispersed sound character. It is always risky to rank products in order, especially when not all competitive units are available for instant comparison. Therefore, we will content ourselves with stating, with cautious conservatism, that the Landmark 100 is one of the two or three best compact systems we have used, and with its little 0.5-cubic-foot speakers, can put many a larger speaker system to shame. The FM tuner is almost as good as you can buy—actually nearly in the class of better component tuners costing at least half as much as the entire system. The phono system was perhaps the weakest part of the unit, but nonetheless sounded fine. The rumble was relatively low (for a low-priced changer), −29.5 dB, which in use was totally inaudible since the speakers have essentially no response at the basic 30-Hz rumble frequency. On our test unit, the flutter was 0.1%, but the wow was a relatively high 0.3%.

As far as volume is concerned, the system can play loud enough to drive most people from the room, although it obviously cannot compete with a high-powered component system. The gains are such that one can often play it at maximum volume without overdriving anything to the point of serious distortion. Nothing can be damaged by such operation, due to the integrated design of amplifiers and speakers, and their inclusion in the amplifier feedback loop.

The *Electro-Voice* Landmark 100 is very worthwhile hearing if you are considering a compact system—or even if you aren't. It is a thoroughly clean, balanced, and musical sound system, and produces more and better sound from a pair of 0.5-cubic-foot speakers than anything else on the market.

The price of the Landmark 100 is $400. An optional smoky bronze molded dust cover is available at $14.95. ▲

Heath AR-29 AM/Stereo-FM Receiver

For copy of manufacturer's brochure, circle No. 2 on Reader Service Card.

THE *Heath* AR-29 stereo receiver is a deluxe, high-powered addition to the company's hi-fi line. It includes such desirable features as fixed-tuned i.f. filters, individual input-level adjustments, and a built-in user-operated checking and alignment facility.

The pre-aligned FM-tuner section's first r.f. amplifier employs an FET followed by bipolar transistors in the second r.f. amplifier and mixer, and the local oscillator. The receiver has non-defeatable a.f.c.; however, its action is moderate and it does not prevent tuning in stations with alternate-channel (400-kHz) spacing, even when there are large differences in signal strength. An IC i.f. amplifier couples the tuner-section output to the fixed-tuned multipole *LC* i.f. filter. Following the filter are two IC amplifier/limiter stages and a ratio detector. The multiplex circuits are essentially contained in a single IC that also provides muting and automatic mono/stereo switching functions.

The AM tuner uses dual-gate FET's in its r.f. and mixer stages because of their ability to handle strong signals without distortion. Two i.f. amplifiers are followed by a voltage-doubling detector and a very effective 10-kHz whistle filter. We made no measurements on the AM tuner, but found its quality to be clean, pleasant, and free from birdies and whistles.

The audio section of the AR-29 follows the design philosophy of the company's widely acclaimed AR-15. The audio power amplifiers have differential amplifier inputs, followed by push-pull drivers and output transistors. They are direct-coupled all the way to the speakers, and operate from matched positive and negative supply voltages to avoid a d.c.-voltage component in the output. The output transistors are protected by a dissipation-limiting circuit that reduces the drive signal when it senses excessive current. Shorting the speaker's outputs cannot damage the amplifier.

The appearance of the AR-29 is quite distinctive. For example, it has only one rotary knob—the tuning control. The flywheel tuning is velvet smooth in operation, and is aided by two tuning meters. One reads relative signal strength, the other is a zero-center FM tuning indicator. The other functions usually associated with rotary knobs, such as tone controls, balance, and volume controls, are all handled by horizontally oriented slide-type potentiometers. They are attractive, make for an uncluttered panel,

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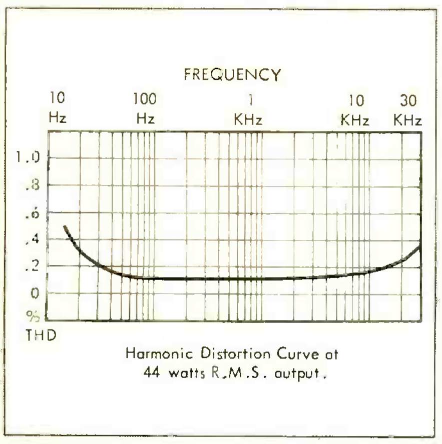
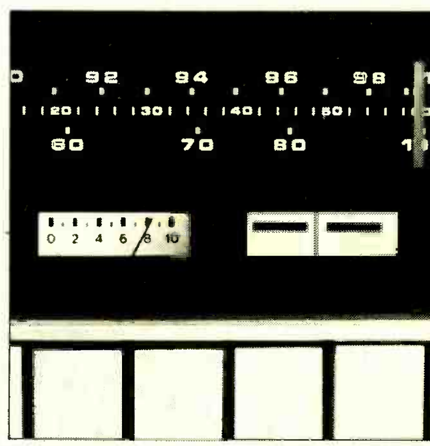
Altec's new 714A receiver. It's built a little better.



Harmonic Distortion Curve at 44 watts R.M.S. output.



With 44/44 watts RMS power at all frequencies from 15 Hz to over 20 KHz (at less than 0.5% distortion). Most receivers meet their power specifications in the mid-band but fall way short at the critical low and high frequencies. The above curve shows the typical low distortion at all frequencies from the new 714A receiver at 44 watts RMS per channel. For comparison purposes, we also rate the 714A conservatively at 180 watts IHF music power at 4 ohms. This means that the 714A will handle everything from a full orchestration to a rock concert at any volume level with power to spare.

With 2 crystal filters and the newest IC's. Ordinary receivers are built with adjustable wire-wound filters that occasionally require periodic realignment. And unfortunately, they are not always able to separate two close stations. So we built the new 714A with crystal filters. In fact, 2 crystal filters that are individually precision aligned and guaranteed to stay that way. To give you better selectivity. And more precise tuning. The new 714A also features 3 FET's and a 4 gang tuning condenser for high sensitivity.

Built a little better.

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And with a lot of other features like these. Separate illuminated signal strength and center tuning meters on the front panel. A full 7 inch tuning scale and black-out dial. The newest slide controls for volume, balance, bass and treble. Positive-contact pushbuttons for all functions. Spring loaded speaker terminals for solid-contact connections.

Altec's new 714A AM/FM Stereo Receiver sells for $399.00. It's at your local Altec hi-fi dealer's. Along with all the other new Altec stereo components—including a new tuner pre-amp, new bi-amp speaker systems and all-new high-performance music centers.

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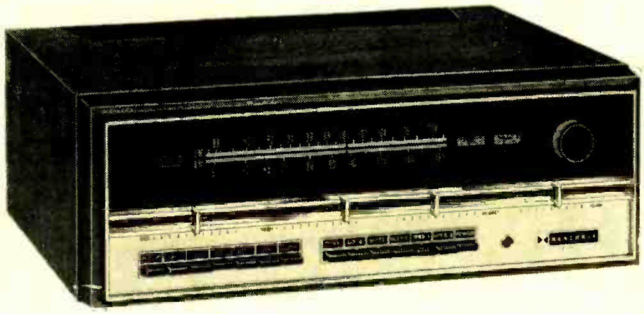


and are smooth and easy to use. All other receiver functions are controlled by fourteen push-buttons, in two groups of seven, below the slider controls.

One very desirable feature is the individual level adjustments for each channel of each input, permitting a system to be set up for equal volume and correct channel balance on all inputs. The controls are reached through holes in the bottom plate of the receiver.

Although we checked a not-normally available factory-assembled unit for this report, we did examine the AR-29 construction. Most of the components are mounted on eight printed-circuit boards. All the boards except the AM-FM r.f. circuit board are plug-in modules, mating with connectors on the chassis. Prewired harnesses are used between the board connectors and other chassis points. The signal-strength tuning meter serves as a voltmeter and ohmmeter during test and alignment, and complete information is provided for pre-operating checks of all boards and subassemblies, together with troubleshooting information on possible causes of incorrect readings.

The AR-29 is a complex receiver but it appears to us that its assembly has been markedly simplified. We would hesitate to recommend it as the very first project for a novice kit-builder, but on the other hand its construction should not require any real degree of expertise. Assembly should take about a week of evenings to complete. The alignment procedure after assembly took about an hour.

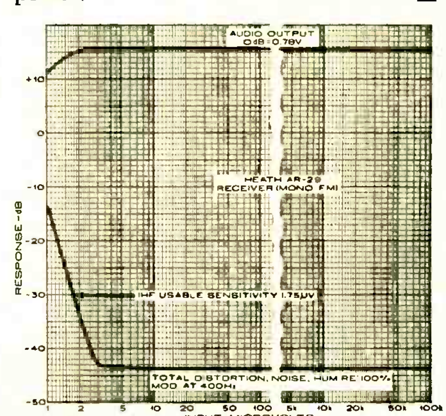
The performance of the AR-29 is very good indeed. Its FM tuner had an IHF usable sensitivity of 1.75 μV, placing it among the finest in respect to sensitivity. Limiting was complete at 3 microvolts. We measured about 0.7 percent distortion at 75-kHz deviation. *Heath* specifies less than 0.5-percent distortion, but since that is at the residual level of our FM signal generator, we could not reliably measure below the figure we obtained. Stereo-FM frequency response was extremely flat $\pm$0.25 dB from 30 to 15,000 Hz. Separation was uniform over a wide frequency range, better than 30 dB from 200 to 3000 Hz, and nearly 20 dB at 15,000 Hz.

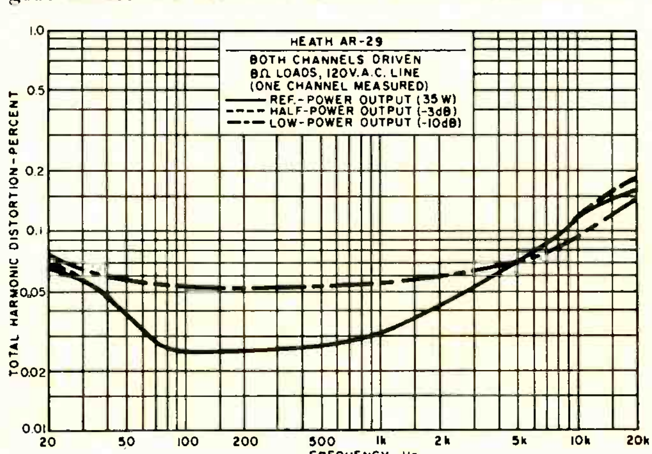
We found the audio amplifiers to be considerably more powerful than their rated 35 watts per channel. With both channels driven at 1000 Hz into 8-ohm loads, we measured about 50 watts per channel just below the clipping level. Harmonic distortion was under 0.1 percent from 0.15 to 50 watts, and under 0.03 percent over most of that range. IM distortion was about 0.1 percent at any level up to nearly 50 watts. At its rated output of 35 watts per channel, or any lower power, the distortion of the AR-29 did not exceed 0.15 percent between 20 and 20,000 Hz. The distortion was typically 0.05 percent over most of the audio range at any power level. Into 4-ohm loads, the AR-29 delivered about 50 percent more power, and into 16 ohms about 40 percent less power than with 8-ohm loads.

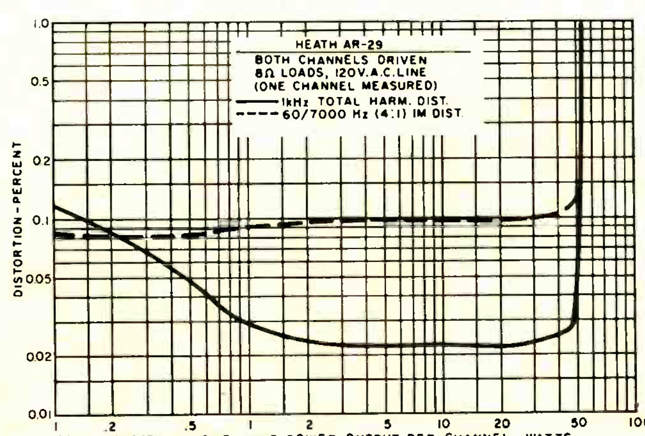
At maximum gain, only about 1 millivolt was needed at the phono inputs for a 10-watt output. It took a 23-mV input signal to produce overload in the stage following the phono preamplifier. When we turned down the phono-level adjustment (which is at the output of the input stage) we were able to make overload occur in the phono preamplifier stage itself at 160 millivolts. At that level, the phono sensitivity was 15 mV for 10 watts output. When the phono-level control is adjusted correctly, the AR-29 can handle any modern cartridge without risk of overload, and provide low distortion and an excellent signal-to-noise ratio. Hum and noise were extremely low: −90 dB at the high-level auxiliary input and −71 dB on phono, both referenced to a 10-watt output level.

The receiver proved to be very easy to use and listen to. All controls operated smoothly and positively. The FM interstation noise muting circuit, in particular, worked beautifully. In the muted condition, the output was weakly audible at about 23 dB below normal level. When tuning is optimum, the station comes in with a slight click. The tuning meter is almost superfluous if muting is used, since a signal can be heard only if it is tuned properly. The stereo-FM light comes on only when a stereo broadcast is tuned exactly "on the nose."

The *Heath* AR-29 receiver is, on the whole, an outstanding performer. It sells for $285 in kit form (it is not available factory-wired). The AR-15, costing $65 more for the kit version, provides somewhat more power and sensitivity. However, for most home requirements, the AR-29 is certainly more than adequate in terms of sensitivity, selectivity, and power. ▲







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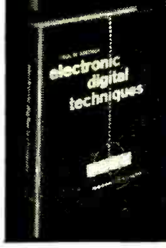

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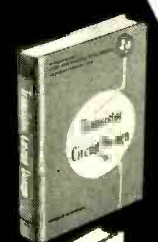

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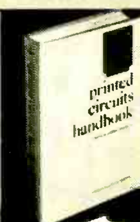

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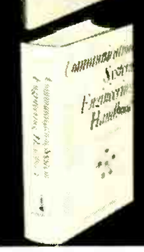

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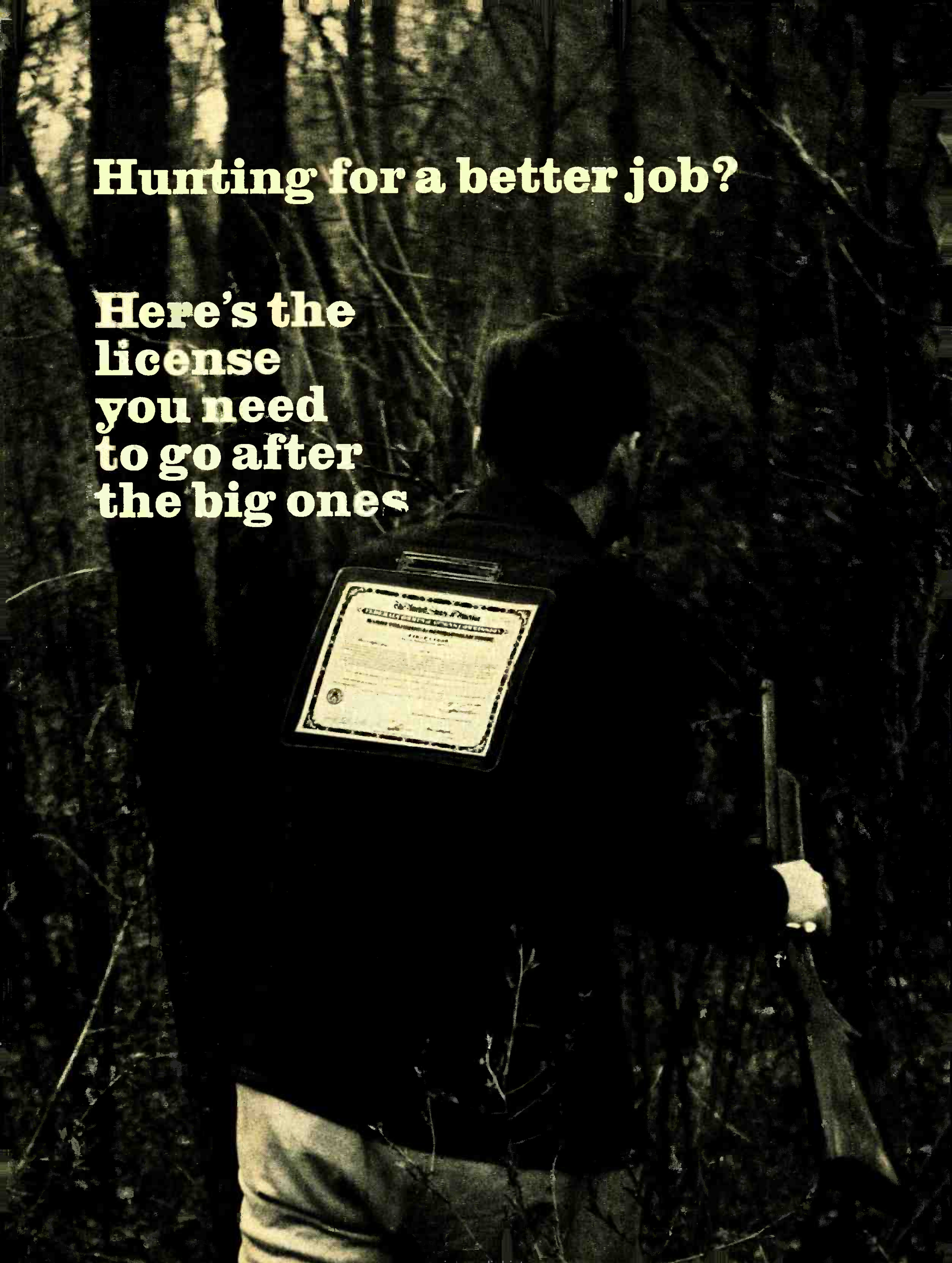
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But you *do* need knowledge, knowledge of electronics fundamentals. And there is only one nationally accepted method of measuring this knowledge... the licensing program of the FCC (Federal Communications Commission).

Why a license is important

An FCC License is a legal requirement if you want to become a Broadcast Engineer, or get into servicing any other kind of transmitting equipment—two-way mobile radios, microwave relay links, radar, etc. And even when it's not legally required, a license proves to the world that you understand the principles involved in *any* electronic device. Thus, an FCC "ticket" can open the doors to thousands of exciting, high-paying jobs in communications, radio and broadcasting, the aerospace program, industrial automation, and many other areas.

So why doesn't everyone who wants a good job in Electronics get an FCC License and start cleaning up?

The answer: it's not that simple. The government's licensing exam is tough. In fact, an average of two out of every three men who take the FCC exam fail.

There is one way, however, of being pretty certain that you will pass the FCC exam. And that is to take one of the FCC home study courses offered by Cleveland Institute of Electronics.

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Ed Dulaney, Scottsbluff, Nebraska, for example, passed his 1st Class FCC License exam soon after completing his CIE training... and today is the proud owner of his own mobile radio sales and service business. "Now I manufacture my own two-way equipment," he writes, "with dealers who sell it in seven different states, and have seven full-time employees on my payroll."

Daniel J. Smithwick started his CIE training while in the service, and passed his 2nd Class exam soon after his discharge. Four months later, he reports, "I was promoted to manager of Bell Telephone at La Moure, N.D. This was a very fast promotion and a great deal of the credit goes to CIE."

Eugene Frost, Columbus, Ohio, was stuck in low-paying TV repair work before enrolling with CIE and earning his FCC License. Today, he's an inspector of major electronics systems for North American Aviation. "I'm working 8 hours a week less," says Mr. Frost, "and earning $228 a month more."

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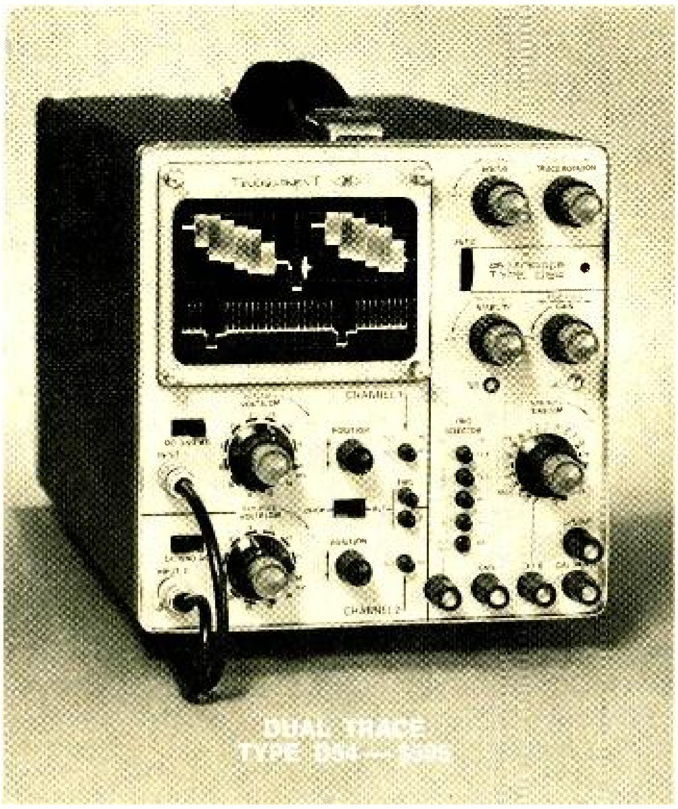

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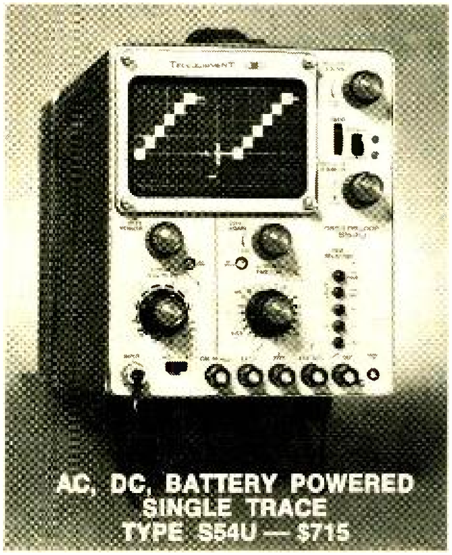

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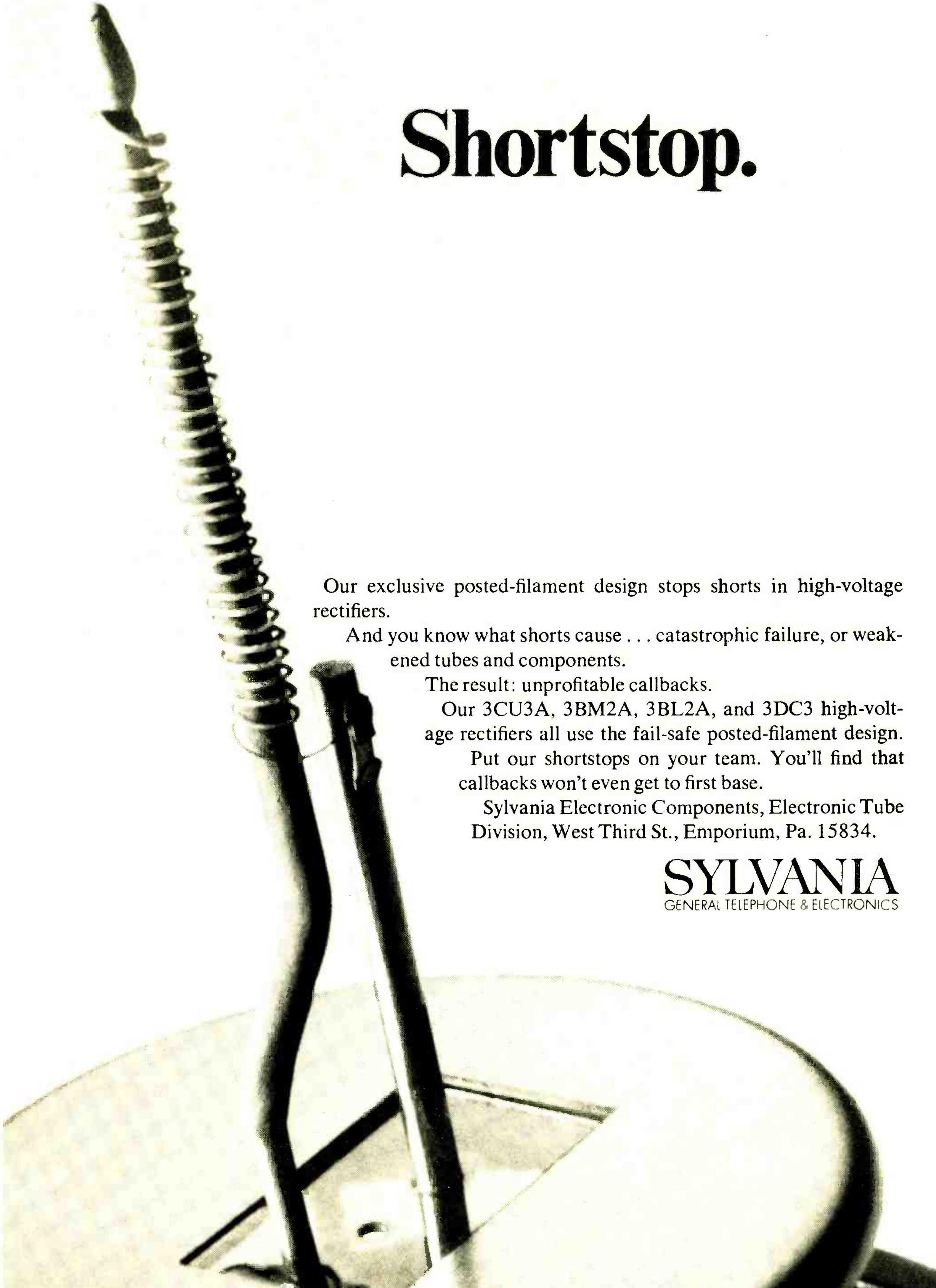


A Little Reminder

In case post-summer-vacation doldrums have you in their spell, here's a little reminder about the first suburban-type Hi-Fi Show to be held in Westbury, Long Island, N.Y. on September 18-20 at the Island Inn Motel. Our staff is proud to have taken part in the preparation of the Seminar Program that will be one of the highlights of the show. Here's an opportunity for you Hi Fi buffs to trade verbal blows with some of the industry's best-known experts. A preview of the Seminar Program follows: Friday, September 18, "Introduction to Hi-Fi Components" by Len Feldman (Consultant) from 7:00-8:00 p.m. and "Taping Techniques & Phono Cartridges" by Bill Cawlfield, *Ampex Corp.* and Bernhard Jakobs, *Shure Bros.* from 8:15-9:15 p.m.; Saturday, Sept. 19: "The Reverberant vs the Direct-Sound Sensation" by Frank Ferguson, president of *Bose Corporation*, and Don Davis, *Altec Lansing* from 3:00-4:00 p.m.; "Introduction to Hi-Fi Components" by Len Feldman from 6:45-7:45 p.m., and "4-Channel Hi-Fi" by Consultants Bert Whyte and Len Feldman, and John Eargle, *Mercury Records* from 8:00-9:00 p.m.; and on Sunday, Sept. 20: "Introduction to Hi-Fi Components" by Len Feldman from 2:00-3:00 p.m. and "Room Acoustics & Speaker/Amplifier Matching" by Abe Cohen, *ISC/Telephonics*, and Don Davis from 3:15-4:15 p.m. Hope all our friends will stop by and say "hello." By the way, don't forget a second Hi-Fi Show to be held Oct. 30 through Nov. 1 at the Marriott Motor Inn in Newton, Mass.

Needed—A CB Calling Channel

When the Federal Communications Commission decided to set aside channel 9 (27.065 MHz) for emergency use exclusively, it left us with mixed feelings. Our first thought was that by providing both services, emergency and "calling" privileges, on one channel there would be more people monitoring channel 9. That arrangement seemed to be ideal except that, looking at it realistically, there are always those who will abuse this privilege. Thus, since channel 9 can no longer be used for calling, there is now a desperate need for a single channel to be made available to use for calling purposes.

REACT headquarters in Chicago has come up with what seems to us to be a worthwhile suggestion. They have proposed that channel 11 (27.085 MHz) be used as a voluntary, nation-wide calling channel. Channel 11 was suggested by them because it is within the legal frequency range for general calling, is relatively adjacent to emergency channel 9, and most transceiver manufacturers furnish crystals for channel 11 in non-23 channel equipment. An industry-wide survey made by REACT along these lines has shown a unanimous agreement that channel 11 be established as the universal, unofficial calling frequency. As for ourselves, we heartily concur. As a result of the FCC decision, look for all sorts of new equipment providing dual-receive capabilities for monitoring posts.

Recording Color Set Purchases

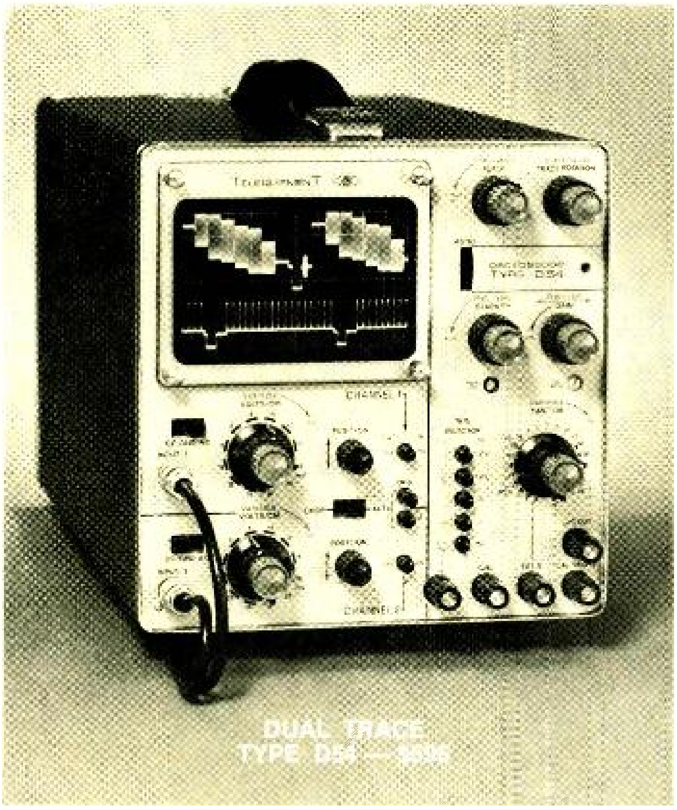
Effective June 27, according to new Federal Radiation Control Regulations, all color-TV distributors and retailers have to keep records of purchasers of all color receivers and 19- and 22-inch (diagonally measured) black-and-white sets. Records, containing purchaser's name and address, must be kept for a period of 5 years to help in tracing purchasers when potential hazard or defects are noted.

To facilitate record keeping, *Sylvania Entertainment Products* has made its electronic data processing facilities available to its dealers and distributors, who need only fill out "sold to," "sold by," and date and place of sale on cards provided by *Sylvania*. Cards are then sent to the company for computer storage.

To obtain a copy of new regulation, write to U.S. Dept. of Health, Education, and Welfare Environmental Health Service, Rockville, Md. 20852 for Health and Safety Act of 1968—Public Law 90-602.

Technician Convention Rescheduled

The National Alliance of Television & Electronic Associations (NATESA) convention, originally scheduled for August 14-16 at the Pick-Congress Hotel in Chicago, has been rescheduled for mid-October. Exact date has not as yet been confirmed. If you're interested in attending we suggest that you check with the Office of the Executive Director, Frank J. Moch, 5906 South Troy Street, Chicago, Ill. 60629 (312-GR6-6363) before making definite plans. ▲



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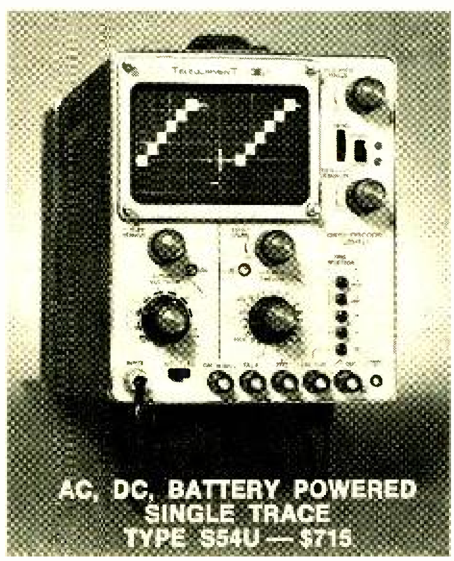

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NEWS HIGHLIGHTS

Graduate EE Fellowship

IEEE announces availability of a Charles LeGeyt Fortescue Fellowship for 1971-72. The $4000 award is made to a post-graduate student in field of electrical engineering who has received his Bachelor degree from an accredited engineering college by time work under fellowship would begin. Applicants will be required to take Graduate Record Examination and should arrange to have scores and application sent to the Fellowship Committee by January 15, 1971. Candidates must pursue their studies at engineering schools and engage in research programs meeting approval of Fellowship Committee. Award will be made as soon after the January 15th date as possible by an IEEE committee that administers the fund. Application forms are available at accredited colleges or may be obtained from Miss Una B. Lennon, Staff Secretary of the Awards Board, IEEE Headquarters, 345 E. 47th St., New York, N.Y. 10017.

Automatic Weather Forecaster

Honeywell Aerospace Division, Florida, awarded contract by Air Force to develop Expendable Remote Operating Weather Station (EROWS). Heart of system is 4-lb. sensor package that includes instruments to measure wind speed and direction, and cloud cover from remote or inaccessible areas. Device, which will be 104 inches long, 6 inches in diameter, and weigh 55 pounds, will be ejected from aircraft. It is designed to implant itself in ground on spear-like tip. Once in ground, sensor package will provide sensing and telemetry transmissions to master control station (also to be built by *Honeywell*). Telemetry equipment will use frequency-modulated/frequency-shift keying (FM-FSK) for communications between remote sensor package and master station. One-man master control station will include digital recording system for easy and accurate readout of telemetered data, an interrogation module to display exact status of EROWS being interrogated, and built-in test equipment for immediate checkout. Using ultra-high coding isolation to prevent erroneous interrogation of an outlying unit, up to 31 EROWS can be interrograted by master station. (If you are interested in weather forecasting, don't miss the story of U.S. Weather Bureau which will appear in our November issue.)

"Elementary, My Dear Watson"

Cornell Aeronautical Laboratory (CAL) awarded $100.000 contract by National Highway Safety Bureau of U.S. to develop program that will permit investigator at scene of auto accident and computer to have two-way conversation in order to reconstruct accident. Computer will be programmed to rank significance and reliability of various items of evidence and to draw sketch of accident scene, with superimposed displays of the reconstructed events. Computer will also be able to inform operator when it has sufficient information to reconstruct accident. In addition, computer will be capable of providing summary statement on contributing factors and principal causes of accident and, if desired, can indicate any possible traffic-law violations.

CCTV Helps Move Mail

Sylvania Electric Products Inc., subsidiary of *General Telephone & Electronics Corp.*, is installing closed-circuit television systems (CCTV) in 10 U.S. Post Offices to speed mail handling. Each system includes cameras, monitors. and associated equipment. Postal supervisors will now be able to monitor movement of mail along conveyor belts and other automated mail-handling apparatus. At first sign of snags in passage of mail from receiving platform to distribution channels, supervisors can dispatch crews to problem area to dislodge letters and parcels before any serious logjam develops.

Long-Lived Laser

Honeywell Systems and Research Center has developed a sealed carbon-dioxide (CO_2) laser that has operated continuously for a record 7000 hours—4000 hours longer than other sealed CO_2 lasers. Dr. Hans W. Mocker, electro-optics section chief for the Center, has set a goal of 20,000 hours ($2\frac{1}{2}$ years) of continuous operation (space-system requirements). Key element is a 2-foot by 3-inch polished-quartz block used as laser cavity. Rigid attachment of two mirrors into optical contact allows maintenance-free performance, compared with some units that need re-alignment of mirrors during operation. Efficiency of sealed laser system (10%) is one to two orders of magnitude greater than helium-neon, yttrium-aluminum-garnet or ruby lasers. A brandy-glass-size gas supply is excited by a battery source of 7000 to 8000 volts and 10 to 20 mA. Generates output power of 15 W and emission occurs into a narrow beamspread of 2 milliradians for transmission over long distances (voice or television pictures from Mars). Long lifetime attributed to self-circulating gas reservoir, electrode design, and special cleaning and sealing techniques. Has convenience of operating without bulky support equipment (gas bottle or vacuum pump) that is ordinarily required.

Western Space Conference

First Western Space Congress, based on theme "Space Sciences—Future Applications for Mankind," will convene in Santa Maria, Cal. on October 27-29. The Congress, sponsored by Vandenberg Scientific and Technical Societies Council, will present 102 technical and scientific papers during 18 programmed sessions (education, medicine, guidance and navigation, communications, space exploration, and international cooperation, etc.). Many major space and defense industries will exhibit daily new and exciting displays of interest to both the scientific community and the general public.

New Trade Association

A new trade association called Semiconductor Equipment and Materials Institute (SEMI) was recently formed for the rapidly expanding semiconductor industry. Raison d'être of new organization is to sponsor trade shows limited to makers of semiconductor equipment and materials and their customers, and to set up machinery for improving Industry-Government relations. Plan is to have one annual show, alternating between San Francisco and Boston. Future plans envision shows held in Europe and Orient. Dr. William B. Hugle, president of *Hugle Industries, Inc.*, Sunnyvale, Cal. named president and Fred Kulicke, president of *Kulicke & Soffa Industries*, Fort Washington, Pa., as chairman of SEMI. Next meeting of SEMI will take place in San Francisco during SEMICON week in November when constitution and by-laws will be voted on and a first-year slate of officers presented. ▲

Important New SAMS Books

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by the HOWARD W. SAMS ENGINEERING STAFF. Fully updated to include tens of thousands of substitutions. Covers all manufacturers and gives proper substitutions for all types of bipolar transistors: U.S. and foreign, home-entertainment and industrial. Computer-compiled for accuracy. Also includes manufacturers' recommendations for general-replacement transistor substitutions. Order **20773** *only* **$1.95**

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by the HOWARD W. SAMS ENGINEERING STAFF. The completely revised third edition of this famous training guide covers all the latest developments in the field. Written for the technician preparing to service color TV receivers. Describes the science of color, requirements and make-up of the color signal, latest color circuits, and practical setup and servicing procedures. Includes full-color picture tube photos. Order **20736**, *only* . . **$6.95**

ABC's of Air Conditioning

by ERNEST TRICOMI. This book presents a non-technical explanation of the laws of physics which relate to air conditioning and shows how these laws are applied practically in the design and manufacture of all types of air conditioning units and their components. Covers components common to all systems, electrical systems, estimating capacity and installation methods, and air conditioning repairs. Order **20725**, *only* **$2.95**

1-2-3-4 Servicing Transistor Color TV

by FOREST H. BELT. The "1-2-3-4 Method" is a simple, logical, step-by-step process which helps do the service job the right way and the easy way. In this book, the fundamentals of transistor color TV are covered, followed by a detailed explanation of how to apply the method for quick troubleshooting and easy repairs. Supported by a wealth of illustrations, charts, and block and schematic diagrams to make understanding easy. Order **20777**, *only* **$4.95**

Tape Recorder Servicing Guide

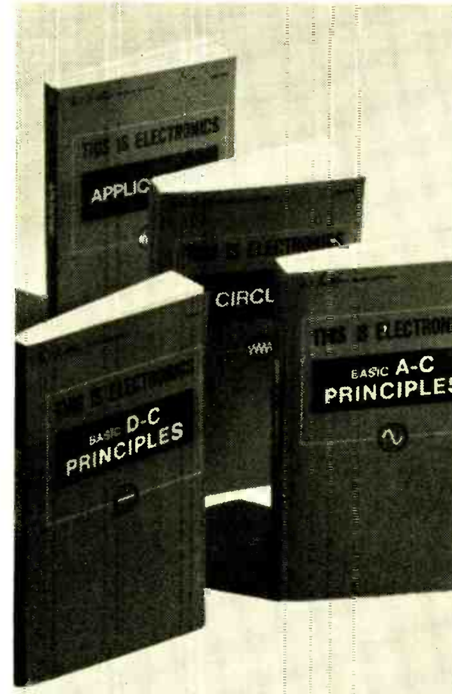
by ROBERT G. MIDDLETON. Thoroughly explains the principles and characteristics of magnetic recorder circuitry, describing the various components and systems. Provides comprehensive instructions on preventative maintenance, adjustments and minor repairs, and solving tape transport, recording, and reproduction troubles. Order **20748**, *only* **$3.95**

1-2-3-4 Servicing Automobile Stereo

by FOREST H. BELT. This book first applies the ingenious "1-2-3-4" repair method to both mechanical and electrical equipment and then proceeds to cover the electronic and mechanical principles of automobile stereo, fm multiplex and tape cartridge systems. Finally, the book shows how to apply the method to auto stereo systems. Includes many schematics, charts and illustrations. Order **20737**, *only* **$3.95**

Workshop in Solid State

by HAROLD E. ENNES. Presents the technology of transistor operation in terms familiar to those educated in tube technology. Provides an orientation in solid state principles, and a detailed analysis of the diode; covers transistor parameters, linear switching and pulse circuits, a wide variety of practical design problems and applications and basic testing and servicing techniques. Order **20735**, *only* **$9.95**



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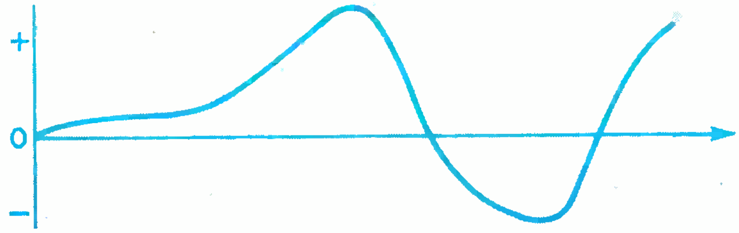
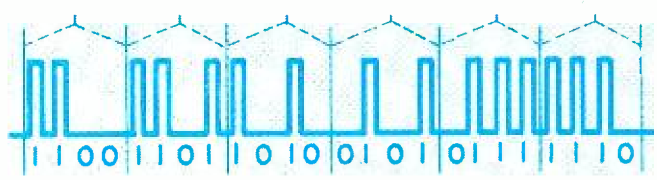


DIGITAL Voice Communications

By SIDNEY L. SILVER

Sophisticated pulse techniques, employing solid-state circuits, are making possible the reliable transmission of high-quality speech in digital form.

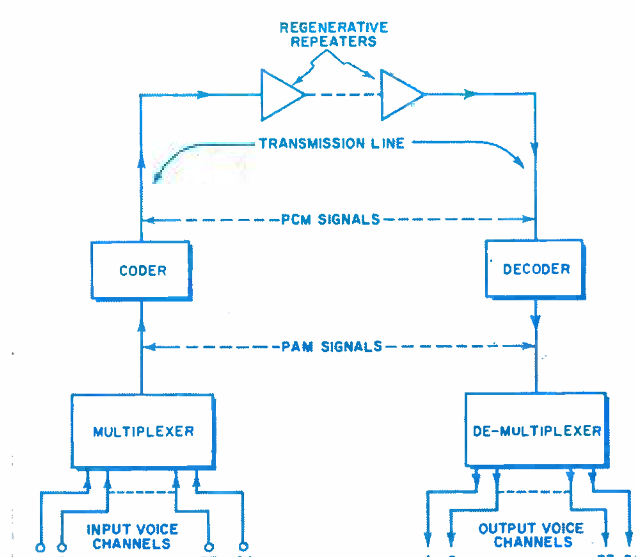


THE idea of transmitting voice signals in digital form was conceived many years ago, but owing to the large number of active elements required, severe limitations were imposed on the design of a practical digital communications system. These limitations were mainly associated with the use of vacuum tubes which were bulky, consumed too much power, and functioned poorly as switching devices. In recent years, however, the advancement of the solid-state art has provided new components and techniques that allow electronic circuits to become more complex, yet smaller and less costly than vacuum-tube circuits. The development of high-speed switching transistors and, more recently, integrated circuits, has made it possible to employ sophisticated pulse techniques which provide reliable, high-quality, digital speech transmission.

Formerly, voice communications over transmission lines was accomplished almost entirely with conventional analog electrical waves. In analog transmission, the audio waveforms vary continuously in proportion to the original speech signals. As these signals propagate along the line, they experience attenuation losses which must be compensated for by high-quality repeater amplifiers. Unfortunately, analog repeaters introduce some noise and distortion into the system, which accumulate as signals are passed through a chain of these devices. Moreover, any extraneous noise or interference picked up by the transmission cable, or coupled in from other lines in the cable, is amplified along with the voice signals.

A digital transmission signal represents a radically different method of communicating speech information. Using such techniques as pulse-code modulation, a given voice signal can be reduced to a stream of binary digits, whereby the intelligence of the speech signal is contained only in a

Fig. 1. Block diagram of a basic pulse-code modulation system.



particular pulse pattern, or code group. The binary pulses are transmitted in a fixed and predetermined time position, and thus can readily carry the message over the transmission path with a high degree of accuracy. During transmission, line attenuation will tend to obliterate most of the high-frequency components of the pulse waveform. In addition,

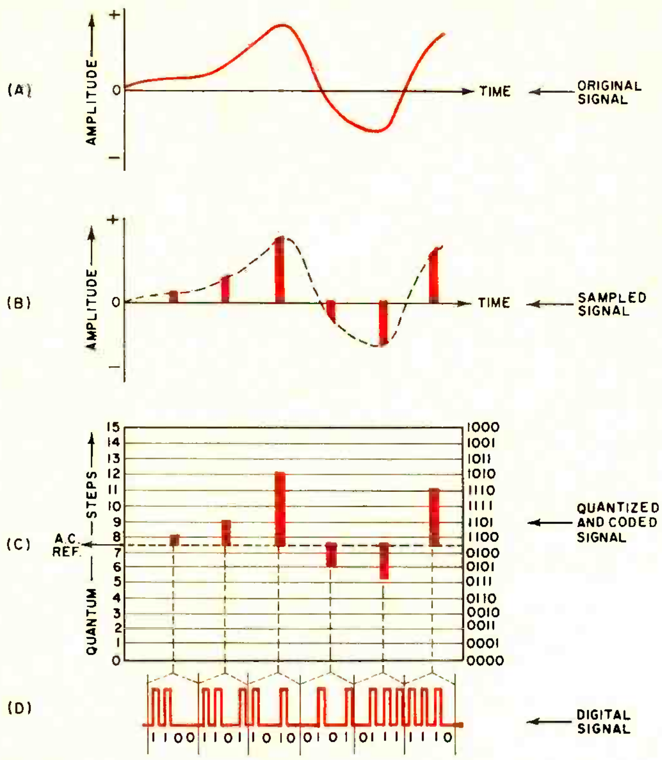
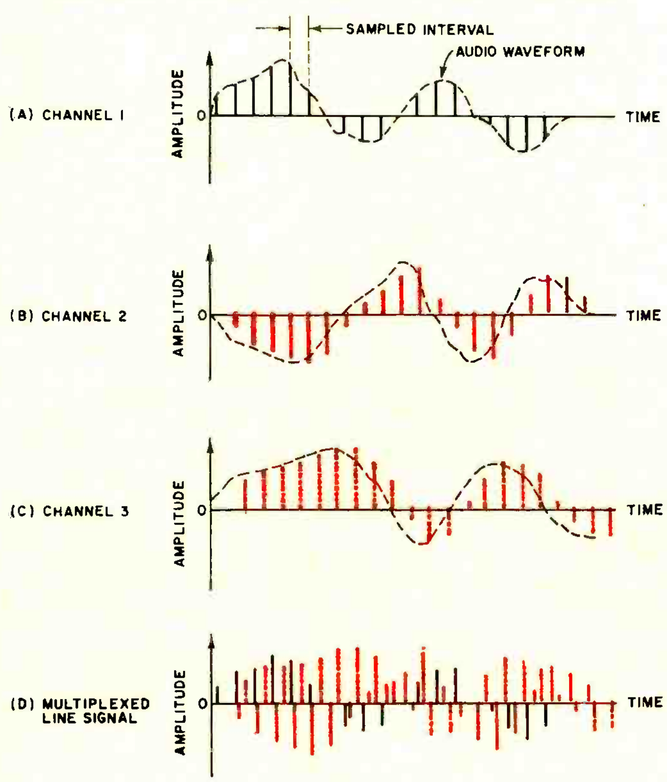


Fig. 2. Basic operating steps in pulse-code modulated transmission. (A) The original speech signal is (B) sampled to produce pulses corresponding to instantaneous voltage amplitude of audio waveform which is then (C) quantized into incremental levels and (D) encoded into equivalent digital signal.

Fig. 3. Sample of time-division multiplexing using pulse-amplitude modulation showing how three (A, B, and C) signal voice channels are (D) interleaved in time to form a single, higher-speed pulse train and fed to common line for encoding.



the presence of noise spikes on the line will further distort the digital signal. These problems are met by placing digital repeater circuits along the line, which are able to completely regenerate the pulse stream. Since all the pulses are of the same size and shape, these devices are simply required to detect the presence or absence of an input pulse and to generate, as often as necessary, a new undistorted output pulse. This process allows a high signal-to-noise ratio to be maintained throughout the system, thus overcoming the problem of cumulative noise which characterizes analog transmission systems. Finally, upon arriving at their destination, the regenerated digital pulses are reconstructed in order to recover the original signal.

Pulse-Code Modulation

At the present state of the art, the most advanced and efficient method of transforming band-limited voice signals into noise-free, wide-band pulse signals is the technique known as pulse-code modulation (PCM). The primary application of PCM is in multi-channel voice communications over wire circuits, although the digital pulse could, of course, be modulated on a carrier wave and then transmitted as a radio signal.

Fig. 1 shows a functional block diagram of the basic PCM system. Here a number of voice channels (24 in this case), representing various speech signals, are sequentially sampled by a multiplexing device, producing an interlaced series of varying-amplitude pulses. These pulse-amplitude modulated (PAM) signals, roughly analogous to the audio waveforms, are processed by a coding device which "quantizes" or divides the sampled signals into incremental amplitude levels. Each finite value is encoded, or translated into a digital number, so that a string of constant-amplitude PCM pulses is delivered to the transmission line. At the receiving end an inverse process, involving decoding and de-multiplexing functions, reproduces a replica of the analog voice signals. With this brief general description, we shall now discuss in detail the three basic steps (illustrated in Fig. 2) which implement the PCM system; namely, the sampling, quantizing, and coding operation.

Sampling

The initial operating step in a PCM process is to sample the voice signals at a suitable rate and measure the amplitude of the signals during the sampling time. As shown in Figs. 2A and 2B, successive portions of the fluctuating signals are extracted at regular intervals to produce a sequence of uniformly spaced PAM samples; the magnitude of each pulse sample corresponding to the instantaneous voltage amplitude of the audio waveform at the moment of sampling. In this process, the minimum allowable sampling rate is quantitatively related to the frequency spectrum of the audio signals, so that information can be lost if the sampling rate is not fast enough. This relationship is known as the *sampling theorem*, which states that if a signal is sampled at a rate of at least twice the maximum frequency, the sample will contain all the information of the original signal. In other words, any complex waveform can be faithfully reproduced if at least two amplitude samples are generated for each cycle of the highest frequency component.

Since voice signals are usually band-limited to reject all frequencies above 4000 Hz, a sampling rate of 8000 pulses per second, or one sample every 125 μs, is generally employed. This rate is sufficiently fast to prevent the listener from detecting any perceptible difference between sampled speech and normal speech. The effect is analogous to what an observer experiences when viewing motion pictures.

An important advantage of the sampling principle is that the discrete time intervals between the samples of a single voice channel can be allocated to other, independent channels by the technique known as time-division multiplexing (TDM). This is accomplished on a time-sharing basis by repetitively scanning each channel in a regular sequence, and allotting a particular time position to each channel. As shown in Fig. 3, the variable-amplitude pulse samples of one channel are interleaved in time between the samples of all the other channels, to form a single higher-speed pulse train. These multiplexed pulses are then applied to a common line for encoding.

The number of channels that can be multiplexed depends, of course, upon the duration of the time interval assigned to each sample; the shorter the time duration, the greater the number of channels that can be accommodated. For the sake of simplicity, a 3-channel TDM system is shown in Fig. 3 but in practice, 24 voice signals are usually multiplexed at one time. Since each channel is sampled at 8000 times a second, there would be 192,000 samples per second on a 24-voice multiplexed line.

Quantizing

Upon completion of the sampling operation, the next step is to quantize the intensity range of the sampled voice signals into distinct amplitude levels, thus permitting binary digital coding. As shown in Fig. 2C, the magnitude of each sample is compared to a scale of discrete values, or quantum steps which are used to represent any level in the dynamic speech range. Each step actually represents a limited range so that, essentially, this process creates only an approximation of the magnitude of the sampled waveform. The quantizing operation is performed by applying the quantum step nearest to the actual value of the pulse sample. For instance, a sample value of 8.21 would be represented by quantum step 8, a sample of 8.98 would be rounded off and quantized as step 9, etc. Obviously, the greater the number of steps, the closer the approximation to the sampled signals.

The difference between the actual value and the measured value of each pulse sample constitutes an error which gives rise to a phenomenon called quantizing noise, or quantizing distortion. This type of noise is inherent in PCM systems and differs subjectively from the continuous noise, *e.g.*, thermal, normally encountered in analog systems. As shown in Fig. 4, the error component tends to spread randomly over the speech range, producing quantizing noise only in the presence of voice signals whose amplitude does not coincide with an exact quantum step. Clearly, maximum error per sample cannot exceed one half the size of a quantum step.

Ideally, it would seem desirable to quantize all the positive and negative peaks in the dynamic speech range, thereby achieving infinite resolution and thus completely eliminating quantizing error. Increasing the number of quantum steps, however, would add to the complexity of the system, since digital components with much higher switching ratios would be required. Moreover, the great number of amplitude levels involved would raise the bandwidth requirements of the coded signals.

One method of reducing the number of quantum steps without sacrificing voice quality is to take advantage of the statistical distribution of speech amplitudes. For example, the normal distribution of voice signals is such that the probability of weak signals occurring is much greater than that of strong signals. Since most of the speech information is concentrated at low amplitudes, using quantum steps of equal size would result in the greatest amount of quantizing error for weak signals. By progressively tapering down the quantum steps so that very small increments are assigned to low levels and larger ones to the rest of the amplitude range, the total number of steps can be greatly reduced.

Another method of preserving voice quality with fewer quantum steps is to compress the magnitude of the pulse samples before applying uniform quantization, and then to expand the amplitude range back to normal at the receiving end. This technique, called instantaneous companding, achieves the same results as changing the size of the quantum steps. The companding action must be extremely fast in order

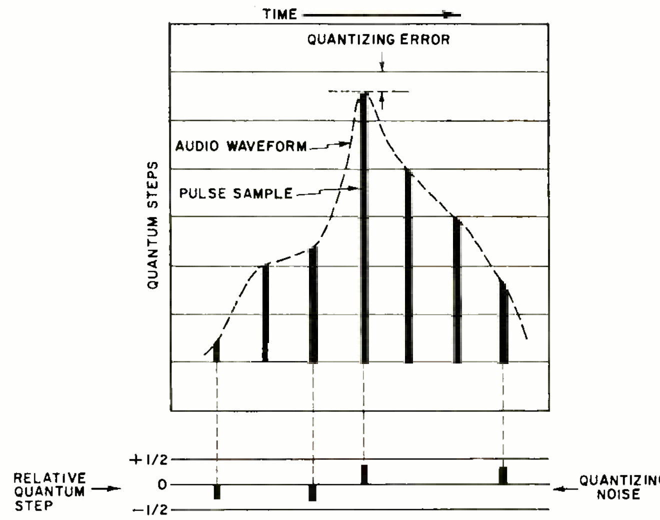


Fig. 4. Quantizing noise, or the difference between actual and measured value of each pulse, is produced only in presence of voice signals whose amplitudes do not coincide with an exact quantum step. As illustrated in graph the maximum error per sample cannot exceed one half size of a quantum step.

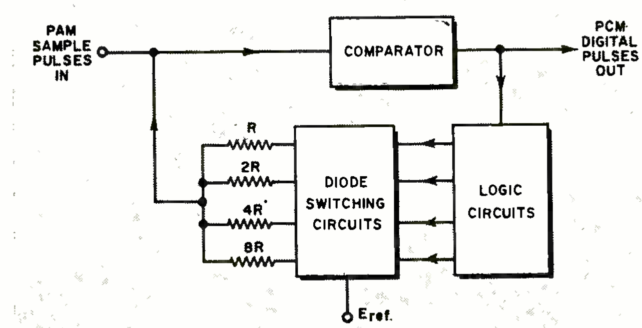


Fig. 5. Functional block diagram of a linear coder that uses the "successive-approximation" technique to determine the digital number representing the amplitude of a PAM sample value.

to respond to the narrow pulse samples. In the transmitting operation, the compressor effectively modifies the normal distribution of sampled speech so that preferential gain is given to low-level signals at the expense of the higher amplitudes. As a result, the signal-to-quantizing noise ratio is kept fairly constant even though the input levels vary over a large portion of the speech intensity range. Usually, the intensity range encountered in voice communications is about 60 dB, which represents the ratio of the loudest to the weakest speech level. By using a compression characteristic that varies logarithmically with signal amplitude, this range can be reduced to about 36 dB while maintaining the same quantizing noise performance.

Coding

The first step in transmitting the PCM signal is to encode the discrete amplitude levels in binary digital form. To form a digital code group, each quantum step is numbered in decimal form and a combination of binary 1's and 0's is used to represent each of the decimal numbers. The number of quantum steps that can be designated by the binary code is given by 2^n, where n is equal to the number of binary digits, or bits, required in each code group. Thus, the 4-bit code illustrated in Fig. 2C requires 2^4, or 16 discrete amplitude levels: with 8 quantum steps positive, 8 quantum steps negative, and zero reference (for the sampled signals) corresponding to the midpoint between steps 7 and 8. The first digit in the code group indicates whether a pulse sample is positive (binary "1") or negative (binary "0"), while the subsequent digits identify the voltage amplitude.

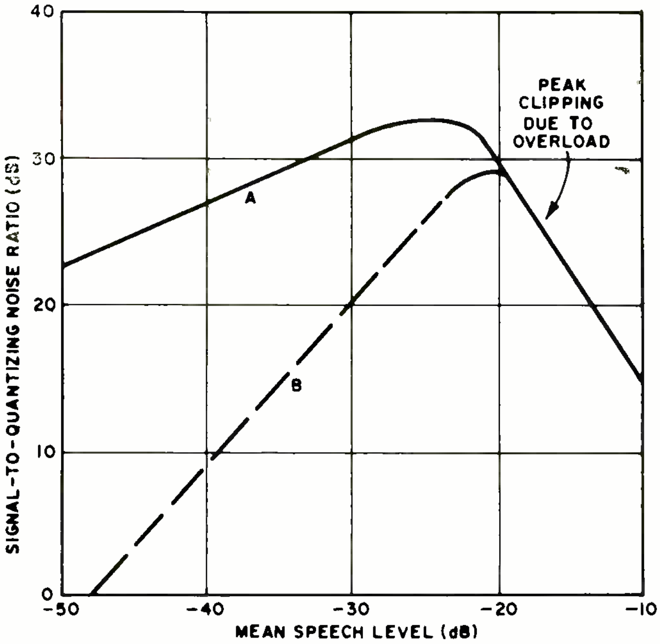


Fig. 6. Signal-to-quantizing noise ratio vs input signal level for 7-bit code using (A) logarithmic and (B) linear coding.

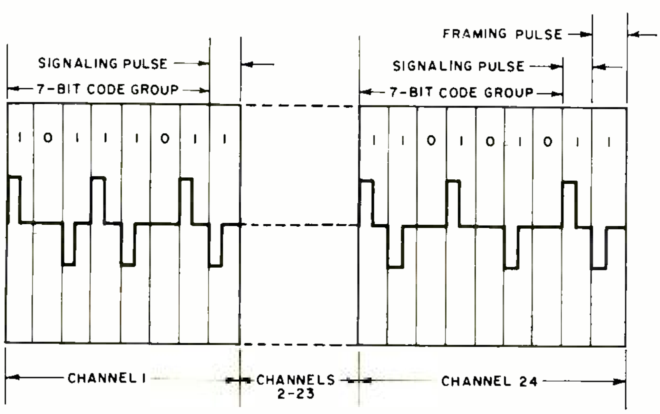


Fig. 7. Digital time slots for binary-coded pulses in a typical pulse-pattern arrangement for a 24-voice-channel system.

Fig. 8. Comparison of energy distribution between unipolar (straight binary) and bipolar signals with 50% duty cycle.

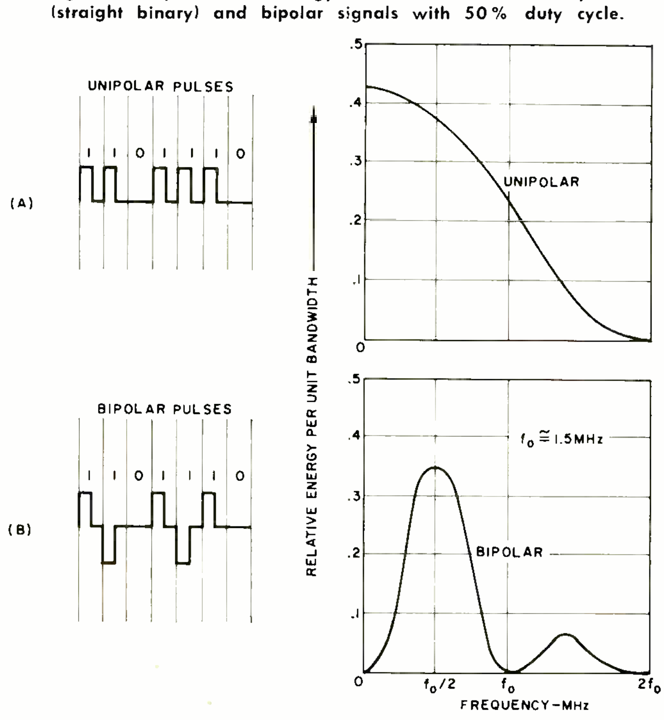


Fig. 5 shows a simplified block diagram of a linear coder which utilizes a technique called "successive approximation." In this arrangement, the digital output is determined one digit at a time, starting with the most significant bit. Initially, a comparison is made between the amplitude of each compressed sample input and a series of reference voltages; a voltage comparator making the decision as to whether a particular reference voltage is greater or smaller than the sample value. The output of the comparator causes the value of the reference to be changed until it approximates the amplitude of the input signal. This is accomplished by a diode switching network which progressively connects a number of precision resistors into the reference circuit; the operation being controlled by the logic elements. The process continues until all the digits of the binary code group are produced at the output.

The first comparison voltage is 50% of maximum amplitude, the second is 25%, the third is 12.5%, etc., so that each precision voltage is one half the value of the preceding one. Thus, when the pulse sample is compared to the first reference voltage, the most significant digit of the code is determined. If the sample is less than 50% of maximum, the logic circuits will generate a binary "0". If it is greater than 50%, the first digit will be a binary "1". As an example, let us assume that the 4-bit code (Fig. 2C) is being used, and the sample of interest is 70% of maximum amplitude. Since this value is greater than the first comparison voltage, the first digit to be generated is a binary "1". Now the second comparison (25%) is combined with the first and the sample value is compared again. Since the sample magnitude is less than 75%, the second digit is a binary "0". At this point, the second comparison voltage is switched out, and the third voltage (12.5%) is switched in. The sample is then compared against 62.5% of full value, and since it exceeds this, the third binary digit is a "1". Finally, the fourth comparison voltage is switched in, and the sample is compared against 68.75%. The fourth digit is therefore a binary "1". Thus, the digital number generated by the logic circuits is 1011, which represents the decimal number eleven (70% of the full-scale value of 16 amplitude levels).

Nevertheless, a 4-bit code group cannot handle the full range of positive and negative amplitudes, and is described here only for reasons of clarity. With this particular code, very weak signals would be completely lost while strong signals would be severely clipped. It has been empirically determined by listening tests that approximately 2^{10}, or 1024 linear quantum steps are required to adequately cover the dynamic speech range. This would call for a 10-bit code which, unfortunately, would be impractical for processing speech signals. However, by employing either instantaneous compression or nonlinear quantizing, this can be reduced to a 7-bit code representing 2^7, or 128 quantum steps. Fig. 6 shows the variations of signal-to-noise ratio with input level for a 7-bit code, and clearly indicates the advantage of logarithmic (A) over linear (B) encoding.

Pulse Transmission Techniques

A fundamental requirement in PCM transmission is that the pulse stream must be held to extremely close timing standards, so that all voice channels can work together without interference. Fig. 7 shows a typical pulse-pattern arrangement in which 24 voice channels are encoded in a 7-bit binary code group. Here the total 125-μs sampling interval, called a frame, is divided into a series of digital "time slots" representing the speech information in each channel. The binary coded pulses have a 50% duty cycle, which means that the width of each pulse is equal to one half the time allocated to each pulse. An extra time slot is added to the code group to carry supervisory and signaling information. Each time the entire frame is encoded, a framing pulse is placed in the last slot of the 24th channel, in order to synchronize the end terminals. Synchronization enables (*Continued on page* 78)

Adding Extra Channel for Improved Hi-Fi Ambience

By DAVID HAFLER/President, Dynaco Inc.

A third channel, derived from the present two stereo channels, can be applied to one or two rear speakers for an extra sound dimension and greater ambience.

SOME of the major benefits of four-channel sound can be had for just the cost of an extra loudspeaker, without need for a special four-track tape player and four amplifier channels. If four-channel systems are designed to help in the re-creation of hall ambience, then we can show a very simple way to do this with many existing two-channel recordings. If four-channel systems are designed to supply an extra dimension or "ping-pong" effect, with sounds in the rear, then our simple way still applies; but it requires the cooperation of the recording engineer.

There is a very simple and practical way to get ambience effects with a speaker at the rear of the listening area. This is not just simulation. It is based on the fact that information in the normal two channels contains ambience data which is lost in normal playback, but which can be partially captured in a rear loudspeaker. Fig. 1 shows the basic method of connecting the extra loudspeaker. The speaker is connected *differentially* across the two amplifier outputs and is placed in the rear of the room.

The differential connection is made from the *high* side of one amplifier output to the *high* side of the other. There is no ground or chassis reference for this speaker. This connection will not affect normal amplifier performance, but it does decrease the load into which the amplifier looks. For practical purposes, the loudspeaker can be considered to be in parallel with one of the side speakers; so if 8-ohm speakers are used for the left and right channels, the amplifier is looking into 4 ohms. It is not practical to use this connection with speakers of less than 8-ohm rating unless the amplifier is operated well below maximum.

The rear loudspeaker reproduces *difference* information only. (If the signals at each end of this speaker were the same, there would be no potential across it and no signal output.) Included in this out-of-phase information is the reflected sounds which reach the microphone in random phase. These sounds produce the ambience effects.

If it is not practical to put a single loudspeaker behind the listener, two speakers, one on each side of the listener, can be used. The two rear speakers can be connected in series or in parallel. The series connection will give less output in the rear. The connection should be chosen so that the sound level from the rear is unobtrusive from the normal listening position.

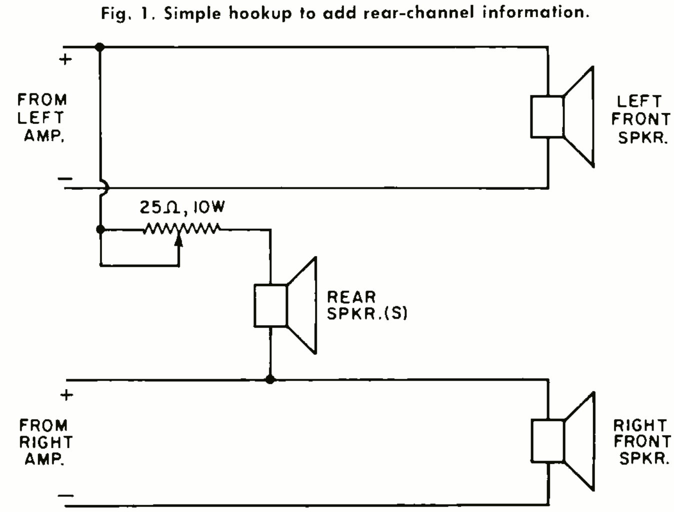
Why it Works

Why does this extra speaker give an additional ambience effect? The answer is that the reverberant sound which is reflected throughout the recording area is at a lower level than the direct sound and has a time delay before pickup as compared to the direct sound. Therefore, it is to a large extent masked by the direct sound when using two stereo loudspeakers. However, when we use the differential speaker, some of the direct sound is canceled (that which is common to the two channels), so there is sound in the front speakers which does not appear in the back, but the reflections of this sound do appear in the back with the same time lag from front to rear speaker as appeared in the original hall between direct and reflected sound.

The *source* of the sound still appears to be in front due to precedence and amplitude effects, in which the first and/or loudest of two identical signals establishes the point source; but the sound in the rear adds to the total sound front in the same way that it adds in a resonant recording environment. Thus, the addition of the rear differential speaker uncovers spatial information which was always in the recording but does not appear in conventional playback.

When using the differential loudspeaker, it carries a sound source in the rear for signals which are in opposite phase. This leads to a most useful opportunity. If the recording engineer deliberately introduces an oppositely phased signal in the two channels, the rear speaker will reproduce this signal in the rear—without apparent front source. This rear signal can be used either for control of ambience or for positioning some sounds in the rear. ▲

Fig. 1. Simple hookup to add rear-channel information.



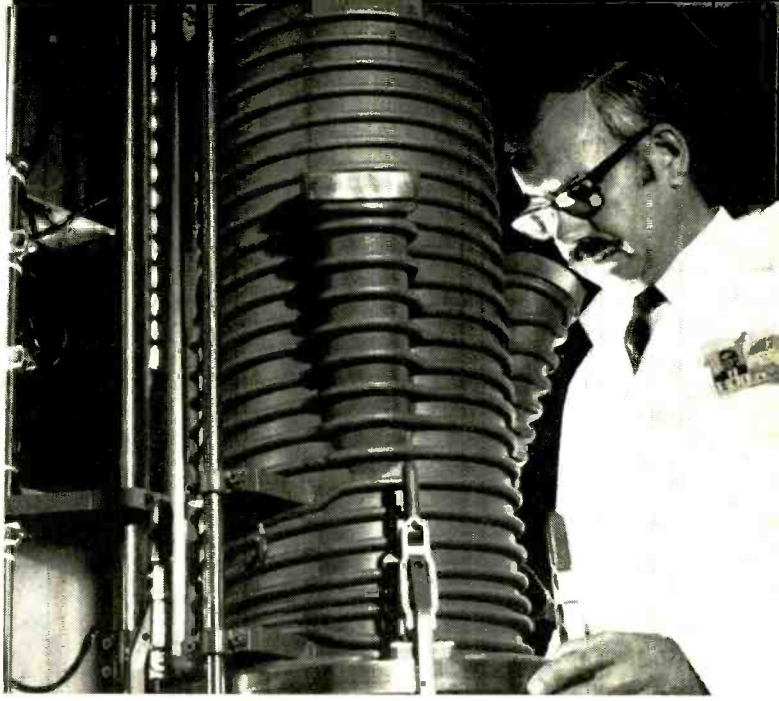
Recent Developments in Electronics

Portable TV Control Center. (Top left) A complete single-cabinet portable television control center is shown here. This new unit electronically combines pictures and sound from a variety of sources for closed-circuit and live TV productions. It provides complete video monitoring and control waveform monitoring and audio mixing all in one compact cabinet. The entire unit weighs only 90 lbs and it measures about 22 by 16 by 20 inches deep. It can be easily transported for on-site productions. In addition, its manufacturer, Ampex Corp., has priced the control center at just under $3000, which they say is less than half the price of comparable systems. The three 5-inch television monitors can be seen along the top of the new portable control center.

Infrared Communications System. (Center) A new data communications medium—infrared—is being used to link two University of Southern California computer installations. The University is the nation's first to use infrared transmission in a fully operational system which allows the two computers to communicate at speeds up to 250,000 bits per second. The device providing this new high-speed capability is called "Optran" and is manufactured by Computer Transmission Corp. of Los Angeles. The distance covered by the IR link is one-half mile across the campus. The optical unit located on a mast atop one of the school's engineering buildings is shown in the photograph. Other infrared transceiver link-ups at the University of Southern California are planned for the future. As many as three or four other campus sites are expected to be interconnected by means of an IR link.

Computerized Heart Study. (Below left) A research system used for heart studies has been set up at the Krannert Institute of Cardiology in Indianapolis. The system is said to be the first designed as a completely integrated unit. It converts physiological analog data into digitized form for analysis and interpretation. Vital life signs of patients, such as the electrocardiogram, external heart sounds, various blood-pressure measurements, and respiration are monitored and recorded by the two analog units on the left. This data is then converted to a format acceptable to the computer units on the right for programmed analysis. The information is then printed out on the typewriter unit for use by the Institute in its heart research. Honeywell instrumentation is used.

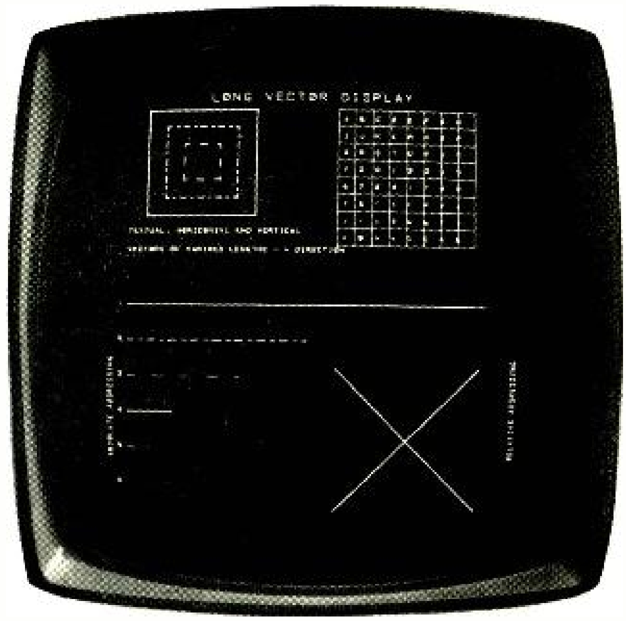
Giant Crystal-Growing Furnace. (Top right) One of the largest commercially available crystal-growing furnaces is shown here. The furnace, with three times greater production capacity than earlier models, is used by semiconductor manufacturers for growing crystals of silicon, germanium, and other materials. The resistance-heated vertical furnace grows $3\frac{1}{2}$-in diameter, 28-in long crystals, each one of which will produce about a quarter million IC chips. Manufactured by Norton Co., the unit has several automatic features. One of these increases or decreases the seed pulling and crucible lift rates to maintain uniform crystal diameter. Another is an optical temperature sensor that maintains the melt surface within ±0.5° C of the freezing point of silicon to assure uniform crystal diameter.



Credit-Card Checker. (Center) Over 1400 keyboard terminals, like the one pictured here, are being installed beside cash registers at all May Co. stores throughout Southern California. These are part of a new credit-authorization system that allows salesclerks to quickly check all credit purchases. The customer's purchase total and account number are punched into this terminal and this information is sent via communications lines to the company's central credit office in downtown Los Angeles. The system was developed by TRW. Perhaps the harried customer, with her credit card being checked and with her moves being watched by CCTV cameras, may get the feeling that she's not really being trusted, especially by some of the unhelpful and discourteous salesclerks that we've encountered recently.

Electronic Carillon. (Below left) At Brandeis University near Boston a glass carillon is reproducing the peals of the world's greatest carillons, but without the use of huge bronze bells. Replacing these bells is a 40-lb device containing 35 glass bells made of fused quartz from GE's Lamp Glass Dept. Various lengths of quartz tubing, with tiny glass-tipped hammers sealed inside, produce very weak bell tones. These are then amplified electronically and fed to loudspeakers mounted in a chapel belfry. Carillon can be played manually through 3-octave keyboard console or programmed to play automatically.

Lightweight Aircraft Communications System. (Below right) A compact, lightweight communications and navigation system for helicopters and fixed-wing aircraft is being flight-tested by the U.S. Army. The 40-lb system, built by Sylvania, is one-third the size and weight of comparable equipment. It uses three solid-state IC modularized transceivers operating on v.h.f.-FM, v.h.f.-AM, and u.h.f.-AM. These can automatically re-transmit point-to-point air, ground, and sea communications. There is also an automatic direction finder and communications control unit that can send and receive digital data.



GRAPHIC COMPUTER TERMINALS

(Part 1)

Editor's Note: This is the first part of a two-part article designed to acquaint the reader with some of today's graphic video display terminals being used as data interfaces between man and computer. Raster-scan display and random point display (RPD) systems are thoroughly described in Part 1. A third type of display terminal—the stroke generator display system—as well as some of the sophisticated circuits that can be used with RPD terminal to both speed up and improve its operation will be described in Part 2.

IN the 1940's, technology gave scientists, engineers, and businessmen the digital computer. Since that time, computer users have been dreaming up problems that require faster and more complicated computers in smaller and less expensive packages.

The biggest stumbling block in man/computer systems, no matter how simple or complex, is the information interface between the machine and the humans who use it. Humans want to put information into the machines with as little physical and mental effort as possible; and they want to retrieve the results of the machines' efforts in the same way.

Interactive graphics is presently the ultimate in information exchange schemes between men and machine. No other computer in/out system can approach graphic terminals in the rate and quantity of easily digestible information it can feed the human mind.

A picture is, indeed, worth a thousand words. A single video computer display is worth a thousand jumbled characters printed out on reams of paper. Instead of spending hours or even days interpreting conventional computer readouts, an operator at an interactive graphics video terminal can interpret his data at a glance, and make any changes or additions in an instant.

Interactive graphics is a phenomenon born in the late 1960's. During the next few years, video terminals promise to become the most practical and efficient way of coping with the rising complexity of computer-solvable problems.

Raster-Scan Video Terminals

By far the most popular kind of video display system today is the TV raster-scan display system (Fig. 1). The things users like most about it are its relatively low cost and its compatibility with existing closed-circuit TV systems.

Raster-scan terminals can be used alone (Fig. 1A), or in conjunction with some kind of data processing (Fig. 1B). Used alone, the terminals serve as high-speed, high-capacity communications systems. Used with a data processor, the terminals become high-performance in/out subsystems for a complete data processing system.

The majority of raster-scan terminal users run the terminal without a data processor. The operator sits at a typewriter-like keyboard (Fig. 2) and types in the desired alphanumeric text. A cursor mark, such as a dash, appears under the point

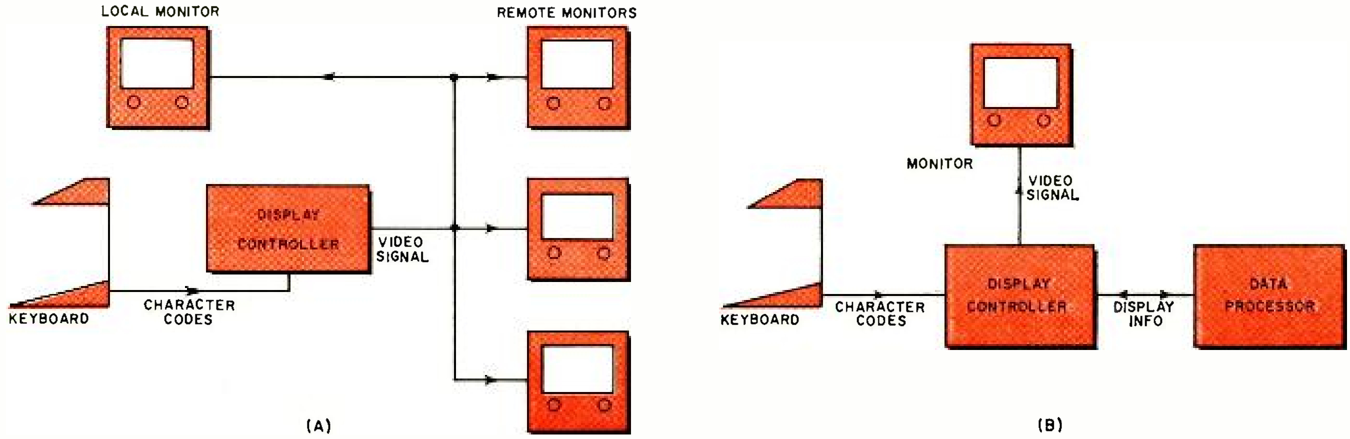


Fig. 1. One of the most popular video display systems today is the relatively inexpensive, CCTV-compatible raster-scan video terminal which can be used either (A) alone as a high-speed, high-capacity communications system or (B) in conjunction with a data processor to act as a high-performance in/out subsystem for a complete data processing system.

By DAVID L. HEISERMAN

By displaying the computer output in picture form, the user is able to quickly interpret the data and act upon it. Widely used in busy air terminals, as teaching machines, and in R & D laboratories, these video display terminals permit good machine-man interfaces, thus expediting all communications.

Univac graphic displays showing (top left across page) the kinds of figures and graphics that can be automatically generated by random-point or stroke generator display systems and (right, this page) the type of display that might have wide applications in the fields of meteorology, law enforcement, and education. See text for descriptions.

on the CRT screen where the next character will appear. When the operator presses a character key, that character appears on the screen, and the cursor mark moves on to the next point.

The operator can delete a character in the text by using a special key to move the cursor under the character to be erased, then pressing the "Erase" key. The character immediately disappears from the text and the operator can replace it with another. With most raster-scan video systems, the operator can delete an entire line of text by placing the cursor to left of the line and pressing "Line Erase" key.

It is possible to connect six or eight TV monitors into the raster-scan video display system. This allows the user to display the text simultaneously at many different locations. Using the system in this way is much like using an ordinary typewriter, but which has the incredible ability to provide printout text at many different places at the same time.

One popular application of this communications feature of raster-scan video terminals is in busy airports. An operator can display up-to-the-instant flight scheduling data on monitor screens all over the airport (Fig. 3).

Used in conjunction with a data processor, the raster-scan video terminal becomes a high-speed readout device. Typical teletypewriters have a printing rate of less than 10 characters per second. With a video terminal, however, the computer can dump a full load of 500 characters onto the screen in one raster-framing time. If the user wants to preserve the display, he can photograph it or record the video signal on conventional video tape.

Using a raster-scan video terminal as a computer input device, the operator can type his program and data onto the CRT screen. Before unloading it into the processor, he can inspect the text on the screen, and make any changes simply by using the cursor controls and erase keys. This video programming technique eliminates the need for special editing languages now needed for most teletypewriter computer terminal systems.

Raster-scan video terminal systems are now commonly used as teaching aids. The processor sends a question that appears on the screen. The student types in his answer to the question and sends it back to the processor. If the answer is correct, the processor goes on to the next question. If the answer is incorrect, the processor might display some kind of text that explains why the answer is wrong.

A serious disadvantage of today's raster-scan video display terminals is the fact that they can be used successfully only with character displays. None of the commercial raster-scan video systems has a line-drawing capability. Most raster-scan users, however, find they can compensate for this inability to draw lines by using the terminal in conjunction with a CCTV system. Whenever the user wants to display pictures on the monitors, he can switch out the character generator and switch in an ordinary TV camera.

How Raster-Scan System Works

A display controller unit (Fig. 4) is the heart of the raster-scan video display system. This unit develops the sync and raster unblanking pulses. The display controller's main job

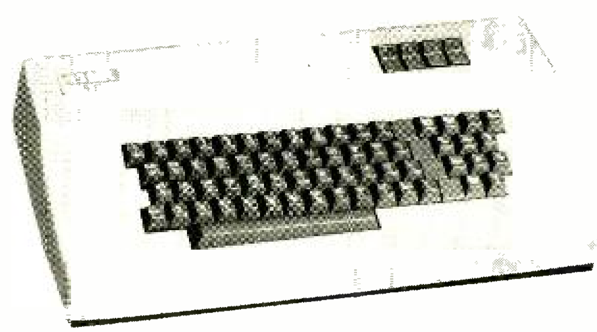


Fig. 2. Terminal keyboard used with A.B. Dick's raster-scan display system. Resembles ordinary typewriter keyboard except for extra keys for moving the cursor, erase operation, and communicating with display controller shown in Fig. 1.

Fig. 3. Typical raster-scan airport video terminal display.

FLT	ARR TIME	GATE	ARRIVING FROM	REMARKS
231	6:00A	12	WILKES-BARRE	ON TIME
117	6:15A	13	HARTFORD-NEW YORK	ON TIME
322	6:45A	22	BRADFORD	DELAYED
456	7:05A	34	PHILADELPHIA	ON TIME
833	7:15A	35	NEWARK	ON TIME
841	7:45A	15	WASHINGTON DC	SEE AGENT
465	8:34A	25	BALTIMORE	ON TIME
888	8:56A	36	NEW YORK	ON TIME
378	9:23A	16	DETROIT	ON TIME
921	9:44A	18	CLEVELAND	DELAYED
678	10:24A	11	AKRON-CANTON	ON TIME
756	10:54A	38	CHICAGO	ON TIME
444	11:15A	41	HARRISBURG	ON TIME
246	1:23P	19	ROCHESTER-UTICA	ON TIME

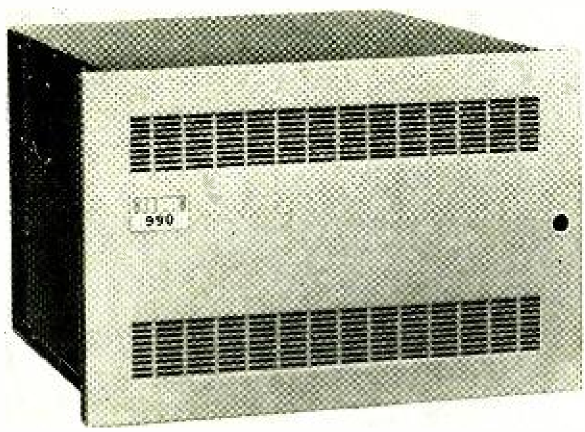


Fig. 4. The heart of any raster-scan video system—the display controller. The unit's main function is to store character text information and read it out as a TV video signal.

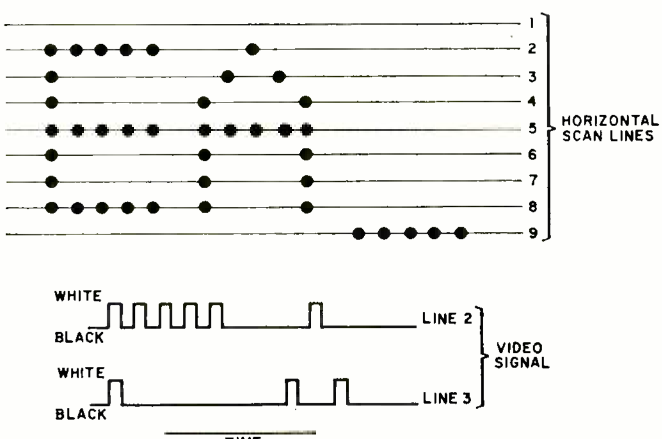


Fig. 5. Examples of two characters and the cursor as they appear on a raster-scan video terminal screen. Note that since display controller is a digital device it displays characters by scanning each horizontal row of character dots, one scan line at a time. The white-to-black video signal ratio is so great that the horizontal scan lines do not appear on the terminal screen as on an ordinary TV display.

is to store the character text information and read it out as a TV video signal. Any character data typed into the display controller or fed into it from the processor goes to a memory section. The sync clock triggers the horizontal scan and, at the same time, begins the memory readout sequence.

Since the display controller is a digital device, the video signals to the CRT must be in the form of "yes" or "no" digital bits. For the sake of economy, the pulse width of all these bits are the same. Thus, a raster display system cannot draw a continuous line segment at one instant and a small dot the next—all displays must be a composite drawing of uniform dot elements (Fig. 5).

A raster-scan display for a single character is much like a scoreboard display at a sports arena. In one way or another, each video character fits into a rectangular matrix of dot elements. Instead of lighting all the appropriate dots simultaneously, the video system display controller builds up a character by scanning each horizontal row of character dots, one scan line at a time.

To do this job, the controller has to break up each character into a series of dot segments. With the exception of the *period* character, no character can be completely drawn in a single horizontal scan. *Beehive Electrotech* markets a raster-scan video terminal for about $3500. The *Beehive* system, typical of the hundred or so on the market today, can write 20 lines of text with up to 40 characters in each line. Each character occupies a 5 × 7 dot matrix.

People viewing an alphanumeric display on a raster-scan terminal will not confuse the character in spite of their somewhat jagged appearance. In the case of graphs and complicated line drawings, interpretation becomes more difficult because of the raster-scan discontinuities. No matter how finely spaced the horizontal dots are in a raster-scan display, the vertical spacing of the raster breaks up any kind of line or curve that has a vertical or Y-axis component. This is why none of the companies that manufacture raster-scan displays bothers to design in line-drawing capabilities.

The Random-Point Display

Today's graphic video terminals can display line drawings as well as alphanumeric text, and the Y-axis components do not appear to be broken up any more than the horizontal components. To display smooth vectors or curves, the controller must be able to place the electron beam at any point on the CRT screen in response to commands from a display buffer.

A controller that can position the CRT beam at any point on the screen is commonly called a random-point display (RPD) controller. Since an RPD controller does its job without any of the Y-component restrictions imposed by a raster-scan display system, it is the take-off point for building up all of today's high-performance interactive graphic display systems.

RPD controllers receive their display coordinate information from a display buffer. The buffer gets its information from a keyboard, a "light pen," or a data-processing unit. In the simplest kind of point-display system, the RPD must have one word from the display buffer for every point plotted on the screen.

Suppose, for example, a display buffer delivers a 21-bit word to the controller. As shown in Fig. 6, 10 of these bits might be for the X-axis coordinates, 10 for the Y-axis coordinates, and 1 bit for the CRT digital unblanking circuit.

The 10 bits for the X-axis coordinate go to a digital-to-analog (D/A) converter that translates the bit code into an analog level. After a stage of amplification, this analog voltage drives the CRT horizontal deflection circuit and positions the beam horizontally on the screen. Likewise, the 10 bits for the Y-axis coordinates go to a D/A converter where they are translated into a vertical deflection voltage for the CRT. A 1-bit unblanking signal drives the grid or cathode of the CRT to display the spot once the beam is in position.

Allowing 10 bits for the X coordinates, the RPD controller can place the electron beam in any one of 2^{10} or 1024 points horizontally. The Y section can similarly place the beam in any one of 1024 points vertically. Thus, a single 21-bit word contains all the coordinate information the RPD controller needs to place the electron beam anywhere within a 1024 × 1024 dot matrix. Such a random-point display controller has a display capacity of over one-million points compared to less than 50,000 for most raster-scan display systems.

In principle, it is possible to draw any kind of figure on the CRT with the point-display controller system described thus far. All that is needed is the appropriate sequence of 21-bit words from the display buffer unit. The buffer might get its information from a full-blown general-purpose computer such as an *IBM* 360, or from a smaller processor such as the PDP-8 by *Digital Equipment Corp.* Of course, the RPD system can also be connected to a remote processor in a commercial time-sharing computer system. (See the author's "Computer Time Sharing" in the March, 1970 issue of ELECTRONICS WORLD.)

Although this simple RPD system works in principle, in reality it has one disadvantage—it is slow. State-of-the-art CRT data storage, readout, and display systems require between 30 and 40 microseconds to run one word from memory to display. Roughly speaking, it takes about 40 milliseconds to display a 1000-point figure on the CRT.

Forty milliseconds doesn't sound like a great deal of time to plot out 1000 random points on (*Continued on page 76*)

The author received his BSEE degree from the University of Illinois in 1960 and later attended New York University and the University of North Carolina. He has worked on special engineering design projects for the IBM 7070, 1410, and 7010 systems. He was also responsible for the attachment of peripheral equipment to the IBM System/360. He is a member of ACM and IEEE.

Computer Storage & Memory Devices

By CARYL A. THORN / Manager, Input/Output Architecture
Systems Development Division, IBM

An overview of the various types of computer memory and storage devices showing their comparative characteristics and how they are used together.

PROGRESS in the digital-computer industry during the past 20 years can be measured in various ways. For example, the number of computers in existence has grown from a few in the 1950's to nearly 50,000 in the U.S. today. One can also speak of the increased speed at which operations are performed by computers, noting that solid-state computers today are in some cases several thousand times faster than the vacuum-tube machines of the early '50's.

Another indication of progress is the increased amount of storage used by computer systems. The internal, addressable main storage available on computers has increased from approximately 10^5 bits in the early 1950's to more than 36 million bits today. On-line external, non-addressable bulk storage (e.g., single disc or drum) has increased from 10^6 bits to more than 10^9 bits during the past decade.

These few examples illustrate the significance of storage in the computer system. In this article, various types of storage and their uses are discussed.

While some uses of storage within a computing system are well known (for example, main memory and bulk storage), many other uses exist within the computer (See Table 1).

1. *Main Memory.* Main memory storage is the one most commonly referred to in a computing system. Its function is to hold programs and data which are awaiting processing or have just been processed by the central processing unit (CPU).

Typically, a program occupies upwards of 10^{14} bits of storage. Associated with this program may be a variable amount of data on which the program works.

When the quantity of data is small, it may be loaded into main memory along with the program. When the quantity is large, it is common to load segments of the data (perhaps from bulk storage) into main memory as needed by the program. Since a program will occasionally have to wait for needed data to be transferred from bulk storage to main memory, it is obvious that initially loading all the data into main memory along with the program will allow that program to be completed more quickly. The performance of a computing system can thus be generally improved by providing a large-capacity main memory.

The need for a large-capacity main memory is also evidenced by applications which require that several programs "time-share" the computer. By time-sharing, we refer to the interleaved use of the computer by multiple programs, each of which is in the process of being executed. One implication of such time-sharing is that main memory must generally hold several programs and several sets of data. It is not unusual to find the main memory capacity requirements for such an application specifying many million bits.

Since main memory must generally be accessed for each instruction in a program, as well as for each piece of data to be processed, the speed of main memory is one of the most critical factors in determining the speed of the computer. Accordingly, various schemes have been devised to reduce the impact on computer performance of a main memory speed, which is slow in comparison with the CPU. One such scheme involves use of *cache* or buffer storage.

2. *Cache Storage.* Cache or buffer storage, when used in a computer system, is interposed between the main memory and the CPU (Fig. 1). Although smaller in capacity than main memory, cache storage is usually ten to twenty times faster than main memory.

The value of cache storage becomes apparent when it is observed that accesses to main memory are not evenly distributed across all of main memory. In a typical data-processing application, a large number of accesses are made to one area of memory, and then a large number of accesses are made to another part of memory. Performance improvement is accomplished by loading into the cache a portion of main memory the first time a location in that portion of memory is accessed. Thereafter, successive accesses to locations in that same portion will not have to go to main memory but need only go to cache storage with its much shorter access time. When accesses are made to different portion of memory, that new portion of memory is loaded into the cache. Portions no longer being accessed are eventually replaced, once main memory has been updated.

3. *Registers.* Another means of avoiding degradation resulting from a slow main memory is the use of registers in the CPU. These registers usually have a relatively small capacity (8-16 registers with 32-64 bits per register) and are very quickly accessed. By placing frequently accessed information or intermediate results in these registers, accessing of main storage can be avoided.

Other registers, not directly accessible by programs, may be used by the CPU to hold addresses, transient data, instructions, or control information. Since these registers are involved in the execution of instructions, the highest possible speed is essential.

4. *Local Storage.* In many data-processing situations it is convenient to have available to the CPU some non-pro-

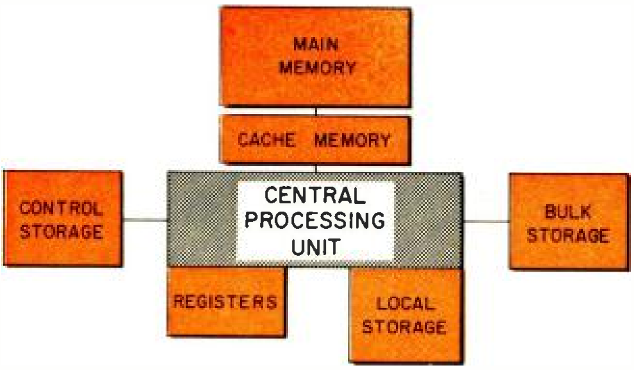


Fig. 1. Various memory functions or functions that are associated with the central processing unit of computer.

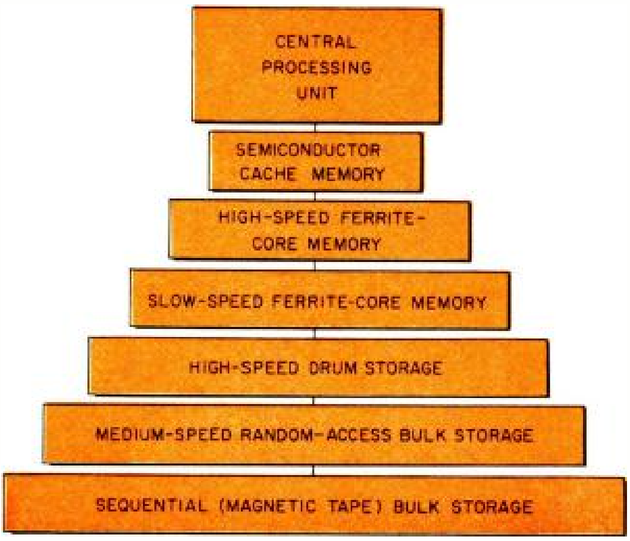


Fig. 2. Arrangement of storage elements into a hierarchy.

gram accessible storage facility which can be used for storing control information and data where accessibility is not as critical as that of the information stored in registers. Local storage can be provided for this purpose. Operations with external devices (card readers, printers, tapes, communications equipment, etc.) frequently require control information which is appropriately kept in local storage. Data being transferred to or from such devices may also be buffered in local storage so that accesses to main storage are required only when a full memory width is needed.

Some CPU's also use local storage for the retention of "check-point" information to be used in the event of an error. By periodically collecting and saving information pertaining to the state of the CPU, the CPU can, upon the detection of an error, perform a check-point restart, *i.e.*, restore the CPU to its earlier state and re-do the operation which encountered the error.

Table 1. Types of storage and memories, and characteristics.

Use / Charac.	Registers	Local Storage	Control Storage	Cache Memory	Main Memory	Bulk Storage
Access Time (sec.)	$2\text{-}50\times10^{-9}$	$50\text{-}200\times10^{-9}$	$.1\text{-}.5\times10^{-6}$	$20\text{-}100\times10^{-9}$	$.5\text{-}5\times10^{-6}$	.02-several
Transfer Rate (bits/sec.)	——	——	——	$.1\text{-}3\times10^{9}$	$2\text{-}100\times10^{6}$	$.5\text{-}50\times10^{6}$
Capacity (bits)	50-1000	100-10,000	$1\text{-}10\times10^{3}$	$10\text{-}200\times10^{3}$	$.04\text{-}100\times10^{6}$	$10^{7}\text{-}5\times10^{10}$
Bits per Access	6-72	6-72	30-100	6-72	6-500	6-25
Readability	Yes	Yes	Yes	Yes	Yes	Yes
Writability	Yes	Yes	Not necessarily	Yes	Yes	Yes
Volatility	Acceptable	Acceptable	Acceptable if writable	Acceptable	Often acceptable	No

5. *Control Storage*. A number of CPU's have been designed to use a technique called "microprogramming." The microprogramming technique is generally used when lower cost is desired and reduced speed can be tolerated. As a by-product, greater functional flexibility can usually be obtained. Microprogramming involves control of the individual gates and logic blocks of the hardware by means of very rudimentary, hardware-oriented instructions. The microprogram is stored in a *control storage* which is not accessible to the program. Since the microprogram determines how the CPU operates, it must always be present in the CPU and is not alterable. For this reason the control store is usually "read-only."

6. *Bulk Storage*. Long-term storage of information (*e.g.*, programs, data) is provided for by bulk storage. Bulk storage is usually in the form of discs, tapes, and drums and has as its major requirement a massive storage capacity. Bulk storage is also referred to as "secondary storage" (main memory is called "primary storage"), since data and programs stored there cannot be directly operated upon by the CPU. Information to be executed or processed must be loaded into main storage from bulk storage.

Bulk storage is used for three purposes: unprocessed input information; processed output information; and information for long-term storage. Input information is loaded into bulk storage from an input device such as a card reader. Output information may be placed in bulk storage prior to transfer of this information to an output device such as a printer. Information for long-term storage is simply data retained for some future use; for example, payroll records or inventory data.

Bulk storage is often spoken of as being "on line" or "off line" storage. On-line storage allows information to be accessed by the computer and transferred to main memory without outside intervention. An example of on-line storage would be a drum which always remains connected to the system. Off-line storage is not accessible without outside assistance. Any bulk-storage device with removable media (such as magnetic tapes) would thus provide off-line storage. While the amount of information which can be stored off-line is thus limited, on-line storage capacity is finite, although generally very large.

Categories of storage uses and their essential characteristics, as discussed above, are summarized in Table 1. With reference to the information contained in the table, several features are noteworthy.

There is, for example, an exception to the need for writability in the case of control storage. This is true because the control storage component contains information which should never need changing.

There is also a difference in the number of bits (or widths) involved in each access. The width for control storage depends upon the hardware makup of the CPU, the number of registers, and the number of conditions which need to be tested. Main memory width is large so that transfer rate can be high. Since accesses to main memory are often sequential (particularly when cache memory is used), accessing many contiguous bits is practical. Bulk storage transfer width is often constrained by cabling considerations.

Hierarchy of Storage

Implicit in Table 1 is a hierarchy of storage among the generalized storage components (all but local and control storage). There is, for example, a progression of access times from 2 nanoseconds to several seconds; capacity goes from 50 to 5×10^{10} bits. There is also a trend in the volatility from registers, where the loss of information is acceptable, to bulk storage, where the loss of information is quite intolerable. These three characteristics: speed, capac-

Characteristic \ Type	Ferrite Core	Thin Film	Semi-conductor	Optical
Access Time (seconds)	.2-5x10^{-6}	70-300x10^{-9}	20-700x10^{-9}	—100x10^{-9}
Cycle Time (seconds)	.5-10x10^{-6}	100-600x10^{-4}	50-1000x10^{-9}	—200x10^{-9}
Cost (cents/bit)	1-4	.5-3	1-10	—
Volatile	Generally no	Generally no	Yes	No
Readable	Yes	Yes	Yes	Yes
Writable	Yes	Yes	Yes	No
Density (bits/in)	—	1000-10,000	1000-10,000	1000-10,000

Characteristic \ Type	Movable-Head Mag. Drum, Disc	Fixed-Head Mag. Drum, Disc	Magnetic Tape
Access Time (seconds)	50-500x10^{-3}	8-25x10^{-3}	—
Transfer Rate (bits/sec)	.5-4x10^{6}	1-30x10^{6}	.05-3x10^{6}
Typical Capacity (bits)	5-5000x10^{6}	5-300x10^{6}	2x10^{8}
Cost (cents/bits)	.0025-.1	.001-1	2x10^{-5}
Volatile	No	No	No
Readable and Writable	Yes	Yes	Yes
Removable	Generally yes	No	Yes
Density (bits/in)	600-1500	500-3000	200-1600

Table 2. Various devices that are employed for the storage or memory function.

ity, and volatility are benchmarks of a storage hierarchy.

The concept of storage hierarchy is not new, but only lately has it been exploited in computer system design. The general idea is to place the most recently accessed segments of information in that storage component which is most quickly accessed. When it is possible to anticipate the need for certain information, that information can also be transferred to a storage component with quicker access. Infrequently used information is generally kept in slow-access storage.

A rather extensive storage hierarchy is shown in Fig. 2. To illustrate how such a hierarchy might be used, we can consider the following application. In a typical business situation, their quarterly reports would be stored on a reel of magnetic tape conveniently kept in the tape library. The executive program, supervising all other programs running in the computer, would be located in main memory, with portions of the executive program residing at times in a cache, or in a slow-access storage component.

During the past 15 years magnetic technology has occucupied a dominant place in computer storage. This is true because magnetic technology is applicable to a very broad range of uses: from bulk storage to high-speed main memories.

In the bulk-storage area, magnetic applications have largely taken the form of ferric-oxide coated discs, drums, and Mylar tape. Other magnetic devices have also been designed; for example, semi-rigid cards or strips. Information is recorded onto, and read from, these devices by passing the oxide-coated medium near a recording and/or reading head which produces minute magnetized spots on the medium or detects spots already recorded. The material technology, in conjunction with precise read/write head alignments, have made possible recording densities up to 3000 bits per linear inch.

The application of magnetic technology in the main memory area is typically represented by ferrite cores and thin films. While reading and recording in bulk-storage magnetic devices is accomplished by media motion, cores and thin films are stationary when accessed. Information is accessed by means of conductors passing through, near, or around the core or thin film. When the conductors are energized, the magnetic-polarity state of the core or thin film can be sensed or changed.

In an effort to obtain greater speed, various semiconductor devices are now being used in mass-storage operations. While the speed attainable for semiconductor devices is more than ten times greater than for cores, the greater cost and volatility of semiconductors have restricted their application. New fabricating techniques, however, are reducing the cost factor, thus a comparable cost for the two techniques can be expected. The accompanying requirements for non-volatility that each memory element constant draw current is a limiting factor for semiconductor storage. Millions of bits of storage in a semiconductor device implies densely packaged components which may require large power consumption and special cooling systems.

A general summary of the various types of storage devices discussed is shown in Table 2. Typical applications of storage devices in computers are shown in Table 3.

Future Trends

Simple extrapolation of storage trends of the past several years indicates that storage-capacity requirements will continue to rise, both in terms of main memory or bulk storage. To manage expected increases in storage capacity, there will be growing use of the storage hierarchy, including a widening range of storage devices.

Attainment of higher computer performance will continue to demand storage devices with even shorter access times. Semiconductor devices seem to be one answer to this requirement, with continued improvement of existing semiconductor devices claiming an attention at least equal to that of cores.

It is likely that developments in storage systems over the next several years will emphasize the organization of the storage, and the information in storage, rather than the technology of the storage devices. However, when different ways of organizing memories are required, new technologies are often necessary and these new technologies will certainly be developed. ▲

Table 3. Here is where the various devices are applied to the different storage and memory portions of computer.

Type \ Use	Registers	Local Storage	Control Storage	Cache Memory	Main Memory	Bulk Storage
Ferrite Core	Generally not used	Used if fast cores and/or slow CPU	Used if fast cores and/or slow CPU	Generally not used	Yes	Generally too expensive
Thin Film	Generally not used	Suitable	Suitable	Suitable	Yes	Generally too expensive
Semi-conductor	Yes	Suitable	Suitable	Suitable	Suitable but somewhat expensive	Generally too expensive
Movable-Head Mag. Drum, Disc	No	No	No	No	No	Yes
Fixed-Head Mag. Drum, Disc	No	No	No	No	Rarely used now	Yes
Magnetic Tape	No	No	No	No	No	Yes

The author specializes in the coordination of magnetics programs across organizational and functional lines. He has been with Burroughs since 1956, and has extensive experience in a wide range of systems, peripherals, and applications. His background in electronic data processing dates back to 1951 when he began four years of work in shipboard electronics. Following that, he obtained one and a half years' experience in guided-missile programs. In all, he has 20 years of divergent types of data processing experience. He has a B.S. in management from Calif. State College with a minor in electronics.

Magnetic Tape, Drum, Disc Memories

By HENRY T. MEYER / Sr. Product Program Coordinator, Burroughs Corporation

Highly versatile and widely used, these devices extend a computer's main memory, provide permanent storage of large amounts of data, and serve as input/output sections.

TAPE, drum, and disc devices are used to record information passed to them by data-processing equipment and, at a later time, reproduce that data, passing it back to any data-processing equipment that requests it. Data is passed back and forth between the storage devices and source or destination equipment in discrete form (as binary information digits, or bits). Information bits are usually collected into eight-bit "bytes;" the various bit patterns in an eight-bit byte are each representative of a specific number, letter, character, or symbol.

Each of the three magnetic devices contains a moving medium capable of being magnetized. This is moved, with respect to record/reproduce heads, allowing data to be recorded in or reproduced from various data tracks. The width of a data track is determined by the characteristics of the head which is, in turn, determined by the speed of the medium, the nature of the medium, and the density at which data is recorded.

The magnetizable material on tape, drum, and disc provides for the "permanent" recording of data. Data, once written, must either be erased or overwritten; it is not lost when power is turned off. Each head can record in one or more tracks. If a head is fixed, it can only record in one track. If the head is movable, it can record in as many tracks as there are head positions. Devices which have one head for each track are commonly referred to as "head-per-track" devices while all others are called "movable-head" devices.

Each type of device is available in models which permit removal of the medium. Magnetic tape is the most common removable medium; discs may also be removable; drums and discs in a head-per-track arrangement, are the least commonly removable medium.

Tape, drum, and disc are all used as extensions of the main memory of a computer; they are also used to provide input to and receive output from either a computer's main memory or its extension. Sequentially oriented data is most often stored on reels of magnetic tape; randomly oriented data is usually stored on discs or drums.

Physical Characteristics

Fig. 1 shows the three magnetic memory systems described in this article. Magnetic tape is usually cut into strips which are wound on reels. Reel diameters vary from 1 to 10.5 inches; with tape lengths varying from 50 to 3600 feet. Tape thicknesses vary from 0.0005 inch to upwards of 0.002 inch; while tape widths vary from .150 inch to upwards of 2 inches. The most common configuration is a 0.5-inch-wide, .002-inch-thick, 2400-foot-long ANSI-compatible computer-grade tape. This .5-inch tape is typically recorded using a head assembly which contains either seven or nine heads; thus, typical .5-inch tape contains either seven or nine data tracks (actually, in both cases, one track is used for error detection). Several devices, which contain tape loops to which heads are transported on a carriage, exist, but these have not had general acceptance.

Drums are rotatable metal cylinders from 6 to 48 inches long, which are magnetically coated over their curved surface. Head-per-track drums contain fixed heads which are usually mounted in the drum housing. Each head records a single circular track. Movable-head drums contain positionable assemblies of heads; this arrangement results in as many tracks per head as there are head positions. In most cases, drums are not a replaceable device; however, there have been cases of small replaceable drum memories.

Discs are rotatable metal platters, varying in diameter from 6 to 48 inches, which are either magnetically coated or electrolytically plated on both faces. More than one disc can be stacked on a single shaft. Discs can be mounted so that they rotate in a horizontal or vertical plane. Both head-per-track and movable-head disc devices are readily available. Head-per-track devices are usually rotated in a vertical plane while movable-head devices usually rotate in a horizontal plane. The medium in movable-head devices can usually be removed, while in the fixed-head (head-per-track) device it cannot.

A look at Fig. 2 shows that the average random-access times for standard 2400-foot tape are quite slow. Even at top magnetic tape speeds of 200 in/s, average random-access time is almost a minute. Speeds from 37 to 200 in/s and costs from $3000 to $60,000 were used to make the 2400-foot tape estimations. Tape devices, using 600 feet of tape on a seven-inch reel, lower average random-access time at the expense of cost-per-bit stored. Still, this access time is hardly suitable for random access, even on slow-speed data processing equipment. Tape devices using

50- to 300-foot cassettes begin to approach acceptability, *i.e.*, 1 to 10 seconds. This is achievable because of fast-search capabilities which are not generally used on standard tapes.

Drums generally have average random-access times in the 8 to 10 ms range, which is faster than their disc equivalents. Disc average random-access times generally run from 17 to 100+ ms. It is possible to build disc memories with access times of less than 10 ms, although these are just beginning to come into being.

Transfer rate (between a magnetic device and a using station) is measured in bits-per-second, characters-per-second, or bytes-per-second. Characters are generally considered to be groupings of six bits, while bytes are generally considered to be groupings of eight bits. Transfer rate is determined by three factors: 1. The density at which data is recorded (called packing density and measured in bits-per-inch), 2. medium movement speed (measured in in/s) for tape and r/min for disc and drum), and 3. the number of parallel data paths.

Typically, the range of packing densities runs from 200 to 4000 bits/in. Tape speeds vary from $1\frac{7}{8}$ in/s (in tape cassettes) up to 200 in/s. Drum and disc rotation rates vary from several hundred r/min up to 6000 r/min. The number of parallel data paths from tape, disc, and drums is dictated by systems uses and costs as well as by standards.

Principal Uses

Drums have found their principal usage as high-speed extensions to a computer's core memory. Because of their high speed, such items as system-control programs, address directories for large random-access storage devices, and other frequently accessed programs and data, are stored on drums. One computer manufacturer uses drums as a mass memory.

Discs have come into much more widespread use than drums. They have been used as extensions to computer main memories like drums; they have been used as an input/output medium like tape; and they have also been accepted as main element of an on-line data memory bank. Small discs are being used in minicomputers where they are employed as fast-access concentrators for data to be subsequently stored on other media.

Magnetic tape devices, although at times used in an on-line mode, are increasingly being used as input and output from other on-line media. Magnetic tape is lower-cost medium than discs or drums. A reel of tape costs approximately $30 while a disc pack costs about $500. Tape is readily replaceable and easily transported. Other advantages include user acceptance over a long period of time, established recording and data-format standards, and lower device cost per bit than either drum or disc.

The two foremost limitations are its non-adaptability to random accessing and its resistance to selective updating. Data must be accessed sequentially and updated sequentially. The comparative market size and projections for the three memory systems described are shown in Table 1.

Transporting & Recording

Tape is usually driven by capstan-like wheels which are brought into contact with the non-record side of tape using direct friction, enhanced by vacuum or positive air, or friction enhanced by other rollers which "pinch" the tape against the drive rollers. Since the speed at which tape is either reeled or unreeled varies with the amount of tape wound on the reel at a given time, and since no irregular resistance can be presented to the drive system, the reeling system must include a means for "buffering" the tape before it reaches the drive roller. This buffering is usually accomplished by using columns which have vacuum applied through the bottom or, in the case of lower-speed units, by using flexible arms. The buffering agents contain sensors which servo-control the speed of the reel motors thus maintaining constant lengths of tape in the buffer for each reel. See Fig. 3A. The tape is guided during the time that it is wound on either reel by means of precision-tooled, double-edged tape guides.

In magnetic drum devices, drive is applied to the drum *via* an axle which passes through its axis. Record/reproduce heads record and reproduce data as the drum surface passes adjacent to them. Thus, when accessing particular items of data, there may be a rotational delay (called latency time) of as much as a complete revolution.

In the case of magnetic discs, one or more discs are mounted on a single shaft in parallel planes. Data is recorded in concentric tracks, usually in bit-serial form, and usually on both faces of each disc. Most discs have literally hundreds of tracks per surface. When two or more discs are ganged on the same shaft, similarly located concentric

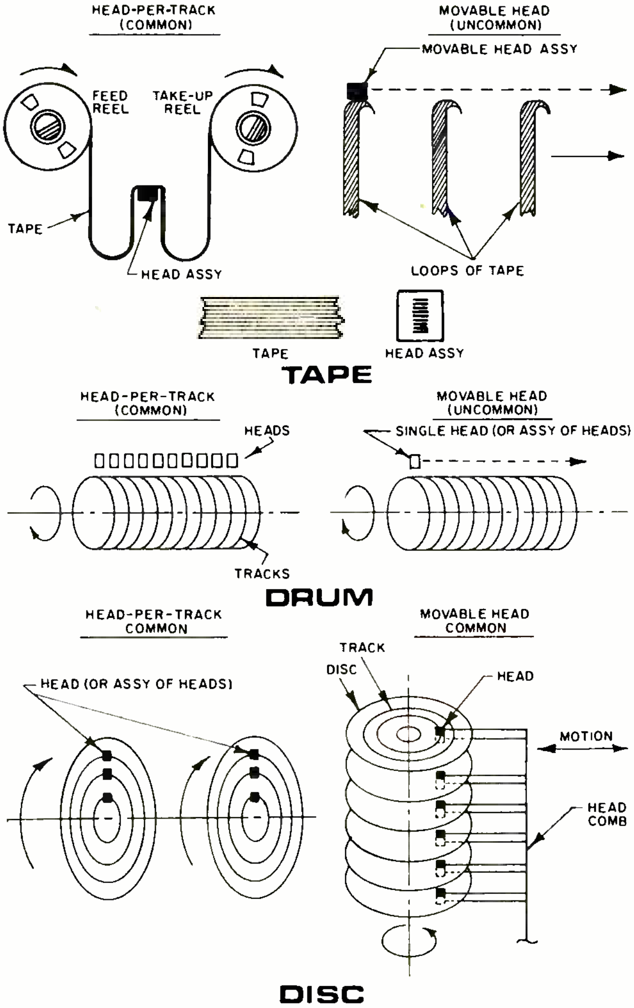


Fig. 1. Physical arrangement used in tape, drum, and disc.

Table 1. Approximate past, present, and future markets for magnetic memories.

	1960	1965	1970	1975
TOTAL COMPUTER SYSTEMS	$800 Million	$ 2.5 Billion	$7.2 Billion	$14.6 Billion
Tape	75 Million	270 Million	810 Million	1.3 Billion
Drum	15 Million	50 Million	110 Million	150 Million
Disc	55 Million	155 Million	890 Million	1.7 Billion
Total: Tape, Drum and Disc	$145 Million	$475 Million	$1.810 Billion	$3.15 Billion

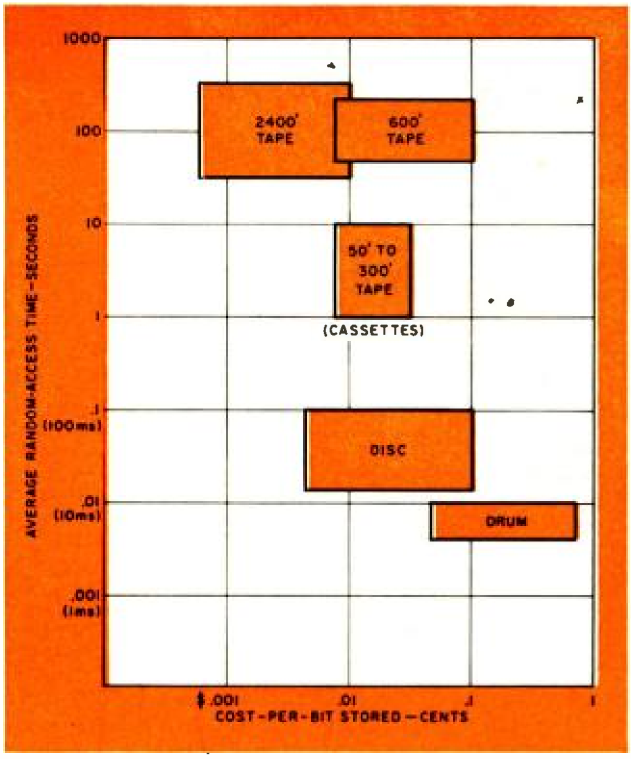


Fig. 2. Access time versus cost of the three memory types.

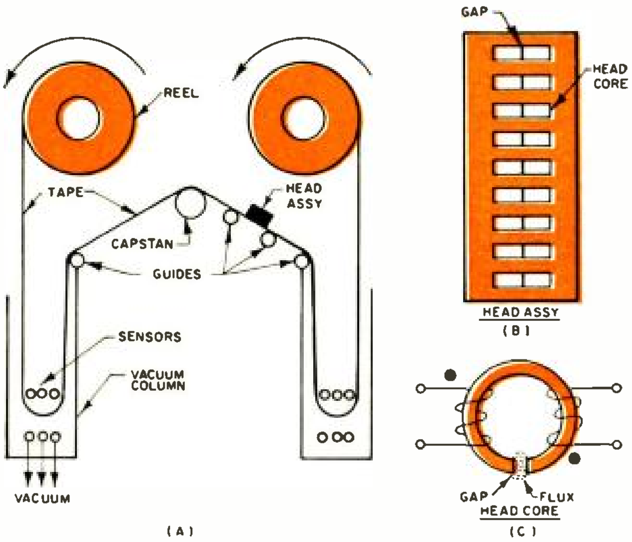


Fig. 3. (A) Tape transport, (B) head assembly, (C) core.

tracks (one per face) are said to constitute a cylinder. The majority of drives in existence today are disc-pack drives. They are characterized by one movable head per face, mounted on a common actuator, as opposed to other movable-head discs which, like movable-head drums, have multiple heads per face. Movable-head discs are usually operated so as to minimize the effects of head-movement time. This is done by orienting the storage of data to a cylinder (*i.e.*, storing it sequentially in long contiguous blocks of data like magnetic tape). This limits access time to latency time (typically 12.5 milliseconds in disc-pack drives).

The recording and reproducing process involves a magnetic pattern, the intensity of which is controlled by the intensity of the current passing through the recording head as well as the ability of the magnetic material to retain the flux pattern induced by the recording current. Fig. 3B shows a nine-head record/reproduce assembly; a head within that assembly is shown in Fig. 3C. When current is passed through the left winding, the core is magnetized in one direction and a directional flux pattern is established at the head gap. The flux thus produced affects a magnetic medium passed through it. The effect is to unidirectionally magnetize the medium in the area where the flux is felt. When current in the left core winding is cut off and current is started in the right core winding, the head core is magnetized in the opposite direction; this results in flux reversal in the head gap. At flux reversal time, there is a heavy concentration of flux in the core gap which results in a heavy concentration of flux in the magnetic medium. The concentration of flux in the magnetic medium is considered a "bit" of information—considered a binary bit because it has two states: it either exists or it does not.

The reproduction process is primarily sensitive to the rate of change in the recorded medium. The reproduced signal then tends to be the time derivative of the record signal. The signal which emerges from the reproduce head must then be integrated in order to reconstruct the recorded signal. The integration usually takes place in electronics that are located in the magnetic storage device or its controller. This process usually includes compensation for distortion introduced by the variables in recording, the medium, and reproducing.

The methods used to give bits of data coded significance are generally separated into non-return-to-zero (NRZ) and phase-coded methods (PE). In NRZ, the medium is either magnetized in one direction or the other of flux saturation. In the straight NRZ method of recording (Fig. 4), a flux transition indicates a change in bit significance; in a modified version called NRZI (for "inverted"), flux transitions are considered to be 1 bits; the lack of flux transition is thought of as 0 bits. Included in the recording methods shown is the phase-encoded method of recording (PE), where downward transitions are 0 bits, upward transitions are 1 bits. Whereas NRZI is preferred over NRZ because, in NRZI, each flux transition is indicative of a 1-bit, PE is preferred over both because at least one flux transition is assured per bit period. However, PE could require up to twice as many transitions to store the same amount of data as NRZ. Double-frequency recording is still another method. It includes one flux change for a 0 and two flux changes for a 1; direction is not important. Thus, the method chosen to record data can affect the "format" of that data.

The physical disposition of bits written on a medium also affects the format of data. This is primarily evidenced by the location of tracks and the arrangement of control data in those tracks. Location of the tracks, width of the tracks, and the arrangement of data within the tracks is related to the way in which a computer system wishes to use the medium, coupled with the often over-riding constraints of compatibility.

Magnetic tape recording usually involves magnetic tape in direct contact with the record/reproduce transducer. At high speeds, however, an air bearing begins to form between the tape and the head. Disc heads, in almost all cases, "fly" at heights of 100 microinches or less above the rotating discs. These heads fly on an air bearing through which recording on the disc surface takes place. A few manufacturers have had limited success with contact-recorded discs; but even in those cases, the degree of contact was minimized. There is usually an adjustable gap between drum heads and drum surface. Thus, the heads do not actually "fly" over the drum surface, in most cases. One manufacturer, who uses a movable-head, mass-memory type of drum, flies heads over the rotated drum surface just as over the disc surfaces.

All magnetic-type media are sensitive to contaminants, such as dust and small particles of dirt. Contaminants cause misreads called "drop-outs" in many cases and, in some cases, can result in crashes between a flying head and its associated rotating medium. For this reason, environmental control of cleanliness is very important.

Magnetic media differ in the methods used to bond oxide coatings to metal or polyester backings. They also differ more dramatically in whether they are "coated" or "plated." Magnetic tape is, for the most part, a coated medium. Disc-packs are also a "coated" medium. Some disc-packs are spray-coated; others are centrifugally spin-coated. The coating is a composition of iron-oxide particles. Fixed discs are often plated; using a nickel-cobalt composition. Plated discs generally have a thinner magnetic medium than coated discs, thus affording higher resolution with less signal strength, more uniform surface flatness, and the capacity for storing higher packing densities than coated discs.

Selection of Memory

The end user of tape, disc, and drum devices is the person referred to in most companies as a Data Processing Manager. DP managers, along with the systems analysts, programmers, computer operators, and key-punch operators who work for them, comprise the team which puts a DP system to work. A DP manager buys tape, disc, and drum devices in either of two situations: as part of a new or replacement system or as add-ons or replacements for an existing system.

Most users of DP systems rent their equipment rather than buy it. Hence, these users want to rent the latest equipment available and turn in any previous generation equipment they may have. An end user who is shopping for a new system will find that all system manufacturers offer a line of tape and disc (or drum) equipment. He will find that whether he chooses disc or drum, he will still be advised to back-up his on-line files on reels of magnetic tape.

The user should strive for system balance, that is, he should seek a blend of performance and capacity which adequately meets the needs of present and planned uses for the equipment. He should weigh systems prices against systems performance, including reliability, expandability, and flexibility.

In applications where accesses are random and transaction turnaround is critical, the user will likely end up seeking devices with very low average random-access time. When discs or drums are operationally loaded and unloaded using magnetic tapes, tape transfer rates which approach those of disc or drum become important.

Compatibility is an important consideration when more than one system is involved. This is especially true when disc packs or tape reels are to be interchanged between systems.

Future of Magnetic Memories

Table 1 shows how magnetic tape device sales, estimated at $810 million in 1970, are expected to grow to $1.3 billion during 1975. This represents a 60-percent increase or an average growth rate of 12 percent a year. During this time period, systems sales are expected to increase to about 100 percent, or an average of 20 percent a year. Tape-device sales, as a percentage of systems sales, is expected to decrease from 11.2 percent in 1970 to 8.9 percent in 1975. This is primarily attributable to inroads expected to be made by disc-pack drives. These inroads might be even more significant if it were not for the impact on the punch-card and punch-tape markets being made by small reel-type magnetic tape units and magnetic tape cassettes.

Table 1 also shows how magnetic drum sales, estimated at $110 million in 1970, are expected to grow to $150 million during 1975. This minimal growth, averaging only 5.3 percent a year, is in contrast to a corresponding system growth of 20 percent a year. Drum sales, which were 1.5 percent of systems sales in 1970, will drop to only one percent of systems sales in 1975. The relatively poor showing for drums is attributable to inroads made by head-per-track discs on one side and by bulk core on the other.

Table 1 shows disc sales estimated at $890 million in 1970 rising to $1.7 billion by 1975. This represents a 90 percent increase—an average of 18 percent a year. The disc figures include both head-per-track disc and disc-pack drives. Head-per-track drives are expected to increase from $70 million in 1970 to $150 million in 1975. This represents an increase of 114 percent or an average of 22.8 percent a year. The increase is attributable to use of the head-per-track disc as a memory extension, *i.e.*, as systems memory, as well as the increased use of head-per-track file in data banks where access time is critical (banking, airline reservations, time-sharing, etc.). Disc-pack sales will increase from $820 million in 1970 to $1.55 billion in 1975—89 percent over a 5-year period—an average increase of 17.8 percent a year.

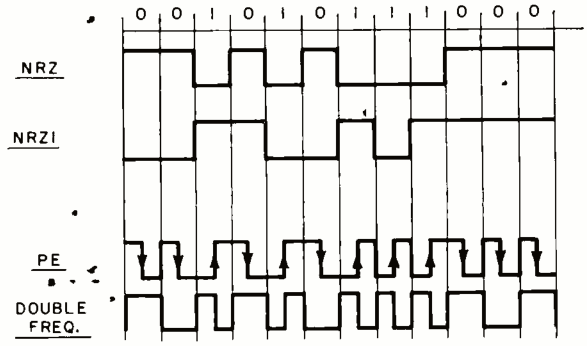


Fig. 4. Various methods of recording information bits.

Large tape systems will require high-speed tape units (200 in/s and higher) with high packing densities (3200 bits/in is reportedly the next step in terms of industry standards). Automatic-loading features and other automatic methods aimed at reducing operator involvement will gain in popularity.

The upper end of medium tape systems will use the same high-speed tape units as large systems; the lower end medium systems will use the low-speed tape units also used by small systems. Most of the medium systems will use manually operated tape units in the 75 to 150 in/s speed category. Their popularity will be attributable to price and reliability.

Small systems will use reel-type tape units varying in speed from 12½ to 75 in/s; reel sizes of approximately 7, 8, and 10½ inches will be used. Small systems will also use cartridge-type tape units varying in speed from 1⅞ to 10 in/s. The *Philips*-type cassette will be a popular type of cartridge in this market area.

Magnetic tape will also find use in the mass-memory field. Mass memories ("trillion-bit stores") are being developed, using video recording techniques and ultra-high packing densities. When used as a mass memory, a tape device loses its systems orientation and becomes an archival storage area which could be accessed by small, medium, or large systems.

Drums will be used on large, medium, and small systems as high-speed memory extension in situations where systems designers choose drum over head-per-track disc. Small drums will find limited use as data concentrators on minicomputers; large drums as mass memories.

Discs will be used in a wide range of systems applications. They will be used in small, medium, and large systems; there will be both fixed- and removable-medium applications. Fixed-medium disc drives will be used as memory extension and as fast-access data banks in applications which demand low access times and predominantly random accessing of data. Removable medium drives will be used when the application contains several data bases, each used at a different time or when the application dictates the intersystem exchange of media. Generally speaking, the prevalence of (and frequency of performing the interchange) disc packs, varies inversely with systems size. As systems get larger, packs are less frequently removed but as systems get smaller, packs are often removed. ▲

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Author Tarbox supervises the engineering group responsible for electrical parameters of existing circuit types and evaluation of new products. He was formerly with MIT Lincoln Laboratory as a Staff Engineer working on such projects as system design, radar telemetry, data acquisition and processing for radar telemetry, and optical systems. He holds a B.S.E.E. from MIT.

Bipolar Semiconductor IC Memories

By JOHN J. RIENZO / Manager and EDWIN F. TARBOX / Eng. in Charge, IC Applications & Evaluation
Semiconductor Division, Sylvania Electric Products Inc.

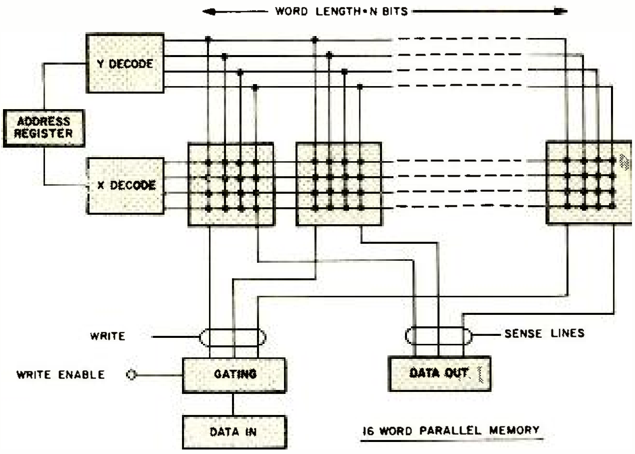
Large arrays of bipolar transistors on an IC provide high-speed data storage at low power in small space. A thousand bits can be readily stored in ¼ square inch and will dissipate less than one-third watt.

MEMORIES can be made of relays, cores, switches, wires, bistable chemical circuits, or any device or mechanism which has more than one possible state, level, or condition, and which can be made to go or stay in a particular state under the user's control. To store information, such as a number or word in binary coding, requires many binary digits (bits) of data. For example, to store the number 8 requires four bits (1000), the number 32 requires 6. Any reasonable amount of information could be stored in a bit pattern using the binary numbering system.

Memory storage of data is accomplished in a memory bank of a computer by writing information to be remembered for a short or long interval of time. The information can be retrieved at the appropriate time by reading out the stored information and using it in add/subtract functions to compare changes or to restore data. Hundreds, thousands, and sometimes even millions of bits may have to be stored.

Bistable circuits made from a large number of bipolar transistors on an IC provide storage of data at low power in very small space. As many as 1000 bits of information can be stored in ¼ square-inch area and dissipate less than 0.3 W.

Fig. 1. Organization of a simple scratch-pad memory.



Memories have many uses, but most applications can be classified as temporary and changeable or permanent. In temporary applications, a device is used into which you can put new information (write) or withdraw (read) old information. Further, it is desirable to have access to any part of the information (random access). This type of memory is therefore referred to as Read and Write Random Access Memory (RAWRAM), sometimes shortened to RAM.

Some of the applications for storing information are transient, *i.e.*, a small amount of information might be stored for nanoseconds in a computer while something else happens and then the information is brought back out and used. The operation is analogous to that of a scratch pad and memories operating in this manner may be referred to as scratch-pad memories.

The *Sylvania* SM82 is one of the first generation of scratch-pad memories (see Fig. 1). This memory device is an array of 16 R-S flip-flops and two write amplifiers connected to form a 16-word by 1 bit scratch-pad memory with direct addressing and nondestructive readout. The flip-flops are arranged in a 4 × 4 matrix and are addressed by the appropriate combinations of 4 X address lines and 4 Y address lines. Addressing of a particular flip-flop is accomplished by raising the X and Y lines associated with that flip-flop to a logic "1" level. Address lines are normally held at a logic "0" level and currents from all conducting flip-flops flow out through these lines. When a storage flip-flop is selected, either the sense amplifier associated with the logic "0" output or the sense amplifier associated with the logic "1" output is activated (in either case the output changes from a logic "1" to a logic "0" level).

The memory is nondestructive, as the states of the flip-flops are not disturbed during sensing. The memory, however, is volatile in that its contents are destroyed when the supply voltage is removed. Information is written into memory by raising the appropriate X and Y address lines and pulsing the write amplifier with a logic "1." A number of these memories may be connected in parallel to give the desired combination of words and bits. The outputs are open-collector transistors which can be *or*-wired to facilitate expansion.

A second-generation read-write memory has 64 storage cells arranged to form 16 four-bit words. Each bit of storage can be addressed separately and the contents can be changed and then read out without changing the contents. It is not necessary to restore information after reading.

For situations requiring permanent storage, a read-only memory can be used, such as the SM320 (see Fig. 2). This read-only memory has a 256-bit capacity arranged in 32-word × 8-bit format. All decoding is done directly on the chip. The outputs have free collectors, thus making it easy to parallel devices to expand system capacity. A 5-bit address code enables the selection of any one of 32 8-bit words stored in the memory.

The read-only memory is shown in block diagram form in Fig. 3. Input address gates and chip-enable gate are located in section A, the address decoder matrix (5 bits for 32 words) is located in section B, and the memory storage (256 bits) is located in section C. Section D contains the output transistors which have open collectors to facilitate feeding data onto a common bus. Selection of any one of the 32 8-bit words stored in the memory is implemented by 32 5-input emitter-selector transistors. Only one word may be selected at a time. The chip-enable signal controls selection or inhibition of all words in the memory.

In a larger system using more than one device, the chip-enable function can be used to select individual units or groups of units. In this manner, for example, data in multiples of 8 bits can be sequenced onto a serial bus line. Decoding of appropriate units, as in character generation, can also be implemented in this manner.

Both read-only and read-write devices are basically random access. To convert these types of memories to sequential-access interlace buffers or other types of memory systems commonly associated with core memories, it is necessary to add counters or read-write timing circuits as is done with core memories.

Applications

Bipolar read-write memories can do just about anything a core memory can in less space. In addition, they consume less power and operate at ten times the speed. Bipolar read-only memories can also do anything that ROM's made with diodes, switches, and resistors can except that bipolar devices take less space and have the advantages of low power and very high speed. In fact, in many MOS memory systems, the address decoding is done with bipolar elements to increase speed.

For large systems, bipolar read-write memories are generally more expensive than cores; however, for small scratch-pad type systems they are definitely more economical, especially when one considers the cost of space and power supplies. Bipolar ROM's, on the other hand, can almost become a basic building block of logic systems. Some applications are:

Character Generators. Letters, numbers or characters may be stored in a 5 × 7 matrix.

Code Converters. When given one binary number and a different or coded number is required, it is only necessary that the coded value be stored at that location which is addressed by the binary number. For example, a binary-to-BCD converter is shown in Fig. 4.

Look-Up Tables. This application is really the same as a code converter. The value in memory can have the value of the *sine*, *cosine*, *tangent*, etc. of the input address number.

Function Generator. Repetitive patterns of "zeros" and

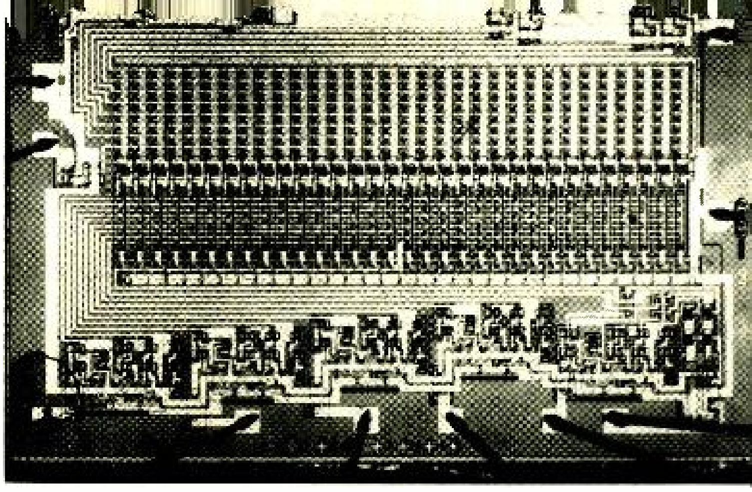


Fig. 2. Photomicrograph of Sylvania's SM320, a read-only memory consisting of an array of bipolar transistors on IC.

"ones" can be stored in ROM's which can then be read out by having a counter address the ROM. A 32 × 8-bit ROM can have eight different stored patterns of 32 bits each.

Mini-Programmers or Controllers. In this application, on receipt of an address word, the ROM will have available at its output commands to a computer to add, or subtract, shift right or left, clear load, or various combinations of each.

The applications of ROM's are practically unlimited. Anytime a fixed value or combination of controls is required from a fixed input, a ROM may be the answer.

In summary, bipolar memories offer the advantages of: high bit density in small area, low power, high speed, single low-voltage supply, are easily expandable, and are compatible with DTL and TTL circuits. ▲

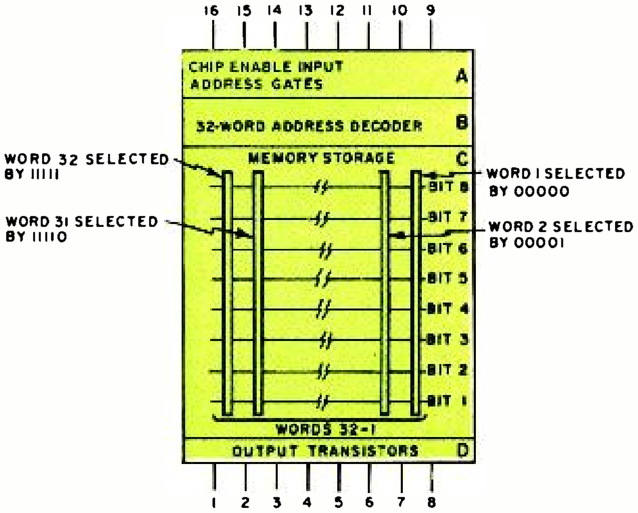
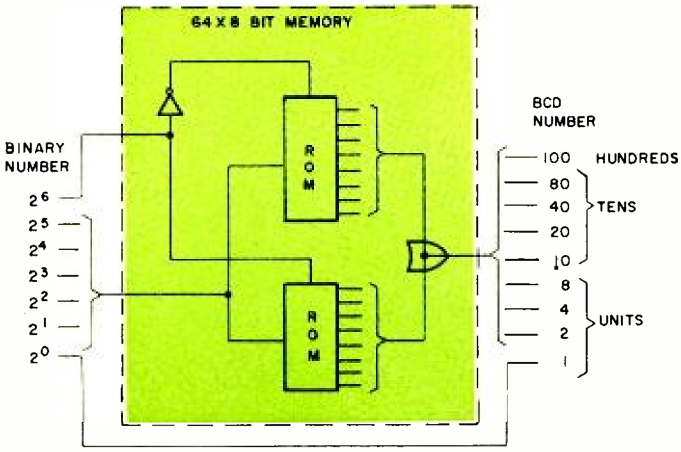


Fig. 3. Block-diagram arrangement of read-only memory.

Fig. 4. Binary-to-BCD (binary-coded decimal) converter.



The author received his Ph. D in Physical Electronics at MIT in 1953. He subsequently joined the Research Div. of Philco Corp., then the Shockley Semiconductor Lab. He was one of the founders of Fairchild Semiconductor in 1957, serving as Research Director and later Group Vice-President. He holds sixteen patents on semiconductor methods and devices. He also holds the basic patent relating to metal interconnect schemes which was the key contribution to IC technology. Dr. Noyce is a member of the National Academy of Engineering, a Fellow of the IEEE, and member of American Physical Society.

MOSFET Semiconductor IC Memories

By ROBERT N. NOYCE / President-Director, Intel Corporation

These solid-state high-speed memories have dropped in price so that they are now challenging magnetic types in many computer applications.

MEMORY functions have been realized through the use of semiconductor devices since they were first employed in any digital application. However, cost of a semiconductor flip-flop has been high in comparison with magnetic elements when used for storing large amounts of information. As a result, semiconductor elements have been used only in high-speed memories, or in registers requiring the storage of a small number of bits.

The cost of semiconductor devices has dropped as integrated circuits have become a reality, and soon semiconductor devices will challenge magnetics on a straightforward cost basis. Today, semiconductor IC devices furnish the lowest cost solution for small buffer memories, and the dividing line will move continuously to larger and larger memory systems.

Factors Involved

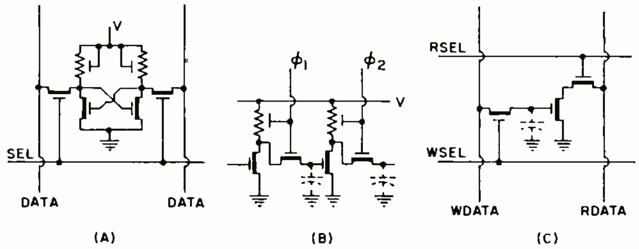
The cost factors involved in producing semiconductor memories may be broken down into three main components:

1. Cost of producing an operational die of silicon performing the memory function.
2. Cost of packaging this die in a practical environment.
3. Overhead costs of drivers, address registers, power supplies, and printed-circuit boards.

The first cost listed above can be derived: silicon processing cost per unit area, yield, and functional density.

Since all processing steps in making integrated-circuit wafers which define the topography are done by photoengraving steps, the processing cost per unit area is relatively independent of the circuit design, or functional density. Somewhat more care is needed when working with higher resolution designs with smaller line widths, since re-indexing must be done more accurately. However, this factor will account for a variation of only, say, ±50% in silicon processing cost.

Fig. 1. Basic cells used in MOS read-write memory. (A) Static flip-flop, (B) dynamic shift register, (C) RAM cell.



The yield depends on the average number of defects which are effective in making the circuit inoperative in a single chip. If average defect densities can be reduced to one-half of today's levels, a circuit with twice the area can be made with the same yield as today's circuit.

Through circuit innovations, new phenomena, or narrower line widths, the bit density can be increased with no penalty in chip cost, and a proportional drop in bit cost will result.

MOS vs Bipolar Memories

It is the last two factors cited that make the MOSFET memory less expensive per bit than the bipolar memory. Hence, for many memory applications which can accept MOS speeds, they represent a better compromise. Nearly all process-induced defects are introduced in the photoengraving operations. Since MOS processes typically use fewer photoengraving steps, defect densities are typically only one-half those for a processed bipolar wafer. Thus, the chip can be made twice the area at a given yield.

Second, the self-isolating feature of MOS devices allows them to be placed much closer together than in bipolar circuits. This permits a functional density of about four times that of the bipolar circuits. In addition, the high impedance of MOS devices makes possible dynamic circuits where information is temporarily stored as a charge on a capacitor, allowing even higher functional density for dynamic circuits.

Basic Memory Cells

Fig. 1 shows examples of the basic cells used in MOS read-write memories. Fig. 1A shows an MOS flip-flop using MOS transistors as load resistors. It is addressed for writing and reading by turning on the transmission gates connected to the data lines.

An example of a circuit using this cell is shown in Fig. 2 which illustrates a 256-bit fully decoded random-access memory, with TTL compatibility at both input and output.

Fig. 1B is a shift-register stage, where on each clock phase a bit of information is inverted and transferred a half cell to the right. A 1024-bit serial memory, or shift register, using this type of cell is shown in Fig. 3. Although this device, the i-1402, contains nearly four times as many transistors as the i-1101, it is approximately the same size. The reason for this is that the dynamic circuit may use only minimum size devices, whereas the static circuit cannot.

Fig. 1C shows a typical cell used in dynamic random-access memory. This can be considered as one-half of the shift-register stage. The other half of the shift-register stage is time-shared by all cells in a column, with the circuit arranged to provide direct access to any cell, *i.e.*, the RAM function. The basic storage element is a capacitor and the charge on this capacitor must be restored periodically. Typically 1% of the total memory cycles are used for this operation.

Fig. 4 shows the i-1102, a 1024-bit fully decoded RAM which uses dynamic storage of this type. Again, the chip is approximately the same size as the two earlier examples, for although the number of transistors per bit has dropped to slightly more than three, as compared with six in the shift register, additional circuitry is put on the chip. This includes X and Y decoders, sense amplifiers, read-write control, and chip select.

Other Cost Factors

If we assume that packaging costs are the same on each of these circuits, the cost contribution of this factor is inversely proportional to the number of bits on a chip. Thus, this cost factor is four times as great per bit for the 256-bit memory as for the 1024-bit memory.

The static memory has very low overhead cost in final use, since its operation requires only that an address be presented at TTL levels and data will be present on the data line at TTL levels. No interface is used, and operation requires only a single d.c. power supply. Thus, the per-bit cost remains constant down to memories of only 256 words, and for small memories is the lowest cost memory available.

The shift registers, on the other hand, require clock drivers, address counters, and recirculate controls to be operative in memory applications. Because of this, overhead cost does play a role. High-speed operation requires high-current drivers, with their cost, so input clock capacitance becomes a significant factor.

In addition to drivers for high-speed operation, the dynamic RAM requires control circuits to assure that every X line is addressed periodically to refresh its content, adding to overhead costs. However, for large systems, the total memory cost is estimated to be less than twice the cost of the memory elements themselves.

From Chip to System

Thus far we have been discussing only the individual memory chip, which includes 256 or 1024 words of a single bit. Of course, in practical systems, larger memories are required. Extension of the number of bits in a word is easily accomplished by adding as many memory chips as required by the desired word length, as shown in Fig. 5.

All address lines, chip select, power supplies, and read-write control are connected in parallel to each package. Data lines are brought out separately from each package. Thus, memories of any arbitrary word length are easy to construct.

To increase the number of words in the memory, another decoding level to the chip-select lines is needed. Only the selected chip will be active. In the circuit shown in Fig. 6 for example, a one-out-of-four decoder is needed to decode the additional two-address bits in constructing a 1024-word memory from 256-word chips. The data lines are connected in parallel (wired "or"), only the selected chip driving the

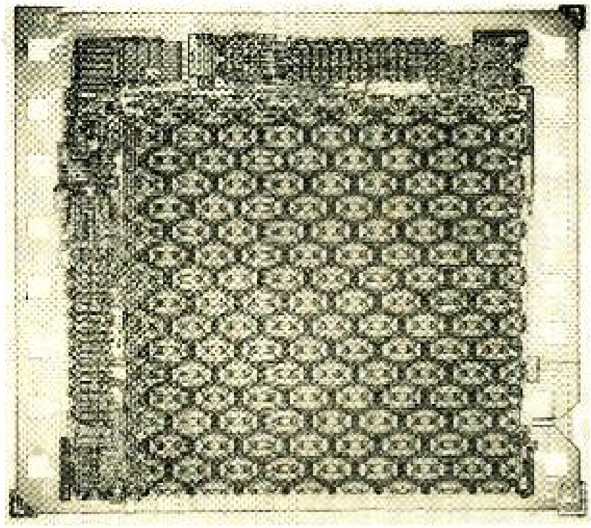


Fig. 2. Photomicrograph of Intel i-1101 256-bit fully decoded RAM with TTL compatibility. This type of memory is most useful for small buffer memories and has an access time of 1 μs. It costs approximately 6¢ per bit in quantity.

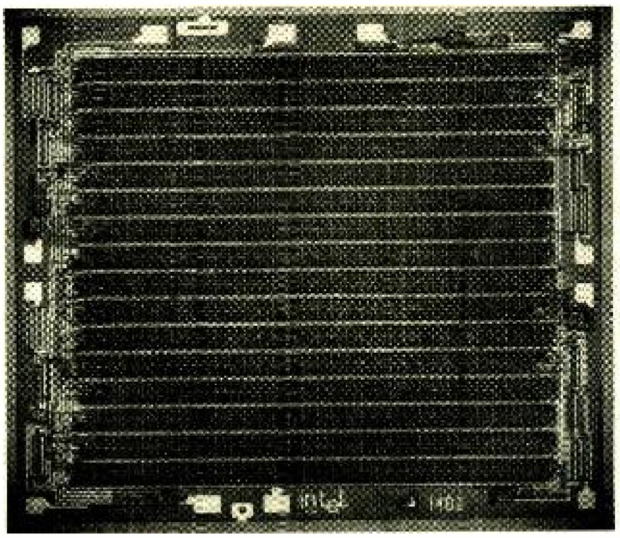
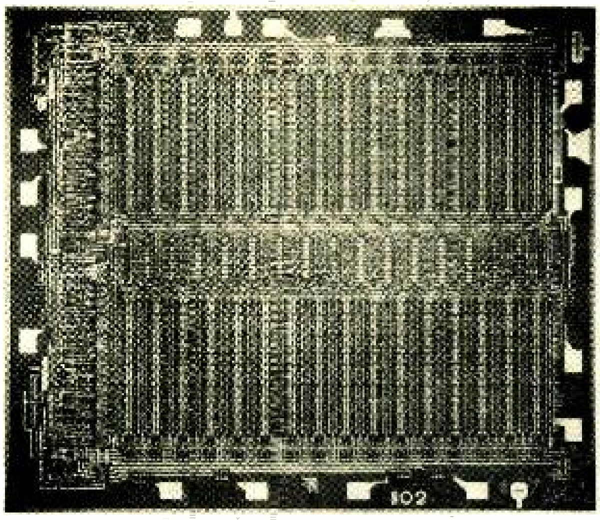


Fig. 3. The i-1402 is a 1024-bit (4 × 256) dynamic shift register with a shift rate variable from 1 kHz to 5 MHz. Its cost is on the order of 1.5 cents per bit in quantity.

Fig. 4. The i-1102 1024-bit random-access fully decoded dynamic memory. This has an access time of 300 nanoseconds and a cost of about 1.5 cents per bit in quantity.



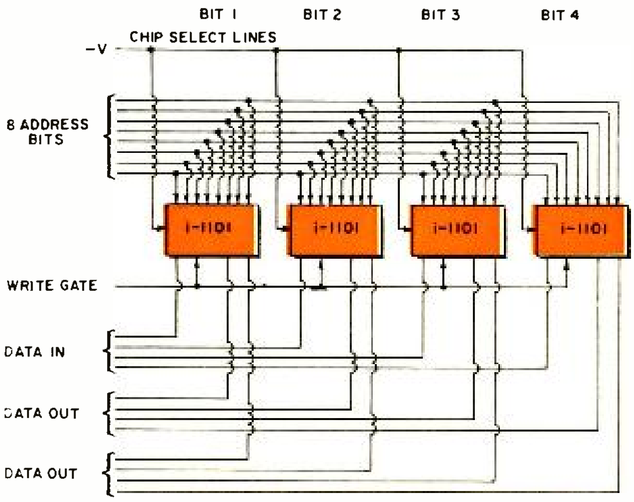
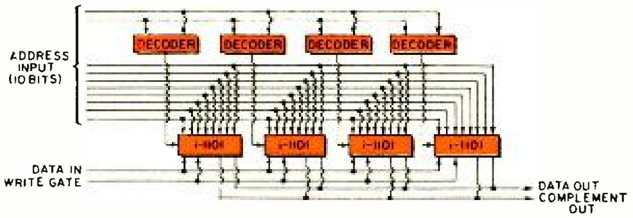


Fig. 5. Four chips are interconnected with all addresses and read-write control in parallel for 256 word × 4 bit memory.

Fig. 6. Larger memory planes are constructed using decoders and some of the address bits to drive the chip select, activating only that chip for read or write function.



(Editor's Note: For further technical details on semiconductor memories of both the MOS and bipolar types, refer to the two-part article "IC Memories—Growth and Future" in our March and April, 1970 issues.)

data line or accepting data from the data line on a write cycle. In circuits intended for memories with a large number of words, several chip select lines will be included, simplifying the decoding problem.

Dynamic Memories

As noted previously, the dynamic memory requires periodic refreshing. This happens each time a particular X-line is addressed for all bits on that line. However, in order to insure that all X-lines are addressed within the required refresh time, other circuitry will be required.

In the i-1102, the chip is internally organized as a 32 × 32 array. This means that 32 addresses must be activated within the refresh time, which is 2 ms for this circuit. This will be accomplished by a 5-bit address counter and a timing signal that initiates the refresh cycle. The memory will, during refresh, send out a busy signal if data is requested by the system during the refresh cycle. Approximately 1% of the memory cycles will be used for this function. The additional memory-refresh circuitry required will, of course, add to the cost. However, for large systems, it will be negligible compared to the cost savings effected by using the dynamic memory cell, and to that of today's core memory systems.

In using the shift register for a serial access memory, the functions required include the read-write-recirculate controls, which are included in the shift-register chip itself. In addition, external clock drivers and a master timing signal or counter is required to synchronize the memory with the rest of the system.

In moderate quantities, the static memory now sells at about 6¢ per bit. The dynamic circuits sell for about one-quarter of this amount. The annual cost decrease for these circuits can be expected to be about 30% a year. Thus, unless magnetic memories can match this price drop, the question of displacing magnetics with semiconductors is answered. The only remaining question is when will it happen? ▲

MAGNETIC-BUBBLE MEMORIES

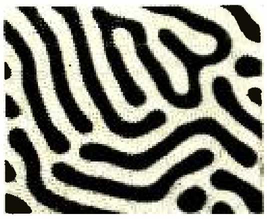
MAGNETIC bubbles, a technology developed by Bell Telephone Laboratories and still in the experimental stage, shows potential for providing low-cost, high-capacity memory (10^6 bits per square inch) and logic functions, all within one solid magnetic material.

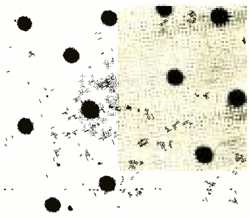
The bubbles, which are actually cylindrical magnetic domains (magnetized regions found in magnetic materials), are formed when a magnetic field of a critical value is applied to an orthoferrite (magnetic material composed of rare-earth iron oxides first grown as crystals at Bell Labs). When the orthoferrite platelet, which is 2.2 thousandths of an inch thick, is subjected to a 50-oersted bias field perpendicular to its surface, its normal strip domains, typically 3.5 thousandths of an inch in width (below, left) shrink to form cylindrical magnetic bubbles 1.4 thousandths of an inch in diameter (below right).

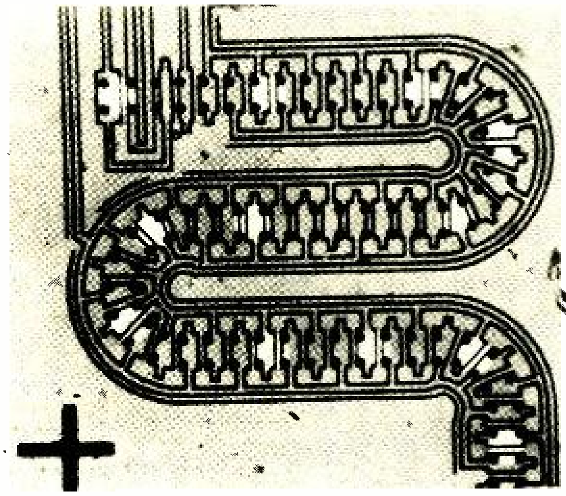
Using this new technology, these magnetic bubbles can be created, erased, and moved at high speed in the plane of the sheet of orthoferrite material either by programming electric currents in an overlay pattern of conductors or—with no connecting wires—by controlling the surrounding magnetic field. It is the presence or absence of a bubble in a particular location that's equivalent to the storage of either a "1" or "0," respectively. The energy required to move such a bubble is a fraction of that needed to switch a transistor.

One experimental device using the magnetic-bubble technology—a photolithographic pattern on the surface of a sheet of thulium orthoferrite of a circuit that can move magnetic bubbles (large white dots) through a shift register—is shown in the photo below. The bubbles seen in this figure are actually 0.004 of an inch in diameter. Data rates of 3,000,000 bits per second have been demonstrated with this technology.

Although only a few processing steps are required to realize its simple structure, and devices of very low cost are anticipated, much work still remains before these devices can be shown to be practical for use in computer or communications systems. ▲







The author has been manager of design and applications engineering of memory components for 5 out of his 9 years with Ferroxcube. Previously, he was with IBM, working first in research on planar magnetic thin-film devices for memory and then high-speed ferrite-core memories. He has a BSEE from the University of Vermont (1957) and has done graduate work at Syracuse University. He is a member of IEEE, Tau Beta Pi, and Sigma Xi.

Ferrite-Core Memories

By RONALD A. HILL / Manager, Advanced Memory Development
Ferroxcube Corp.

These memories continue to dominate storage market because of their relatively low cost, versatility, and non-volatility.

FERRITE-core memories will continue to dominate the digital data storage market during the 1970's. Excluding peripheral storage, core memories constitute 95% of the total installed memory today. By 1980, the percentage will be reduced to 60%, but the total ferrite core storage market will sustain a growth rate undiminished from that of the past decade. Three factors have put core memories where they are now, and will continue to maintain the importance of core memories. These are low cost, versatility, and non-volatility.

Core memories are low in cost because they are produced in large quantities by companies with vast experience and continually improved manufacturing methods and designs. Other factors lowering costs are reduced associated semiconductor prices and reduced labor costs resulting from off-shore (Hong-Kong, Taiwan, Singapore) and automated wiring.

Memory cores are produced in a wide variety of sizes, from 10-mils outside diameter to 150-mils outside diameter. Since they are produced as separate entities and wired by hand for small quantity and prototype orders, core planes and stacks can be made in an immense variety of configurations to fit many sizes and shapes without expensive retooling. Re-packaging of "standard" electronics permits rapid design and fabrication of systems for all but the largest or the fastest storage applications.

Volatility is the capacity to lose stored information if power fails. Storage in magnetic elements such as cores and plated wire is non-volatile. Power can be shut down, as during maintenance, and stored data and programs will not be lost.

The design and production of ferrite-core memory systems is a well-developed industry, producing about $1.3 billion worth of memories this year. At the heart of each memory system is a ferrite core "stack." This assemblage of tiny magnetic, ceramic doughnuts (toroids) is the most costly single part of the memory system (typically 20 to 40% of the total). In addition, the "stack" is by far the most critical determinant of system speed. It is the storage properties of the ceramic toroid, the ferrite core, which make it all possible.

Core Requirements

The ferrite memory core toroid is pressed or stamped from a powder material containing a binder, to hold the shape. The powder is an iron oxide with other metallic compounds, formulated to provide the desired properties. After compression, these "green" cores are fired in a kiln at temperatures of 1300 to 1500°F. During firing, the final chemical and crystalline properties are achieved, making each core an individual storage cell.

In order to store digital data, a device is required to meet several requirements. First, the device or cell must have at least two stable states. Second, it must be possible to set the device into each state, as by passing electric current through wires threaded through the ferrite core. The ferrite memory core can be magnetized in either of two directions, and has a relatively high residual flux level after being magnetized. Third, it is necessary that the data be retrievable: that is, by interrogation of the device, a detectable output can be obtained. Passing a current pulse of proper amplitude and polarity through a ferrite memory core will cause the flux state to be reversed; the change in flux will generate a voltage on another wire (the sense wire). This voltage is amplified to logic levels in the memory system.

The first magnetic memory cores were Permalloy tape-wound cores, consisting of very thin Ni-Fe tape (ribbon) wound on a ceramic bobbin. These cores had excellent storage properties and temperature characteristics, but were very slow (long switching time) and expensive to make and to wire. The development of square hysteresis loop ferrite cores produced by automatic pressing, firing, and testing made possible low-cost random-access storage. Early ferrite cores had less square hysteresis loops than modern cores, and had longer switching times.

In the never-ending drive toward larger and faster memories, smaller memory cores were developed. Why smaller cores? For one thing, the wired core arrays took up less space. Current pulses required less time to propagate down the wires. Resistance, inductance, and power requirements were reduced. More important are the memory device design trade-offs in size, drive current, and switching time. A small core will switch much faster for the same drive current than a large core. Increasing the driving current will provide a still shorter switch time. Conversely, if no change in switch time is required, a smaller core can be made which can operate with a lower drive current than the larger core. The past 15 years have seen the transition from 80-mil (o.d.) cores to 18-mil (o.d.) cores in volume production. At present, 14-mil core types are being wired in prototype quantities, and some 10- and 12-mil (o.d.) cores

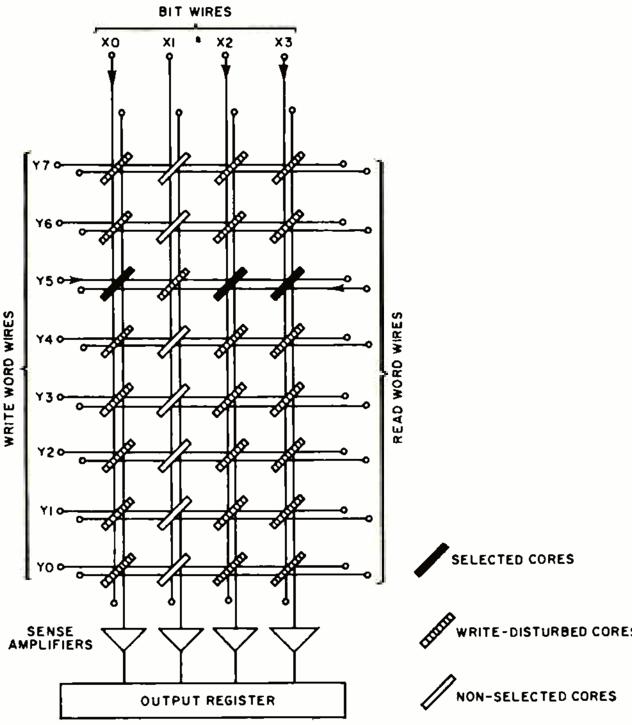


Fig. 1. 2D ferrite-core memory array for eight 4-bit words.

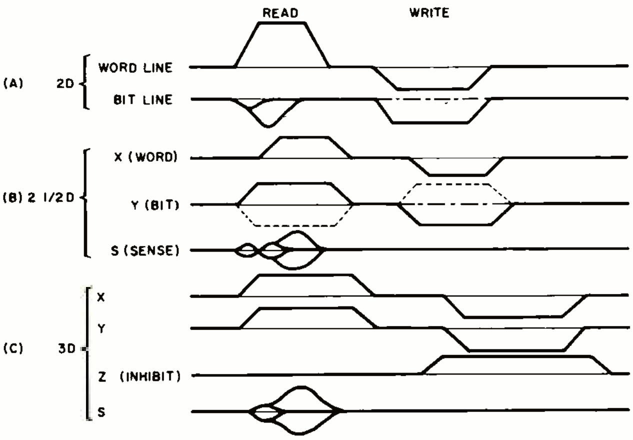


Fig. 2. Current pulse timing diagrams for core memories.

have been used. Switching times of less than 150 ns are possible with these small cores under full switching conditions, and switch times around 50 ns or less are possible under partial or impulse switching conditions. At the other extreme are the low-drive cores, with switch times around 500 ns or more, with drive currents of 100 mA to 200 mA, well within the capability of low-cost IC drivers.

After cores are pressed and fired, they are 100% tested by fully automatic test equipment. The test program simulates the conditions of an operating memory-core plane, and verifies the level of residual flux density of one and zero states, as well as determining within limits the threshold level and the switching time. After quality-control verification by sample testing of the test results, memory cores are fed into a loading fixture or filler plate, which is a vacuum jig used for aligning cores in a neat row and column matrix array preparatory to wiring. Initial X and Y wires are fed through the rows and columns of cores by machine or by hand.

Core-Plane Assembly

After core alignment on the vacuum jig, cores are adhered directly to a printed-circuit board, a metal plate, or to a flexible plastic tape, for later placement on a final support. For high-speed operation, cores are adhered to a metal plate with an adhesive, such as RTV silicone rubber compounds, having good thermal conductivities to make sure that all cores are close to the same temperature as possible. Printed-circuit boards usually have copper-clad areas under the memory cores for the same purpose. In addition, the metal area serves as a ground plane, improving the transmission-line characteristics of the various drive and sense wires that are used.

Wires are threaded through the cores by hand or by machine. By hand, the wires are pushed through one at a time. Machines push through 64 or 128 rows simultaneously, greatly reducing the wiring time and labor content. After wiring, the wires are terminated by wrapping, soldering, or welding to terminals and printed-circuit pads. Automatic systems for re-flow soldering with infrared and resistance-soldering devices are in use for termination.

In order to reduce still further the number of wires threaded and terminated, designers of core memories have required larger numbers of cores on a single plane, creating so-called *planar arrays*. A typical core stack containing 4096 words and 18 bits per word will contain 18 areas each of 64 by 64 cores (4096 total) on a single printed-circuit board, together with 256 diodes in 8 by 8 selection matrices for X and for Y drive lines, and 9 dual inline package IC sense amplifier modules, each containing 2 independent sense amplifiers. This planar stack will be pluggable into the memory system *via* PC edge connectors. An advantage of pluggable stacks is ease of test after assembly, since no special fixtures are required. The reduced number of wire terminations improves reliability.

In most facilities, the cores are retested after wiring, at a subassembly stage of manufacture. In the early years of ferrite-core memory production, the defect level of cores was too high to permit wiring of cores directly into large assemblies. Separate subassemblies or *core planes* were wired, tested, repaired, then interconnected into *stacks* and retested before inclusion in a memory system. Evolutionary improvements in core-making process and core-stringing technique have permitted wiring of large arrays, with 256 × 576 (147,456 cores) a typical size, and 1000 × 2000 or larger planes (2 million cores) being used, with all or nearly all cores in one plane. Planar arrays have the advantage of minimizing wiring time, reducing the number of interconnections, and reducing the number of assembly steps. Numerous smaller capacity systems have been produced with all cores and associated electronics on one large printed-circuit board. This is the ultimate in packaging core memory systems; however it does introduce logistics and inventory problems for the systems manufacturer who goes to an outside source for cores and wiring of the cores.

Our discussion of core plane wiring has been general and independent of the way the memory system is logically developed to utilize the core array. In all systems core planes are interconnected by solder or welded joints between terminals, wires, and printed-circuit boards to form a core stack if more than one such sub-assembly is required. Electrically, the way in which the stack is connected to the system is dependent upon the organization of the memory.

Memory Organization

Four major memory organizations have evolved within the memory industry. These have become known as 2D, 2½D, 3D 4-wire and 3D 3-wire. The most popular has been the 3D 4-wire memory, with 3D 3-wire moving up rapidly in popularity as a result of its inherent advantages. 2½D and 2D have great utility also, in particular application areas. The four organizations represent four ways of wiring cores to route the electric currents necessary to change the direction of the magnetic flux stored in the memory cores. During operation, in each organization, the core sees a magnetic field during "read" sufficient in amplitude to change the flux state of the core to "0" if it is not already there. In a 2D memory, this field is generated by current in a single wire. In 2½D and 3D organized memories, two currents of half amplitude in time coincidence on two separate wires (X and Y) produce this magnetic field. Similarly, during a "write" operation, a core will see a "full-select" magnetic field if it is to switch to a "1" state, and a lesser field if it is not to switch, but rather to stay in the "0" state. Only the way the field generating electric currents are introduced to the cores differs in the different organizations.

The simplest, and the earliest used, organization is the 2D organization. 2D memories are also known as word-organized or linear-select memories because a single wire is used to select each word. A 2D array for 8 words of 4 bits per word is illustrated in Fig. 1. Information is stored by coincidence of two partial-write currents, one provided along the selected word wire, the other on the bit wire. For writing a "0", the bit wire is not driven. In the example shown the information 1011 is written into the memory. All cores on the selected bit line see a partial write pulse, below the switching threshold of the core.

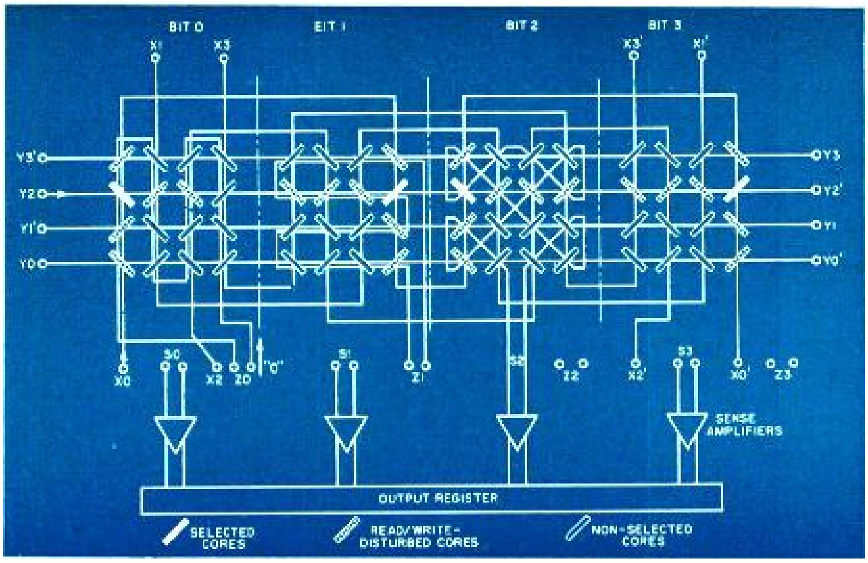


Fig. 3. A 3D array for sixteen 4-bit words. In bits 0, 1, and 3 sense wire is not shown. In bits 2, 3 Z wire not shown.

The read operation is accomplished by sending a full read current down the selected word wire, driving all cores to the "zero" state. Those cores which were in the "one" state are fully switched, generating a large "one" voltage on the bit line. This voltage is sensed by a sense amplifier. The cores in a zero state cannot switch further, so a much smaller voltage appears on the bit line, which is insufficient to actuate the sense amplifier. Since the word current passes through all the cores of the word, and cores from no other words, it does not disturb any cores. As a result, larger word currents can be used, resulting in shorter switch times. This organization is especially well suited to small memories (few words), to memories with very many bits per word, and to high-speed memories.

Advantages of the 2D organization are: (1) faster memories are possible; (2) wide tolerance on drive currents and temperature range; (3) good signal-to-noise ratios; and (4) core requirements are less severe.

2D memories are made in 2-, 3-, and 4-wire models, with 2-wire systems becoming more popular as cores become smaller and more difficult to thread. In the 2-wire version, the word wire is used for both read and write currents, the bit wire is used for digit drive as well as sensing core outputs. Fig. 2A shows a basic current pulse timing diagram for the 2D memory.

A disadvantage of the 2D memory is the larger number of selection circuits required. At the same time the simplified wiring (2 wires per core) and ability to handle very long words (many bits per word) make the 2D organization attractive for very large memories.

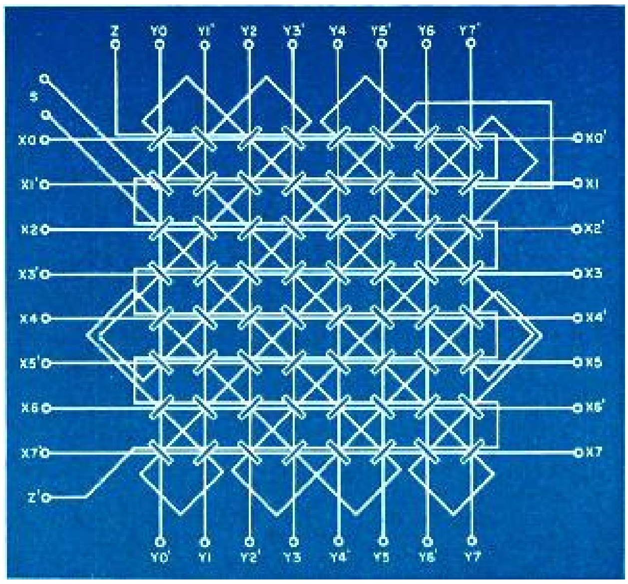
3D memories, also commonly known as *coincident-current memories*, provide a less-expensive solution to most memory requirements. Operationally the 3D 3-wire and 3D 4-wire memories work in the same way, except that the digit (called "inhibit" in 3D) function is shared on one common sense-digit wire per bit in the 3D 3-wire unit; 2 separate wires are used for the digit functions in the 4-wire scheme. An example of a 3D array containing 16 words of 4 bits each is shown in Fig. 3.

Reading is accomplished by time coincidence of two half-select currents on a X and a Y drive line. Only those cores intersected by both the selected X and the selected Y wire see a full-select current pulse. During read, outputs from all such cores in the "one" state will appear on the respective sense wires. During the write portion of the memory cycle, similar but opposite polarity current pulses pass down the same X and Y wires. These currents will write ones into every core in the selected word, except where a digit current is turned on to prevent (or inhibit) core switching. The inhibit current has a current polarity opposite that of the X and Y, and a half current amplitude. Cores along the selected X and Y line other than selected word are said to be "read-disturbed" during read and "write-disturbed" during write by the half-select pulses on X and Y wires. All cores in each bit area where the inhibit current has been turned on see a half-select "disturb" current also, having "read-disturb" polarity. Here the term "disturb" is used to denote the pulse history seen by the core, and does not mean that the partial select current exceeded the core switching threshold, changing the storage state of the core.

In the 3D 4-wire and the 3D 3-wire systems, the sense wire is threaded in such a pattern that one half of the half-selected core outputs are of one polarity, the other half opposite in polarity, providing cancellation of this inductive or difference-mode signal at the sense amplifier input. This cancellation of half-select outputs is not perfect; the remaining difference between them is known as "*delta* noise".

Figs. 4 and 5 show sense-wiring patterns for 3D 4-

Fig. 4. 3D 4-wire plane with sense (S), inhibit (Z) windings.



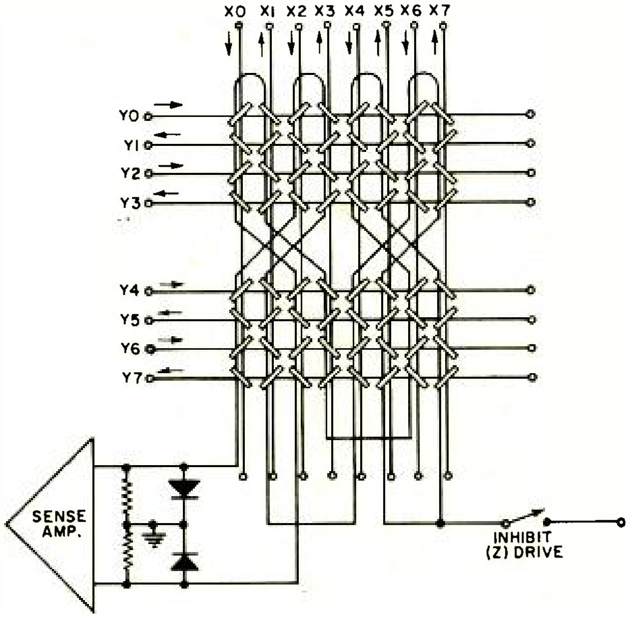


Fig. 5. A 3D 3-wire plane with a common sense-digit wire.

wire and 3D 3-wire arrays. The sense pattern of the 3D 3-wire organization must be parallel to the Y wires (or X) because the common sense-digit wire is used to carry inhibit current during write time, and relative current polarities must be maintained throughout each bit in order to write zeros. X and Y wires are electrically continuous through all bits of the core stack. Recent designs have cores wired all on one plane so that wires are physically continuous as well, with fewer solder joints required, enhancing reliability of the system.

The principal advantage of the 3D systems is that the total number of drive lines (X + Y) required to select all words is lower than other organizations. In the case of a square matrix (X + Y) the number of drive wires is $2\sqrt{N}$ where N is the total number of words. In the 2D memory the number of word lines which must be selected is N.

Several disadvantages exist for 3D systems, such as rather large power dissipation in inhibit windings, relatively slow speed (cycle time) due to current amplitude limits caused by half selection of many cores, and time delay required to allow inhibit noise to decay to a low level before next read cycle. Use of a 3D 3-wire system permits use of larger sense-digit wire, reducing inhibit power and labor in wiring. Fig. 2C shows 3D organization timing.

The 2½D organization is a hybrid of the 2D and 3D systems, usually implemented with 3 wires, occasionally with 2 wires (known locally as 2¼D). An X wire, a Y wire, and a sense wire pass through each core. Read out of information is done as in a 3D memory. Writing of data into the cores is accomplished as in a 2D memory. Fig. 2B shows a timing diagram for this operation. To read, current pulses are simultaneously introduced on one X (word) line and one Y (bit) line in each bit area. The Y lines are independent and are driven "in parallel," as opposed to the 3D systems where one wire is threaded through all bits. During the write operation, the X (word) wire is driven with a current pulse of opposite polarity to that for read. A simultaneous Y current pulse is sent down the Y (bit) lines in each bit area where a "1" is to be stored. No write current is sent along the Y lines where "0" is to be stored. Thus independent control is required of the Y line current by bit in order to store the proper data pattern in each word.

A disadvantage of the 2½D organization is the additional drive selection circuitry required for the Y axis, since this must be repeated for each bit. This makes 2½D matrices most favorable for words of few bits per word. The Y selection matrix can be simplified by use of "phase" selection or "anticoincident" selection of half the addresses, reducing the total circuit requirement. This technique is sometimes effectively used in 3D units as well.

Advantages of 2½D include reduced power dissipation and resultant heating, since there is no inhibit and, on the average, the Y write current turns on in only half the write cycles. Also there is no inhibit wire to thread, and no inhibit noise on the sense wire. 2½D planes lend themselves readily to wiring in a planar array, with all cores on a single mounting surface, with wiring simplified and the number of terminations reduced. A choice of "aspect ratio" or the number of X (word) *vs* Y (bit) wires is possible to optimize line lengths, delays, and circuit requirements. Since there are more drive selection (X and Y) wires in a 2½D unit than in a 3D memory of the same capacity, there are fewer cores on each of these wires. This results in lower back-voltage on the line (lower inductance) so that lower voltage power supplies and even IC drivers and switches can be used to drive 2½D arrays.

The 2½D stack designs became extremely popular in 1965 as an effective means of building larger and faster memories. At that time, the goal was to build 1-μs cycle-time memories, using 30-mil o.d. cores, in capacities around half a million bits. Since that time, efficient systems with 750-ns cycle times have been built using 22-mil cores, and 500-ns systems have been made using 18-mil cores.

Presently in design are 2½D units using 14-mil cores which will cycle in 300 ns. Systems much larger than a million bits can be made more effectively in 2D organizations, because drive limitations are eventually seen in larger 2½D units as well. Cost analyses have indicated 2D 2-wire systems achieve the lowest costs of any device yet known for use in direct electronic random-access memories of large capacity.

So far, we have looked only at the storage devices themselves, the core, core plane, and stack. To be useful in a computer or other data-handling equipment, additional components are required to form a memory system. A complete memory system consists of the core stack plus address drive and selection switches, data circuits, input and output interface timing and control circuits, and power supplies. Additional circuits may be provided to perform special functions when the memory system is used in a small data processor. On the other hand, a memory system will have certain functions deleted when used with a central processor which already contains these functions. Examples of the first category are error detection and correction circuits and data-protection circuits. Examples of possible deletions are address and data registers, timing and control functions, and power supplies.

A memory system has one over-all function: to store digital data and to give this data back upon request. Two main operations occur, write to store data and read to take data out. The location of the data is determined by the address data, which is given to the memory by the external system. The address (typically in binary or octal code) is decoded and the proper drive and select switches are activated. Data to be written is received from the outside by data registers, then placed in storage during a write cycle. As a result of differing needs of users, several cycle types such as read/write (most basic), read-only, write-only, read-modify-write, and split cycle are established.

The memory stack is incapable of performing any function except that of holding the data; it must be operated upon by active, programmed elements that can cause it to accept and relinquish data according to a plan, that can time and sequence all of the individual steps required, and that can perform all of the conversions, translations, interpretations, and adaptations necessary to enable full, compatible communication between the external EDP equipment and the stack. This combination of stack and essential interface constitutes the memory system, or "memory." ▲

The author received his B.Sc. and M.Sc. degrees in electrical engineering from MIT in 1951. During 1951 through 1956, he did research and advanced development on color-TV receivers for Philco Corp. He joined the advanced development group at Univac in 1956 working on high-speed core-memory systems. He is presently responsible for work on random-access memories, advanced OCR techniques, micrographic techniques, and other related techniques and devices. Four patents have been issued in the computer-memory area. He is a member of the IEEE, Magnetics Group and Electronics Computers Group, Tau Beta Pi, and has served on several industry technical committees.

Plated-Wire Magnetic Film Memories

By GEORGE A. FEDDE/Mgr., Data Processing Research, Univac Div., Sperry Rand Corp.

By using this lower-cost manufacturing process, we gain the advantages of nondestructive readout, fast response, and adaptability to wide range of uses and environments.

THE very desirable characteristics of nondestructive readout of stored information, very fast response, information retention without power, easy adaptability to a wide range of applications and environments and, most importantly, low-cost manufacturing processes are combined in the plated-wire memory element. This electroplated cylindrical thin magnetic-film element has many similarities to both ferrite-core and planar magnetic-film memory elements.

Memory Operation

In its simplest form, a plated-wire memory consists of a number of parallel, 5-mil diameter (or smaller) wires with a 20 to 40 millionths of an inch thick plating of a nickel-iron alloy on the surface. They are also called "sense-digit lines." These wires are encircled by an orthogonal set of parallel drive conductors, round wires or flat strips called "word drive lines."

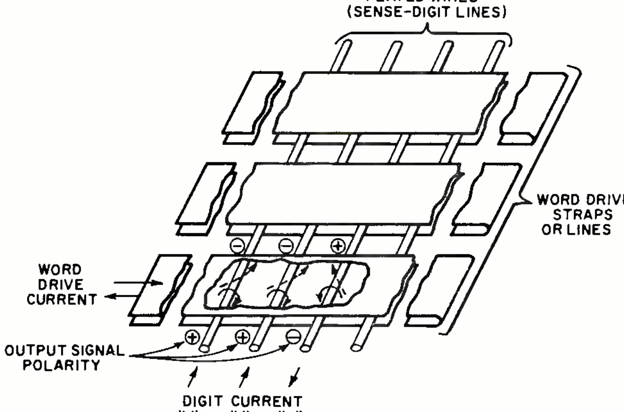
Fig. 1 shows a simplified drawing of a portion of a memory plane. Reading information stored in the memory is performed by sensing the polarity of voltage induced in the sense-digit line when current flows in one of the word drive lines. Readout voltage will be induced in all the plated wires encircled by the word drive line. These will be all of the bits associated with one particular memory word which, as is commonly done, may contain 8 to 16 processor words.

Writing information is done by the time coincidence of current pulses in the word strap and the sense-digit line. The digit current may be either positive or negative depending on whether a "1" or a "0" is to be written. Fig. 1 shows the direction of the magnetization when the element is storing information (solid arrows) for a 1-1-0 pattern. When drive current is applied to the word drive lines, the resultant magnetic field between the parallel strip lines causes the direction of magnetization in the film to be rotated toward the axis of the wire, as shown by the dotted arrows. The resultant change of magnetic flux linking the sense-digit lines induces a voltage of the polarity shown in the diagram. This voltage is amplified and its polarity detected to generate a standard "1" or "0."

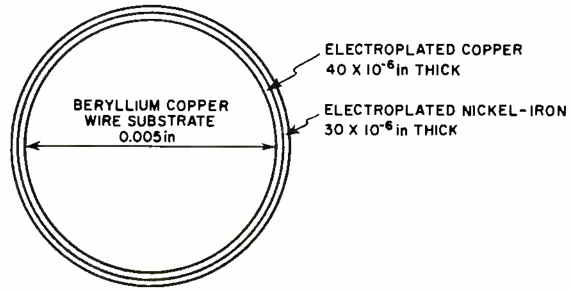
If the word drive current is now turned off, the magnetization returns to its original direction under the influence of the film anisotropy. The readout is thus nondestructive if the amplitude of the word drive current is limited to value less than the threshold value which would cause the magnetization direction to be rotated parallel to the wire axis. If the magnetization had been rotated parallel to the wire axis, approximately half of the electron spins would return to the "1" direction and the other half to the "0" direction when the word drive current was turned off. The bit would now be demagnetized and the information destroyed.

Most plated-wire memories operate to always limit the word drive current to amplitudes less than the destructive readout threshold. Writing new information is accomplished by applying digit current in the plated wire for a period of

Fig. 1. (A) Portion of a memory plane that uses plated wires. (B) Cross-section (not to scale) of plated wire.



(A)



(B)

INFORMATION	PLATED WIRE	PLANAR FILM	FERRITE CORE
Stored	by clockwise or counterclockwise flux around sense conductor		
Retained	without power applied		
MATERIAL			
Composition	80% Ni- 20% Fe	80% Ni- 20% Fe	oxides of Mn, Mg, Fe
Magnetically Isotropic	no	no	yes
Magnetostriction	zero	zero	low
Temperature Coefficient	−0.07%/°C	−0.07%/°C	−0.15%/°C
GEOMETRY	hollow cylinder	layered rectangles	hollow cylinder
SIGNAL			
"One"	+5 to +10 mV	+0.5 to +1 mV	±20 to ±50 mV
"Zero"	−5 to −10 mV	−0.5 to −1 mV	±5 to ±10 mV
Element Individually Tested before Assembly	yes, as part of a group		yes

Table 1. Similarities and differences for the two magnetic-film memories as compared to ferrite magnetic core memories.

time before and after the turn-off of the word drive current. The circumferential magnetic field created by the digit current is large enough to cause the magnetization direction to be rotated from one dotted arrow direction to the other.

Typical pulse-current waveforms and sense signals during a NDRO (nondestructive readout) cycle followed by a write cycle are shown in Fig. 2. Typical current-pulse rise times for a 600-nanosecond (ns) cycle time are 30 ns to 40 ns, while the duration of the pulses may be 100 ns to 200 ns. These values will be smaller by a factor of two or three for a 100-ns cycle time memory.

Planar Film Element

The operation of a planar film memory is very similar in many respects to that outlined for the plated wire. Fig. 3 is a simplified drawing of the *Sperry Rand* Mated Film[R] memory element in production for certain military computer systems. By a series of depositions of various materials by vacuum evaporation, the layered structure is built up to form a complete closed flux path around the sense-digit line. The word drive lines are a pair of wires that, in conjunction with a flat magnetic keeper, provides the magnetic drive field parallel to the axis of the sense-digit line.

The sequence of operations is the same as described for the plated wire. Usually, the NDRO signal from the thinner planar films, 0.1 to 0.2 micron, is smaller than desirable for reliable operation in a practical environment. Thus, most planar film memory designs operate in a destructive readout mode (DRO), and stored information must be rewritten if it is to be saved after readout.

Table 1 shows some of the similarities and differences of the two magnetic-film memories described here as compared with ferrite magnetic cores.

NDRO Organization

NDRO plated-wire memories are usually organized to minimize cost in commercial environments. The minimum size memory for a Univac 9200[R] or 9300 is 8192 bytes of eight bits plus parity. Since only nine bits are handled in parallel each memory cycle, only nine sense amplifiers are needed for reading and nine digit drivers for writing. Thus one possible organization of the memory stack consists of nine sense-digit lines, each one 8192 bits long. There are then 8192 word drive lines, one diode for each word line and perhaps 16 matrices of 32 × 16 word current diverters to select one of the 8192 word lines. Fig. 4 outlines this organization and the more economical one actually used.

An analysis of the memory costs shows that 8192 word drive circuits would cost 8 to 16 times more than the nine sense-digit circuits. The actual design, therefore, used only 512 word drive lines and 16 × 9 = 144 sense-digit lines. Since the memory is operated with NDRO, still only nine sense amplifiers and digit drivers are needed. Each amplifier-digit driver pair can be connected to any one of 16 sense-digit lines.

During readout all 144 plated wires (16 × 9) generate signals, but only 9 are sensed and the other signals ignored. Information is not lost because of the NDRO operation. Similarly, during a write cycle, only 9 plated wires receive digit current and the other 135 wires are not affected. This 16:1 reduction of word drive circuits was accomplished by adding a switch element in series with each plated wire. The cost of the switches is part of the sense-digit electronics.

The cost for a fixed-capacity memory system is larger than the calculated minimum by 5% to 10% for small variations from the optimum ratio of number of word drive circuits to number of sense digit lines. As with all magnetic memory systems, the cost per bit decreases substantially as the capacity of the basic module is increased. The ratio is approximately an inverse square-root relationship.

In addition to utilization of NDRO to achieve the most economical ratio of word drive lines to sense-digit lines, it also permits higher average speed operation and allows read-only operation. The main memory of general-purpose processors typically receives 4 read commands to each write command. Contrasted to a read command in a destructive readout memory which involves a read and rewrite sub-cycle, the plated wire performs only the read portion. In the Univac 9300 memory, the read access time is 300 ns and the write cycle time is 600 ns. Although not used in this particular system, it is possible to design the processor to utilize 300-ns read cycles and 600-ns write cycles. Using 4 read cycles to 1 write cycle gives an average cycle time of:

$$\frac{(4 \times 300) + (1 \times 600)}{5} = 360 \text{ ns}$$

Table 2. Summary of plated-wire and planar film memory characteristics.

MEMORY TYPE	PLATED WIRE		PLANAR FILM
Characteristic	0.005-in dia. 0.050-in long	0.0025-in dia. 0.020-in long	0.015-in wide 0.042-in long
Switching Time	≤ 15 ns	≤ 15 ns	≤ 10 ns
Switching Energy	0.5 x 10^{-9} joule	0.1 x 10^{-9} joule	0.1 x 10^{-9} joule
Curie Temp.	≈500°C	≈500°C	≈500°C
Drive Current Temp. Coefficient	−0.07%/°C	−0.07%/°C	−0.07%/°C
Nominal Output	6 mV x 100 ns x 1/2	2.4 mV x 100 ns x 1/2	3 mV x 100 ns x 1/2
Digit Drive	40 mA–50 mA	20 mA–25 mA	40 mA–50 mA
Word Drive No Keeper	900 mA x 1 turn or 500 mA x 2 turns		
Word Drive Magnetic Keeper	750 mA x 1 turn or 400 mA x 2 turns	400 mA x 1 turn	500 mA x 1 turn

This is 600/360 = 1.67 times faster than if equal-length read and write cycles are used.

In some instances, it will turn out to be more economical to incrementally increase the size of the main memory than to add a separate read-only memory (ROM). The most important factor in this decision is whether or not the system requires true simultaneous access to both the random-access memory (RAM) and the ROM. If simultaneous access is not needed, then the two functions, ROM and RAM, can share common sense and word drive electronics and a common memory stack.

One significant advantage of such a memory organization is that the ROM can be altered electrically. This is really a contradiction in terms since a ROM is usually considered to have its information content fixed by a manufacturing process. During the design phase, changes in the desired information content do occur and a true ROM is awkward. Also, some applications will best be met by the ability to change information occasionally to meet users' needs. This use of plated-wire memories has not been exploited in commercial systems thus far.

Memory-Selection Criteria

For commercial use, it is fairly easy to state the selection criteria for choosing among the competing memory technologies. Applying the criteria may be quite complicated and difficult. The criteria are:

1. Carefully define the memory characteristics and interface that must be achieved. Estimate the relative extra value that could be realized from improvements in access time, cycle time, power consumption, and other characteristics.
2. Select the memory technology that will fulfill the requirements most economically over the expected life of the product.

The first criterion requires a thorough study and evaluation of the real needs of potential users. It requires comprehensive system trade-off studies and a careful balance among the conflicting requirements for broad general-purpose applications or more selective specialized applications.

The second criterion requires careful forecasts of cost and availability for 5 years or more in the future. It must take into account usage and best allocation of resources internal to the company as well as impact from competitors. It should be obvious that two similar computer manufacturing companies may come to different conclusions. For example, one company has internal semiconductor manufacturing capability while another does not. This is significant in trying to forecast the most economical memory technology five or more years into the future. One company may choose to fund proprietary development at an independent semiconductor manufacturer while another may choose internal development of plated-wire memories. Each decision may be best for the respective companies, depending on the alternate uses made of the available resources.

For the company that does not have its own memory manufacturing facility, plated wire is probably the best choice among magnetic-film memory devices. Memory planes and systems are available from a number of independent memory suppliers and more companies can be expected to enter the market. The drive and sense requirements vary widely depending on the plane configurations and the plated wire properties. Table 2 summarizes some of these characteristics.

The annual production of plated-wire memories in the United States is expected to grow approximately 70% a year, reaching an anual rate of 2×10^9 bits per year at the end of 1972. The total random-access memory production is expected to grow about 15% to 18% a year during the same period to 40×10^9 bits per year.

Current plated-wire memory systems operate with cycle times of 500 to 600 nanoseconds. New designs now becoming available will operate in the 200 to 300 nanosecond cycle time range. Laboratory models of 100 nanosecond read cycle and 150 nanosecond write cycle time are operating to show the potential for low-cost main memories of more than 500,000-bit capacities. The plated-wire growth rate could continue to be substantially larger than the market as a whole as its potential for extended main memory applications is realized. It appears to be possible to design and build a ten million-bit modular plated-wire memory with a 500-ns cycle time. Manufacturing costs as low as several tenths of a cent per bit seem within reach. ▲

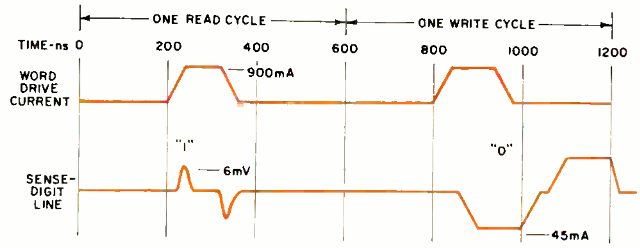


Fig. 2. Typical pulse-current waveforms and sense signals during nondestructive read, followed by write cycle.

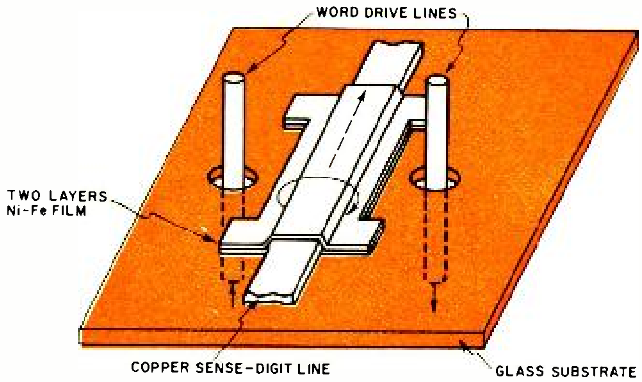


Fig. 3. Simplified diagram of planar film memory element.

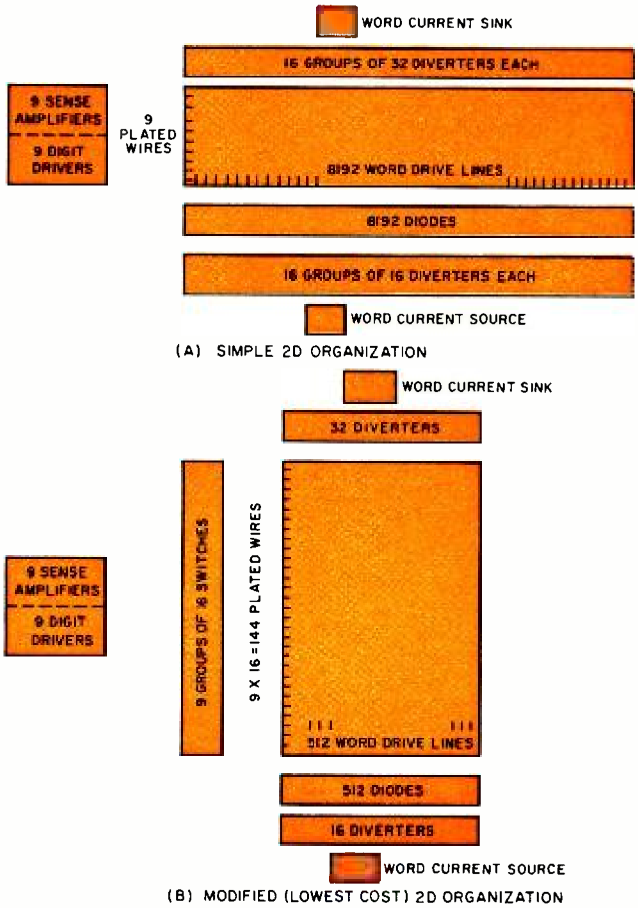
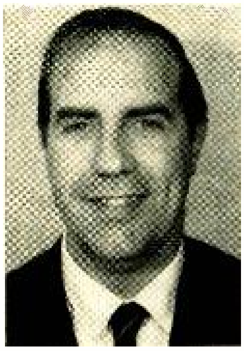


Fig. 4. Organization of NDRO plated-wire memories.

Dr. Chen received his B.S. from National Taiwan University, M.S. from University of Minnesota, and Ph.D. from Stanford University, all in Electrical Engineering. He joined Honeywell Corporate Research Center in 1962, after three years of teaching and working on laser research at the University of Minnesota. Since then, he has been doing research in laser usage and magneto-optic effects in ferromagnetic materials.



Dr. Tufte received his B.A. from St. Olaf College and a Ph.D. in physics from Northwestern University. He joined the Honeywell Corporate Research Center in 1959 where he has carried out research on the preparation and properties of semiconductor materials and devices and development of solid-state sensors.

Optical Memories—Now and in the Future

By DI CHEN /Staff Scientist and OBERT N. TUFTE /Mgr., Solid-State Physics Dept.
Honeywell Corporate Research Center

These computer memories of the future use laser beams and holograms for mass storage. Advantages include higher packing densities permitting smaller memories, elimination of mechanical wear and damage, and higher speeds.

THE ever-increasing needs for the storage of large quantities of data in modern computer systems require new techniques for mass storage. Optical techniques permit information packing densities much greater than those attainable with conventional magnetic recording. Consequently, smaller memory systems having less mechanical complexity and power consumption or memory systems with significantly larger capacities are possible. Also, addressing the memory optically by means of a laser beam eliminates wear or damage problems associated with read-write heads contacting the storage medium. Certain optical addressing techniques can lead to a reduction in the time required to access information in the memory by a factor of 1000 compared with conventional disc or drum-type magnetic memories of similar capacity.

A non-erasable optical storage having a capacity of a trillion (10^{12}) bits has been developed by *Precision Instrument Corp.* Other permanent optical storage elements utilizing photographic film have also been developed. However, a write and erase capability is required for optical memories to reach their full potential. Significant progress is now being made in the development of alterable storage media that can be read, written, and erased by means of a single laser beam.

The high packing density potential of optical memories is a result of a basic principle of optics which states that an optical beam can be focused to a diffraction-limited spot whose diameter is approximately equal to the wavelength of the light. For visible light having a wavelength of approximately 0.5 micron (or micrometer, μm), the potential density of resolvable focused spots is in excess of 1 billion per square inch. In a memory, the spots must be separated by at least one or two beam diameters to uniquely define a bit, so that densities of more than 100 million bits per square inch can be expected. By contrast, conventional magnetic recording on drums, discs, cards, and tapes currently offer densities of 100,000 bits per square inch. Future projections indicate that improvements in the existing techniques may lead to packing densities of approximately one million bits per square inch.

In a mass memory, the packing density is of primary importance in determining the speed, mechanical complexity, and size. For example, disc pack memories having on-line storage capacities of approximately 10 billion bits are currently being developed. With a packing density of 100,000 bits per square inch, 100,000 square inches of recording surface are required. This results in a very large, multiple-surface system. With an optical memory, the same capacity would require only 100 square inches, which would be attainable on a single surface, but mechanical motion would probably be necessary to address the memory, as will be discussed later. For smaller capacity memories (100 million bits), the increased packing density and beam-addressable features of optical memories make it possible to use entirely non-mechanical beam deflection addressing methods. Using holographic storage of the bit pattern, mechanical motion may be entirely eliminated thereby significantly decreasing the memory access time.

Current developmental work on optical memories emphasizes two methods of organization: storage of bits as discrete spots on the memory medium and a holographic approach in which the image of the bit pattern is stored in the memory medium in the form of a hologram. In this article we will review briefly both methods of storage as well as the current status of research and development on materials for the storage medium and addressing techniques. Finally, we will discuss the projected costs of optical memories and the future prospects for this technology.

Optical-Memory Organization

Conventional memories are bit-organized, where every memory bit is physically located at an assigned address. The read and write operation is achieved by sending electric-current pulses to probe and alter the magnetic state of the memory bit, respectively. Extending this approach to an optical memory, a light beam is used instead of the electric current to read and write on a suitable medium on a bit-to-bit basis.

The use of an optical beam offers many advantages. Unlike the conventional memory where the read-out signal depends on the stored energy within a bit, the optical memory read-out signal is proportional to the read beam intensity, thus allowing the high packing density to be realized. Furthermore, the optical beam can, in principle, be deflected to any address location inertialessly, so that a fast random-access memory should be possible. The basic system of an optical memory will include a beam source, a beam control device, a memory medium, a beam deflector, focusing and pivoting optics, and a detector. Fig. 1 shows the conceptual building blocks of such a memory.

To give a definite example of the bit-to-bit type optical memory, let us consider an optical memory using a uniformly magnetized thin film of manganese bismuth (MnBi) as the memory medium. A polarized laser beam, such as that of a helium-neon (HeNe) laser, can be focused to a 1-μm spot on the film, causing a localized heating of this spot to above the Curie temperature. Using a 10-mW laser, the required temperature rise can be obtained in less than one microsecond. Upon cooling, the heated region regains its magnetization, with the direction determined by the sum of the demagnetization and the applied field. This is the Curie-point writing technique.

Using the same beam at reduced power level, the written information can be read by means of the magneto-optic effect. A polarized light beam, when transmitting through or reflected from such a medium, will have its polarization direction rotated. The sense of the direction of magnetization that the beam "sees," either up or down, left or right (in computer language, "1" or "0") dictates the sense of rotation of the light polarization direction. Depending upon whether it has "seen" a "1" or "0" bit, the polarization of the beam will be different, which can further be transformed into bright or dark by letting it pass through an analyzer of suitable orientation and be detected.

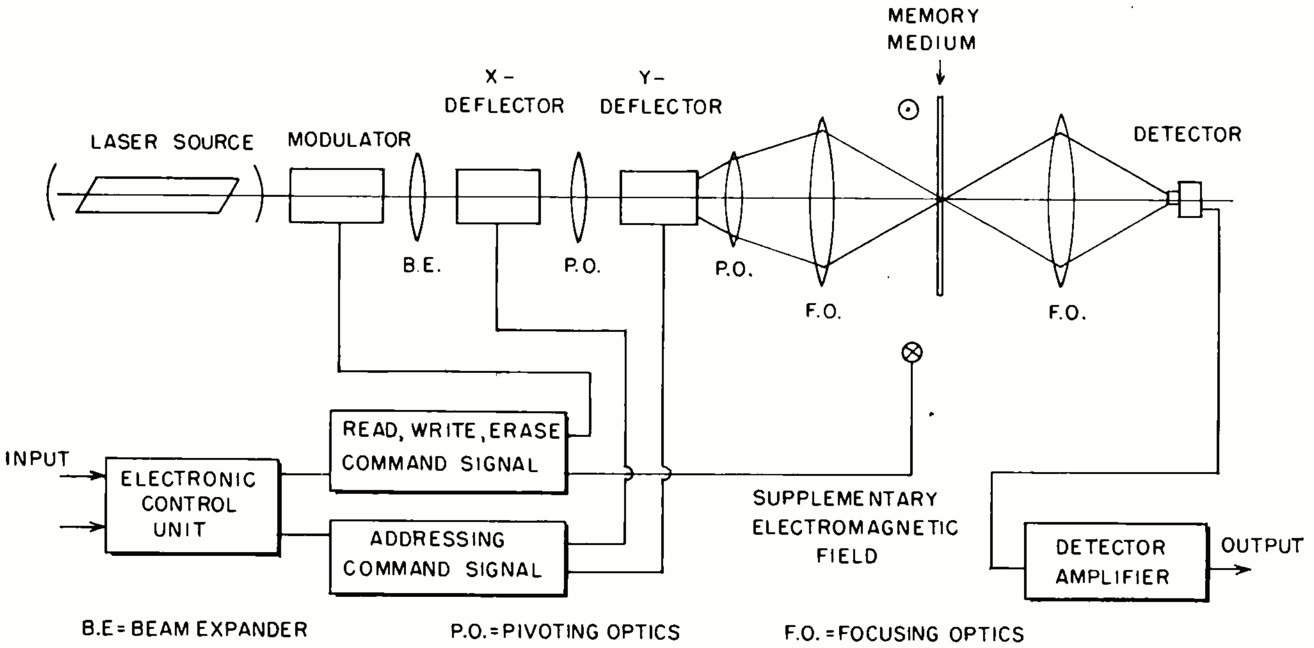
A 16-by-16 bit pattern on a MnBi film using the laser Curie-point writing technique was photographed by using a polarizing microscope. The result is shown in Fig. 2. In this figure, the spot size is approximately 1.5 μm and the spacing between spots is approximately 3.5 μm, giving rise to a packing density of 0.5×10^8 bits/in.^{2} Packing densities as high as 1.5×10^8 bits in^2 have also been shown experimentally. This demonstrates one of the major advantages of the optical-memory technique.

A second method of optical-memory organization that is currently being investigated at a number of laboratories utilizes a holographic approach. In a holographic optical memory, a page of data consisting of an array of approximately 10^4 bits is stored in a hologram having a diameter on the order of 1 millimeter. A hologram is a recording of the interference pattern formed by the superposition of two coherent laser beams. One of the beams passes through a data mask which contains the bit array to be recorded and the second beam (formed by splitting the original laser beam) is a reference beam which is required to form an interference pattern. An image of the data mask or page can be reconstructed by illuminating the hologram with a laser beam which is incident at the same angle as the original reference beam. In a holographic memory, a large number of pages of data are stored in an array of holograms and the beam is deflected to the desired page or hologram for readout.

The system used to read the data from a hologram consists of a laser source, a deflector system, the holographic storage medium, and an array of photodetectors, as shown schematically in Fig. 3. The reconstruction beam is deflected to a specific hologram and the original bit pattern in the page is reconstructed and imaged directly on an array of photodiodes and phototransistors. The bit pattern for each hologram can be reconstructed on a single array of photodetectors without the use of lenses or focusing optics. This is an important feature of the holographic approach since it simplifies the design and alignment of the memory.

A second important feature of the holographic approach is the reduction in the light beam deflection requirement since each hologram contains a page of data consisting of approximately 10^4 bits. Acousto-optic deflectors capable of

Fig. 1. A conceptual schematic diagram illustrating the organization of an optical memory.



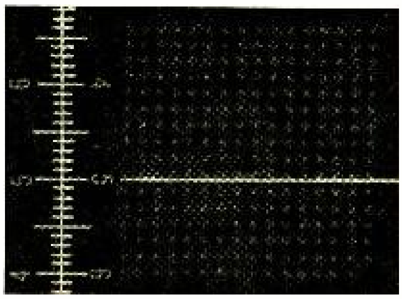


Fig. 2. Photo of array of 16 × 16 bit pattern written by laser Curie-point technique on a MnBi film, as observed through a polarizing microscope. The scale shown on the photo is 2 μm (micrometers or microns) per each small division on the film.

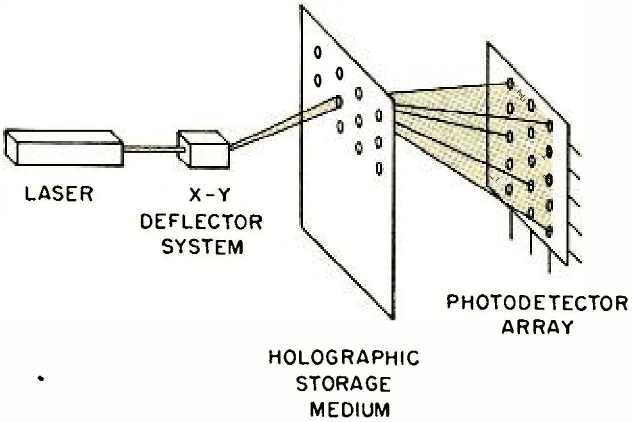
two-dimensional deflection to an array of 64 × 64 holograms with an access time approaching 1 μs are presently feasible. Each hologram can contain 10^4 bits so that approximately 4×10^7 bits of data are available with an access time of approximately 1 μs. Systems having capacities greater than approximately 10^8 bits are probably not feasible without mechanical motion since the area of the storage medium that must be addressed becomes too large to be practical.

A third feature of holographic storage is that the information is redundantly stored in a hologram. If the hologram is partially obscured due to dust particles or medium imperfections, the signal level on all of the photodetectors will be slightly reduced but all of the bits in the hologram will be read out. Conversely, the page orientation of the holographic memory requires that the bits be read out by pages and storage of data requires a new data mask to be generated and a new hologram written. If holographic memories are to be used for on-line storage, an alterable data mask or page composer must be developed. A page composer consists of an array of non-mechanical light valves or shutters which can be opened and closed electrically or optically in approximately a microsecond. A suitable light valve has not yet been developed but the electro-optic and magnet-optic efects appear to offer the best possibilities. The possibility of liquid-crystal shutters has been suggested by *RCA* as an interim approach but the speed of the liquid-crystal switching effect is probably not adequate for an ideal shutter. The photodetector array required for the readout of a holographic memory appears to be within the present state of the art of silicon integrated-circuit technology.

Optical-Memory Materials

A large number of materials have been investigated for optical-memory applications. For permanent or read-only storage, photographic transparencies are used for both holographic and bit-type memories. In bit-type optical memories, metallic thin films deposited on Mylar tape are being used for permanent storage by *NCR* and *Precision Instruments*. A focused laser beam is used to burn minute holes in the tape for writing. However, permanent memory media have only limited applications and the full potential of optical memories will be attained only with alterable memory

Fig. 3. Elements needed to read out holographic memory.



materials which are capable of being written, erased, and rewritten.

The alterable storage media can be classed as magneto-optic, electro-optic, photochromic, and amorphous-semiconductor materials. A summary of the properties and the present status of development of several materials within these classes is given in Table 1. The physical mechanisms employed in each class of materials will be reviewed in this section.

Magneto-Optic Materials. Certain ferromagnetic materials possess a large magneto-optic effect and these materials were among the first suggested for optical-memory applications. The method of operation of these materials in a bit-oriented memory was previously discussed. Typical materials that have been investigated are MnBi films at *Honeywell* and EuO films at *IBM*. MnBi has also been investigated as a holographic storage medium at *RCA*. The Curie-point technique is used to write a magnetic hologram with a short, intense laser pulse. However, the diffraction efficiency of the magnetic holograms in MnBi is approximately 0.01%, *i.e.*, during reconstruction 0.01% of the light in the readout beam will be diffracted onto the photodetectors.

Another technique being investigated is to use a medium where the coercivity decreases with a temperature rise so that the heated region can be switched by a suitable external field without affecting the surrounding material. Gadolinium iron garnet (GdIG) and phosphorous-doped cobalt are examples of materials of this type.

Electro-Optical Materials. Ferroelectric materials can also have two stable polarization states and the state of the polarization can be switched by means of an electric field in conjunction with an optical beam. The polarization in a ferroelectric material induces a change in the refractive index through the electro-optic effect. A probing beam will therefore experience a different optical path length in the material, depending on the state of the polarization. This optical path difference can again be transformed into beam intensity variation and be detected by a detector. Several writing mechanisms have been advanced as shown in Table 1. However, the bit packing density is rather low with these techniques.

Recent research at *Bell Telephone Laboratories* has shown that ferroelectric materials such as lithium niobate and barium titanate can be used as alterable holographic storage media. The mechanism in this case is slightly different in that the incident light produces optical damage in these materials. Optical damage is a change in refractive index of the material that has been illuminated with high-intensity light. This technique results in a phase hologram since the pattern is reconstructed by changing the phase at different points on the wavefront of the readout beam. The refractive index change produced in the material is small but the interaction can take place through a thickness of material on the order of a centimeter so that the over-all diffraction efficiency can be greater than 40%. Presently, the thermal stability of the holograms written in this manner is not satisfactory for most applications but future research may lead to improvements.

Photochromic Materials. In certain materials, such as alkali-halides, the optical absorption for a given wavelength of light can be increased by irradiating or writing on the medium with a shorter wavelength. This written information can be erased by irradiating the medium with a longer wavelength. In this case, laser beams of different wavelength are used. The photochromic materials are of particular interest as holographic storage media since the information is stored in a volume. This feature leads to a high diffraction efficiency and a high information storage density. At the present time, material fatigue and poor stability are the major difficulties to this approach.

Amorphous Semiconductor Materials. Certain glassy semiconductors were found by *Energy Conversion Devices*

MATERIAL	WRITING TECHNIQUE	ERASURE TECHNIQUE	TYPICAL MEDIUM	COMPANIES CONCERNED	PRESENT STATUS AND COMMENTS
Magneto-optic	Curie-point writing: Laser heating to above T_c. The closure flux provides the writing field	Coincident erasure magnetic field and laser heating pulse	MnBi (360°C)	Honeywell, RCA	Packing density: 10^8bits/in^2; Writing: 1μs, 5-mW laser for 1-μm bit. Device in advanced development stage.
			EuO (—190°C)	IBM	Packing density: 10^7bits/in^2; Writing: 10ns, 10-mW laser for 1-μm bit. Device in advanced development stage. Requires cryogenic environment.
	Compensation temperature: Laser heating to above compensation temperature with coincident writing magnetic field	Coincident erasure magnetic field and laser heating pulse	GdIG ($\sim$20°C)	Univac, IBM, Bell	Packing density: 10^6bits/in^2; Writing: 1μs, 10-mW laser for 10-μm bit with 50-Oe field. Device beyond laboratory demonstration stage. Medium in film form offers packing density of 10^8bits/in^2, requires 500-Oe field.
	Coercivity change by laser heating		Co(P) with NiFe overlay	Ampex	Packing density: 10^7bits/in^2; Writing: 0.1μs, 0.5-W laser with 150-Oe field achieved. Device in final development stage.
Electro-optic	Pulsed electric field for electric polarization switching	Pulsed electric field	PZT ceramic	Sandia	Packing density: 2x10^5bits/in^2; Writing: application of localized poling electric field. Laboratory demonstration achieved.
	Ferrotron technique: combination of photoconductivity and ferroelectric effect	Laser pulse to select bit for field to penetrate over photoconducting layer	CdS on $BaTiO_3$	Melectro	Packing density: estimated below 10^5bits/in^2.
	Laser damage effect: laser beam induces local refractive index change	Heating the memory plane	$LiNbO_3$	Bell	Packing density: 10^8bits/in^2; Writing: 100 s, 1-W/cm^2 laser power density. Laboratory demonstration achieved.
Photochromic	Illumination of UV or blue beam for writing	Illumination of long wavelength beam for erasure	KBr	Carson Lab., RCA, Univac, IBM, NCR, Itek	Packing density: 10^8bits/in^2; Writing: 100 s, 5x10^{-2}W/cm^2 at 6328A wavelength. Laboratory demonstration achieved. Fatigue and lack of long-term stability are major problems.
Amorphous semiconductor	Laser heating to effect switching between two material structures	Laser heating	Chalcogenide films	Energy Conversion Devices	Packing density: 10^8bits/in^2; Writing: 1 μs, 2-W laser. Device in laboratory-demonstration stage.

Table 1. A summary of the various optical memory techniques along with their present status.

Inc. to have two stable electric conduction states. These materials can be switched back and forth by the application of a long or short heating pulse produced by a focused laser beam. The optical absorption was found to differ for the two states. This will allow a mechanism for optical reading of the written information.

Addressing Techniques & Laser Requirements

Addressing of an optical memory requires relative motion of the laser beam and the medium, which can be accomplished by moving the beam or the medium or a combination of both types of motion. If the medium is held fixed and the laser beam deflected, the capacity and speed of the memory are limited by the deflector. Motion of the medium can be accomplished by either a tape transport device or a rotating disc as is used in a disc pack memory. The moving-medium approach greatly increases the capacity of the memory since large areas of the medium are addressable but it does not allow the potential for fast access time offered by optical memories to be fully realized. However, this approach still takes advantage of the high packing-density of the optical memory and eliminates recording-head wear. Practically, a combination of both types of motion will be utilized in large-capacity optical memories and as the state of the art in laser-beam deflection advances, the amount of mechanical motion will be reduced. Consequently, the development of improved methods of inertialess laser-beam deflection is important in addressing all types of optical memories.

At present, there are four basic types of light-beam deflection schemes:

1. *Mechanical-Beam Deflector:* The most obvious method of deflecting a light beam is by spinning a mirror. This type of deflector is especially useful in a sequential addressing system. Although the speed is limited in this case, a large number of spots can be addressed using this technique.

2. *Vibrating-Mirror Deflector:* An alternative to the rotating mirror technique is to vibrate the mirror by mount-

ing it on a taut band as in the case of a galvanometer deflector or on a piezoelectric cell. This type of deflector is capable of intermediate speed and number of deflected spots and does not suffer from mechanical wear as is the case with the rotating mirror.

3. *Electro-Optic Technique:* As indicated earlier, optical refractive index in a suitable material can be altered by the application of an electric field through the electro-optic effect. If a prism is made out of an electro-optic material, the diffracted light beam will change its angle in accordance with the electric field applied to the prism. Thus we have an analog deflector. An alternative method is to change the polarization direction of the beam by the electro-optic effect. This polarization direction change can be transformed into a beam path direction change in a crystal such as calcite. Therefore, a digital deflector can be made. The electro-optic deflection technique allows a high deflection speed but with limited number of spots. It is fairly difficult to obtain a two-dimensional beam deflection using this particular technique.

4. *Acoustic Deflection Technique:* When an acoustic wave is excited in a material medium, periodic compression and rarefaction regions are created. These can be transformed into regions of higher and lower refractive index through the acousto-optic effect. Effectively, this is like a traveling grating. Light beam incident at a suitable angle upon such a medium can be diffracted with an angle depending on the acoustic wavelength excited in the medium. This type of deflector is capable of two-dimensional deflection of a large number of spots. However, the speed is somewhat less than with the electro-optic technique.

For an optical memory with a large bit capacity, it is advantageous in some cases to be able to address in a block form. For a stationary medium optical memory, every bit must not only be covered by the deflector, but also by a lens for imaging and focusing. Lens or lens system capable of resolving large number of bits are required. It seems that presently available lenses cannot exceed approximately 10^8 resolvable spots, but some improvement is to be expected.

The continuous-wave laser sources presently available in the visible range are capable of delivering a few watts of power in the case of an argon laser and around 50 mW for the HeNe laser. These lasers are suitable for most of the optical memory needs. Semiconductor lasers in an array form have been suggested. This technique offers advantage in that it reduces the beam deflection needs. The detectors required for detection of information bits are readily available. Photomultipliers offer higher signal level but solid-state detectors are preferred in most cases for their signal-to-noise advantages at high data rates. It appears that no major development effort is needed in either the laser source or detectors for optical memories.

Future of Optical Memories

During the few short years since the inception of the optical memory concept, we have witnessed dramatic progress by the computer industry in bringing the various optical memory ideas to reality. The "Unicon" read-only storage of *Precision Instruments Inc.* is already a commercial product. The magneto-optical memory using tape by *Ampex* has passed the prototype stage. We can safely predict that in the next few years one or more of the more sophisticated optical memories will be introduced. Since the inertialess beam-deflection technology is still in its infancy, we will expect the early bit-type optical memories to incorporate either a moving medium approach or some form of mechanical beam deflection.

The memory capability will have to exceed 10^9 bits at an access time comparable to the disc pack memory in order to compete with present mass-memory technology. After all, the success or failure of a new technology hinges on the final test of the economic feasibility. The cost in a 10^9-bit memory is expected to be 0.01¢ bit. With further improvements in materials and beam addressing techniques, a bit memory with a capacity of up to 10^{12} bits at less than 1-second access time, costing 10^{-3}-10^{-4}¢ bit appears feasible.

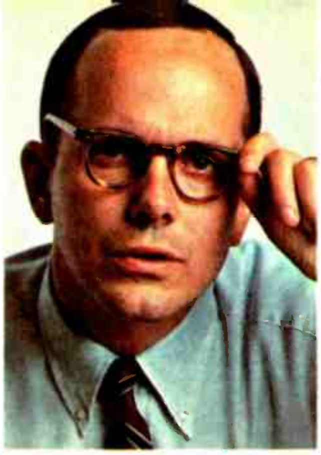
Extensive research is presently being carried out at a number of laboratories to solve the problems associated with holographic optical memories. It now appears that the pay-off will be a memory having a storage capacity in the 10^7 to 10^8-bit range with no moving parts and an access time of approximately one microsecond. The holographic memory will, initially at least, be a permanent storage and the projected cost is 0.1 to 0.01¢ bit, which is comparable to the present disc pack memory. Holographic storage in a bulk medium promises to offer 10^{12}-bit capacity but requires materials and technologies that have not yet been developed. This form of memory is therefore expected to be further in the future.

While it is safe to predict that optical-memory technology will be used in the computer industry, it is equally safe to predict that, because of the competitive nature of computer business, most of the approaches of optical memory discussed here will not pass beyond the stages of laboratory demonstration. Only the future will show which of these approaches can be developed to the point that it is both technically and economically competitive with other memory technologies.

The authors wish to thank their colleagues at *Honeywell Research Center* for helpful discussions and F. Schmit for the use of Fig. 2. ▲

BILLION-BIT FERROELECTRIC MEMORY

BASED on work being done with ferroelectric films at *IBM's* development lab in San Jose, Calif., the development of a fast, reversible memory capable of holding up to 10^9 bits of data has become a possibility. The storage medium, described as a small ½-in square chip of metalized ceramic covered with a thin ferroelectric film supporting a photoconductor film topped by a transparent electrode, will store ¼ to ½ million bits of data. Data is written into and read out of spot on the film by applying voltage pulses to photoconductor-ferroelectric sandwich at same time that a light spot is pulsed onto photoconductor film through the transparent electrode. Depending on polarity of voltage pulse, a "1" or "0" is written at location of light spot when pulse is applied. To read stored data, pulse is applied in same direction as required to write a "0." If a "0" is at address, there will be no output voltage pulse but if "1" is stored then an output pulse will occur and be detected. Calculations show that an array of 256 lenses can image light from same spot on a CRT screen to simultaneously address bits on 256 chips in 25 millionths of a second. This could be achieved within a total storage capacity of 50-100 million bits for the array if a 7-in square CRT screen is used. By linking 10 such systems, a mass store of up to 10^9 bits is a reasonable long-term objective. ▲



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V.H.F. MONITOR RECEIVERS

Modern police monitors use sophisticated circuitry, but there is still no consensus regarding their use by the general public.

By **John Frye**

BARNEY came into the service shop humming "September Song," but he stopped abruptly at the unmistakable nasal sound of a squad-car radio. The sound came from the back room. Cautiously he pushed the swinging door open a narrow crack and saw Mac, his employer, chin in hand, sitting on a stool listening to two small radios resting on the service bench. Both had short whip antennas protruding from their tops, but there the resemblance ended. One, obviously the older, had a speaker grille on the left front of its wooden case, a lighted rectangular dial reading "152-162 Mc., *RAC*, Policalarm" on the right, and volume control and tuning knobs below the dial. It looked like many broadcast a.c.-d.c. radios of the pre-plastic era.

The other was quite different. It was compact, low-profile affair in a black metal case that measured only 7″ deep, including the brushed aluminum hood projecting over the 4″ × 9″ panel. A 3″ round speaker grille was on the right side of this panel, but there was no dial. Instead eight numbered red plastic lens caps were arranged in a row along the top left, and below each lens cap was a red slide switch. A Squelch and Volume control were below the respective ends of this row of switches, and between the controls were a pair of black slide switches, one labelled Man.-Scan and the other Chan.-Sel. Along the bottom in modified script appeared the legend "Bearcat by *Electra*." Lamps behind the lens caps were lighting in rapid repeating sequence from #1 on the left to #8 on the right.

Suddenly this relay movement of light stopped with #3 lamp staying lighted, and a voice issued from both speakers crisply asking, "Car 3-7, what's your 10-20?" As soon as the voiced ceased, the restless sequential lighting of the lamps continued for a few seconds and then paused briefly on #2 lamp while the squad car told its location. This time the only sound from the speaker of the older receiver was the hissing of an unsquelched FM receiver not tuned to a carrier.

"I didn't know you were a police-call listener," Barney said, "How come you're listening to two receivers tuned to the same frequency? And how come you hear the squad car on one and not the other?"

"Whoa; easy, boy!" Mac admonished. "Let's take things one at a time. I've been listening to police calls since they first came on the air on AM just above the broadcast band. The Policalarm receiver, Model PR-6, manufactured by the *Radio Apparatus Corporation*, is one I bought better than twenty years ago so I could listen to the then-new v.h.f. FM police transmissions. It's a straightforward continuous-tuning a.c.-d.c. superhet FM receiver using two 6BJ6 stages of wide-band i.f. and a 19T8 tube as a ratio detector. There's no squelch; it drifts badly during warm-up; it's critical to tune with present-day narrow-band stations: and it's comparatively insensitive. With the self-contained whip you can pick up squad car transmissions for only five or six blocks, and you hear very few out-of-town base stations. While it did a darned good job in its day, I was just comparing its performance with this brand-new Model BCH Series 2 monitor receiver by *Electra Corporation* of Cumberland, Ind."

"How does that Bearcat work? Where's the tuning dial?" Barney demanded.

"I'll get to that, but first let's sort of review the various kinds of v.h.f. police monitors that have developed since that old Policalarm blazed the way. Direct descendants are much more sensitive, selective, and stable. This has been achieved by hotter front-ends, more and better i.f. stages, double-conversion superhet circuitry, and temperature-compensated tuning circuits. Squelch circuits, of course, have been added. Many of these continuous-tuning receivers have provision for switching the tunable oscillator over to crystal control for the reception of one or more spot frequencies. Others are entirely crystal-controlled with broad-banded front-ends and with a switch being used to select any one of several crystals to control the local oscillator for the reception of a desired, pre-determined frequency.

"Solid-state devices have made possible the design of very compact and light battery-powered v.h.f. monitors, both tunable and crystal-controlled, that have most of the features of their bigger brothers. Lots of multi-band transistorized receivers now cover one or more of the police bands. For cheap and dirty reception of police calls, there are the transistorized converters, both tunable and crystal-controlled, that convert v.h.f. transmissions to low-frequency signals for radiation into the antenna of a nearby broadcast-band receiver tuned to a blank spot on the dial.

"As you can see, there's a wide variety in performance, sophistication, and price in readily available modern v.h.f. monitors; but to my way of thinking, the 'scanner' type of monitor—which I believe *Electra* was the first to introduce in September of 1968—is the most versatile and technically intriguing.

"The Bearcat is a solid-state dual-conversion superhet with a high-gain broad-band r.f. section consisting of two insulated gate field-effect transistors. The first i.f. frequency is 10.8 MHz and this is converted to 1.65 MHz. After two stages of amplification, the signal enters an integrated circuit that acts as both a limiter and discriminator. There are two stages of audio amplification and then a class-B complementary symmetry output stage which drives the 8-ohm loudspeaker directly.

"Two transistors serve as squelch amplifiers that unsquelch the first audio amplifier when a signal is present. At the same time the output of the squelch amplifiers stop the action of two transistors connected in a multivibrator circuit free-running at approximately 20 Hz. Output of the multivibrator is applied to four identical flip-flop integrated circuits in proper phase and sequence to effect the sort of logic found in electronic counters—logic circuits we read about recently in ELECTRONICS WORLD.

"The several outputs of these flip-flops are applied in proper phase and sequence to two more integrated circuits serving as four gates and to two enabling transistors. Outputs from the gates and the enabling transistors control eight switching transistors so that in a bucket-brigade or ring-circuit sequence their collectors are effectively grounded. When a particular switching transistor is thus activated, a lamp in its collector circuit lights and any crystal plugged into a socket in that circuit controls the received frequency. I have five crystals in this receiver: #1 channel receives all city fire department equipment; #2, city and sheriff squad cars; #3, city and sheriff base stations; #4, city, county, and state police point-to-point transmissions; #5, local light department base and trucks. Channels 6, 7, and 8 are not active.

"If you want to omit one or more channels temporarily, all you have to do is move down the associated slide switch, like this, and that channel is removed from action." Mac slid down #3 red switch and the #3 lamp remained unlighted during the scanning sweep.

"Suppose you want to listen only to one channel, say #2, the squad car frequency." He moved the Man.-Scan switch to Man., and the scanning stopped abruptly with #5 lamp as it happened, remaining lighted. Then he pushed the spring-loaded Chan.-Sel. switch down repeatedly, and with each motion the light advanced a channel: 5-6-7-8-1-2. "However, the scanning principle lets you hear both sides of the brief, often-monosyllabic exchanges between dispatcher and squad cars—something that's nearly impossible with manual tuning or switching.

"Don't think the receiver is just a novelty, though," Mac warned; "it's also a darned good receiver, employing thirty transistors, six integrated circuits, and six diodes to achieve a sensitivity that makes a signal of only 0.3 microvolt readable and produces 20 dB quieting with one microvolt. I hear squad cars out to ten and fifteen miles and base stations at least twice that far using only the self-contained whip. However, if I want to listen to only strong local stations, I advance the squelch so only they can stop the scanning and be heard."

"Does any other company make scanner-type monitors?"

"Yes, at least two. *Regency* of Indianapolis makes one, and so does *Peterson Radio* of Council Bluffs, Iowa."

"What do police think of the public's using police monitors?"

"Candidly, most of them dislike the idea. They point out criminals have used monitors to keep track of the police while committing a crime. They argue such receivers encourage ambulance chasing and just plain nosiness. A receiver owner may broadcast the fact the police had to stop a family fight between Joe Blow and his wife, even though Joe manages to keep this out of the paper. To restore secrecy to their transmissions, some PD's are experimenting with Teletype, scrambling, and other methods."

"What do you think about that?"

"I think the police are kidding themselves if they believe scrambling or anything else is going to prevent criminals from monitoring their transmissions. Given a little time and plenty of money, a smart electronics engineer can come up with a decoding device for any mode of transmission the police can dream up, and criminals will furnish the money; so all that will be achieved will be to discourage reception by many of the police-call buffs.

"I honestly feel this may be a serious mistake. War against crime involves all of us. It cannot be won by law officials alone. They need all the financial and moral support they can get. Right now we are in a critical period. We have law officials on one side, criminal elements on the other, and the vast majority of people in between. In the past we have always taken for granted this majority automatically sided with the police against the criminals, but the past few years have revealed disturbing evidence many non-criminals look upon the police as the enemy. Common use of epithets like 'fuzz' and 'pigs' point up what I mean."

"Can't the police see this?"

"Smart ones are beginning to. Syracuse police operating in neighborhood teams are holding *kaffeeklatsches* to introduce themselves to local residents and involve them in police problems. Many communities are publicizing *Crime Alert* telephone numbers and inviting people to call these numbers if they see anything suspicious.

"*Time* recently wrote: "Big-city (police) departments often become as isolated as Tibetan kingdoms.' There's no room for that kind of isolation these days, and I believe widespread use of police monitors would help tremendously in establishing a rapport between the public and law officials. Moreover, such use would provide several concrete advantages: (1) citizens learning how demanding police work is are more likely to vote for better police salaries and equipment; (2) knowledge gleaned from listening will result in more meaningful tips containing accurate descriptions, license numbers, times, etc.; (3) knowing taxpayers are listening may help sharpen police radio techniques; (4) identifying with the police will automatically make listeners more law-abiding; and (5) just as many radio amateurs are recruited from SWL's, so will knowledgeable and badly needed police recruits come from families who listen to police calls. Listening to a policeman doing his job will impress kids a lot more than seeing him playing sand-lot baseball in his shirt sleeves. Kids may need a policeman hero more than they do an out-of-uniform pal."

"I agree," Barney said, "although I must add that if you are inclined to be an ambulance chaser, if you're tempted to 'play policeman' or be a vigilante, or if you blab everything you hear, a police monitor is not for you!" ▲

SIMPLE FIELD TEST FOR TV X-RADIATION

THE ability of glass to prevent the emission of x-rays from television receiver components can be determined by a quick and relatively simple field test which has been developed by the Environmental Health Service's Bureau of Radiological Health.

The new test makes it possible for technical personnel to estimate accurately the lead content of glass in TV set components, such as picture tubes. Leaded glass is also used as a shield for diagnostic fluoroscopic x-ray screens. The more lead the glass contains, the more effective it is as an x-ray shield.

Development of the test was stimulated by findings that some color-TV sets emitted x-radiation at levels higher than the recommended maximum. A Federal standard issued under the Radiation Control for Health and Safety Act requires that x-ray emissions from receivers made after last Jan. 15th shall not exceed 0.5 milliroentgen per hour even under operating conditions which increase set potentials for emitting x-rays.

The Bureau's test of glass for lead content involves a mixture of hydrofluoric acid and sodium iodide which reacts on lead in glass to produce a yellow precipitate. A drop of the mixture is applied to the glass and then quickly washed away to avoid glass damage. An estimate of the lead content is made by comparing the intensity of the precipitate's color with standards prepared from powdered glass samples containing known amounts of lead.

The newly developed test, which eliminates the conventional chemical analysis generally performed in the laboratory, is designed to save time and effort. It is expected to aid in field surveys of TV receivers and diagnostic x-ray fluoroscopic equipment by technicians from state and local health departments, industry, and other groups interested in electronic product radiation control.

A comparison study by the Bureau has shown the field test to obtain approximately the same results as may be had by conventional laboratory methods of testing glass for lead content.

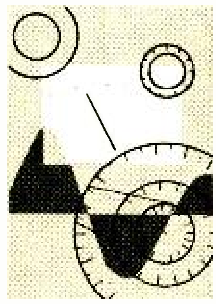
A report describing the test, "A Field Method for the Determination of Lead in Glass Used for Shielding Television Receiver Components," may be obtained from the Office of Information, Bureau of Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852. ▲

ABOUT YOUR SUBSCRIPTION

Your subscription to ELECTRONICS WORLD is maintained on one of the world's most modern, efficient computer systems, and if you're like 99% of our subscribers, you'll never have any reason to complain about your subscription service.

We have found that when complaints do arise, the majority of them occur because people have written their names or addresses differently at different times. For example, if your subscription were listed under "William Jones, Cedar Lane, Middletown, Arizona," and you were to renew it as "Bill Jones, Cedar Lane, Middletown, Arizona," our computer would think that two separate subscriptions were involved, and it would start sending you two copies of ELECTRONICS WORLD each month. Other examples of combinations of names that would confuse the computer would include: John Henry Smith and Henry Smith; and Mrs. Joseph Jones and Mary Jones. Minor differences in addresses can also lead to difficulties. For example, to the computer, 100 Second St. is not the same as 100 2nd St.

So, please, when you write us about your subscription, be sure to enclose the mailing label from the cover of the magazine—or else copy your name and address exactly as they appear on the mailing label. This will greatly reduce any chance of error, and we will be able to service your request much more quickly.



TEST EQUIPMENT

Product Report

B&K Model 176 Solid-State V.O.M.

For copy of manufacturer's brochure, circle No. 3 on Reader Service Card.

TEST-equipment manufacturers have been transistorizing their vacuum-tube voltmeters and operating them from batteries to make these meters truly portable and free them from the a.c. power line. They have also been putting transistors, particularly FET's, into their v.o.m.'s in order to give these instruments the high input impedance that v.t.v.m.'s have. What has evolved is the modern solid-state v.o.m., which provides the best characteristics of both instruments.

A recent version of such a unit is the *B&K* Model 176. This battery-operated FET v.o.m. has the high input impedance (10 or 11 megohms) and sensitivity of a v.t.v.m. along with the portability and convenience of the v.o.m. The meter has 9 a.c. and d.c. voltage ranges, 7 resistance ranges, and 6 d.c. current ranges. Push-buttons are used to reverse polarity and to change to a.c. r.m.s. and to a.c. peak-to-peak measurements.

The transistor circuitry uses complementary symmetry to provide identical calibration of the plus and minus voltages and for balanced temperature compensation. The circuit also protects the FET's from over-voltage transients. In addition, a fuse and diodes protect the meter against accidental overloads. A unique voltage-regulator circuit is also used to maintain constant battery voltage for the transistor amplifiers throughout their entire life.

The batteries employed are a single "C" cell for the ohmmeter and two 9-volt transistor batteries in series for the meter amplifiers. Output from this battery supply is regulated at 13 V d.c.

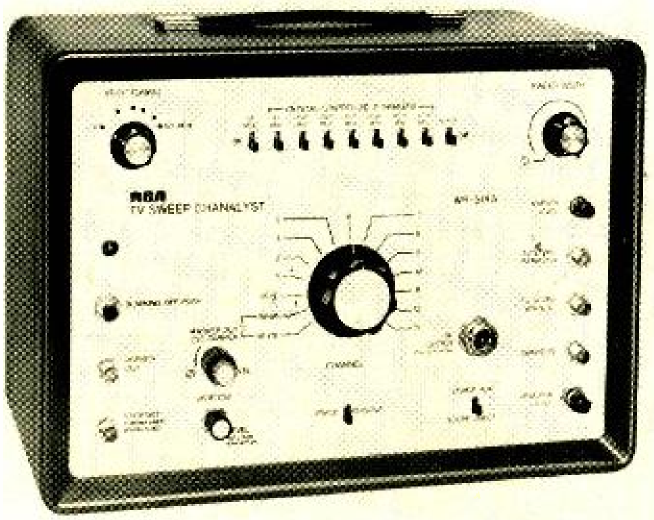
The instrument uses an insulated case to eliminate shock hazard. Price of the Model 176 FET v.o.m. is $99.95. Optional r.f. and high-voltage probes are also available for the meter. ▲

RCA WR-514A Sweep/Marker Generator

For copy of manufacturer's brochure, circle No. 4 on Reader Service Card.

IN order to sweep-align a black-and-white or color-TV receiver, the technician needs a good sweep generator to produce the r.f. or i.f. sweep signal, a good marker generator (preferably with crystal-controlled markers) to spot the various important frequencies on the response curve, a bias supply for the receiver, and, of course, a good scope to display the curve. It has been common recently for test-equipment manufacturers to combine the sweep and marker functions in a single instrument. *RCA's* version of such a unit is the new WR-514A "Sweep Chanalyst."

The generator is a hybrid unit; it uses transistors for the various crystal marker oscillators and marker amplifier, and tubes for the v.h.f. sweep and v.f.o. oscillators, mixer, and cathode follower.



R.f. sweep output is provided for each of the 12 v.h.f. television channels. In addition sweep output is available for the FM broadcast band (88 to 108 MHz) as well as at 10.7 MHz for the alignment of FM receivers and tuners. The r.f. signal is frequency-modulated by a precision vibrating capacitor and output is on fundamental frequencies.

A special chroma sweep signal, combining a 45.75-MHz carrier and an i.f. sweep signal is provided for aligning color bandpass amplifiers in color-TV sets. An over-all response curve is obtained showing the response all the way from the mixer input to the chroma demodulator. This is obtained by connecting a detector probe from the chroma output test point to the scope. The chroma sweep signal (CSS) is similar to the video sweep modulation (VSM) signal recommended by many color-TV manufacturers. While the CSS carrier is modulated in the TV receiver, the VSM carrier is modulated by a video sweep signal externally before it is applied to the receiver. The bandpass curve that is obtained and the alignment technique used are the same in either case.

Seven crystal-controlled i.f. markers are provided to identify points on the sweep curve. Marker frequencies are 4.5, 41.25, 41.67, 42.17, 42.67, 45.75, and 47.25 MHz. An external or additional marker frequency can also be provided. A marker-adder stage inserts the markers on the demodulated sweep curve obtained from the TV receiver. This system of adding the markers prevents distortion of the sweep curve caused by marker overload.

Price of the WR-514A, is $375. ▲

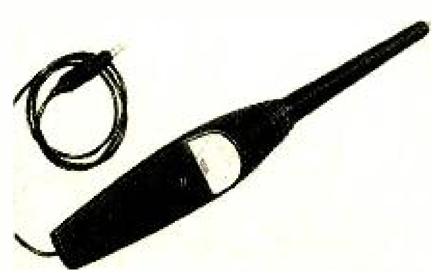
Eico HVP-5 High-Voltage Probe

For copy of manufacturer's brochure, circle No. 5 on Reader Service Card.

ONE of the most important adjustments that must be made by the color-TV technician is the proper setting of the set's high-voltage output. If this voltage is too low, picture brightness will be reduced and focus may be degraded. On the other hand, if voltage is too high, there will be increased x-radiation and some of the h.v. components may be overloaded. The voltage to be measured is on the order of 25 kilovolts.

Adjustment of the high voltage requires the use of a meter that can be applied directly to the high-voltage electrode of the picture tube. The careful technician does this with the power turned off, the high voltage discharged, and one hand behind his back.

The common v.o.m. can be used for this measurement provided you have a high-voltage probe for it that can handle the high voltages present. A more convenient method is to use a high-voltage probe that has its meter built in. There are a couple of such units on the market. The latest one we have used is the *Eico* HVP-5 shown here.



This is a specially constructed probe whose over-all length is about 15 inches. Built in is a long high-resistance (600-megohm) multiplier resistor and a 50-μA microammeter. The meter is calibrated in kilovolts, up to 30 kV. Accuracy is within 3% of full-scale. The user merely connects the clip lead to chassis ground, touches the tip to the high-voltage electrode of the picture tube, and reads the high voltage. We checked the *Eico* probe against a similar unit from another manufacturer that we previously reported on, and were pleased to find the readings on both meters exactly alike.

Price is $19.95, wired only. ▲

BOOKS

"HANDBOOK OF ELECTRONIC CHARTS, GRAPHS, AND TABLES" by John D. Lenk. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 07632. 219 pages. Price $10.95.

The author has provided a nicely balanced and useful assortment of nomograms which will prove helpful to technicians, students, and engineers.

The material is divided into twelve sections covering mathematical calculations, d.c. calculations, a.c. calculations, inductance and capacitance calculations, phase-angle and impedance calculations, antenna and transmission-line calculations, filter-circuit calculations, attenuator and pad circuit calculations, solid-state calculations, and vacuum-tube and transistor amplifier calculations.

In addition to providing the appropriate nomogram for making each of the listed calculations, the author has supplied pertinent formulas for obtaining more precise answers, plus explanatory material on using the graphs and formulas.

* * *

"HANDBOOK OF SEMICONDUCTOR ELECTRONICS" edited by Lloyd P. Hunter. Published by *McGraw-Hill Book Company*, New York, N.Y. 10036. Price $27.50.

This is a revised and updated Third Edition of a volume which originally appeared in 1956. Like the earlier volumes, this new Handbook is designed to offer the practicing engineer help in designing any type of semiconductor circuit. It also offers valuable background material on device physics and device and circuit fabricating techniques as well as measurements techniques so that the engineer can make an educated evaluation of the devices he plans to use.

This new edition includes a wealth of new material on IC's, including their physics, fabrication, and design as well as updated data on computer-aided circuit design, IC techniques, avalanche diodes, the injector laser, the Gunn-effect oscillator, FET devices, and the design of integrated operational amplifiers.

As was the case with the earlier editions, the editor has assembled an impressive group of specialists, each of whom deals with his particular area of competence. The result is a complete and authoritative compilation which should be on the reference shelves of every R&D lab and engineering department.

* * *

"ESSENTIALS OF ELECTRONICS" by F. H. Mitchell & F.H. Mitchell, Jr. Published by *Addison-Wesley Publishing Company*, Reading, Mass. 266 pages. Price $10.50.

This volume is designed as a textbook for a one-semester course in electronics fundamentals for students in the applied science curriculum. Since instrumentation plays such an important role in all phases of scientific investigation, the authors feel that some basic knowledge of electronics is absolutely essential for anyone following any of the scientific disciplines.

The eleven chapters cover d.c. circuits, a.c. circuits, electron emission from metals and conduction in semiconductors, thermionic and junction diodes and rectification, diodes and transistors and direct-current amplification, a.c. amplification, high-gain and multistage amplifiers, distortion, control and computer circuits, oscillators, and instrumentation.

As is the case with most textbooks, each chapter carries a series of problems and examples worked out for the student to review. Six appendices provide basic reference material needed by the student using the text. The book is illustrated by graphs, line drawings, and photographs to aid in amplifying the text material.

* * *

"SIMPLIFIED RADIOTELEPHONE LICENSE COURSE" by Leonard C. Lane. Published by *Hayden Book Company, Inc.*, 116 W. 14th Street, New York, N.Y. 10011. 136 pages. Price $3.95 soft cover. Vol. 1.

This is the introductory volume of a three-volume course for would-be FCC ticket holders and covers the rules and regulations as they apply to a Radiotelephone Third Class License.

After an introductory chapter which deals with various miscellaneous data regarding licenses, the balance of the book is divided into three elements dealing with basic law, basic operating practice, and third-class permit endorsement. The presentation throughout follows closely the format of actual FCC exams and includes detailed answers, formulas, sample problems, and test questions by means of which the student can gauge his progress.

The text is lavishly illustrated with sketches to emphasize certain points in the text. The subsequent volumes, due later this year, will cover Second- and First-Class ticket exam material.

* * *

"DESCRIPTIVE ELECTRONICS" by Ralph R. & Charlotte A. Huffsey. Published by *Holt, Rinehart and Winston, Inc.*, New York, N.Y. 10017. 356 pages. Price $9.95.

This is an introductory text for the non-specialist or those who work in non-electronic fields but need a background in basic electronics in order to handle their specialties; for example, biology, chemistry, psychology, or premedicine. By limiting themselves to the mathematics most people have acquired in basic high-school algebra courses, the authors have extended the audience for this text to laymen as well as non-specialists.

The 28 chapters cover everything from a.c. and d.c. theory through tubes and semiconductors, to various types of test instruments used in all types of measurements. Appendices carrying equations, scientific notation, resistor color codes as well as schematic symbols make the volume self-contained for those who might not have engineering reference books in their libraries.

* * *

"THEORY AND APPLICATIONS OF FIELD-EFFECT TRANSISTORS" by Richard S.C. Cobbold. Published by *John Wiley & Sons, Inc.*, New York, N.Y. 10016. 515 pages. Price $19.95.

This comprehensive treatment of FET's is designed both as a textbook for graduate engineering students and as a reference work for practicing research and design engineers. Since the author has delimited his audience in this manner, he has made no concessions to those without the requisite engineering background and/or knowledge of semiconductor device physics. With this *caveat*, the book provides a wealth of useful and pertinent material in three broad, general categories: fabrication, theory and properties, and applications.

The treatment is highly mathematical and at an advanced engineering level. Each chapter carries an extensive list of references, graphs, diagrams, cross-section views, line drawings, and charts to amplify the text material.

Five appendices plus a listing of symbols used throughout the text and their definitions, an Author index, and a Subject index complete this useful reference volume.

As a consolidation of published data and reports on the subject of FET's and their applications, this book should provide a helpful adjunct to the libraries of all those who use, specify, or fabricate FET's and the equipment in which they are used. ▲

Up-Down Level-Sensitive Trigger

By FRANK H. TOOKER

Simple digital-like circuit that can be used as a level monitor for pressure, temperature, fluid, and other similar types of sensors.

FIGS. 1 and 2 are the logic and schematic representations, respectively, of a circuit designed to monitor a d.c. level of 9 volts. If this level goes high or low by as little as 0.5 volt, the circuit triggers. The *output* terminal is at zero level when the voltage at the *input* terminals is normal. It goes to better than +3 volts (open circuit) when triggering occurs. Once triggered, the circuit remains latched until the input voltage is returned to normal and the "Reset" push-button is pressed.

The normal input level is determined primarily by the voltage rating of zener diode *D*3. With no zener at this point, *i.e.*, with the input terminal connected directly to the junction of resistors *R*1 and *R*3, the circuit has a normal input level of about 1.5 volts. It triggers if the input drops to 1 volt or increases to 2 volts. Thus, the zener-diode voltage rating for any desired input voltage is very nearly equal to the desired input voltage minus 1.5 volts.

How it Works

The up-down level-sensitive trigger may be constructed using a *Motorola* MC789P hex inverter and a HEP584 dual 2-input gate. Only four of the six inverters are used in this circuit. The remaining two inverters have their inputs grounded. The HEP584 is connected as an RS flip-flop and used as an electronic latch.

With the input terminals open, or at the 0 (ground) level, inverters *A*1 and *A*3 are without bias. The output from each of these inverters is therefore at the positive level. Output from *A*1 is inverted by *A*2, so the output from *A*2 is at the 0 level. The positive output from *A*3 is conducted *via* diode *D*2 to the latch input (pin 1). Output from the latch, at pin 7, is thus at the 0 level. This is fed to the input of inverter *A*4, making the output terminal positive. If the "Reset" push-button is pressed under these circumstances, the output goes to zero momentarily, but returns to positive output as soon as the push-button is released.

When the input voltage level is sufficient to put the junction of resistors *R*1 and *R*3 at +1.5 volts, *A*3 is biased fully on. Output from *A*3 is therefore at the 0 level. Because *A*1 is biased *via* the voltage divider, *R*1 and *R*2, the voltage at the input to *A*1 is insufficient to turn *A*1 on. Output from *A*2 is thus also at the 0 level. With the output from both *A*2 and *A*3 at 0, the input to the latch is 0, and pressing the "Reset" push-button will latch the output terminal at 0. The circuit is now operating in its normal state.

If the input potential rises sufficiently to put the junction of resistors *R*1 and *R*3 at 2 volts, inverter *A*1 is turned on, turning *A*2 off. Output from *A*2 is now positive and triggers the latch, sending the output terminal to the positive level. On the other hand, if the circuit is operating in the normal state, and the input potential decreases sufficiently to put the junction of resistors *R*1 and *R*3 at 1 volt, inverter *A*3 turns off, its output goes positive, triggering the latch and, again, sending the output terminal positive.

Thus, the circuit triggers with either an overvoltage or an undervoltage. The occurrence need not be sustained. A transient excursion in either direction triggers the latch. It can function as a "trouble on the line" detector.

The input signal may be derived from any source capable of providing the required information. It may be a temperature sensor, a light-level sensor, a fluid-level sensor, or a pressure sensor; the output can be biased from a bridge or biased from a discriminator—even the output from a power supply or a battery with a charger will do. ▲

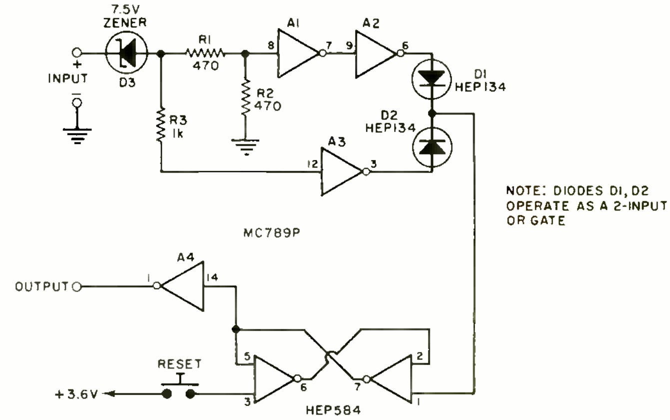
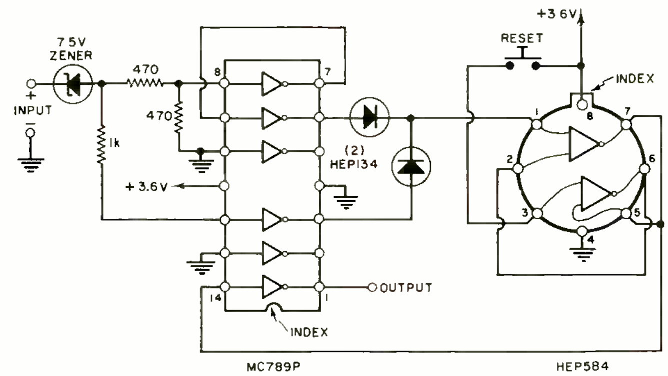


Fig. 1. Logic diagram of d.c. level monitor described here.

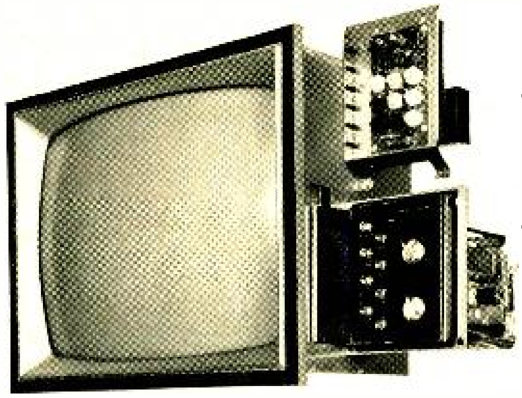
Fig. 2 Schematic diagram of the up-down level-sensitive trigger circuit shown set for normal level input of 9 volts. Circuit will trigger if level falls to 8.5 or rises to 9.5 volts. Note that top view of both IC's (MC789P and HEP584) are shown.



New Heathkit® Solid-State

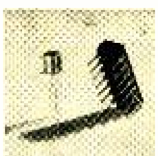
Design and performance features add up to one-of-a-kind superiority.

Over five years were spent in research and development to achieve the notably superior performance, improved convenience features, and ease of service now embodied in the new GR-270 and GR-370. They are premium quality receivers in the truest sense, and, we believe, the finest color TV's on today's market. Here's why...



Compare these features:

- Modular plug-in circuit board construction.
- MOSFET VHF tuner and 3-stage IF.
- Adjustable video peaking.
- Sound instantly, picture in seconds.
- Built-in Automatic Fine Tuning.
- Pushbutton channel advance.
- Tilt-out convergence and secondary controls.
- Hi-fi sound outputs — for amplifier.
- Virtually total self-service capability with built-in volt-ohm meter, dot generator, and comprehensive manual.
- Premium quality bonded-face etched glass picture tubes.
- Choice of 295" or 227" picture tube sizes.



Exclusive solid-state circuitry design...total of 45 transistors, 55 diodes, 2 silicon controlled rectifiers; 4 advanced Integrated Circuits containing another 46 transistors and 21 diodes; plus 2 tubes (picture and high voltage rectifier) combine to deliver performance and reliability unmatched by conventional tube sets.

Exclusive design solid-state VHF tuner uses an MOS Field Effect Transistor for greater sensitivity, lower noise, and lower cross-modulation ...gives you sharply superior color reception, especially under marginal conditions. Gold/Niborium contacts give better electrical connections and longer wear. Memory fine tuning, standard. Solid-state UHF tuner uses hot-carrier diode design for increased sensitivity.

3-stage solid-state IF has higher gain for better overall picture quality. Emitter-follower output prevents spurious signal radiation, and the entire factory-aligned assembly is completely shielded to prevent external interference.

Automatic Fine Tuning — standard on both sets. Just push a button and the assembled and aligned AFT module tunes in perfect picture and sound automatically...eliminates manual fine-tuning. Automatic between-channel defeat switch prevents tuner from locking in on stray signals between channels. AFT can be disabled for manual tuning.

VHF power tuning...scan through all VHF and one preselected UHF channel at the push of a button.

Built-in automatic degaussing keeps colors pure. Manual degaussing coil can be left plugged into the chassis and turned on from the front panel...especially useful for degaussing after the set is moved some distance.

Automatic chroma control eliminates color variations under different signal conditions.

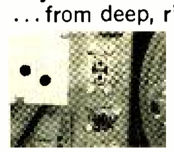
Adjustable noise limiting and gated AGC keeps pulse-type interference to a minimum, maintains signal strength at constant level.

High resolution circuitry improves picture clarity and new adjustable video peaking lets you select the degree of sharpness and apparent resolution you desire.

"Instant-On". A push of the power switch on the front panel brings your new solid-state set to life in seconds. Picture tube filaments are kept heated for instant operation, and extended tube life. "Instant-On" circuit can be defeated for normal on-off operation.

Premium quality color picture tubes. Both the 227 sq. in. GR-270 and 295 sq. in. GR-370 use the new brighter bonded-face, etched glass picture tubes for crisper, sharper, more natural color. And the new RCA HiLite Matrix tube is a low cost option for the GR-370. See below.

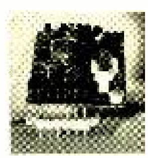
Adjustable tone control lets you choose the sound you prefer ...from deep, rich bass to clean, pronounced highs.



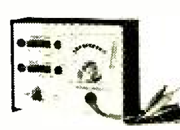
Hi-fi output permits playing the audio from the set through your stereo or hi-fi for truly lifelike reproduction. Another Heath exclusive.

Designed to be owner serviced. The new Heath solid-state color TV's are the only sets on the market that can be serviced by the owner. You actually can diagnose, trouble-shoot and maintain your own set.

Built-in dot generator and tilt-out convergence panel let you do the periodic dynamic convergence adjustments required of all color TV's for peak performance. Virtually eliminate technician service calls.



Snap-out glass epoxy circuit boards with transistor sockets add strength and durability and permit fast, easy troubleshooting and transistor replacement. Makes each circuit a module.



Built-in Volt-Ohm Meter and comprehensive manual let you check circuits for proper operation and make necessary adjustments. The manual guides you every step in using this built-in capability. Absolutely no knowledge of electronics is required.

Easy, enjoyable assembly . . . the Heathkit way. The seven-section manual breaks every assembly down into simple step-by-step instructions. With Heath's famous fold-out pictorials and simple, straightforward design of the sets themselves, anyone can successfully complete the assembly.

Heathkit Solid-State Modular Color TV represents a significant step into the future...with color receiver design and performance features unmatched by any commercially available set at any price! Compare the specifications. Then order yours today.

Kit GR-270, all parts including chassis, 227" picture tube, face mask, UHF & VHF tuners, AFT & 6x9" speaker, 114 lbs. **$489.95***

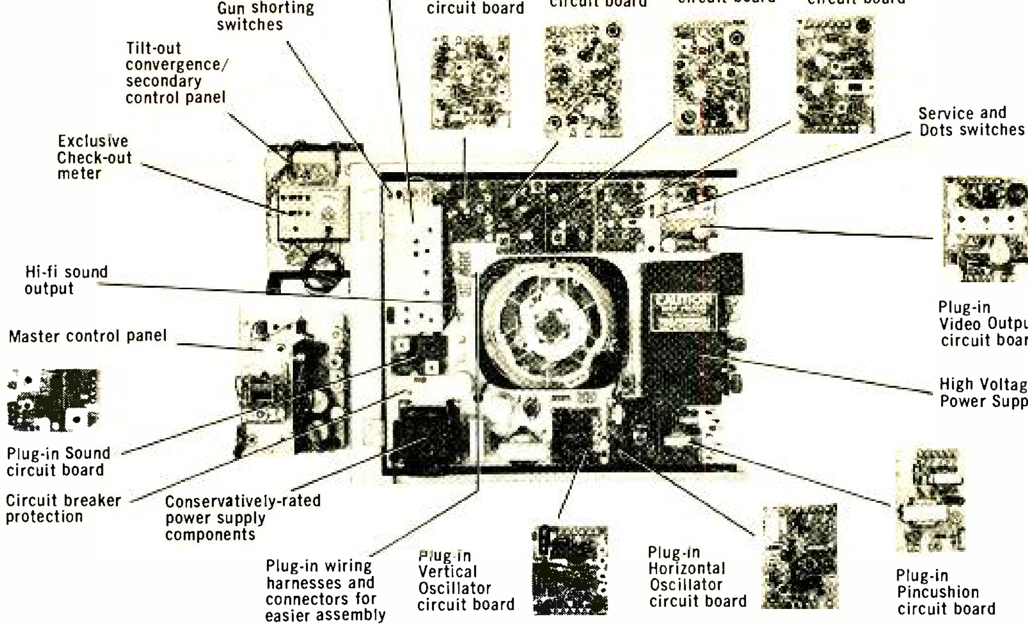
Kit GR-370, all parts including chassis, 295" picture tube, face mask, UHF & VHF tuners, AFT & 6x9" speaker, 127 lbs. **$559.95***

Kit GR-370MX, complete GR-370 with RCA matrix picture tube, 127 lbs. **$569.95***

GR-270 AND GR-370 SPECIFICATIONS — PICTURE TUBE SIZE: GR-370 Approximate Viewing Area: 295 Sq. In. GR-270 Approximate Viewing Area: 227 Sq. In. **DEFLECTION:** Magnetic, 90 degrees. **FOCUS:** Electrostatic. **CONVERGENCE:** Magnetic. **ANTENNA INPUT IMPEDANCE:** VHF 300 ohm balanced or 75 ohm unbalanced. UHF: 300 ohm balanced. **TUNING RANGE:** VHF TV channels 2 through 13. UHF TV channels 14 through 83. **PICTURE IF CARRIER:** 45.75 MHz. **SOUND IF CARRIER:** 41.25 MHz. **COLOR IF SUBCARRIER:** 42.17 MHz. **SOUND IF FREQUENCY:** 4.5 MHz. **VIDEO IF BANDWIDTH:** 3.58 MHz. **HI-FI OUTPUT:** Output impedance — 1 k ohm. Frequency response — ±1 dB 30 Hz to 10 kHz. Harmonic distortion — less than 1% at 1 kHz. Output voltage — 0.3 V rms nominal. **AUDIO OUTPUT:** Output impedance — 4 ohm or 8 ohm. Output power — 2 watts. **POWER REQUIREMENTS:** 110 to 130 volts AC, 60 Hz, 240 watts. **NET WEIGHT:** GR-370, 114 lbs.; GR-270, 101 lbs.

Modular Color Television!

Exclusive Modular Design . . . Circuit Boards snap in and out in seconds for easy assembly, simple servicing



New Expedited 48-Hour No-Charge Warranty Service Plan for Solid-State TV Modules! Special service facilities have been established at the factory and all Heathkit Electronic Centers to expedite service and return of Solid-State TV circuit modules within two working days. During the 90-day warranty period, TV modules will be serviced or replaced with no charge for labor or parts. After the initial 90-day warranty period expires, TV modules will be serviced or replaced at a fixed charge of $5.00 per module for labor and parts for a period of two years from date of original kit purchase.

Add extra convenience and versatility to your new GR-270 or GR-370 Solid-State Color TV with this new ultrasonic remote control kit. Lets you turn the set on and off, adjust volume, change VHF channels and adjust color and tint from the comfort of your chair. Assembles and installs complete in just a few hours and the built-in meter on the receiver makes final adjustment a matter of minutes.
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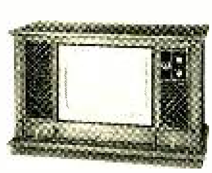

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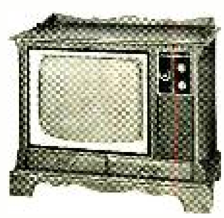

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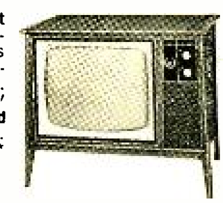

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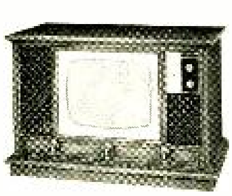

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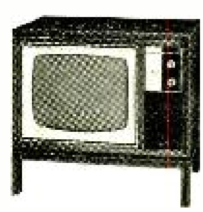

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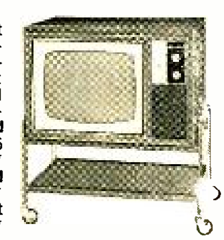

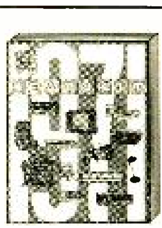

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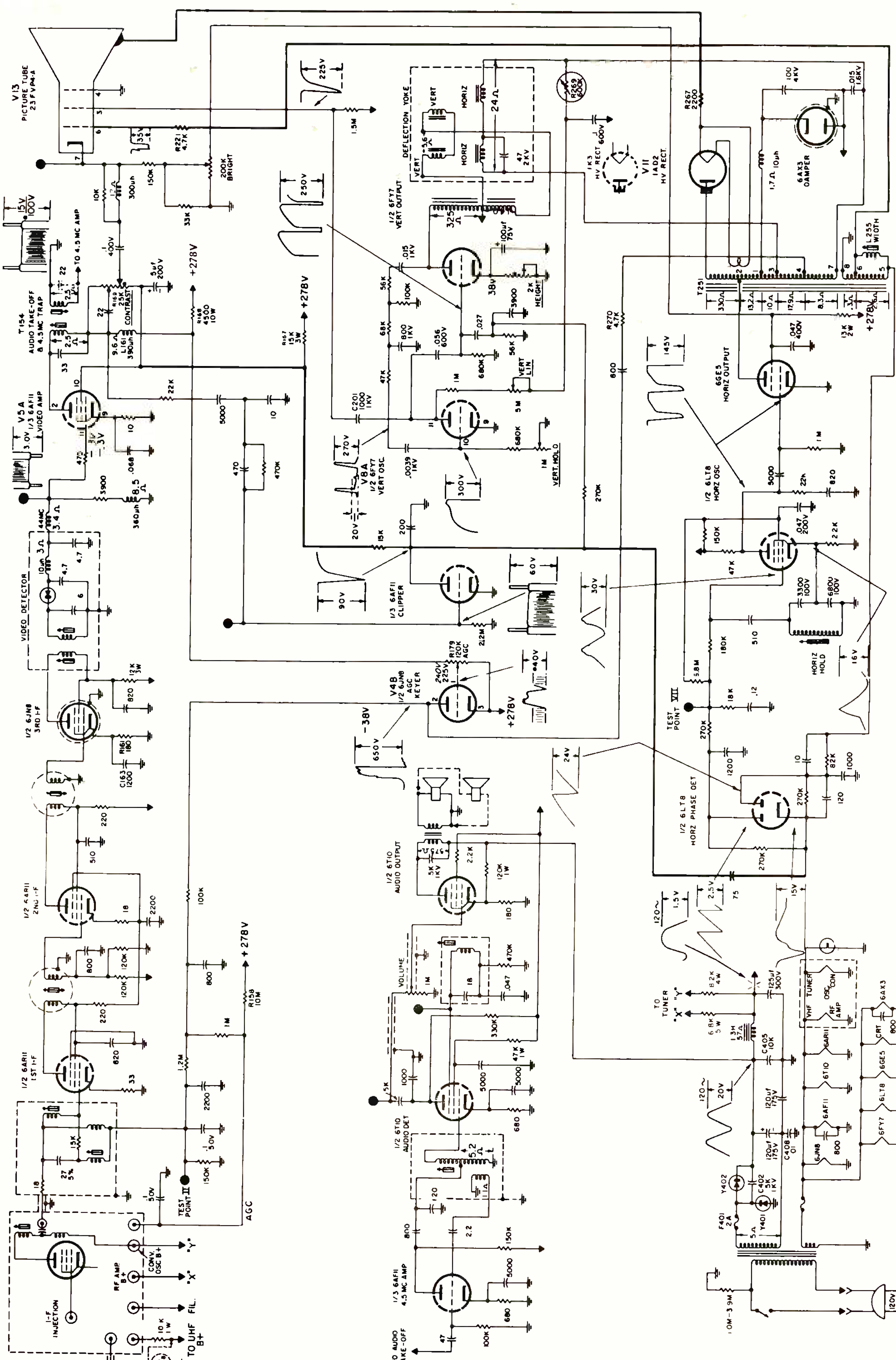
CIRCLE NO. 130 ON READER SERVICE CARD

Schematic of General Electric AC chassis used in the company's line of black-and-white TV receivers. It is to be used in conjunction with the ten troubleshooting questions on facing page comprising C.E.T. Test, Section #9. GE's original component callouts have been retained to make the diagram useful with other service data.



C.E.T. Test, Section #9

TV Circuit Analysis

By DICK GLASS*

What is your electronics servicing I.Q.? You must get 75% on entire exam to pass.

This is the ninth in a series of 12 test sections to be published monthly. While these test exam sections are not part of the actual NEA C.E.T. examinations presently being administered, they are similar in nature. Should you find you are able to correctly answer 75% or better, you might be a candidate to become a registered CET. You can take the exam in your area but you must show 4 years of experience to qualify.

(Answers will appear next month.)
Answers to last month's quiz appear on page 89

1. In the schematic (opposite page), C163 in 3rd i.f. cathode circuit opens. The result will be:

(a) burned out R161
(b) stage will have lower gain
(c) stage will have higher gain
(d) plate voltage will rise

2. R221 (pin 6, picture tube) decreases to 2400 ohms. The result will be:

(a) no noticeable change
(b) horizontal blanking will be insufficient, retrace smear will be evident
(c) V13 emission level will be reduced
(d) the 35-volt p-p horizontal blanking will be reduced by approximately one half

3. C408 (power supply) develops a direct short and a 20-A fuse is found in place of F401. The result:

(a) Y402 and Y401 will probably short from excessive current
(b) Y401 conducts excessively and normally would short or open
(c) Y402 conducts excessively and normally would short or open
(d) circuit operation remains normal, except that the 20-V hum level at C405 increases greatly

4. R270 (pin 4, flyback transformer) opens. The result:

(a) T251 (flyback transformer) overheats
(b) V4B conducts constantly
(c) a.g.c. voltage at TP II would be reduced to near zero volts
(d) V4B plate voltage may become more negative

5. If L161 (video amp plate circuit) opens:

(a) V5A loses its plate voltage
(b) V5A plate voltage is greatly reduced
(c) Picture detail is reduced but otherwise operation seems normal
(d) pin 9 voltage rises

6. If R158 (a.g.c. bus) opens, the effect would be:

(a) a.g.c. control does not work and there is loss of contrast
(b) a.g.c. control has less effect and TP II voltage becomes less negative
(c) a.g.c. control works, but excessive snow seems evident on medium to strong stations
(d) a.g.c. control does not work, there is no picture

7. If C201 (pin 11 of V8A) opens, the effect will be:

(a) several diagonal retrace lines will appear in picture
(b) vertical deflection will be reduced
(c) the vertical hold control may not be able to stop vertical from rolling
(d) most of the picture would be blanked out

8. If the symbol for R269 (vertical oscillator plate circuit) included within the circle a small letter "T", it would indicate that R269 is a:

(a) thermistor
(b) surgistor
(c) varistor
(d) potentiometer

9. If R267 (V11 filament circuit) increases to 5 megohms, you would expect:

(a) the picture to bloom
(b) no picture
(c) no effect would be seen
(d) width will decrease

10. A direct short occurs from primary to secondary of T154 (pin 2, V5A). The result would be:

(a) R167 (between +278V and pin 10) would draw excessive current and open
(b) R169, the contrast control, would open
(c) Transformers such as T154 do not short
(d) R168 (between L161 and +278V) would draw excessive current and open

*Executive V.P., NEA, 1309 W. Market St., Indianapolis, Ind. 46222, assisted by Lew Edwards, chairman of Test Make-up Subcomm.

Graphic Computer Terminals

(*Continued from page 36*)

a CRT. The difficulty arises from the fact that ordinary CRT phosphors retain displayed information for only a few milliseconds. To keep the image visible, the RPD controller has to refresh the frame by continually running through the display program. If the refresher rate is less than about 30 frames per second, the viewer gets the annoying impression that the image is flickering.

To keep the refresher rate greater than 30 frames per second, the time to display one frame cannot be greater than 1/30th second, or 33 milliseconds. The largest number of points that can run the gamut from memory to CRT is somewhat less than 1000 points. Any display having more than that number of display command words will appear to flicker on the screen.

This 1000-point limit is less than 0.1% of the total million-plus display capacity of an RPD system. The emphasis in modern graphic display research today, then, is upon finding ways to better exploit the million-plus potential display capacity of random-point display systems.

Special Circuits

RPD system manufacturers step up the performance of their basic display controllers with different kinds of specialized circuits. In some instances, the special circuits are add-ons the customer can order. In other cases, the manufacturers build the specialized circuitry right into the RPD box. The basic difference in the performance (and price) of RPD systems on the market today is largely due to the kind and quantity of special circuits used to step up performance.

It is possible to program a general-purpose processor to continually refresh the graphic display. This refresh technique, however, uses up a lot of valuable logic and data storage space in the processor. For this reason, a refresh buffer subsystem is a common feature of today's RPD systems. Thus, placed between the display buffer and the RPD controller, the refresh buffer takes over the display refresh function.

The Refresh Buffer

The refresh buffer can serve as a signal conditioner as well as a device for relieving the processor of a routine refreshing job. Graphic terminal users often have to connect their display units to a remote data processor. The communications link between the processor and display terminal seriously limits the rate of data transfer between them. With a refresh buffer installed at the terminal, the only data that has to cross the communications link are those signals that call for a change of some kind in the display. All of the high-frequency refresher signals remain within the "black boxes" which are located at the display terminal.

Many R&D labs have investigated the possibility of using storage CRT's in graphic terminal systems. The idea is to eliminate the need for refreshing the display once it is written out. Storage tubes, unfortunately, require a very long writing time. Whenever an operator wants to edit the CRT display, he must wait several seconds before the updated information appears on the screen of the CRT.

A handful of video terminal manufacturers, including *Tektronix* and *Digital Equipment*, market video terminals using storage CRT's. The users, nevertheless, have to confine their applications to jobs that do not call for rapid and frequent display updating.

(*Concluded Next Month*)

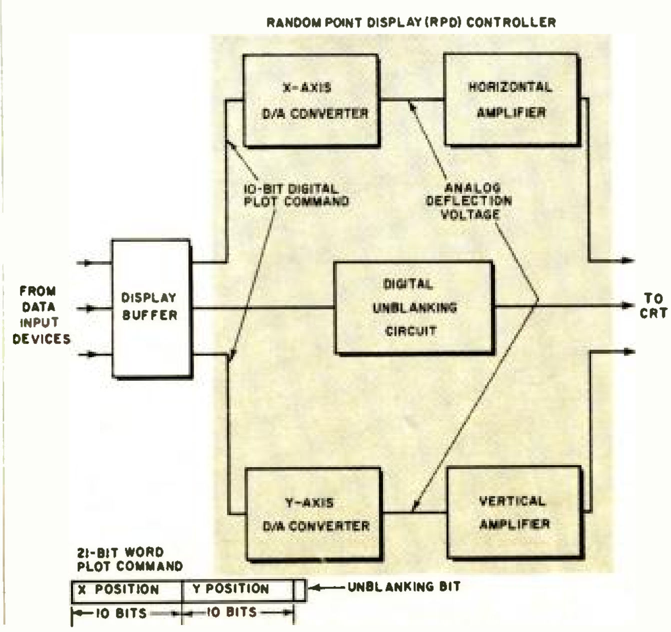


Fig. 6. Block diagram of random-point display controller. Twenty-one-bit plot commands come from display buffer and are translated into X and Y deflection voltages for positioning the CRT beam.

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Digital Communications

(Continued from page 30)

the receiving functions of the system to "lock" with the incoming digital signals, so that the pulses are sorted out and directed to their appropriate receiver channels. Altogether, there are 193 time slots per frame and since the system uses an 8000-Hz sampling rate, the output pulse train fed to the transmission line has a maximum bit rate of 1.544 megabits per second.

An essential feature of the pulse pattern illustrated in Fig. 7 is that the polarity of alternate pulses is inverted to form a bipolar code group. There are several advantages in this arrangement over the straight binary, or unipolar pulse pattern, in which all of the pulse amplitudes are positive-going. In a unipolar pulse code (Fig. 8A), the average value of the digital pulses has an undesirable d.c. component which is difficult to transmit, especially if the pulse stream has to be fed through numerous transformers in the transmission line. However, with a bipolar pulse code (Fig. 8B) the signal is forced to change successively between positive and negative values, so that it behaves like an a.c. signal and permits transformer coupling at the repeaters. All digital pulses, of course, regardless of polarity, are processed as binary "1's" at the receiving end.

A useful parameter in determining the energy distribution of the PCM signals is an analysis of the power-spectrum density. In this measurement, the energy content is divided into narrow bands and swept across the frequency range of interest; the readings being averaged over the time interval. According to the curve in Fig. 8A, the bulk of the spectral energy in the unipolar waveform is concentrated near zero frequency, thus producing unwanted d.c. levels. Furthermore, there are considerable energy levels near the pulse repetition frequency, f_0, resulting in the coupling of energy (crosstalk) to other systems in the same transmission cable. In the bipolar curve given in Fig. 8B, the energy spectrum is modified by shifting the peak energy level to one-half the plus repetition rate, $f_0/2$, so that nulls are produced at f_0 and near zero frequency. Accordingly, not only are the d.c. levels effectively eliminated, but cross-coupling of the high-frequency energy is considerably reduced.

Regeneration

In the course of traversing the transmission line, the digital signals are subjected to the usual forms of noise and distortion, thus causing the pulse train to deteriorate rapidly. However, if the pulse waveshapes are still recognizable, they can be regenerated into their original undistorted form. This function is performed by digital repeaters (spaced about a mile apart) which equalize the line, retime the pulses, and regenerate the pulse stream. As shown in Fig. 9, the PCM signals are fed to an equalized preamplifier to compensate for the distortion introduced by variations in frequency response with line attenuation. By this means, the pulses are reshaped in order to reduce "spillover" into adjacent time slots. The preamp output drives not only the regenerator but also the retiming circuit, which locks itself to the timing information in the signal. This allows the retimer to excite the regenerator when it is time to make a decision on the amplitude of an incoming pulse.

The regenerator establishes a reference level which is compared to the height of the received pulse. If the pulse in a particular time slot exceeds one quarter of the received pulse height, a new pulse will be generated at the output. Thus, any noise spike picked up by the repeater whose amplitude is equal to or below this threshold level will be eliminated. Occasionally, the presence of strong noise impulses can cause extra, or "false," pulses to be generated, resulting in audible clicks in the speech signal. However, if the error rate is about 10^{-6}, or less than one error per million pulses, this impairment is usually not detectable.

Conclusion

There is no doubt that the transmission of information in the form of binary digits will ultimately dominate the communications field. The main problem is to standardize the operating parameters so that all digital systems can be interconnected successfully. Once this problem is resolved, it is possible to conceive that all types of PCM signals, including voice, television, and data, can be intermixed in a vast international digital network. ▲

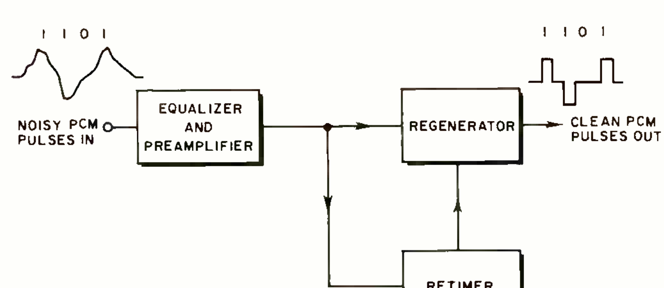


Fig. 9. Simplified block diagram of a digital repeater.

TRIANGULAR-WAVEFORM GENERATOR

By FRANK H. TOOKER

Description of a circuit that produces a triangular output from a sawtooth wave.

A signal of triangular waveform is ordinarily obtained by integrating a square wave, using a basic circuit similar to that shown in Fig. 1. However, at least two transistors will be required to generate the square wave, and the output of the integrator should preferably be fed into an emitter-follower or source-follower to prevent loading capacitor *C*, making a minimum total of three transistors required. Additionally, if the frequency is to be made variable, a three-gang potentiometer will be needed: two to vary the frequency-determining resistances in the square-wave oscillator, and one to vary the value of *R* (in Fig. 1) simultaneously.

The circuit of Fig. 2 is much more simple. It generates a triangular waveform from a sawtooth waveform. Thus only two transistors are needed: a UJT (*Q*1) to generate the sawtooth, and an FET (*Q*2) for the source-follower. Frequency is continuously variable from about 80 to 800 Hz, using a two-gang potentiometer (*R*1*A*-*R*1*B*).

When power is applied to the circuit, capacitor *C*1 tends to charge through resistances *R*1*A*-*R*3 in series. This biases diode *D*1 in the forward direction, causing capacitor *C*2 to be charge simultaneously. When UJT *Q*1 fires, capacitor *C*1 discharges through *Q*1. But capacitor *C*2 cannot discharge *via* this route because at this instant of firing of *Q*1, diode *D*1 becomes reverse-biased and exhibits a very high resistance. *C*2, therefore, must discharge through resistances *R*1*B* and *R*4.

When the value of *C*1 is equal to that of *C*2 (as shown), and the sum of *R*1*B* and *R*4 is equal to about ten times the sum of *R*1*A* and *R*3, the voltage change across capacitor *C*2 is of true triangular waveform. This signal is fed to the gate of FET *Q*2, and output is obtained from *Q*2's source electrode *via* capacitor *C*3.

Some TIS43's work somewhat better in this circuit than others, although all produce an acceptable waveform. If you have several TIS43's, try them all, and choose for your final asembly the one which produces the most symmetrical output waveform. ▲

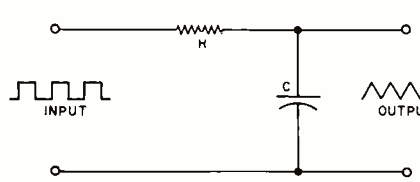


Fig. 1. Basic integrator circuit.

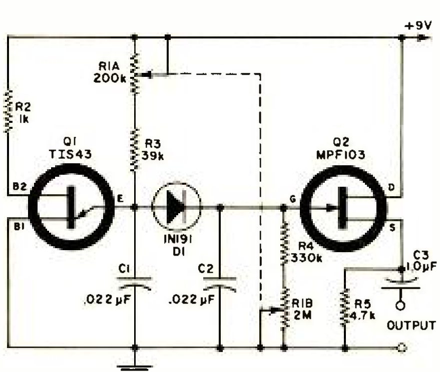
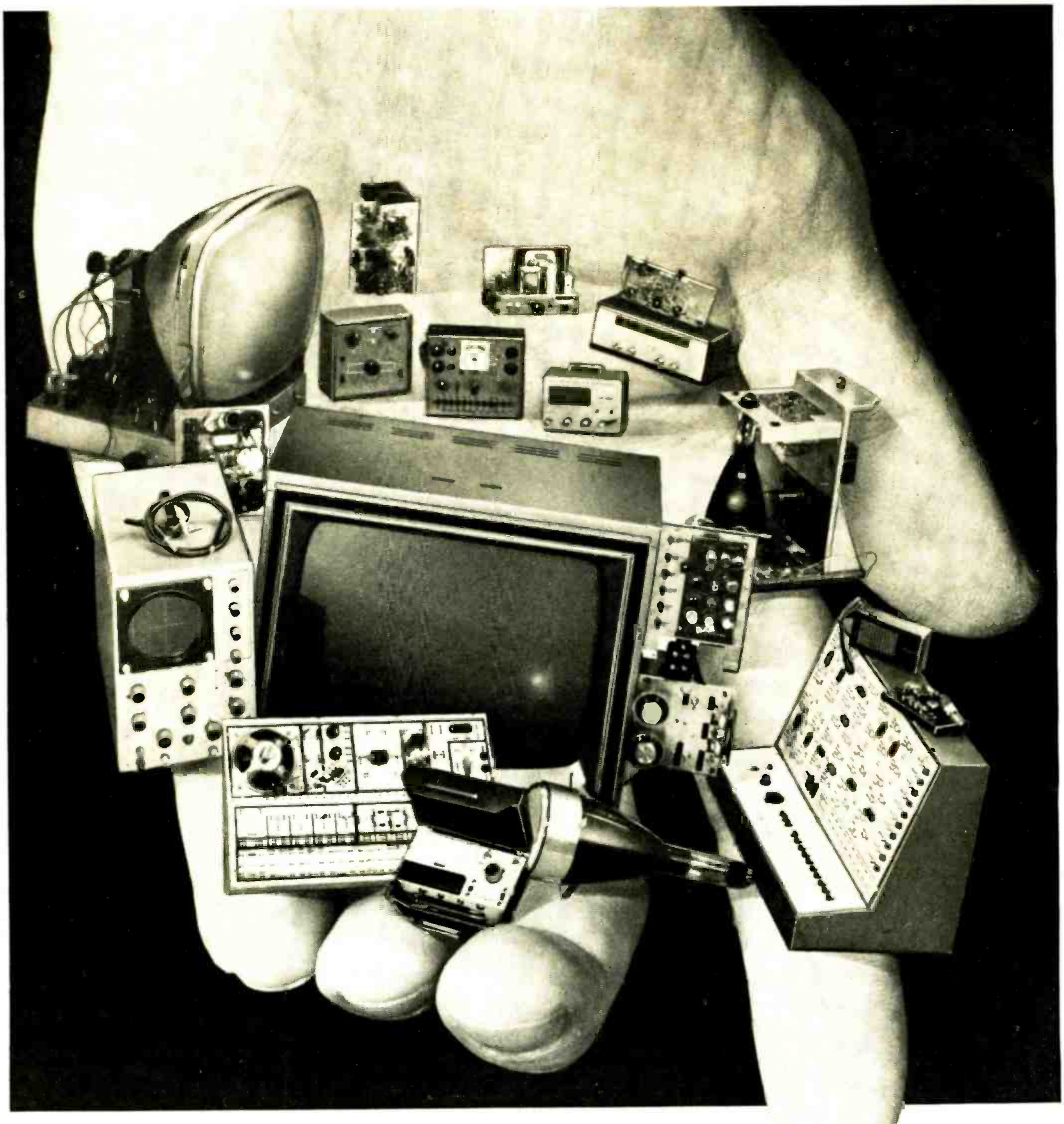


Fig. 2. Triangular waveform generator with output from 80 to 800 hertz.



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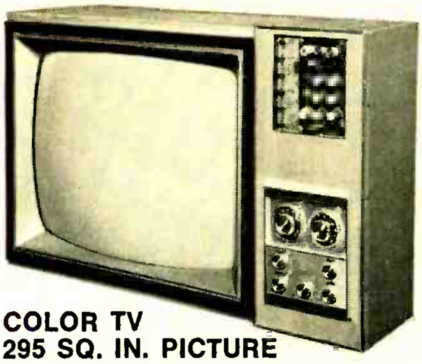

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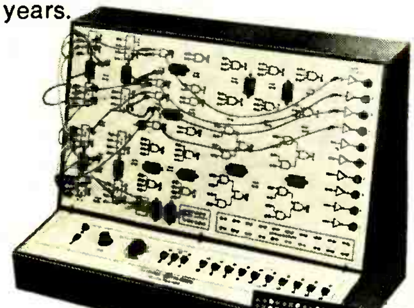

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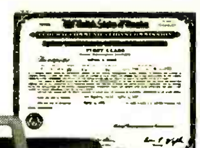

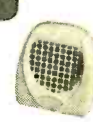

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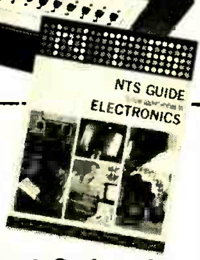

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NEW PRODUCTS & LITERATURE

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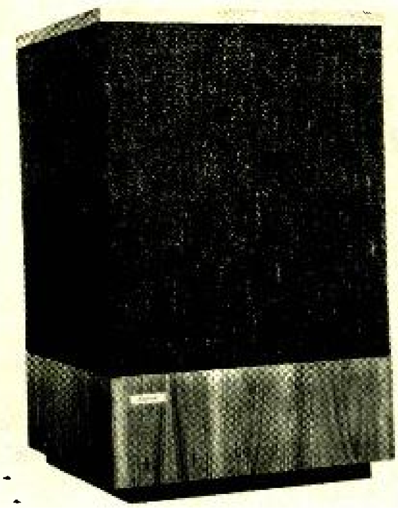
COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • COMMUNICATIONS

TWO-WAY SPEAKER SYSTEM

The new Model 501 two-way speaker system is a "direct-reflecting" unit incorporating an integrated woofer and two tweeters, balanced for both direct and reflected sound.



Power requirements are 20 watts r.m.s. and nominal impedance is 4 ohms. The system is housed in a walnut-grained cabinet with dark brown grille cloth on three sides. The enclosure measures 24" high x 14½" wide x 14½" d. Bose

Circle No. 6 on Reader Service Card

INTRUDER DETECTOR

A new ultrasonic intruder detector has been recently introduced as the Model DS-500. It is designed to detect moving objects in a protected area and incorporates non-linear processing circuits to reduce sensitivity to false-alarm-producing phenomena.

The unit has an elliptical beam pattern extending 20 feet from the unit. Range can be controlled by setting a sensitivity control. Slight movement of an intruder anywhere within the protected area produces an alarm signal for transmission to a security or guard service.

A data sheet giving full details on the DS-500 is available on request. Detection Systems

Circle No. 7 on Reader Service Card

CATV/MATV SYSTEMS ANALYZER

A "Systems Analyst" which is designed to be faster and easier to use than existing methods of checking CATV and MATV systems is now on the market.

The new Model 7500 can be used for a wide variety of applications including sweeping cables for return loss and frequency response, troubleshooting trunklines, checking amplifiers for gain, splitters, directions and taps for loss and v.s.w.r., measuring bandpass of filters and single-channel amplifiers, as well as calibrating field-strength meters.

The unit emits a continuous flat signal from 50 to 220 MHz, with an accuracy of ±1 dB. It also provides a narrow-band crystal-controlled reference signal at 73.5 MHz. The amplitude of the reference signal is accurately monitored on a panel meter and calibrated to within ±0.5 dB. The instrument also includes a built-in 75-ohm comparison bridge, enabling the technician to measure directly the return loss of any passive or active 75-ohm device.

The instrument is portable, weighing only six pounds, and is powered by a rechargeable battery. JFD Electronics

Circle No. 8 on Reader Service Card

200 A/300 V POWER TRANSISTOR

A 200-amp/300-volt "n-p-n" silicon planar power transistor has just been put on the market as the SDT9650, the second in a series of high-density transistors to be introduced by the company over a six-month period.

The SDT9650 has a usable h_{FE} at 200 amps, V_{CEO} up to 300 volts, saturation voltage at 200 amps of less than 1.0 V, and I_{CBO} less than 100 μA at 150-volt V_{CB}. It is available in a TO-68 or TO-114 package.

Typical applications for the device include high-current control circuits, converters, inverters, and beyond state-of-the-art power supplies. Solitron Devices

Circle No. 9 on Reader Service Card

ALL-CHANNEL AMP

The "Gibralter" line of solid-state amplifiers for color and black-and-white MATV systems is now available for distribution.

For small and medium-sized systems, the Model 4330 all-channel unit includes a switch-selected input that allows either a single all-channel input or separate v.h.f. and u.h.f. inputs. Additional features include duo-diode lightning protection, tunable FM trap, and flat response at ±1.5 dB through all 82 channels. Jerrold Electronics

Circle No. 10 on Reader Service Card

MULTI-UNIT STROBE

A multi-unit strobe light is now available for more precise viewing of very wide areas and more concentrated light on small areas for analyzing any parasitic oscillations, flaws, or unwanted distortions while a machine is operating.

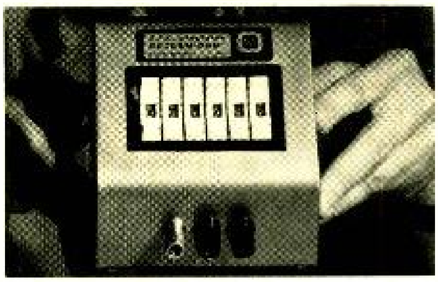
The unit consists of a control box with a manual speed control for adjusting the rate of flash from 350 per minute to 5000 per minute. By plugging in the phone jack on the trip cord and connecting it to a Microswitch or magnetic switch, it will slave trip the multiple strobes that are plugged into the control box. As many as twelve strobes may be flashed simultaneously. Park-Products Engineering

Circle No. 11 on Reader Service Card

PRECISION DECADE BOXES

A new line of ±0.1 percent precision decade boxes, offering a choice of three four-decade and one six-decade models to cover the resistance range from 1 ohm through 1 megohm, is now available.

Called "Determ-Ohm," the new boxes feature resistance values easily dialed by operation of continuous rotation (either direction) rocker-type thumbwheel switches. Resistance setting is indicated by a direct, in-line numeric readout. All units are housed in functional sloping metal



panel cases equipped with a five-way binding circuit plus a grounded metallic binding post for shielding.

A data sheet covering these four units will be forwarded on request. Ohmite

Circle No. 12 on Reader Service Card

PROTOTYPE PC BOARDS

A new system for prototyping printed-circuit boards and test circuits directly from the schematic is now possible with the new "Circuit Zap SpeedKit."

The system consists of 1-ounce copper circuit component patterns, pads, and conductor paths precision-etched on 5-mil glass epoxy-base material, backed by a special pressure-sensitive adhesive.

The kit contains everything needed for instant PC boards—a complete assortment of Circuit Zaps, plus all associated hardware and laminate boards. The system includes male/female jumper wires for testing circuits and insulated copper circuit conductor paths which may be spot-soldered for permanent installation.

Technical bulletin 1003, available on request, explains the system and how it works. Bishop Graphics

Circle No. 13 on Reader Service Card

MULTI-OUTPUT POWER SUPPLY

Varadyne Power Systems, 14943 Califa Street, Van Nuys, California 91401 has introduced a line of multiple-output power supplies which has been specifically designed for integrated circuit/computer applications.

The design features low-cost, high-efficiency all-silicon switching regulators which make it suited in applications where light weight, high reliability, and economy are prime requisites. The unit includes overvoltage protection, output voltage sequencing, and remote programming as well as provision for fail-safe short-circuit protection.

Drop a line on your company letterhead for further information on these supplies.

THREE-IN-ONE RECORDER

A new three-way reel-to-reel/cartridge/cassette all-in-one unit has been introduced as the "Triple Threat 333X."

The reel-to-reel section has 4-track stereo/mono record and playback with 1⅞, 3¾ and 7½ in/s speed (plus 15 in/s with an accompanying adapter). The unit uses the cross-field head system, includes automatic shut-off, pause control, index counter, tape lifter, built-in reel retainer, and a tape-speed equalizer.

The cartridge section permits 8-track stereo record and playback and features a program selector with optional remote control, a program indicator light, and automatic stop. The cassette section permits 4-track stereo record and playback push-button control, automatic stop, index counters, and provides one-hour continuous performance.

The unit includes two built-in high-compliance speakers, dual vu meters, "off-on" speaker switch, and DIN jacks. The accessory pack includes two dynamic microphones with stands, a 7" reel of tape, an 8-minute demonstration cassette, a 15 in/s adapter kit, a spare fuse, a silicone oil kit, and a head-cleaner pen. Roberts

Circle No. 14 on Reader Service Card

ELLIPTICAL-STYLUS CARTRIDGE

A new elliptical-stylus phono cartridge which fills the intermediate range for which the standard ellipticals are too sensitive and the spherical configurations give less performance than the elliptical has been introduced as the Model 681SE.

Like earlier models in this company's 681 Series, the 681SE has an interchangeable stylus, comes with a "Longhair" dust brush, has high output, offers uniformity and ease of cueing, and has excellent shielding, according to the company. Stanton

Circle No. 15 on Reader Service Card

4-CHANNEL TAPE DECK

Three models of "Simul-trak" 4-channel tape decks have been introduced as the Model TCA-40, a ¼-track, 2-channel stereo playback and 4-channel stereo playback (in-line); the Model TCA-41 which has 2-channel and 4-channel playback, 2-channel record; and the Model TCA-42 which has 2- and 4-channel playback, 2- and 4-channel record, automatic reverse for 2-channel operation, and a total of eight separate solid-state playback and record amplifiers and includes off-the-tape monitor selectors.

A data sheet giving complete electrical specifications on all three decks is available and will be forwarded on request. Teac

Circle No. 16 on Reader Service Card

NEW TYPE CASSETTE TAPE

A new high-performance magnetic recording tape which uses a chemical particle composed around chromium rather than iron as the magnetic element in the tape coating has appeared in the cassette format.

The most important advantage with the new chromium-dioxide tape is the increasing sensitivity from 1000 Hz up to beyond audibility. This feature is accompanied by a corresponding ability to accommodate signals of greater strength at high frequencies. Advent

Circle No. 17 on Reader Service Card

PRE-SET FM TUNING

The Model TX-700 solid-state AM/stereo-FM tuner permits the pre-setting of up to five FM stations by means of the individual tuning meters and dial scales. After pre-setting, tuning is ac-

complished by touching a push-button. Manual tuning is still available. With the manual tuning knob "on," either AM or FM can be tuned separately. Simultaneously, the tuning needle lights up on the dial scale.

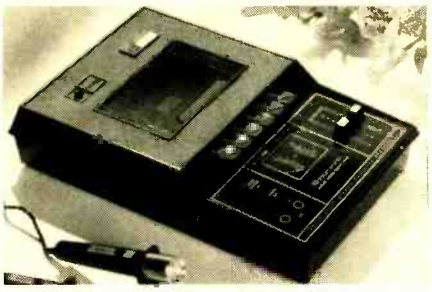
The FM circuit uses FET's and variable capacitance (varactor) diodes. IHF sensitivity is 2.2 μV, capture ratio is 1.8 dB, and selectivity is 35 dB. There are IC's in the FM i.f. section to provide better limiting and capture ratio. Pioneer

Circle No. 18 on Reader Service Card

CASSETTE DECK

The new RC-80 cassette deck features the Dolby noise-reduction system which virtually eliminates tape hiss, even at 1⅞ in/s.

Frequency response is 30-12,000 Hz. A newly



designed tape transport mechanism with a d.c. drive motor has reduced wow and flutter, making tape movement smooth and exact to permit complete utilization of the Dolby system. Fisher

Circle No. 19 on Reader Service Card

MICROCIRCUIT TRIMMER

The smallest available microcircuit trimmer capacitor, the 7200 series, has been announced by Johanson Manufacturing Corp., 400 Rockaway Valley Road, Boonton, New Jersey 07005.

Designed for IC, hybrid circuit, microstrip circuit, and microwave applications, the new trimmers are suitable for u.h.f. oscillators, striplines, balancing of semiconductors and microwave components in addition to serving as trimmers for small fixed capacitors.

The new units have a 10:1 tuning ratio or better and offer capacitances ranging from 0.1 to 2.0 pF. Constructed of gold-plated brass, the units use high-K glass and alumina ceramics. They are available in both PC or chip mountings.

A letterhead request to the company will bring full details.

MARINE RADIOTELEPHONE

The Model T v.h.f. marine radiotelephone is a compact unit measuring less than 9" x 11" x 3" and comes with quick-release mounting cradle for installation in various positions.

The unit comes with crystals for four channels, unity-gain fiberglass antenna, mount, a carbon microphone, and coiled cord. The entire unit is housed in a vinyl-clad aluminum housing with a stainless-steel mount.

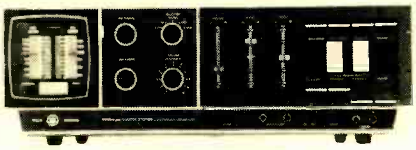
The 6-watt transmitter/receiver operates from 12-volts d.c. and features push-button channel selection. Simpson Electronics

Circle No. 20 on Reader Service Card

200-WATT STEREO RECEIVER

A new 200-watt AM/stereo-FM receiver which features advanced solid-state electronics and a unique front panel has been put on the market as the Model 1101.

The plug-in circuit boards have six FET's, twelve IC's, crystal filters, and advanced triple-MESA silicon power transistors for fast servicing and replacement.



The front panel has a black glass which lights up according to the AM or FM function selected. Two internally lighted vu meters provide a precise means of balancing stereo programs.

Dynamic power rating of the amplifier is 200 watts at 4 ohms (±1 dB) or 140 watts at 8 ohms. Similar IHF music power ratings are 160 and 112 watts respectively. Frequency response is 10-70,000 Hz ±1 dB.

A four-color brochure with complete technical specifications on the Model 1101 is available on request. Nikko

Circle No. 21 on Reader Service Card

PADDLE-LEVER SWITCHES

C&K Components, Inc. has added a new series of paddle-lever switches designed for computer applications and other sophisticated instrumentation to its line. According to the company, the new switches provide reliable snap action, offer an enclosed case, and are of rugged construction.

All of the switching configurations in the company's 1-, 2-, 3-, and 4-pole standard toggle switch line are also available in the new paddle switch series.

For full details on this new line, write on your business letterhead to the company at 103 Morse Street, Watertown, Mass. 02172.

PLUG-IN SCOPE

An all-purpose, plug-in oscilloscope which has a CRT display area 85% larger than 8 x 10 cm displays and over three times larger than smaller models has been introduced as the Model 182A. The CRT graticule has the conventional form (8 x 10 squares) but each square is 1.34 cm on a

side. One of the 13 plug-ins for this instrument gives it 100-MHz response, making it unique among large-screen scopes.

Advances in CRT mesh electrode technology make possible the larger CRT display area without loss of compatibility with the company's existing plug-ins. Details on the mainframe and available plug-in's will be supplied on request. Hewlett-Packard

Circle No. 22 on Reader Service Card

COMPACT INTERCOM

A compact intercom unit designed for business applications provides "hands-free" communications with up to any one of several hundred stations by means of digital push-button selection and electronic plug-in duplex amplifiers. The use of a handset for confidential conversation is optional.

Various features such as volume control, microphone cut-out, multi-registers, secretary transfer, privacy, group call, pocket paging, party line, and others are available. Contact Telecommunications

Circle No. 23 on Reader Service Card

REEL/CASSETTE MODEL

The new Model 330 is a reel-to-reel tape recorder plus a cassette stereo tape system/control system designed to be used with a record changer and tuner to make up a complete stereo system.

The black-and-silver unit has two 5-inch lid-integrated full-range stereo speakers which detach from the unit. Separate bass and treble controls are located next to the volume controls. A five-position selector switch selects phonograph, auxiliary, microphone inputs, and either one of the two built-in tape recorders. Other conveniences include a stereo headphone jack, two tape counters, three tape speeds on the reel-to-reel recorder, and a built-in cassette compartment which will hold up to a dozen cassettes. Sony/Superscope

Circle No. 24 on Reader Service Card

STEREO RECEIVER

The Model 714A AM/stereo-FM receiver provides 90 watts/channel (IHF) dynamic power at a harmonic and IM distortion of less than

0.5% at all frequencies from 20 to 20,000 Hz.

The FM tuner section features three FET's and a four-gang tuning capacitor for optimum sensitivity. Two crystal filters and IC's are used for maximum stereo separation, capture ratio, and selectivity, according to the company.

Frequency response is 20-15,000 Hz ±1 dB. IHF sensitivity is 1.9 μV, and capture ratio is 2.0 dB. The AM tuner section has a sensitivity of 18 μV at a 20 dB signal-to-noise ratio.

The receiver measures 5⅜" high x 16⅝" wide x 13⅜" deep. An accessory walnut cabinet to house the receiver is available. Altec Lansing

Circle No. 25 on Reader Service Card

BLANK CASSETTES/CARTRIDGES

A line of hi-fi blank cassettes and cartridge tapes for the consumer market is now available, using polyester base for high durability and strength. The tapes are sealed in precision housings and have mechanisms to assure perfect fit and uniform speed to prevent jamming, according to the manufacturer.

The cassettes are available in 30, 60, and 120 minute lengths while the 8-track cartridges are supplied in 32 and 64 minute lengths. GC Electronics

Circle No. 26 on Reader Service Card

DIGITAL MULTIMETER

A battery-powered digital multimeter that eliminates zero adjusting and circuit loading has just been introduced as the Type 341.

The meter will operate from a self-contained rechargeable nickel-cadmium battery pack pro-

viding up to four hours of operation between charges or from the standard power line.

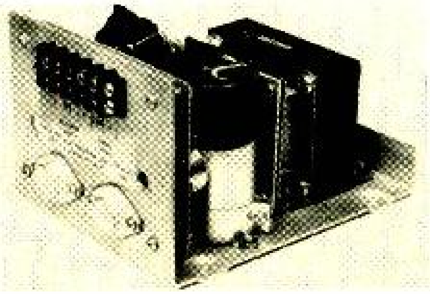
The 3½-digit meter does not disturb the test circuit due to an exclusive input amplifier technique that does away with circuit loading through the test function.

Complete technical specs and additional details will be forwarded on request. Digilin

Circle No. 27 on Reader Service Card

DUAL POWER SUPPLY

A dual power supply featuring 1-amp output each side has been introduced as the Model 50.



According to the company, the unit has low ripple, good regulation, and fold-back current limiting.

Three models, with separately adjustable voltage, are available with outputs of ±10-13.5 V, ±13.5-16.5 V, and ±16.5-20.0 V. Maximum ripple is 500 μV r.m.s. Line regulation is 0.01% and load regulation is 0.10%. Electrostatics

Circle No. 28 on Reader Service Card

COMPONENT STEREO KITS

Three all-silicon solid-state units, a 50-watt AM/stereo-FM receiver, a 50-watt stereo amplifier, and an AM stereo-FM tuner, are now being offered in kit form in the "Cortina 2" line.

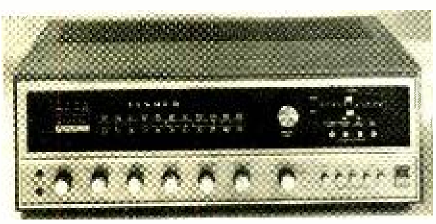
The receiver, Model 3780, from which the tuner and amplifier are derived, has an IHF usable sensitivity of 3.5 μV for 30 dB quieting, HD of less than 1.75%, capture ratio of less than 4%, and a signal-to-noise ratio of 60 dB. Frequency response is 20-20,000 Hz ±3 dB and power output is 16 W/ch (IHF).

Details on all three units in this new line are available on request. Eico

Circle No. 29 on Reader Service Card

4-CHANNEL RECEIVER

The new Model 701 four-channel receiver includes every possible refinement to make it a state-of-the-art AM-FM unit, according to the



company. IC's are used throughout the FM and AM sections (a total of 14 IC stages), the selectivity block of the FM section features sophisticated filters, while the amplifier section incorporates the industry's first integrated Darlington output stages.

The receiver is push-button tuned electronically without moving parts. Maximum output from the four amplifiers is 250 watts music power and 40 watts per channel r.m.s. power—sufficient to drive inefficient speakers to the highest volume levels. Fisher

Circle No. 30 on Reader Service Card

BUSINESS INTERCOM

A new solid-state intercom that is designed to provide efficient internal communications for every kind of business is now available for distribution.

The system provides all standard intercom features plus background radio/music to all station locations, waiting rooms, and lobbies, or any other selected listening area. There are four different modes of operation to suit changing office requirements: hands-free answering, complete privacy, silent (call lights only), or alter-

nate-station transfer. Background music is automatically muted.

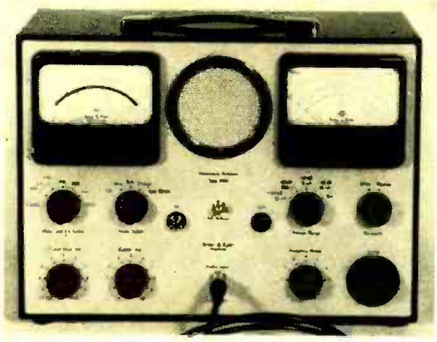
A colorful brochure, BI-800-3, describing the complete system and available options will be forwarded on request. NuTone

Circle No. 31 on Reader Service Card

SELECTIVE R.F. VOLTMETER

A selective voltmeter, the Model 2006, is a versatile r.f. measurement system, according to its manufacturer. It features a complete solid-state chassis and a multiple readout system and is designed for use in the 0.1 to 230 MHz frequency range.

Measurement versatility is maintained by using the high-impedance FET or the 50-ohm probe



input. According to the company, its high sensitivity and wide dynamic range (2.5 μV to 50 V) coupled with two fixed bandwidths makes it suitable for application to nearly all AM-FM carrier or percent-of-modulation measurements.

The voltmeter will operate from 110 to 240 volts (50-400 Hz) or on internal batteries. B & K Instruments

Circle No. 32 on Reader Service Card

STEREO POWER AMPLIFIER

The Model SM-700 stereo power amplifier is rated at 80 watts (IHF) across 8 ohms and has a power bandwidth which extends from 15 to 60,000 Hz $\pm$5 dB. The signal-to-noise ratio is 100 dB with sensitivity and impedance of 0.5 V across 65,000 ohms, 1.0 V across 80,000 ohms, and 2.0 V across 200,000 ohms, switchable.

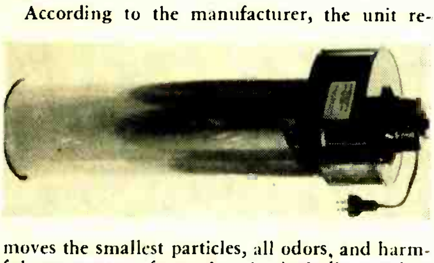
The amplifier measures 11 13/16" wide x 4⅝" high x 10" deep and comes with a pair of contrasting wooden end pieces. Pioneer

Circle No. 33 on Reader Service Card

AIR CLEANER

A unit designed to reconstitute the atmosphere in confined areas such as offices, homes, hospitals, and the interior of cars or ambulances has been introduced as the "Triple XXX Smog Control Unit."

According to the manufacturer, the unit re-



moves the smallest particles, all odors, and harmful smog gases from the air, including carbon monoxide.

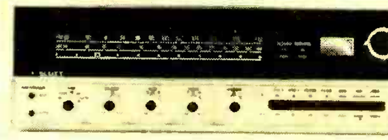
Technical details will be forwarded on request. Snowden Research

Circle No. 34 on Reader Service Card

HIGH-POWER RECEIVER

The 387 AM/stereo-FM receiver provides 100 watts per channel (IHF dynamic) at 4 ohms and is rated 100 watts/channel at 4 ohms continuous power.

New features include a full complement of lights on the front panel to indicate reception of AM or FM, stereo or mono broadcast, phono or extra function, and whether or not the receiver is tuned for best reception. The circuit includes



instant-acting electronic protection and an electronically regulated power supply.

The crystal-filter i.f. design virtually eliminates the need for periodic realignment, according to the company. Much of the circuitry in the multiplex section is encapsulated in an IC and easy service, when required, is assured by the modular construction techniques involved.

Power bandwidth is 10-38,000 Hz (IHF), cross-modulation rejection is 80 dB, and usable sensitivity is 1.9 μV. H.H. Scott

Circle No. 35 on Reader Service Card

MANUFACTURERS' LITERATURE

PRODUCT LISTING

Edmund Scientific Co., 555 Edscorp Bldg., Barrington, N.J. 08007 is now offering copies of its Catalogue 705 which contains 148 pages and covers over 4000 unusual and hard-to-find items for every department from engineering to plant operations.

Among the new items listed is an extensive line of fiber-optic components and accessories; a "Dangerous Material Chart," which is color coded for quick action in every area where potentially dangerous chemicals are used or stored; a magnetic chemical mixer; and hundreds of other devices and items of scientific equipment to check, measure, speed up work, improve quality, and cut production costs.

Copies of this up-to-date listing are available on letterhead request.

ROTARY SWITCH BULLETIN

Subminiature, one-inch-diameter acorn rotary switches with dimensions and configurations designed to meet MIL-S-3786/SR-05 requirements are described in a new bulletin just released by Oak Manufacturing Co. of Crystal Lake, Ill. 60014.

Highlights of the three-hole punched, 8½" x 11", two-color technical bulletin include 32 standard circuit configuration examples, available options, clip information, and PC clip patterns.

When writing for your copy, please specify the "Acorn Rotary Switch" catalogue.

POWER-SUPPLY DATA

Deltron Inc., Wissahickon Ave., North Wales, Pa. 19454 has issued a comprehensive 32-page catalogue containing valuable engineering and application data on a complete line of modular and laboratory power supplies.

The catalogue includes specifications, mechanical drawings, features, electrical connection data, and accessory information on each series of supply. A unique power-supply locator chart is provided so the user can easily decide which series of supply will best fit his needs.

Your letterhead request will bring a copy of this handy catalogue.

TUNNEL DIODE DATA

KMC Semiconductor Corporation, Parker Road, Long Valley, N.J. 07853 has announced the availability of a 4-page tunnel diode brochure. The publication features performance curves, typical circuit configurations, and general engineering data on amplifier diodes, switching diodes, oscillator diodes, and mixer and detector diodes.

Copies are available on letterhead request.

EQUIPMENT & COMPONENTS

A 116-page catalogue covering electro-mechanical equipment and components for engineers, scientists, and teachers has been issued by the Electronics Division of American Relays, 39 Lispenard Street, New York, N.Y. 10013.

Included in this new edition is a transducer selection guide and conversion charts, as well as price and performance data on an extensive line of products ranging from accelerometers to welding controls.

Write on your business letterhead for a copy of this handy source book for surplus products at bargain prices.

INSTRUMENT RENTALS

The Electronic Instruments Division of Beckman Instruments, Inc. has just published a 22-page bulletin describing the division's recently announced instrument rental program.

The publication lists more than 55 instruments that are currently available. Essentially all of the division's instruments are included in the program. As new ones are developed, they, too, will be added to the availability list. The monthly rental price for each of the listed instruments is included, along with a brief description and basic specifications.

Requests for a copy of Bulletin RC110 should be addressed to the Technical Information Section of the company at 2200 Wright Ave., Richmond, Calif. 94804.

COAXIAL CABLE CATALOGUE

A 28-page catalogue on "Coaxitube," a semi-rigid coaxial cable, has been issued by Precision Tube Company, Inc., Church Road & Wissahickon Ave., North Wales, Pa. 19454.

The new publication provides complete information, including mechanical data and electrical characteristics, on standard solid-dielectric and air-articulated coaxial cables as well as special cable constructions. Graphs are provided showing attenuation and power ratings vs frequency characteristics.

AUDIO CIRCUITS TO BUILD

A line of audio modules which includes high-gain amplifiers, stereo amplifiers, a stereo magnetic phono preamp, and guitar amplifiers is pictured and described in a two-color, 6-page data sheet which is now available for distribution.

Each circuit module is pictured, described in detail as to performance and specifications, and a schematic of the unit is given. Information on a cabinet/chassis kit which can be used to house the various items as they are built is also provided. Calectro-Amperex

Circle No. 36 on Reader Service Card

DIGITAL V.O.M. DATA

A two-page data sheet featuring the company's new Models 8000 and 8000-A digital volt-ohm-milliammeters is now available.

The two-color sheet, punched for use in three-hole binders, provides complete electrical ranges and mechanical specifications on both units as well as information on suggested user net prices. Triplett

Circle No. 37 on Reader Service Card

TOOLS FOR TECHNICIANS

A two-page bulletin, No. N470, illustrates and describes a number of "fix-it" tools with special applications in the servicing of TV, radio, and hi-fi equipment.

Each tool is described in some detail and most of them are illustrated and their application demonstrated. Xcelite

Circle No. 38 on Reader Service Card

INTERCOM SYSTEMS

A colorful 20-page catalogue describing an entire line of music-intercom and stereo music systems has just been released for distribution.

The catalogue lists, pictures, and describes built-in FM/AM intercoms, a "Musicom" center, built-in stereo units, surface-mounted stereo gear, and a "Commu-Ni-Com" system for homes, offices, retail stores, plants, or factories. NuTone

Circle No. 39 on Reader Service Card

SHRINKABLE TUBING

An 8-page catalogue which covers various types of irradiated heat-shrinkable tubing pre-cut to standard lengths has been issued.

Covering polyolefin, semi-rigid polyolefin, dual-wall polyolefin, polyvinylidene fluoride, polyvinyl chloride types, the publication describes how material waste, lead time, and internal labor costs can be reduced since the tubing can be supplied in standard diameters from 3/64" up to 2 inches and in cut lengths from ¼" up to 2 inches. Russell Industries

Circle No. 40 on Reader Service Card

INDUSTRIAL SOLDERING TOOLS

The Weller Division, Box 345, Easton, Pa. 18042 has issued a completely revised and expanded catalogue of industrial soldering tools. A wealth of technical and performance information on controlled-output soldering tools is provided as well as data on a broad array of tip styles and accessories. Standard, miniaturized, isolated, and low-voltage tools required for today's sophisticated electronic work are included.

In addition, a comprehensive "basic soldering tool selector guide" relating specific tools to typical soldering situations, is included.

Write on your business letterhead for a copy of this handy publication.

CARTRIDGE GUIDE

A one-page "DCF Application Guide" has been issued to facilitate the selection of the correct stereo cartridge for a particular record changer or turntable.

Ten of the best-known lines are listed along with a wide range of model numbers represented in each line. The correct elliptical or spherical stylus in either the company's DCF or Dustamatic series is listed for each of the record changers or turntables.

The tabular presentation makes it easy to spot the correct unit for a particular record playing model. Pickering

Circle No. 41 on Reader Service Card

SURPLUS BARGAIN LISTING

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A new "Heat-Shrinkable Insulation Reference Chart," measuring 15" x 22", is now available without charge to design, materials, and specifying engineers to help them select a suitable heat-shrinkable material for electronic, electrical, and electro-mechanical applications.

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Answer to Electronic Crosswords appearing on page 94.

E	S	T	I	A	T	R	O	N		G	A	S
P		O		R		I		E		A		Q
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K	I	C	K	S	O	R	T	E	R		M	A

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A 68-page catalogue of selected electronic products for technicians, engineers, and experimenters is just off the press and available for distribution.

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Copies of Catalogue N-71 are available on request. North American

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66	B&K Division, Dynascan Corp.
67 (top)	RCA Electronic Components
67 (bottom)	Eico Electronic Instruments Co.

Answers to C.E.T. Test, Section #8

Published in Last Month's Issue:

1. **(c)** No drop across a collector load resistor would indicate no current through the transistor, or possibly an "open" transistor.
2. **(c)**
3. **(d)**
4. **(d)** 35% of peak-to-peak scope measurement.
5. **(d)** The current-limiting resistor in series with the voltage supply drops the voltage in proportion to the current drawn. Shorts that might damage other elements in the circuit can be located by troubleshooting with power on, using this method.
6. **(a)**
7. **(b)** A "ringing" test simulates transformer or yoke action at a lower voltage level.
8. **(a)**
9. **(d)** 60 Hz is a readily available signal for signal-tracing in vertical, audio, or video circuits.
10. **(c)**

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Can you solve these problems in electronics?

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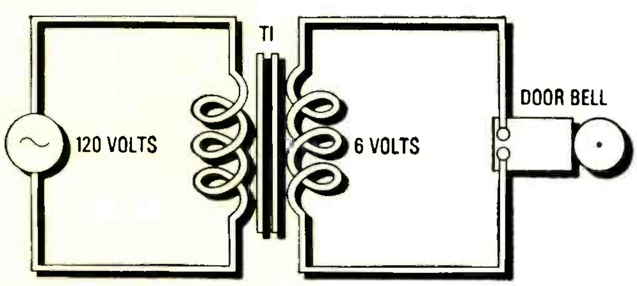
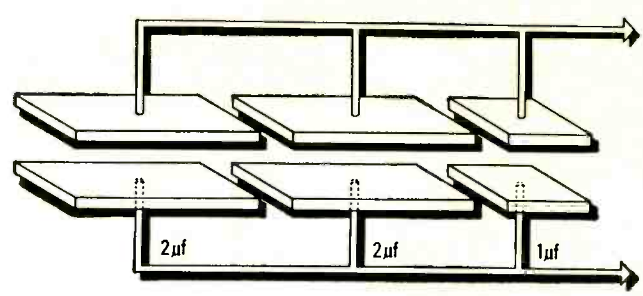


In this door bell circuit, which kind of transformer is T_1 — step-up or step-down?

Note: if you had completed only the first lesson of *any* of the RCA Institutes Home Study programs, you'd easily solve this problem.

This one is more advanced.



What is the total capacitance in the above circuit?

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Answers: Step-down.
5 μf

ELECTRONIC CROSSWORDS

By JAMES R. KIMSEY

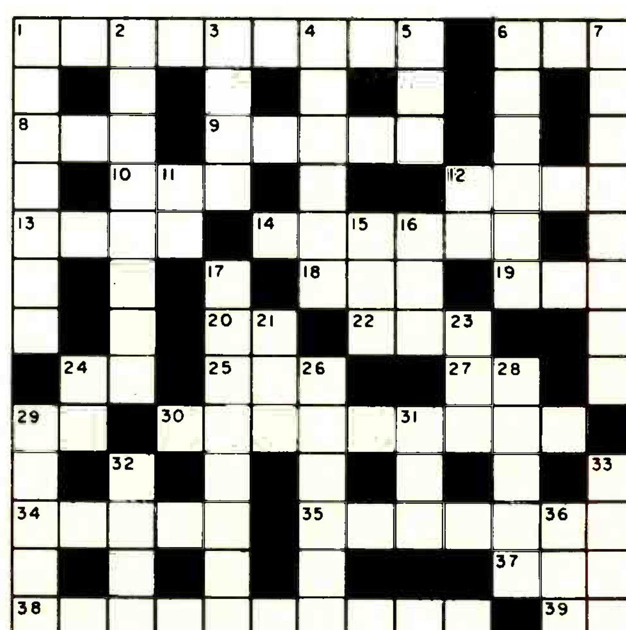
(*Answer on page* 89)

ACROSS

1. A special type of electrostatically focused traveling-wave tube.
6. One of the three states of matter.
8. An electrically charged atom or groups of atoms.
9. ____impedance. The impedance a transducer presents to a source.
10. Not new.
12. Capable.
13. Part sung by low female voice.
14. An alloy used in permanent magnets for speakers, magnetrons, etc.
18. Long period of time.
19. Radio record book.
20. Elevator direction.
22. Type of explosive (abbr.).
24. Switch position.
25. College cheer.
27. A crystal slab cut at a 35-degree angle with respect to the optical, or Z-axis, of the crystal.
29. A person older than another (abbr.).
30. A building is one.
34. The first sign of the zodiac.
35. Long pulses that are separated by very short pulses.
37. ____line, also called interconnection.
38. British term for pulse-height analyzer.
39. One one-thousandth (.001) of an ampere (abbr.).

DOWN

1. Oriented undergrowth between two crystals.
2. Multimode, selective-erasure storage tube.
3. Dry.
4. A.c. component arising from sources within a d.c. power supply.
5. Organization of stations.
6. Prank.
7. Self-quelching oscillator in which the suppression occurs in the grid circuit.
11. Expression of wonder or surprise.
12. Common house current (abbr.).
15. ____AND circuit. An AND gating circuit which inverts the pulse phase.
16. Hotel.
17. Degree of curvature of the peak of a probability curve.
21. Average.
23. Greek letter used in electronics.
24. A gate that produces an output whenever any one (or more) of its inputs is energized.
26. A dark band extending across the picture (2 words).
28. To provide with enjoyment or gratification.
29. Pile up.
31. Necessary evil.
32. A metal used in dry cells.
33. Perplexed.
36. ____magnet, field-neutralizing magnet.



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ELECTRONICS WORLD

October 1970

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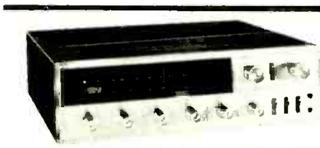
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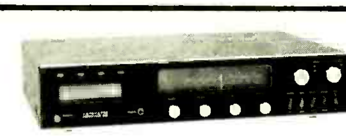
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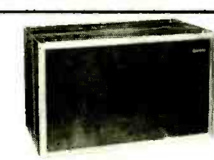
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46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
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106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
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61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
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61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
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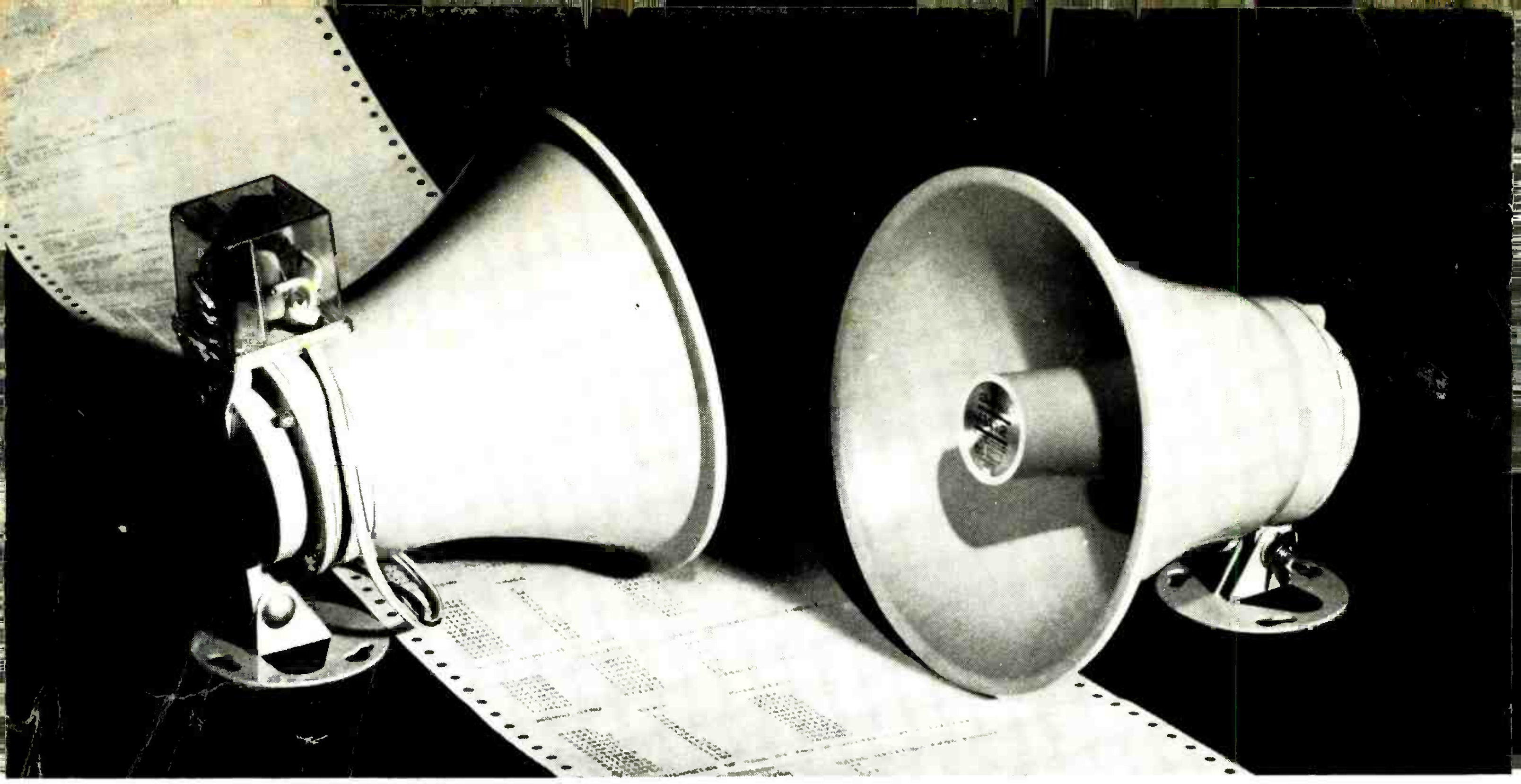


Now that the new Electro-Voice PA12 is here...the competition is either underpowered, or overpriced...or both.

The new E-V PA12 may not look very startling, but appearances can be deceiving. Because while it's priced with the lowest-cost U.S. made compression-driver reentrant horns, it performs like units costing as much as 28% more. Here's proof — in capsule form — gleaned from published data:

Specification	E-V PA12	Competitor 1	Competitor 2
Power Handling	12 watts	6 watts	10 watts
Dispersion	130°	125°	120°
Sound Pressure Level (at 4′ on axis with full rated power)	119 db	112 db	119 db
Horn Diameter	7-1/2 in.	6-1/4 in.	7-13/16 in.
List Price	$27.00 (Zone 2: $28.40)	$29.25	$34.60

Computer Calculated Horn

The PA12 is indeed better. But frankly, we could hardly help ourselves. Our design goal was simply the creation of a good, new, low-cost paging speaker. But to save time we first developed a computer program to help in the usually tedious and often inexact layout of the reentrant horn.

The computer not only saved time (and money) but gave our engineers the tool needed to create a significantly superior horn. With much better response at the extremes of the range, plus a smoother, peak-free curve, and higher efficiency.

High Efficiency Driver

Of course the engineering didn't stop with the new Implex horn. We are using a new Kapton voice coil form that is unusually rugged. Literally a space-age plastic unaffected by extremes of heat — or almost anything else! And a sophisticated new driver assembly that gets the most from every ounce of ferrite magnet.

All this adds up to higher intelligibility, higher efficiency, and better value than you have come to expect for the price. Which means that even on competitive bids you can afford to specify better sound without reducing your profit.

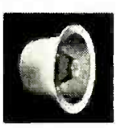
Vacuum-Varnished Transformer

But the PA12 has more going for it than sound. For instance the TR-12 25-volt (or 70.7-volt) transformer. Simple to attach. Easy to check settings in its transparent snap-on case. Quick to adjust with push-clip terminals. And just as reliable as the PA12 because it's vacuum-varnished to resist moisture, corrosion, and fungus. ($7.25 List; Zone 2, $7.60.)

Comprehensive Spec Sheet

And wait until you see the spec sheet. An honest frequency response curve, plus complete octave band polar response information. Real, meaningful data that permits accurate layouts. And helpful nomographs to simplify power and distance calculations. It's all there.

New Flush-Mounting PA12F



There's more. The new PA12F flush-mounting speaker. So shallow it fits between ceiling joists or wall studs. With a cast aluminum outer bell finished in neutral Mesa tan. Electrically similar to the PA12. 6″ diameter and 3-7/16″ deep to back of flange. $33.00 List; Zone 2, $34.50.

All told, the PA12 and PA12F reflect a most businesslike approach to paging. With advantages in performance and cost that can help you on every installation. Your E-V distributor can arrange a demonstration, or write us today for details. But do it soon. Your competition won't wait!

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