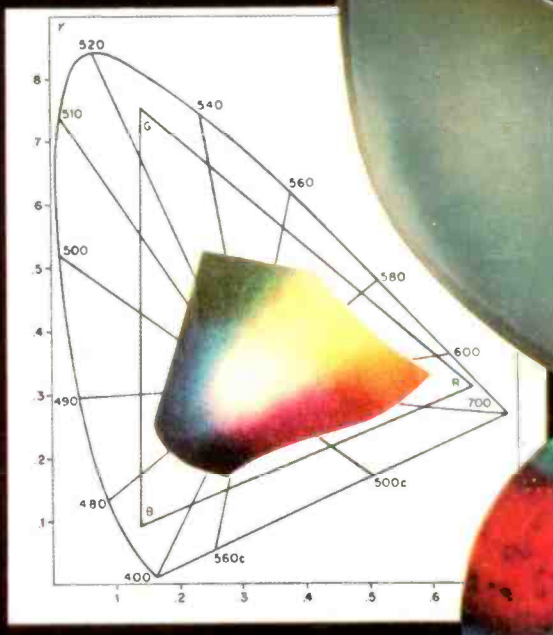
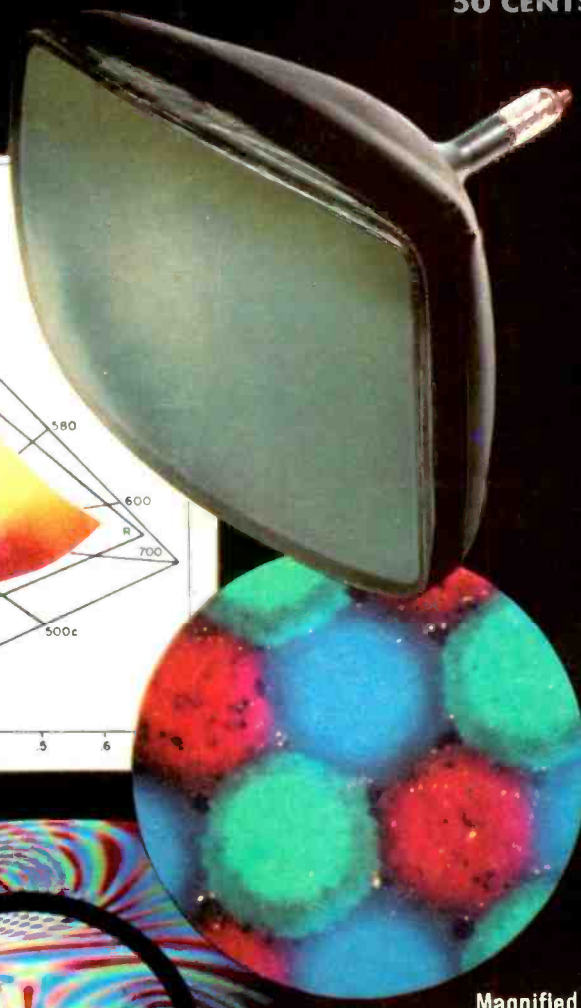
Electronics World

DECEMBER, 1965
50 CENTS

SPECIAL ISSUE ON COLOR TV





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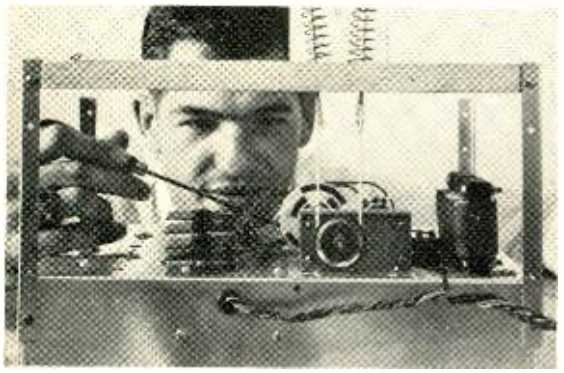

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"I can recommend the NRI course to anyone who has a desire to get ahead," says Gerald L. Roberts, of Champaign, Ill., whose Communications training helped him become an Electronic Technician at the Coordinated Science Laboratory, U. of Illinois, working on Naval research projects.

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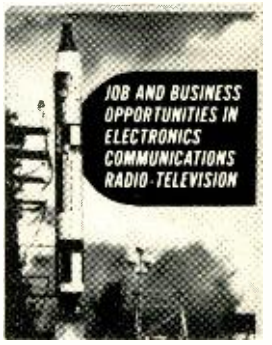

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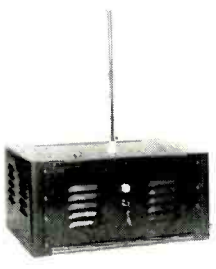

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Electronics World

CONTENTS

DECEMBER 1965
VOL. 74, No. 6

MONTHLY FEATURES

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OUR COVER includes a grouping of photographs that illustrate some of the feature stories in this issue dealing with color television. The picture tube at the top right is 23-in. 92° Motorola-developed rectangular color tube. The chromaticity diagram (from RCA) compares the color gamut of color printing inks with that of an early color-TV tube, shown by triangle. The circular pattern shows a magnified portion of the screen of an RCA color tube producing a white raster. The pattern at the center (from "RCA Color TV Pict-O-Guide", prepared by RCA Institutes, Inc.) shows what happens when a degaussing coil is placed before the screen. Finally, the group of five photos at the bottom of the cover (from Sylvania) show normal and abnormal color-bar patterns.

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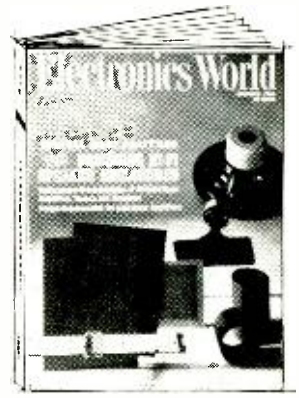

SPECIAL HI-FI FEATURES

Designing Hi-Fi Speaker Enclosures—James F. Novak, Senior Engineer, Jensen Mfg. Co., explains why there is an optimum volume for best transient performance and maximum efficiency. Also included are a number of nomograms permitting anyone to design a ducted-port/bass-reflex enclosure to meet his specific requirements.

Design Requirements for Solid-State Amplifiers—Victor Brociner of H.H. Scott describes how the important factors of good performance, reliability, long life, reasonable immunity to abuse are designed into solid-state high-fidelity power amplifiers.

Hi-Fi Equipment Survey—A complete listing of all commercially available solid-state amplifiers, tuners, and receivers, with full details on their performance.

V.H.F.: MARINE RADIO'S NEW HORIZON
With congestion on the 2-3 mc. marine band becoming worse by the year, the author explains the advantages of moving to the 156-mc. VHF Maritime Band. The article will also include details on some of the commercial equipment available for use in this service.

A PROVEN TRANSISTOR IGNITION SYSTEM
Data collected over 60,000 miles of driving show an increase in gas mileage, more power, fewer tune-up expenses, as well as no ignition component failures. How this system can be built for your 12-volt negative-ground car for $25 to $35 is fully covered.

TIME SCALES & TIME MEASUREMENTS
A description of the various time scales and their significance covers solar, universal, ephemeris, atomic, and sidereal time standards.

LINE-OPERATED TRANSISTOR TV SETS: SYLVANIA
The second of a series covering unique circuits used in a.c.-operated, transistorized TV receivers. Sylvania's 19-inch television set using the AO1-2 chassis is discussed.

All these and many more interesting and informative articles will be yours in the JANUARY issue of ELECTRONICS WORLD . . . on sale December 16th.

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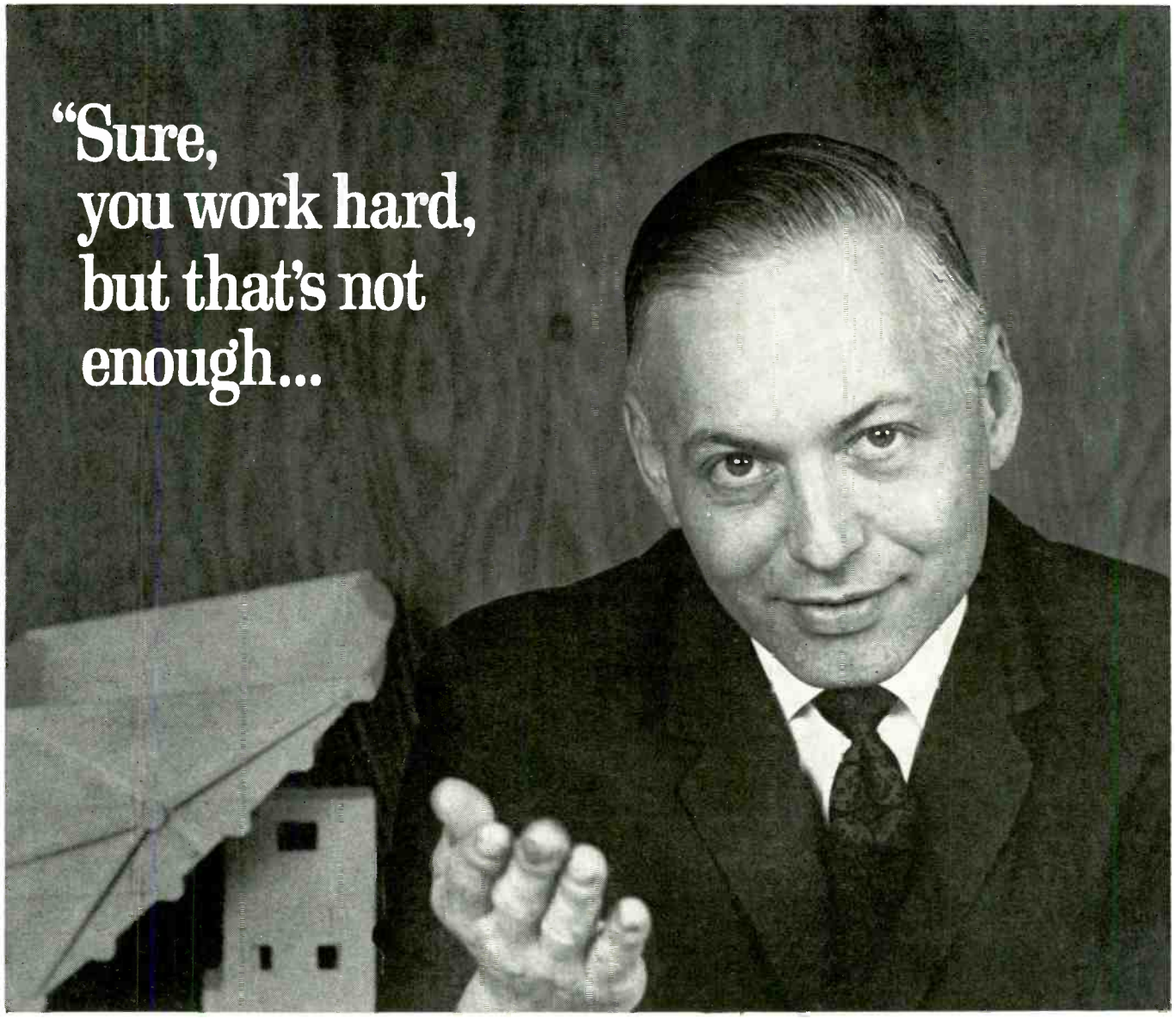

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For the record

WM. A. STOCKLIN, EDITOR

COLOR-TV SHORTAGE

THE color boom is really on. TV networks are now devoting 60 percent of their prime time to color transmissions and this percentage will increase as more color transmitting equipment is made available to the stations. In fact, many all-monochrome programs carry color commercials, breaking up the continuous black-and-white programming.

Industry estimates put the total number of color sets to be sold this year at about 2.1 million, as compared with 1.3 million for 1964. Estimates for next year are even more optimistic since it is anticipated that sales will reach 10,000 color sets a day or over 3.5 million.

RCA, the biggest money-maker, expects to sell 660,000 color sets this year, which is about 26.5 percent of the total industry sales.

Zenith, in second place, has estimated that 330,000 of its color sets will be sold this year—about 13 percent—with *Motorola* and *Admiral* tied for third place, each expecting 6.2 percent of the market.

The remaining large manufacturers (*G-E, Philco, Magnavox, Sylvania,* and *Emerson*) share the bulk of the remainder of the market.

Some Japanese sets are also making their appearance. *Sears Roebuck* is presently marketing the *Toshiba*-built 16" set. *Sony*, on the other hand, is presently test-marketing a 16" single-gun Chromatron color set in Japan and hopes to introduce it to the American market within a year.

In view of the extreme interest in color-TV sets on the part of the consumer, problems do exist. Unfortunately, the industry seriously underestimated potential sales for 1965. Customers today are finding a relatively long waiting period between the time of purchase and delivery of a color set. In fact, today's guess is that some 350,000 disappointed potential buyers of color sets will have to view their Christmas programs in black-and-white. The problem is simply not enough color tubes.

RCA not too long ago announced a $50-million expansion program in both tube and set facilities. *Zenith* has $15-million tied up in its new color-tube plant. *Sylvania* is in the midst of a multi-million-dollar expansion and *Corning Glass* is constructing a new plant for tube envelopes in Indiana. In fact, all manufacturers involved in TV set production are embarking on big expansion programs.

Why this sudden interest on the part of the consumer? Timing seems to be the most important factor. Black-and-white sets have just about saturated the country, the economy is good and thus it did not take much to stimulate color-TV set sales. Besides increased color programming, the elimination of excise taxes has reduced prices across the board. A 21" set costing $800 last year has dropped to $675 this year. A 23" combination dropped from $995 to about $875. Quite often it is this price difference which encourages many prospective purchasers. Many are also feeling that sets may be almost at their lowest price level.

As to the sets themselves, the introduction of the rectangular tube, resulting in improved cabinet styling, and the introduction of rare-earth phosphors, with their brighter pictures, have also helped influence many customers.

Although total sales are important statistics in that they show the vitality of an industry, we believe that there are many other aspects of more direct importance to the consumer. At the present time we feel too many viewers are concerned with color simply for the sake of color. Granted that every dollar spent on a color set is certainly worth it, and even a poorly adjusted color set adds a new dimension to color-TV viewing—but there is no real enjoyment until one has both a good installation and the knowledge to adjust the set for proper color rendition. It is unforgivable, the number of black-and-white sets which are in use today with pictures that are blurry, ghosty, out of tune, and improperly adjusted.

Manufacturers and consumers alike pay too little attention to antennas, transmission lines, and the application of multiset couplers. Unfortunately there are many old antenna systems that can't provide proper color reception.

A combination of inferior antennas and distribution systems, coupled with over-zealous and, in many cases, untrained color set salesmen, does create a poor image of color reception. It may not be too important this year, but in following years when it becomes more of a buyers' market, many sales will be lost or made on the basis of showroom demonstrations. We have seen showrooms of large manufacturers and display rooms of large department stores where a great number of sets were being demonstrated and no two provided the same color rendition.

Color-set manufacturers provide excellent operating manuals for the viewer and good service notes for the technician to enable him to set up the receiver properly. It is our hope that continued color viewing, but with a more critical eye, will become popular. ▲

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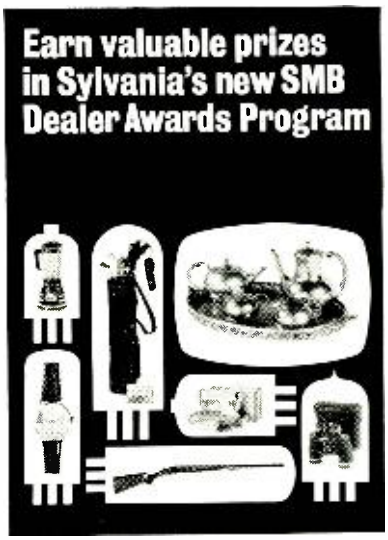

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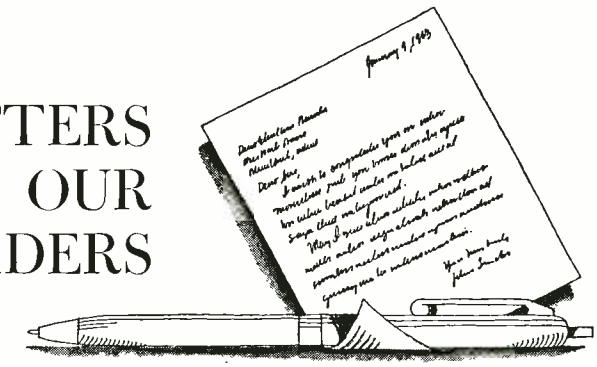

DUAL-POWER CB TRANSCEIVERS

Our September "New Citizens Band Circuits" contained a description of a dual-power transceiver that operates with either 5 watts or 100 mw. input. It was said that when the unit is switched to a lower power device, it comes under Part 15 of the FCC Regulations and that it could be operated without call signs, station identification, or the operating limits of class D. We have learned of a more recent FCC clarification of their regulations on this type of operation to the effect that although such operation is encouraged, class D operation and station licensing must still apply. This is true even for the 100-mw. operation because the transmitter power can be raised by the user. A letter from the FCC puts it this way.—Editors.

To the Editors:

The use of reduced power by Citizens Radio licensees would reduce interference in that service. Consequently, the provision of a power-reduction switch in Citizens Radio transmitters is not only permissible but is encouraged.

We must emphasize, however, that a transmitter capable of input power greater than 100 mw. does *not* comply with the requirements of the Commission's rules, Part 15. Such a transmitter must not be operated without a license.

Accordingly, a transmitter having a switch to reduce input power to 100 mw. cannot be operated under Part 15 of the rules without a license. Furthermore, such a transmitter cannot be properly certified as meeting the requirements of Part 15 for operation without a license.

BEN F. WAPLE, SECY.
Federal Communications Comm.
Washington, D.C.

° ° °

SCR IGNITION SYSTEM

To the Editors:

Mr. William Sturgeon's letter in your August issue about his experience involving failures in switching transistors used in the SCR ignition system (originally described in the November, 1964 issue) was quite interesting. After removing the resistor type of ignition harness, we experienced a similar fate where the transistors failed after a few minutes of operation. A silicon diode (1 amp.) placed in series with the distributor-point line cured our problem. Prior to this, we tried inserting a small capacitor as well as diodes similar to Mr. Sturgeon's schematic. The best results were obtained with a single diode.

JAMES TAKEMOTO, Gen. Mgr.
Universal Electronic Corp.
Denver, Colo.

° ° °

SPECTRUM ANALYZER USE

To the Editors:

The article on "Spectrum Analyzers" by Jim Kyle in your May, 1965 issue was very interesting and quite timely.

May I suggest another use for the *Singer Metrics* SPA-4a spectrum analyzer? By setting the sweep width to minimum, i.f. bandwidth to maximum, amplitude on "Lin," adding an antenna, and coupling the vertical output to an audio amplifier, we have a pretty good substitute for an FM tuner. Using slope detection, the tuning and gain settings are critical but not impossible. It's like music on a long night shift.

R. A. M.
Fullerton, Calif.

° ° °

CITIZENS BAND OPERATION

To the Editors:

On p. 14 of the September, 1965 issue of ELECTRONICS WORLD, you quote Rep. Frank T. Bow (R-Ohio) as saying that FCC failure to explain or enforce limitations on Citizens Radio Service hobby operation encouraged its development and "it seems to me that justice requires us to find a means of continuing to permit hobby-type operation in the Citizens Band."

To me, this statement is little short of amazing. To clarify the principle involved, this can be stated in more general terms: "When poor law enforcement encourages an illegal activity, then justice requires that the illegal activity be made legal."

LOUIS T. MAHN
Beaverton, Ore.

° ° °

TOUCH-PLATE LIGHTING SWITCH

To the Editors:

This letter is in reference to R. Wayne Simister's article "Capacitance Touch-Plate Lighting Switch" in the ELECTRONICS WORLD issue of August, 1965.

When I tried out the circuit, substi-

FREE!

From now through December 15, 1965

Get a Color-TV TEST Picture Tube with every RCA WR-64B Color Bar/Dot/Crosshatch Generator you buy

Yes! You read right!

From now through December 15, 1965—with every purchase of an RCA WR-64B Color Bar Generator—you get a FREE color-TV TEST picture tube for use in your color-TV test jig. This is a 21-inch 70° round color-TV TEST picture tube, electrically guaranteed six months from first installation date. These tubes will have minor mechanical (not electrical) defects... they're not quite good enough to go into a new TV set but perfectly adequate for testing purposes.

How to get your FREE Color Test Tube

Simply buy an RCA WR-64B Color Bar Generator—*THE* essential color-TV test instrument—between now and December 15, 1965. Fill out your warranty registration card and attach the red identification label on the WR-64B carton. Send them to RCA, Test Equipment Headquarters, Bldg. 17-2, Harrison, N.J. We send you the tube (either from Lancaster, Pa. or Marion, Ind.) freight charges collect. To allow for postal delay, we will honor cards received up until December 31st.

Don't miss out on this never-before offer. You've got to have a color-bar generator anyway—so be sure you buy it now—at the regular price—while you can get a FREE color test tube.

$189.50*

Optional distributor resale price; subject to change without notice. Price may be higher in Alaska, Hawaii and the West.

RCA WR-64B Color Bar/Dot/Crosshatch Generator

RCA ELECTRONIC COMPONENTS AND DEVICES, HARRISON, NEW JERSEY

The Most Trusted Name in Electronics

tuting components that I had instead of using what was specified, the load on the power supply was changed, and this changed the voltage on the transistors. When load current was less, load voltage rose and damaged the transistors.

I found an easy remedy for this voltage rise by connecting a 24-volt, 15-ma. zener diode across capacitor C8.

I think this addition to the circuit should be made to protect the transistors from switching transients present in a flip-flop circuit.

My circuit functions perfectly with all *n-p-n* transistors.

Rex Harris
Burlingame, Calif.

* * *

WWV AUDIO TONES

To the Editors:

I know that WWV's r.f. carrier is very accurately maintained right on frequency, but what about the audio tones that are broadcast? Why were these tones chosen and are they accurate enough so that I can use them to calibrate my audio oscillator?

Eric Lewis
Denver, Colo.

The audio tones broadcast by WWV are 600 cps and 440 cps. Each tone is broadcast for 2 minutes out of every 5 minutes and they alternate, starting with 600 cps on the hour. The frequencies were chosen because 600 cps has a large number of integral multiples and submultiples so that it can be used to check power-line frequencies (60 cps) and many other convenient audio frequencies, such as 100 cps or 1000 cps. The 440-cps was chosen as it is standard musical pitch, the note A above middle C.

The accuracy of the audio frequencies, as transmitted, is the same as the carrier or better than one part in 10^{11}, plus a fixed offset of −150 parts in 10^{10}. Changes in the transmitting medium may result in fluctuations in the audio frequencies as received, but accuracies of one part in 10 million are common. Hence, the accuracy is very much better than most a.f. generators.—Editors.

* * *

DEMODULATOR PRINTED BOARDS

To the Editors:

A set of two undrilled printed-circuit boards for the transistorized FM-stereo demodulator which appeared in the December, 1964 issue of this magazine is available from the address below at $6 for the set. Each board is 3″ wide by 4¾″ long. With the components mounted, the units can be stacked to fit a box 3″ x 3″ x 5″. The boards include the modified circuitry for high-sensitivity tuners. Assembled units to fit the "Citation III" tuner are also available.

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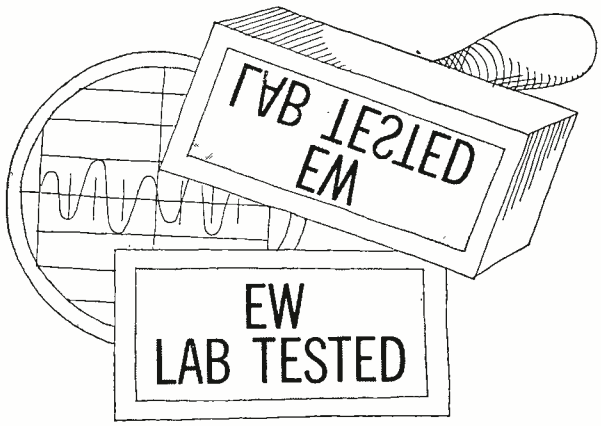


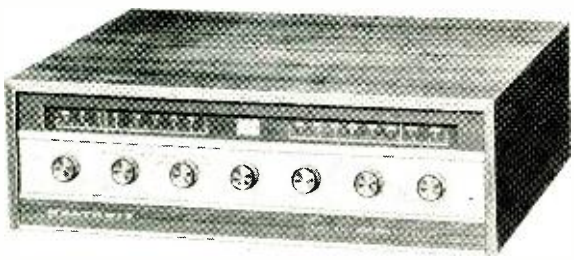
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Heath AR-13A Stereo Receiver
Shure SA-1 "Solo-Phone" Amplifier

Heath AR-13A Stereo Receiver

For a copy of manufacturer's brochure, circle No. 24 on Reader Service Card.



THE *Heath* AR-13A is a compact, attractively styled, solid-state stereo receiver, which offers superior performance at an unusually low price.

Functionally, the AR-13A is a combination of the company's AJ-33 AM-FM stereo tuner and the AA-22 stereo amplifier, which are available as separate components. Little or nothing of the flexibility and performance of the separate components is sacrificed by combining them on a single chassis, yet the installation and operation of the system is appreciably simplified.

The front panel of the AR-13A appears deceptively simple, showing only the tone-control knobs, volume control, source and mode selectors, and the separate AM and FM tuning knobs. The two slide-rule dials are colinear, with a miniature tuning meter separating them. A neon indicator lamp on the FM dial glows when a stereo broadcast is received. The power is turned on by pulling out the treble tone-control knob so that the volume may be left undisturbed at a predetermined setting when the set is turned off.

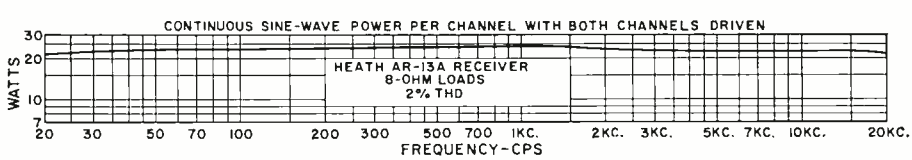
The bottom section of the panel is hinged and swings downward to reveal a row of 15 secondary controls, few of which are used after the initial installation. These include individual level setting adjustments for "Mag. Phono" and "Aux." inputs; balance, separation, and phase adjustments for the FM-stereo circuits; an interstation FM squelch threshold control; and an audio balance control. Although the latter might seem to be needed on the front panel, we found that the tracking of the two ganged volume controls was exceptionally close (within 0.8 db) so that the balance need not be adjusted when the volume control setting is changed. Also concealed behind the hinged panel are slide switches for a.f.c. "on-off," local/distant FM sensitivity, SCA filter, FM noise filter, and speaker phase.

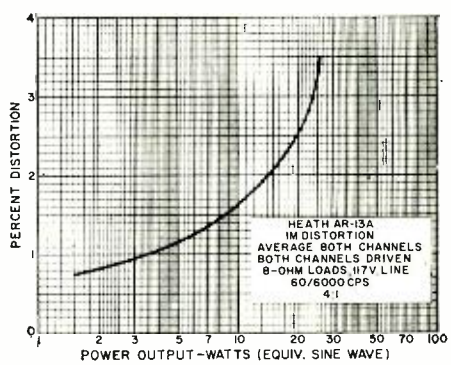
The various inputs and outputs, as well as the ferrite loopstick AM antenna, are located on the rear of the chassis. Although there are tape-recording outputs, the playback from a recorder must be connected to one of the two "Aux." inputs. This precludes using the receiver for monitoring off the tape with a three-head recorder, and is possibly the only worthwhile feature omitted from this unusually flexible receiver.

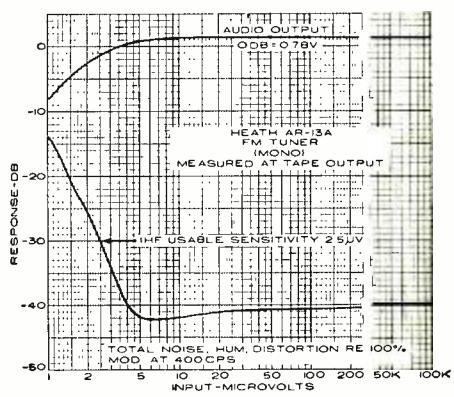
The audio amplifier of the AR-13A, rated at 20 watts per channel with both channels driven, delivered 24 watts per channel at 1000 cps with 2% distortion. It fell off only slightly, to 22 watts at 20 and 20,000 cps, resulting in one of the flattest power bandwidth curves we have ever measured on any amplifier, tube or transistor. The IM distortion was under 1% up to about 4 watts output, rising smoothly to 2.5% at 20 watts and clipping at about 25 watts per channel (into 8-ohm loads). The output into 4 or 16 ohms is somewhat reduced.

The frequency response and RIAA phono equalization of the AR-13A were both very good, within about 1 db of the ideal curves over the entire audio range. Hum and noise, referred to 10 watts output, were −55 db on phono and −70 db on "Aux." inputs; both are inaudible levels.

The FM tuner was surprisingly sensitive, with IHF Usable Sensitivity of 2.5 μv. and distortion less than 1% for all signal levels over 4 μv., with 100% modulation. This is in the vicinity of the residual distortion of our FM signal generator. Almost any FM signal which can be received at all is heard with full limiting and good entertainment quality. The







Some plain talk from Kodak about tape:

The meat of the matter... and some boxing news

Undistorted output from a tape—as from any other link in the chain of audio components—is at the very heart of high fidelity enjoyment. Distortion (or the lack of it) is in theory simple enough to evaluate. You start out with something measurable, or worth listening to, and you reproduce it. Everything added, subtracted or modified by the reproduction, that can be measured or heard, is distortion. Since most kinds of distortion increase as you push any component of your system closer to its maximum power capability, you have to label your distortion value to tell whether you did this while coasting or at a hard pant.

Cry "uncle"

To make the distortions contributed by the tape itself big enough to measure and control, we simply drive the tape until it hollers "uncle" and use that power reference as our benchmark. Here's the procedure. Record a 400-cycle signal (37.5-mil wavelength at 15 ips) and increase its level until in a playback, which is itself pristine, you can measure enough 1200-cycle signal (third harmonic) to represent 2% of the 400-cycle signal level. This spells "uncle!" We use 400 cycles for convenience, but insist upon a reasonably long wavelength because we want to affect the entire oxide depth.

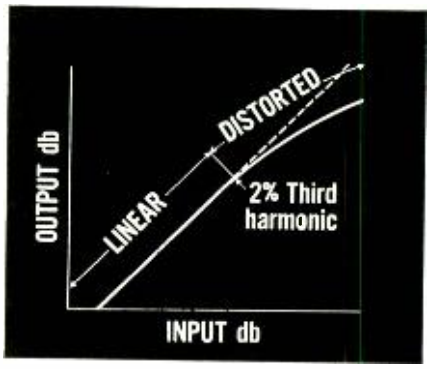
The more output level we can get (holding the reproduce gain constant, of course) before reaching "uncle," the higher the undistorted output potential of the tape.

Simple, what?

"Wadayamean—undistorted output at two percent?"

That's what makes a Miss America Contest. Two percent third harmonic is a reference point that we like to contemplate for a picture of oxide performance. Since distortion changes the original sound, it becomes a matter of acumen and definition how little a change is recognizable. If you're listening, two percent is a compromise between a trained and an untrained ear. If you're measuring, it comes at a convenient point on the meter. It's like a manufacturer testing all sports cars at 150 mph, even though some cars are driven by connoisseurs and some by cowboys. Same goes for tape. Two percent tells us a lot about a tape even if, on the average, you never exceed the 0.5% level.

Because undistorted output helps to define the upper limit of the dynamic range, it has a further effect on the realism of the recording. The higher the undistorted output, the easier it is to reproduce the massed timpani and the solo triangle each at its own concert hall level. And this is just another area where Kodak tapes excel . . . our general-purpose/low-print tape (Type 31A) gives you up to 3 decibels more crisp, clean output range than conventional tapes.



2% third harmonic distortion represents the practical limit to linear recording.

The great unveiling—Kodak's new library box with removable sleeve!

Kodak tapes—in the five- and seven-inch sizes—now *look* as good as they sound. We've put package identification on a removable sleeve and designed a tape library box with a smart new look. This box features durable one-piece construction, full index space, plus detailed tape use instructions on the inside. *Kodak* Sound Recording Tapes are available at most electronic, camera, and department stores.

New 24-page, comprehensive "Plain Talk" booklet covers all the important aspects of tape performance, and is free on request. Write: Department 8, Eastman Kodak Company, Rochester, N. Y. 14650.

EASTMAN KODAK COMPANY, Rochester, N. Y.

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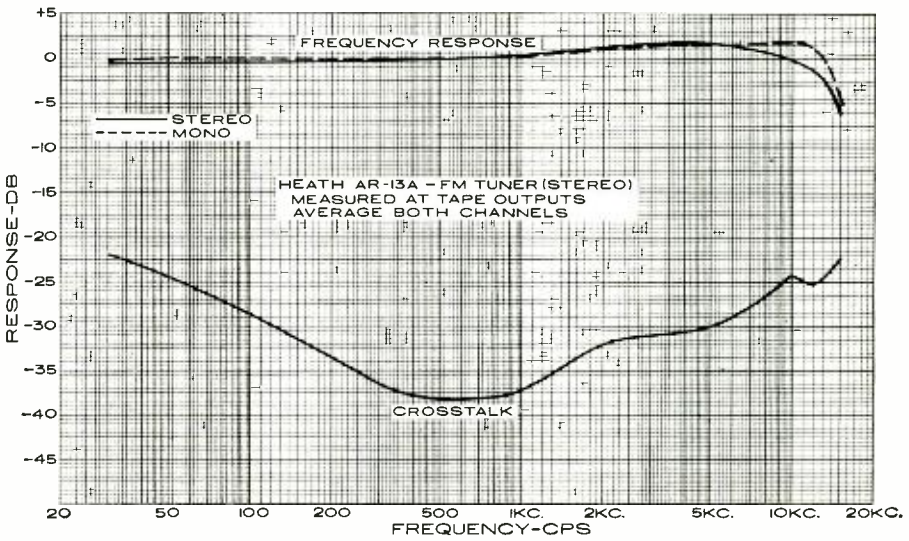
tuner had no drift that we could ascertain, so that its a.f.c. is hardly needed. The frequency response, measured at the tape outputs, was within ±1.5 db from 30 to 12,000 cps, falling to −5 db at 15,000 cps. FM-stereo channel separation was exceptionally good, exceeding 22 db from 30 to 15,000 cps and better than 35 db from 250 to 1500 cps. The FM tuner hum level was −54 db referred to 100% modulation, and its capture ratio was 3.9 db.

The *Heath* AR-13A has an AM tuner which is a rarity among stereo receivers today. We made no measurements on the AM tuner, but it sounded as good as most such tuners do and had adequate sensitivity for our suburban location.

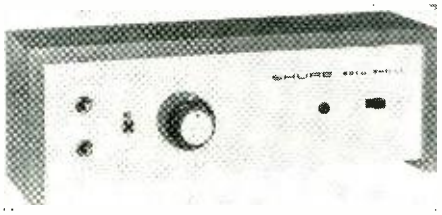
Although the AR-13A is a rather complex kit to construct, its assembly is simplified by the use of printed boards and pre-aligned FM front-end and AM-FM i.f. strip. All necessary final alignment can be performed with received stations and the tuning meter. Instrument alignment may improve performance slightly, but should not be necessary in most cases.

The *Heath* AR-13A, complete with an oiled-walnut cabinet, sells for $184 in kit form. Despite its low price, it is one of the best stereo receivers we have tested and is comparable to many manufactured units costing twice as much. ▲



Shure SA-1 "Solo-Phone" Amplifier

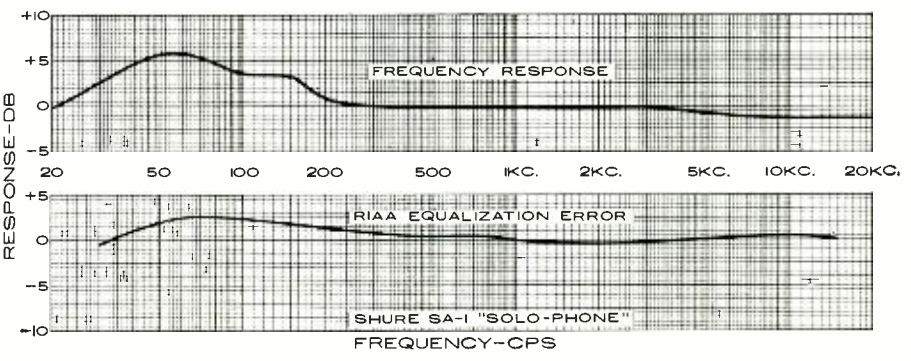
For a copy of manufacturer's brochure, circle No. 25 on Reader Service Card.



STEREO music, heard through a good pair of stereo headphones, sounds quite different from the same music heard through loudspeakers. The almost total separation of left- and right-channel sounds, plus the exclusion of room noise, gives headphone reproduction a startling and unique sense of immediacy. Even though most headphones do not have the wide frequency response or smoothness of a good loudspeaker, their subjective effect often seems to be more natural and cleaner.

Practically all model stereo headphones have 8- or 16-ohm coils and are meant to be driven from the speaker outputs of a stereo amplifier. Since phones require only a few milliwatts of power, this is rather wasteful when a power amplifier is used. Sometimes special attenuator circuits are built into the amplifier to prevent damage to the phones.

(*Continued on page 76*)



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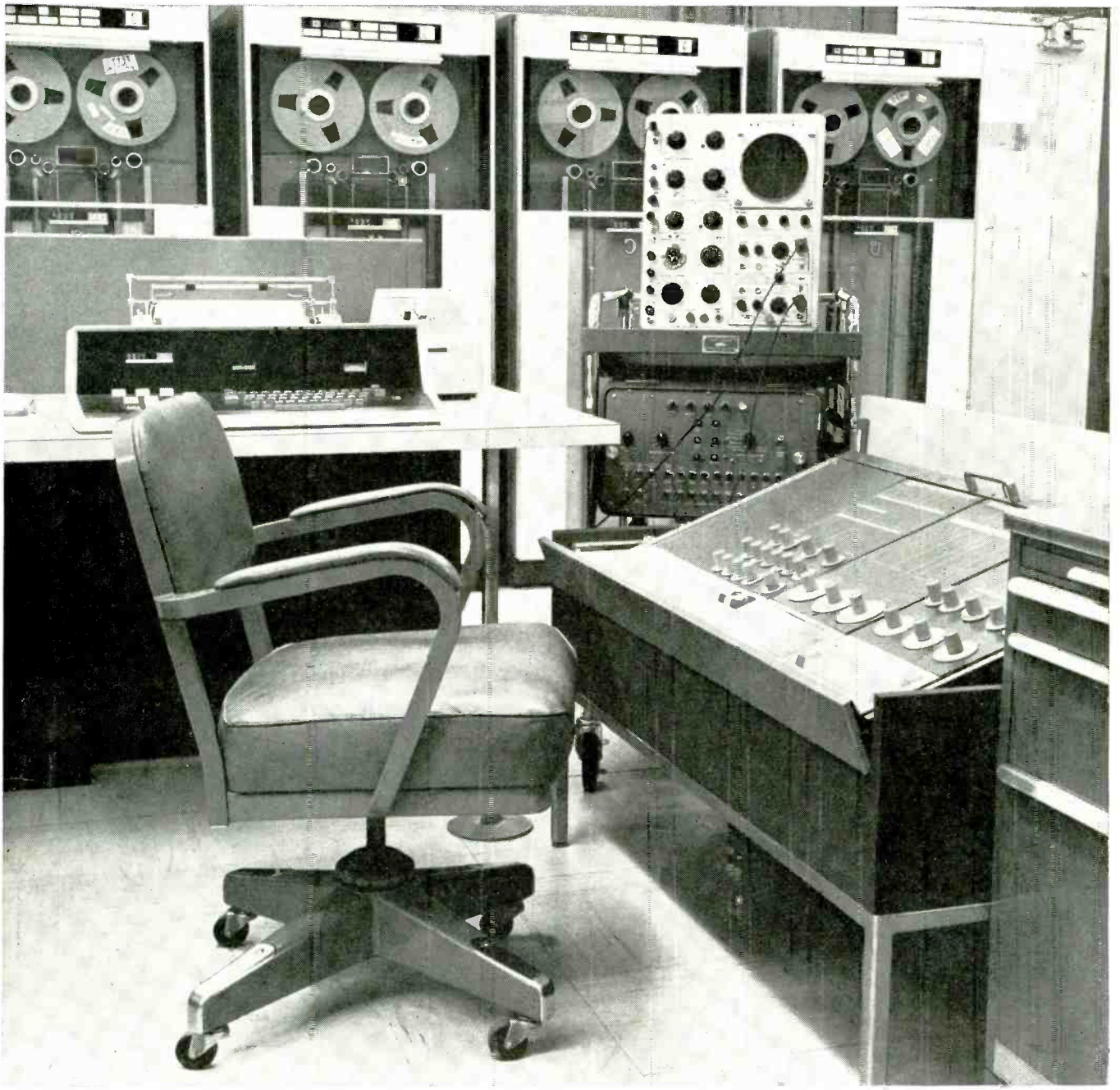

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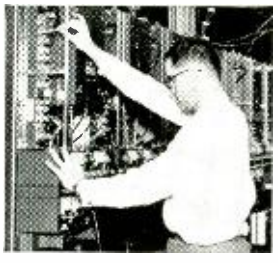

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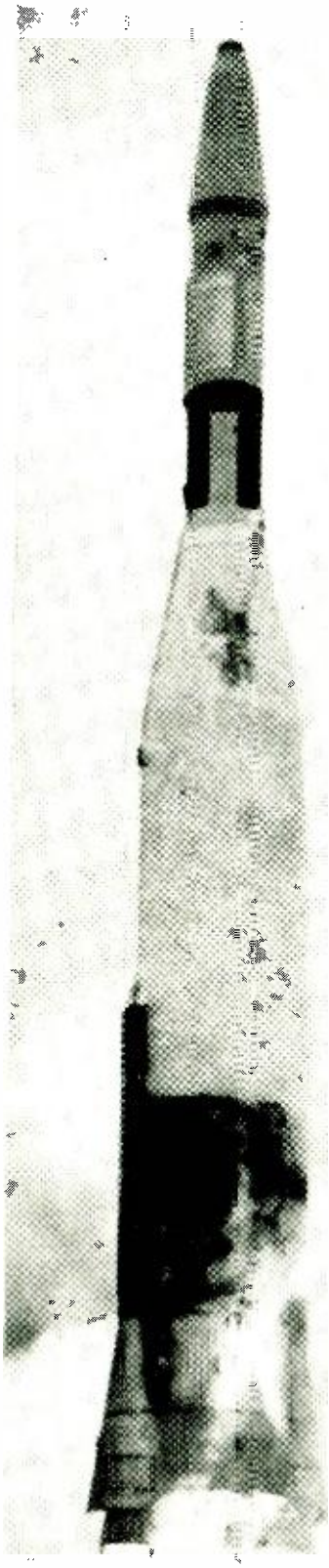

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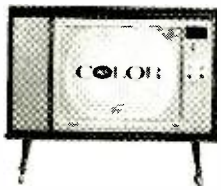

The reliability of RCA circuitry. The solid kind.

Solid Copper circuit, shown, from RCA Victor Color TV.

RCA Solid Copper Circuits won't come loose. Won't short circuit. Won't go haywire. They're the latest advance over old-fashioned "hand wiring" and bring Space Age dependability to Color TV.

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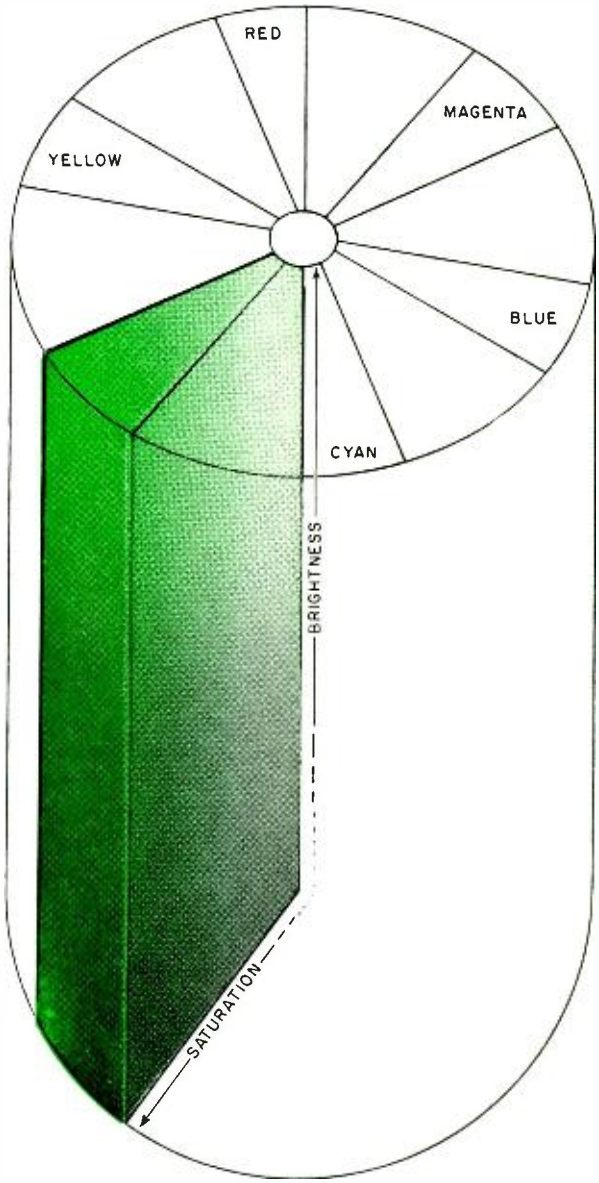
COLORIMETRY IN COLOR TELEVISION

By J. F. HOLAHAN / RCA Electronic Components and Devices

Although the exact mechanics of color vision are unknown, experiments over the years have laid down many basic principles. This article covers color perception principles applied to color TV.

Color solid visualization of the relationship among hue, brightness, and saturation of optically visible colors.



HUMAN color vision is an extremely complicated process, occurring partly in the eye and partly in the brain. In this process, the stimulus of light from some object is transformed into the conscious sensation of color experienced by a person observing that object. Because two observers having so-called "normal" vision often see the same color somewhat differently, the perception of color has not yielded to a satisfactory all-inclusive theory. However, experiments over the years do indicate certain practical principles of color perception. To help understand these principles, it is helpful to remember that both light and radio waves are electromagnetic in nature and that light waves are detectable by the human eye. In other words, the eye and brain form a receiver having a fixed selectivity characteristic and a variable sensitivity characteristic. Roughly, the eye's "r.f. circuits" respond to light having a wavelength range of 400 to 700 millimicrons.

Unlike a radio, the eye cannot tune in on one wavelength but responds simultaneously to all radiation in the visible band. It is capable of distinguishing light of one particular wavelength (color) only when it is presented alone. For example, the eye easily identifies green in a spread-out spectrum but is quite unable under normal conditions to isolate a green sensation from white light.

How We See Color

The exact process by which the human visual system is able to translate light of different wavelengths (and mixtures of wavelengths) into color sensations is still not known. Yet, practical experiments have shown that almost the full range of color sensations can be obtained by suitable mixtures of the light from three "primary" color sources: blue, green, and red. One theory of color vision based on this *trichromatic* color-matching property holds that the retina

Fig. 1. Cover the white circle. Stare fixedly at the yellow circle center mark for 20 seconds. Then uncover the white circle and rapidly shift your gaze to the white circle center mark. After a second, you will see a bluish afterimage that gradually fades.

of the eye consists of a mosaic of three different types of elements, one responsive to light of wavelengths corresponding to blue, one to green, and one to red. Further, the three elements appear to overlap considerably in sensitivity. These three groups of receptors are separately connected to the brain through nerves, where the sensation of color is derived from the brain's automatic analysis of the relative stimulations from the three receptors.

The trichromatic theory tends to be substantiated by the way in which blue, green, and red combine to form other colors. Consider three separate light sources projecting overlapping circles of green, blue, and red light on a screen. Where all three beams overlap, the effect is white because all three receptors are stimulated equally. The area of blue and green overlap is, quite predictably, blue-green, or cyan. Similarly, a reddish-purple, or magenta, is formed where blue and red overlap. However—and this usually startles the layman—the combination of red and green produces yellow.

This phenomenon becomes easier to understand if we realize that the yellow we see is not the yellow of the spectrum but is rather a broad band of radiation containing substantially all wavelengths of visible light except those at the blue end of the spectrum. Since blue light is absent, only the red and green receptors are stimulated equally. It follows, then, that if the red and green receptors are blocked out so that only blue receptors operate, a white surface should appear blue. One way to effectively block out color receptors is to overstimulate them to the point of insensitivity. Stare fixedly at the yellow circle of Fig. 1 for about 20 seconds and then quickly shift your gaze to the adjacent white circle. You see a blue afterimage because the red and green receptors of the eye have become fatigued and do not respond to the red and green wavelengths in white light. The afterimage will gradually fade as the receptors recover their sensitivity.

The unexpected behavior of red, green, and blue primaries results from the fact that they are "additive," and as such differ from the "subtractive" primaries of red, blue, and yellow. Actually, the subtractive primaries are not red, blue, and yellow but magenta, cyan, and yellow—the complementaries of the additive primaries. Herein lies the major difference between color television and other common color-reproducing media. *Additive* primaries are so called because they are self-luminous sources of light—the phosphors coating a color picture tube, for example—whose visible light outputs are added together to yield a desired color. *Subtractive* primaries, on the other hand, are absorbers of light that are used in series (layers) to create color by removing selected wavelengths from a white source. Subtractive primaries in the form of dyes and various types of pigments are used in photographic and printing processes.

The Elements of Color

We perceive color, as a conscious sensation, in terms of three major subjective attributes. Primary among these, and the only one of them exhibited by both neutral or gray (achromatic) tints and truly colored colors, is *brightness*. Brightness is a matter of over-all intensity of light given out by objects seen. The physical term is *luminance* and is expressed in such units as footlamberts. A second major attribute, and the most characteristic of color, is the distinction between redness, yellowness, blueness, greenness, and so forth. This attribute is called *hue* and, among the pure colors of the physical spectrum, corresponds rather directly to wavelength. Finally, distinguishing strong colors from pale ones of the same hue, as red from pink, is the attribute of *saturation* or *chroma*. Saturation may be thought of as related to physical purity, or freedom from dilution with white.

Fig. 2 illustrates the interrelationship of hue, saturation, and brightness. The upper third of this figure shows a strip of white, the middle third a strip divided by a red hue at low and high saturation for a certain brightness level, and the lower third a strip with the same red hue at the same saturations but for a higher brightness level. Notice that your eye can detect a difference. All four colors are red, yet all are different because the strip has been altered step-by-step from original white (the same white of black-and-white television) by the three basic characteristics of color.

The three variables, hue, saturation, and brightness, define completely the qualitative aspects of color as a mental phenomenon. It is apparent that these three may be made the basis of a three-dimensional system for plotting, or at least for describing, a particular color. For example, all possible mental colors may be thought of as distributed through the interior of a solid, as shown on page 21, in which brightness varies vertically, hue varies with the position about the center in a horizontal plane, and saturation varies with the distance outward along straight lines perpendicular to a vertical through the center of the solid. In this diagram, the vertical bar through the center of the solid has zero saturation (hence zero hue) but varies in brightness from one end to the other. Along any radial line, that is, a line perpendicular to the brightness axis, saturation increases with distance from the center, and hue varies with the angular position of the line as seen from the top or bottom of the solid.

Color Matching

Although the eye is unsuitable for measuring color directly, it is a highly sensitive color-matching instrument. It is this property of vision that is utilized in colorimetry. Thus, any color stimulus may be specified by finding a known second stimulus which the eye establishes as being equivalent to it. In modern colorimetry, the second stimulus is taken as a combination of red, green, and blue light; however, any three monochromatic (single color) colors can be used as primaries as long as no two of them can be mixed in some proportion to match the third. Specifying an unknown color consists of giving the amounts of each primary stimulus required for matching.

Such direct colorimetry is usually accomplished by means of specially designed instruments so arranged that the observer sees the unknown color as one half of a field visible through the eyepiece. This "colorimetric field" is usually of some simple geometric pattern, such as a square, and the two halves are divided by a sharp diagonal boundary. The observer mixes the proportion of primary lights until both halves of the field match precisely in color and intensity.

In a good direct colorimeter, the dividing line will disappear completely when a good match in color and intensity has been attained.

Fig. 3A shows a set of curves, obtained experimentally by the direct colorimetry method, which represents the average color-mixture data of a number of normal observers. These curves specify the amounts of three monochromatic primaries the average observer needed to match all of the spectrum colors. If other primaries had been used, a different set of curves would have been obtained, but since there is nothing unique about any set of primaries, one set of curves obtained with one set of primaries is transformable into any other set obtained with other primaries.

Color Measurement

For convenience of computation, in 1931 the International Commission on Illumination (CIE) standardized on the set of color-mixture curves shown in Fig. 3B. These curves, based on idealized supersaturated primaries not physically realizable, were derived from the experimental color-mixture curves of Fig. 3A. Although the original color-mixture curves were established by human observers, the use of actual observers in everyday work is impractical. As a result, an indirect method of colorimetry is now generally used. This method consists of the computation of standard colorimetric specifications from the curves on Fig. 3B and spectroradiometric data from the sample to be matched. Specifications computed by indirect colorimetry permit the classification of ordinary colors in a manner corresponding quite closely to the appearance of the colors for over 90% of the population.

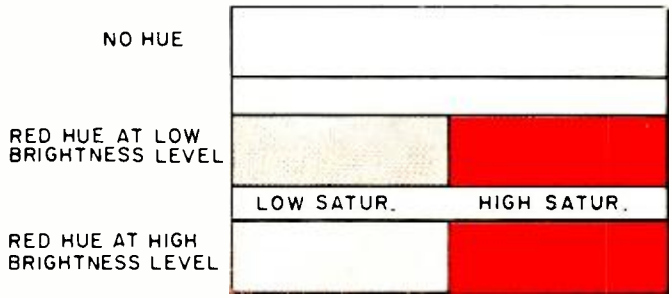


Fig. 2. Relationships among hue, saturation, and brightness.

The ordinates of the standard CIE color-mixture curves $\bar{x}$, $\bar{y}$, and $\bar{z}$ at any wavelength give the tristimulus values of a spectrum color at that wavelength. For example, the tristimulus values of green light of wavelength 520 millimicrons are $\bar{x}=0.0633$, $\bar{y}=0.7100$, and $\bar{z}=0.0782$. So that these numbers can be presented graphically on a two-dimensional diagram, the quantities $x=\bar{x}/(\bar{x}+\bar{y}+\bar{z})$ $y=\bar{y}/(\bar{x}+\bar{y}+\bar{z})$ and $z=\bar{z}/(\bar{x}+\bar{y}+\bar{z})$ are defined so that $x+y+z=1$, and therefore any two of these quantities are sufficient to specify a chromaticity (the sum of the x and y values subtracted from 1.0 gives proportion of third primary. Thus the (*Continued on page 70*)

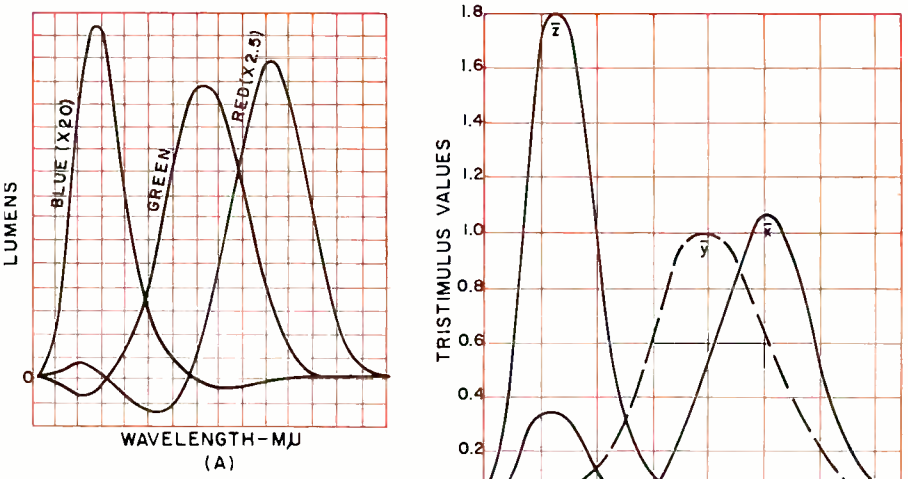


Fig. 3. (A) Color mixture curves showing the number of lumens of three monochromatic primaries required to match one watt of radiant power of a color of certain specified wavelength. (B) International Commission on Illumination (CIE) standard color mixture curves based on (A).

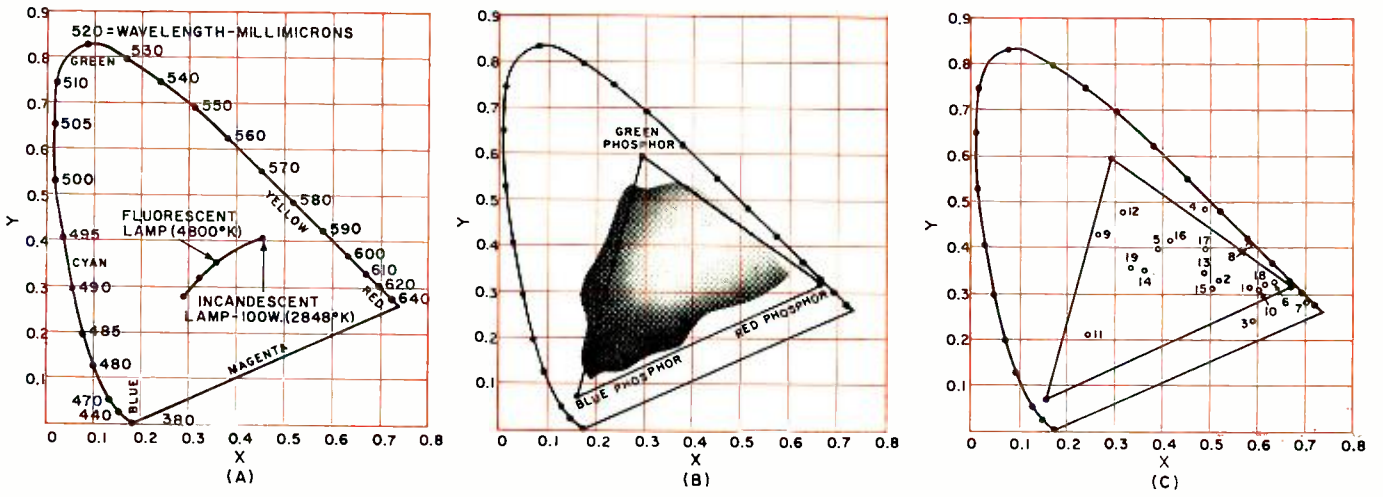


Fig. 4. (A) CIE chromaticity diagram shows complete color range closed by nonspectral colors. (B) Triangle shows coverage of CRT phosphors, irregular area shows gamut of printing inks for daylight illumination (6770° K). (C) Location of some common items; (1) RCA monogram, (2) apple (Stehman), (3) rose (Best Times), (4) dandelion, (5) banana, (6) tomato juice, (7) red traffic light, (8) amber traffic light, (9) green traffic light, (10) U.S. flag red, (11) U.S. flag blue, (12) green grass, (13) chocolate bar, (14) leather briefcase, (15) clear red lipstick, (16) lemon, (17) orange, (18) Coca-Cola sign, (19) light at 6000°K.

Color-TV Set-up Problems & Adjustments

By VIC BELL / Chief Service Engr., Entertainment Products Div. Sylvania Electric Products Inc.

(Editor's Note: A number of the faults described in this article are illustrated by the picture-tube patterns that are shown on our cover. Although a color-bar generator was employed for these illustrations, the color defects shown may also be observed on a normal color-TV program.)

PLUGGING a new color-TV receiver into the power line, connecting the antenna lead, and watching a color program immediately was unheard of until recently. It is becoming increasingly common although, in general, color-TV manufacturers don't recommend it. Some set-up adjustments are usually necessary if the receiver is to give optimum performance. Many of these adjustments can be made with little or no test equipment simply by observing the picture.

When an adjustment is not indicated or when the adjustment results are not normal, the screen display or control effect may indicate where the problem lies. Pulling a tube, with the receiver in operation, may pinpoint the trouble to a specific stage or, in other cases, to a component.

Check the Antenna

The purpose of the set-up is to "trim" adjustments which may have changed from shipment vibration, from aging, or from temperature changes.

A major item which is often overlooked in the set-up is the antenna. An antenna which provides an acceptable picture on a black-and-white set will not necessarily be good enough for a color set. Noise in the picture caused by a weak signal is often unobjectionable (possibly even unnoticed) on a black-and-white set. But on a color set the same signal may be entirely too weak. This is true for two basic reasons: color sets generally have a wider bandwidth than a black-and-white set and colored noise (confetti) which will be present in color pictures is more objectionable than black-and-white "snow."

For these reasons, the antenna should rate high on your check list. If the picture on the original black-and-white set was "clean," generally you will not have trouble with the color signal. This is especially true of antennas manufactured in the past few years. Older antennas may have response dips which might cause a color-information loss. Even in these cases, the signal is frequently borderline. Thus, with the antenna considered (and don't forget the lead-in and any multiset couplers), you are ready to investigate other troubles. For example, there may be no color on the set.

Color-Signal Chain

Any time that color is not present (while a color program is on the air), some part of the color-signal chain must be suspected. Often when color cannot be obtained from the "air" signal, a color-bar generator can be employed and the set will appear to function normally. This is true because the color-bar generator is normally capable of delivering a stronger-than-normal signal which overrides set faults. The one time a generator should be used to check such complaints is when the generator has been calibrated so that it can be set for an output equivalent to the signal normally delivered to the set.

An easy first check to make for "no color" (or weak color) is to check the setting of the color killer. The killer should be set so that confetti is just cut off when the set is tuned to a noisy, no-station channel. If confetti cannot be obtained at any setting of the color-killer control, it should be left in the "wide open" position while troubleshooting progresses.

Most of us are familiar with the rainbow-hued pattern sometimes generated when a set with an out-of-sync 3.58-mc. oscillator is tuned to a color signal. Many are not aware, however, that this same condition can cause a complete apparent loss of color. This condition can be very difficult to recognize because the rainbow pattern is moving at a very rapid rate, resulting in a near-normal black-and-white picture. This condition can be detected more easily if the chroma control is advanced to maximum.

Depending on the set, only a few tubes are associated with a "no-color" malfunction. These are the chroma amplifier, the bandpass amplifier, the killer, killer detector, reactance control tube, 3.58-mc. oscillator, or phase detector. Although these can be checked in a tube tester, the most foolproof method is substitution with known-good tubes. Do not overlook the possibility of a tuner tube or an i.f. tube causing a loss of color; it can happen.

Sometimes the reproduction of a black-and-white signal is normal but the color reproduction is abnormal (as opposed to missing). One of the most common symptoms is an over-all green color; that is, all of the normally colored areas of the screen become some shade of green. If the killer is set properly, loss of the 3.58-mc. oscillator may cause a loss of color. On the other hand, if the killer is misadjusted or has been "opened," the colors will all appear as shades of green. This symptom can be demonstrated quite easily by simply pulling the oscillator and opening the killer while observing a color program source.

Any one of several components can cause this malfunction but the easiest to check are the tubes. The reactance control and oscillator tube are prime suspects but the phase detector may be at fault as well. Loss of the sync burst may cause the

Picture symptoms can help solve color-TV problems. Here are some quick checks that will save time & trouble.

oscillator to run out of sync but will not normally stop it from oscillating. Burst amplifiers and gating tubes should also be suspected in sync troubles.

Demodulator troubles can also affect the color yet leave the black-and-white picture normal. The effect of this can be demonstrated easily in most sets by removing one of the demodulators while observing a color picture. The results are the same as if the 3.58-mc. injection were deprived of one of the demodulators.

The 6GY6 is commonly used as a color demodulator and since both the X and Z demodulators are identical, they can be interchanged. If the symptom is similar but with a different color, one of the tubes is at fault.

Convergence & Purity Problems

Every so often a receiver refuses to provide an acceptable picture. Convergence has created some concern since color's beginning so let's look at some of the things that can cause "impossible-to-converge" situations.

Static convergence is generally considered to be the "easy" part of the set-up. Occasionally even static convergence can give the technician hours of trouble. Generally, the trouble is not that he cannot get the dots to coincide, but that one dot is larger than another or that the dot convergence appears better than the picture convergence. In some instances one of the dots may be oblong and hang out on both sides of the other dots.

Some say that the dot should be as small as possible and that brightness and contrast should be turned down until the dot display is as small and as sharp as possible. Using this method can lead to poor convergence on the final picture. If the brightness and contrast are turned to normal viewing levels, then the same beam "scattering" takes place as when watching a program, and the convergence will be more accurate. When watching a small, low-level dot pattern, the edges of the dot must be observed so closely that each individual color dot stands out and the degree of convergence cannot be determined accurately.

Oblong dots may be caused by a faulty picture-tube neck component or direct current in one of the convergence coils. What actually happens is that a magnetic field is caused by a fault somewhere in the circuitry which introduces a static error because of d.c. in the coils. This offsets the "center dot" position with no magnetic correction. To correct this shift in static convergence, the static magnets are moved to the other extreme. The total effect of these two forces is an elongation of the dot.

The convergence circuitry can be checked for this error by simply unplugging the convergence assembly and removing it from the neck of the tube. If the dots are still more than a quarter of an inch off center, remove the yoke and demagnetize the picture tube thoroughly. Turn the brightness and screen controls to a minimum and then advance them slowly until a small dot for each gun is visible. These dots should be within a quarter inch of one another. If they are not, the picture tube is at fault.

After good static convergence has been obtained, dynamic convergence is next. This is the most trying part of the set-up because absolutely perfect convergence over the entire screen is just about impossible to obtain. Therefore, the technician often must compromise to some degree. Even after all normal steps have been taken to converge the set properly, some sets are still not acceptable. In such cases it is wise to change the deflection yoke. This, of course, necessitates a complete new set-up.

Purity can also be a headache. Most purity problems can be blamed on poor degaussing. When installing a new set, manual degaussing is usually a "must." It is not material that the set does or does not have automatic degaussing. Automatic degaussing is intended only to remove normal magnetization to which the set might be subjected during normal operation. Best purity results will probably be obtained on automatic degaussing sets if the set is degaussed when it is cold and turned off. Be sure to degauss the set thoroughly. Only after a 15-minute warmup with the brightness at its normal setting will you be ready to set the purity.

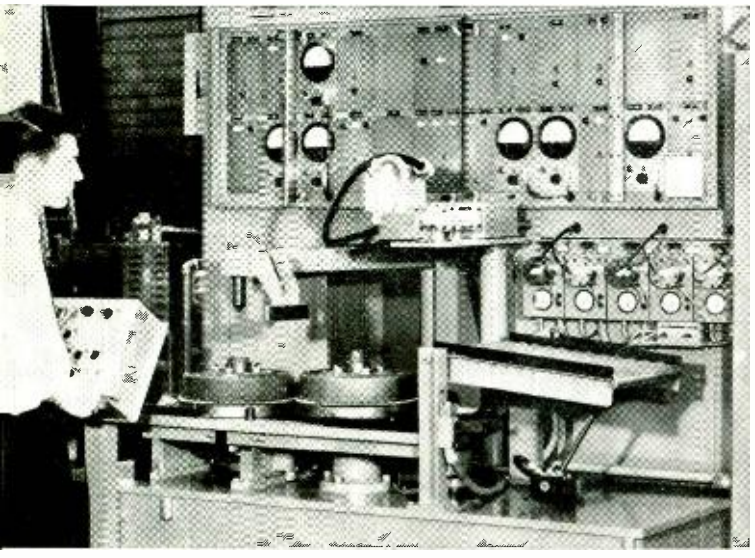
Color Temperature

Manufacturers' instructions are not always sufficiently explicit when describing the set-up procedure for the screen and drive controls. In fact, the instructions given by the manufacturer are only rough or preliminary adjustments in many cases. If, after using the manufacturer's instructions, you find that the screen has an over-all undesirable shade, you can easily determine which control or controls should be adjusted.

For example, suppose that after the preliminary adjustments the brightest objects appear white but the grey or less bright objects take on a green hue. Such a problem can be easily corrected by remembering this relationship: screen controls affect the low-brightness areas and drive controls (background controls on older sets) affect high-brightness areas.

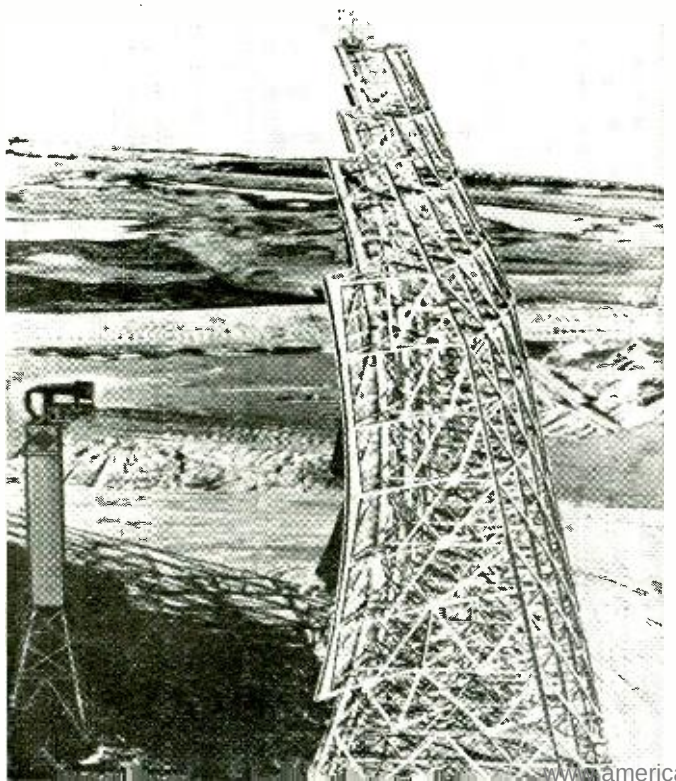
The brightness control and a no-station channel can aid in applying this principle to obtain perfect color tracking (no color change from low to high (*Continued on page* 56)

RECENT DEVELOPMENTS IN ELECTRONICS



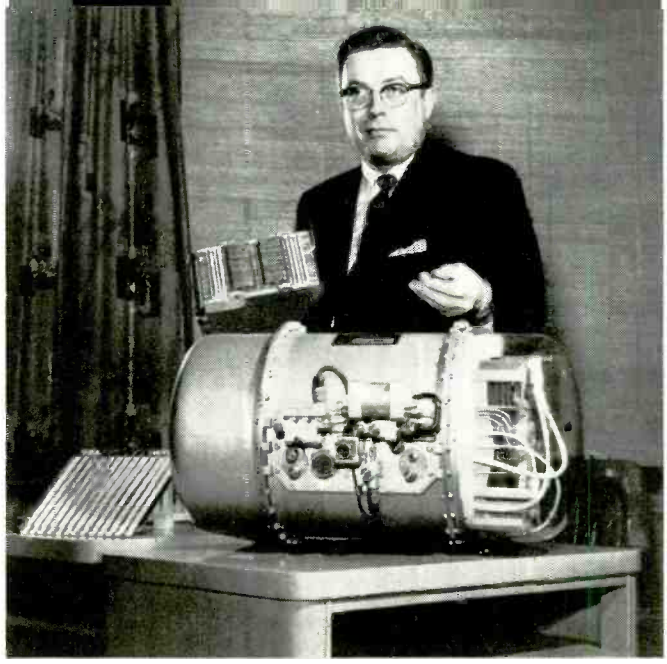
Ultrasonics Tests TV tower. (Above) A 215-foot television mast located some 800 feet above street level on the new 1000 Lake Shore Drive Building in Chicago, is shown here having its welds tested with ultrasonics. The antenna will be used by WTTW and WXXY. A portable Magnaflux ultrasonic flaw detector, using an oscilloscope readout, was located on the roof of the building. The transducer was connected to the equipment with a long cable. Ultrasonic pulses are passed through the welds at an accurately predetermined angle. Discontinuities and the opposite surfaces reflect the pulses back to the transducer and to the instrument. The time lapse between initial pulse and the return of the reflections is indicated by pips on the scope screen. Location of pips and their relative heights indicate the location and the severity of any discontinuity.

Brake Drums Checked Electronically. (Center) An automated gaging system that performs seven separate inspections on the inside diameter of automotive brake drums within 6 seconds is shown here. Six of the units, which have an individual capacity of 600 brake drums an hour, are in regular use by a major automobile manufacturer. Brake drums are inspected by air-electronic gages for concentricity, ovality, true and average inside diameter size, taper, and rate of change with respect to two radii spaced 30 degrees apart. In addition, a contact gage checks lateral runout and water groove depth. An interesting feature of the RCA-designed gaging machine is its system for spotting a defective brake drum with a droplet of colored wax to indicate the reason for rejection.



Longest FM Tropo Link. (Left) The North American continent's missile-defense chain was strengthened recently by the implementation of the longest and most powerful FM tropo scatter communications link in the western world. The new Arctic communications network extends from Thule Air Force Base, Greenland to Canada's Melville Peninsula in a single 591-mile hop. Using 100-kw. power amplifiers developed by Radio Engineering Laboratories, the new system provides static-free, reliable, multichannel telephone and teletypewriter circuits. The frequency-modulated system transmits and receives wideband communications in the 345 to 455 megacycle range. Some of the channels are priority links from radars of the Ballistic Missile Early Warning System (BMEWS) which guards this hemisphere.

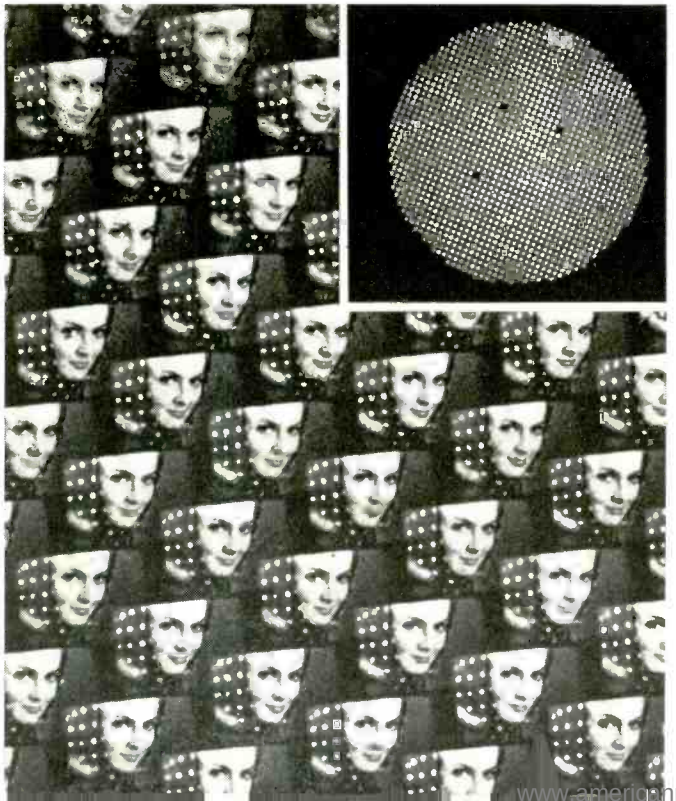
Gemini Fuel-Cell Battery. (Right) A cut-away mockup of the fuel-cell battery that was used in the Gemini 5 flight is shown along with one of three fuel-cell stacks (being held) forming the battery and a single fuel cell (extreme left). Ninety-six individual cells are contained in the battery. In spite of some early difficulties with the oxygen line heater, the battery acquitted itself admirably throughout the 8-day flight. Similar fuel-cell batteries, manufactured by G-E, are scheduled for future Gemini missions. The fuel cell contains an anode and cathode which are in contact with a solid Teflon-like electrolyte that permits hydrogen ion exchange. Hydrogen fuel is introduced at one electrode and oxygen at the other. With the aid of a catalyst, the hydrogen atoms are ionized and the ions move through the solid electrolyte to the cathode where they combine with oxygen. Electricity is produced along with water as by-product.

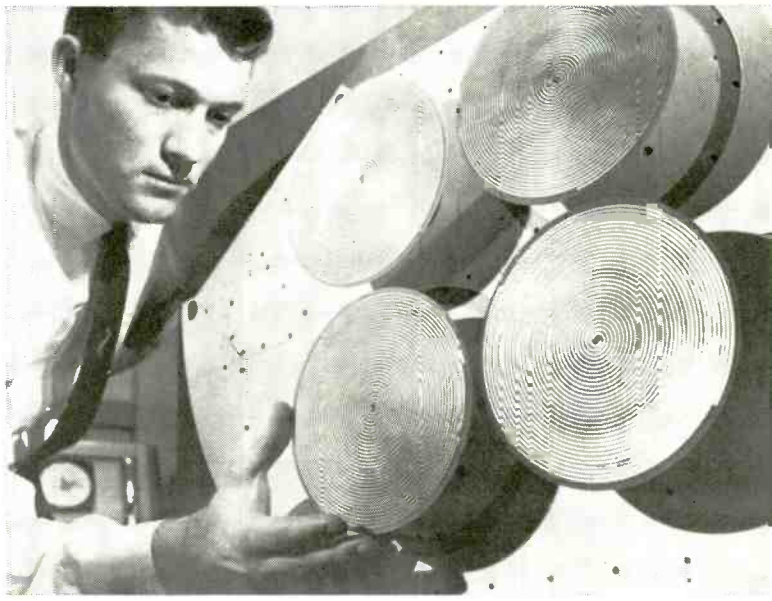


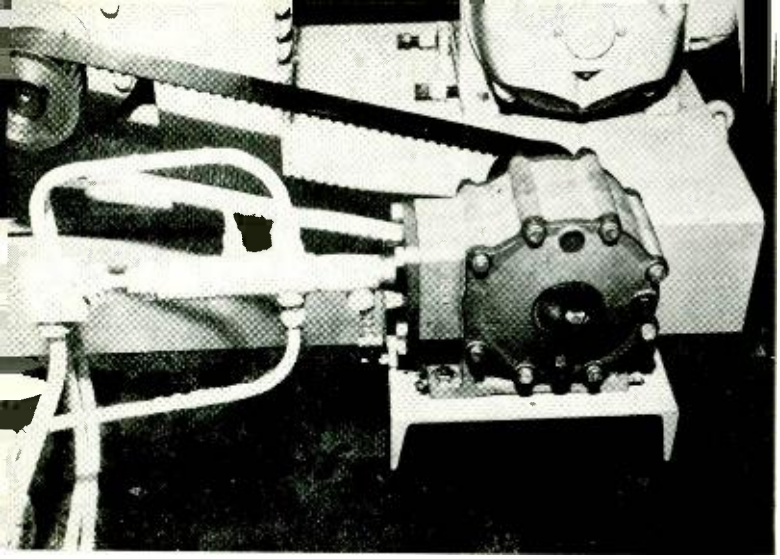
Sonar Dome. (Center) The big bulge is an acoustical "window" for a bow dome that will be mounted below the water line on the bow of the Navy destroyer Willis A. Lee, where it will house and safeguard sensitive sonar equipment. The window, made of special rubber that has acoustical properties similar to sea water, permits sound to pass with minimum distortion. Ten feet high, 20 feet wide, 37 feet long—and weighing 18,600 lbs.—the window is the largest molded rubber product ever manufactured, according to B. F. Goodrich, its producer.

"Fly's Eye" Lens for Integrated Circuits. (Below Left) More than 1300 clear images, some of which are shown greatly magnified, can be produced in a single exposure by a 1¼" "fly's eye" lens developed by IBM. The photo, illustrating the multi-image capability of the lens, was made from the negative shown full size in the inset. The lens and its camera were designed to reproduce patterns for the ultra-precise microelectronic circuitry of the company's recent line of System/360 computers.

Radar Antenna for Gemini. (Below Right) Four circularly polarized radar antennas are used in the Gemini spacecraft for rendezvous experiments. Although such experiments could not be performed in the Gemini 5 flight, future missions are expected to employ the Westinghouse radar. The antennas are built as spirals printed directly on epoxy board. This results in a very lightweight construction. Angles in two orthogonal axes are measured with three receiving antennas, one of which is common to both axes. Azimuth and elevation are determined by use of these antennas. The fourth antenna is for radar transmission.







Single-cylinder high-pressure (10,000 psi) cryogenic pump.

CRYOGENICS IN ELECTRONICS

By WILLIAM NELSON

Important uses for equipment producing ultra-low temperatures include space environment simulation, low-noise amplifiers, and superconducting magnets.

BY the 100th day after Mariner 2 was launched, with Venus still nine days away, the spaceship temperature had climbed to an alarming average 40°F higher than had been predicted. The battery which supplied power to the electronic system had reached its uppermost limit. The earth-sensor had passed its limit; other electronic systems were approaching limits. Moreover, with solar radiation impinging at greater than 250 watts on each square foot of Venus, the situation could only get worse.

This crisis in space came close to aborting one of America's most successful space probes. It came about because there was, at that time, no way on earth to adequately simulate the space environment. Space has no temperature and the heat dissipated by circuits operated in outer space must be removed, just as on earth, to preserve electrical properties and prevent damage.

Recent advances in cryogenics now make space probes more reliable by providing knowledge of outer space effects before the vehicle leaves earth, as well as providing refrigeration for removing heat generated in the vehicle during its voyage into outer space.

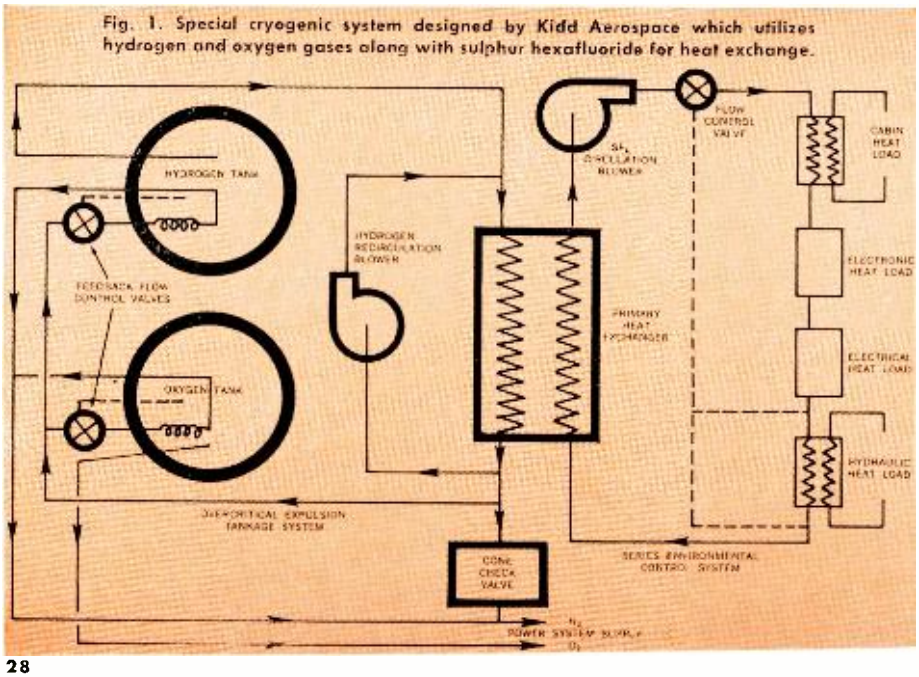
Cryogenics is the science of low-temperature physics concerned with the behavior of matter at very low temperatures. (*Cryogenic temperatures are frequently defined as those below −297°F, the boiling point of liquid oxygen. . .Ed.*) The function of the cryogenic system is to transfer waste heat from heat sources to a heat sink.

Highly specialized refrigeration systems are needed to achieve and maintain cryogenic temperatures. Fundamental to all cryogenic systems is the method of removing heat from the warm high-pressure area and transferring it to the cold low-pressure area. Heat exchangers are used for this purpose and may employ coiled tinned tubing wrapped in a mandrel, resulting in a densely packaged, highly efficient unit.

Two methods are available for accomplishing this heat transfer. One makes use of a liquid, ethylene glycol, to effect heat exchange with nitrogen. The other uses a gas, sulphur hexafluoride. These two systems are competitive on a weight basis, the gaseous system offering some control advantages. (See Fig. 1.)

The basic cooling cycles used in cryogenic refrigeration are the *Joule-Thomson* cycle and the *expansion-engine* cycle. Each exhibits advantages for specific cooling requirements. The Joule-Thomson cycle is the simplest method of providing refrigeration since cold moving parts are not required.

Fig. 1. Special cryogenic system designed by Kidd Aerospace which utilizes hydrogen and oxygen gases along with sulphur hexafluoride for heat exchange.



Inherent in the use of cryogenic temperatures with electronic systems is the associated design problems of the electronics. Electronic components and fabrication techniques must be able to withstand the ultra-low temperatures; insulation and circuit connections must endure changes from ambient to cryogenic temperatures. It is hard to provide connections which hold together conductors with different thermal expansion coefficients. Contamination, which at cryogenic temperatures causes malfunction of electronics circuits, must be eliminated by special techniques.

Insofar as electronic applications of cryogenics are concerned, the sky seems to be the limit. While outer space provides many of the conditions for optimum use, here on earth there seems to be virtually no limit. New types of power generating devices are being designed;

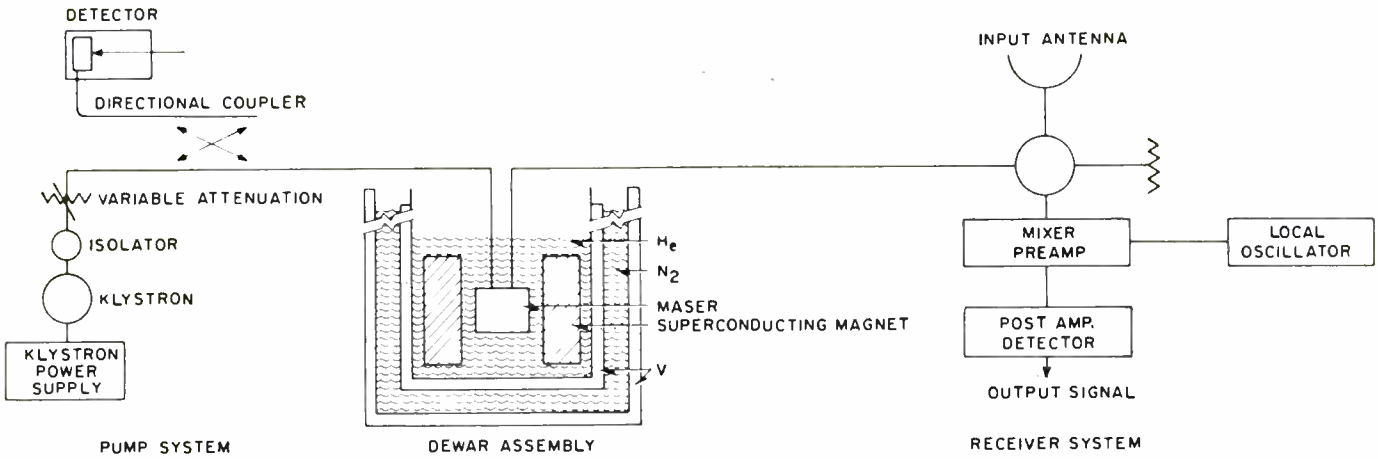


Fig. 2. A 70,000-mc. traveling-wave maser system operating at constant cryogenic temperature for improved frequency stability.

cryogenic gyros, motors, and solenoids are already in use. New cryogenic computer elements appear almost daily.

One of the earliest applications of cryogenics to electronics was the development of an echo box having a "Q" of about 500,000. This is an unheard of occurrence in equipment operating at ambient temperatures. Recent advances in superinsulation make possible substantial improvements in this early device.

Many of the latest devices in electronics either must operate at low temperatures or their operating characteristics are considerably improved by such operation. This includes ultrasensitive detectors, masers, lasers, paramagnetic amplifiers, infrared detectors, diode luminescent devices, new sources of electromagnetic energy, and a host of others. (See Fig. 2.) The time is probably not far distant when many electronic systems will operate at cryogenic temperatures.

One cryogenic system provides a low-temperature environment for stable low-noise parametric amplifier performance for periods of 2500 hours without adjustment or maintenance. Conductive cooling quickly lowers the parametric amplifier system from ambient to the operating temperature when the unit is operated in a vacuum-insulated enclosure. The net refrigeration removes the combined electrical and thermal (conductive and radiant) loads of the amplifier assemblies that are employed.

50,000-gauss superconducting magnet used to study properties of matter in high magnetic fields at very low temperatures.

Superconductivity

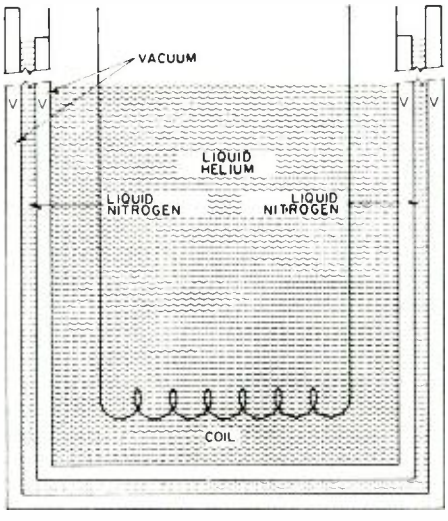
When certain materials are cooled below a critical temperature and close to absolute zero (about −460°F), their electrical resistance approaches zero. As a result, the material becomes a *superconductor* of electrical current. Passing an electrical current through a superconductor does not result in any heat being produced. (See Fig. 3.) This phenomenon of superconductivity occurs in many metallic elements and in over 100 different alloys.

In a superconducting coil where there is virtually no resistance, a current can be maintained for a year or longer with virtually no excitation.

Since the discovery of this phenomenon in 1911, the possibility has been recognized in the use of superconductors for constructing efficient solenoidal magnets. They would require no power and present no problems associated with heat transfer to cooling media.

A superconducting magnet consists of a coil of very special wire, such as niobium-zirconium or niobium-tin, which is immersed in a bath of liquid-helium. At this cryogenic temperature (−452°F) the wire has zero resistance and can carry tremendous d.c. electrical currents (200,000 amp./cm.^{2}) without heating.

Fig. 3. Superconductivity is produced in coil of special wire submerged in liquid helium. Liquid nitrogen at 322 F and the two vacuum chambers keep the helium from boiling off. The entire vessel (called a "dewar") is made of stainless steel and operates as double-insulated vacuum bottle.



It is thereby possible to wind very compact, very strong d.c. electromagnets that consume virtually no power and with considerable saving in over-all cost.

Most of the applications of superconducting magnets at present are in the area of basic research, particularly physics. Considerable application has also been made in electronics. As the technology develops, there is a definite application to atomic particle accelerators, magnetohydrodynamic generation of electrical power, and countless types of instrumentation.

Superconducting magnets are a natural in maser and laser applications since the maser and laser crystals must be at liquid helium temperatures for most ef-

(*Continued on page 54*)

Probably the most complex device to be mass-produced for the consumer market, the color CRT requires the most exacting optical, chemical, metal-working, glass-fabrication, electronic, and assembly procedures.

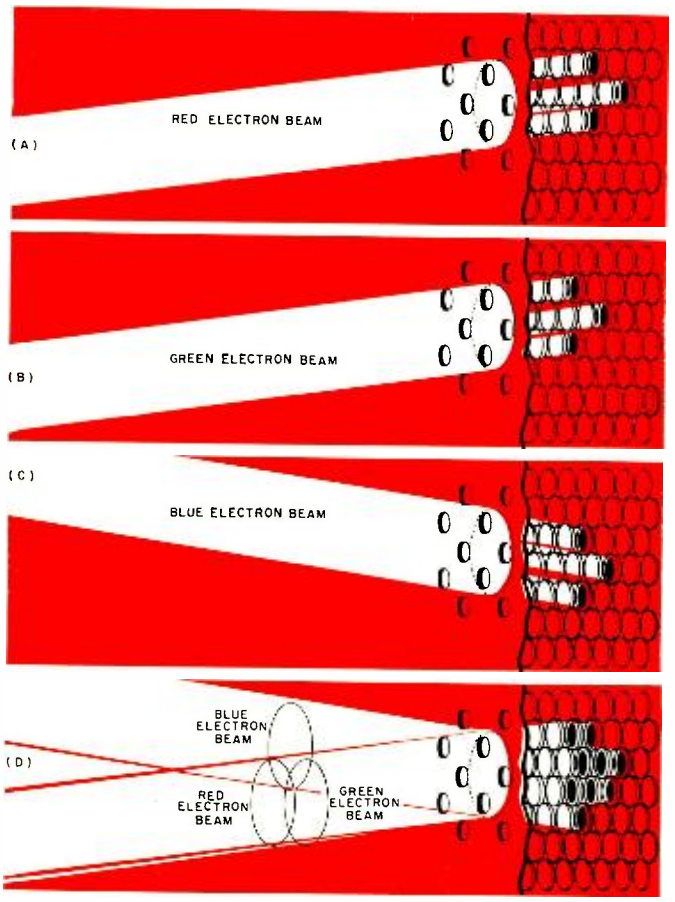
MANUFACTURE OF COLOR PICTURE TUBES

By J. F. HOLAHAN / RCA Electronic Components and Devices

A COLOR-TELEVISION picture tube is an enormously complex device. Consider the problem of precisely aiming three separate electron beams at a fluorescent screen between one and two feet away. The screen is made up of nearly 1¼ million red, green, and blue color phosphor dots. The beams must pass through some 400,000 tiny holes, as small as 0.010-inch in diameter, and each beam must strike only those phosphor dots of a single color. Consider further that these three electron beams must sweep over an area of about 300 square inches, 60 times each second, and that they must maintain their relation to each other throughout. Added to all of this is the problem that the three beams can be deflected very easily even by the weak magnetic fields produced by the earth and nearby magnetized objects.

It is obvious that some very special manufacturing techniques must be used in order to produce such a complex device, yet one that still creates accurate color pictures. This article describes the techniques used by *RCA* at its color-tube manufacturing plants at Lancaster, Pa. and Marion, Indiana.

Fig. 1. The three electron beams approach the shadow mask at angles so that each beam hits its own color phosphor only.



The Color Tube

The modern color-television tube differs from a black-and-white tube in the makeup of the phosphor viewing screen, in the configuration of the electron gun, and in the presence of an additional element within the envelope, called a shadow mask. These differences are fundamentally the result of the fact that a color-picture tube is actually three complete picture tubes built within a single envelope.

Instead of a single solid layer of phosphor emitting only white light, the color-tube screen is made up of small individual dots of phosphor arranged in orderly trios. Each trio includes three dots, each of which emits a characteristic color when excited by an electron beam. Thus, the television picture may be considered to be made up of minute spots of light varying in brightness and placed very closely together so that the eye integrates them.

The primary colors used are red, blue, and green. With this system of primaries, the color tube is capable of producing a wider gamut of colors; greater, in fact, than that obtainable from either color printing or color film. (See "Colorimetry in Color Television" in this issue.)

Similarly, the color-tube electron gun is really three guns combined into a single assembly. One gun creates a beam of electrons which is controlled in such a manner that it strikes only the red-light-emitting phosphor dots to paint a red picture. The beam from the second gun strikes only the blue-light-emitting phosphors and creates a blue picture. In the same way, the third gun provides the green picture information.

Between the electron gun and the phosphor screen is the heart of the color-television tube—the shadow mask. The shadow mask is a sieve-like disc containing about 400,000 holes, one hole for each phosphor-dot trio. These holes vary in diameter across the mask, according to a precise mathematical formula, from 0.010 to 0.012 inch. As shown in Fig. 1, the function of the shadow mask is to keep the three color pictures separated by shadowing two of the three arrays of phosphor dots from two of the three electron beams, while exposing the proper array to bombardment by its particular beam.

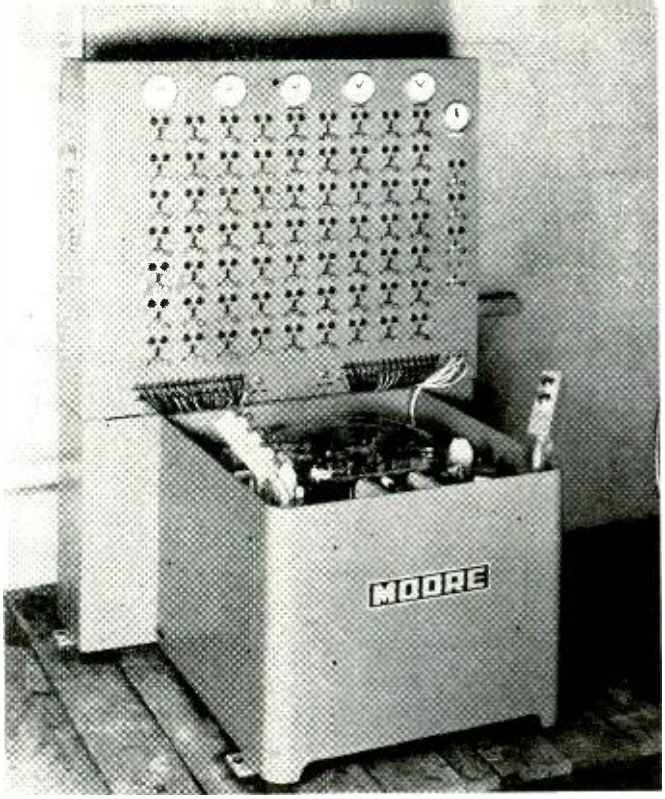


Fig. 2. Automatic gauge checks contour of CRT faceplate or panel at 125 points. Failure to meet contour is signalled by red indicator lamp on panel. One red light means reject.

Although the shadow-mask color picture tube is probably the most complex "chemelectromechanical" device ever to be mass-produced for the consumer market, it is compiling a record of reliability and long life which rivals that of its relatively uncomplicated predecessor, the black-and-white tube. How is it done? The answer lies in the almost incredible precision used in every step of color-tube manufacturing —from inspection of raw materials, creating the color tube, to packaging and shipping of the finished device.

Incoming Inspection

All parts and materials used in the manufacture of the color-television picture tube are thoroughly inspected prior to use. Individual lots are acceptance-inspected on the basis of the same statistical sampling plans used for military and government space programs. Acceptance specifications involve visual, mechanical, and dimensional standards and, in many cases, also involve laboratory tests for elemental purity as well as for exacting chemical and physical characteristics.

One of the newer pieces of inspection apparatus in use at *RCA's* Lancaster plant is shown in Fig. 2. This automatic gauge is used to measure the contour of the tube face plate or panel. The gauge checks 125 points on the face of the panel by means of small, air-regulated pressure points which have been precisely set. As the panel depresses the pressure points, red and green lights on the display board, corresponding to specific pressure-point locations, indicate whether or not the contour of the panel meets specifications. One red light is sufficient to reject the panel. Similar comparator gauges check the trueness of the panel and funnel periphery. Seal lands (the surfaces at which the panel and funnel are joined) are checked for flatness on granite plates ground and polished to a tolerance of 0.0001 inch.

Some parts and materials require even more complex inspection techniques. An example is the inspection process of nickel material used in the manufacture of the cathode, a vital component of the electron gun. At incoming inspection, an inspector removes a 2-foot section from each coil of metal, and forwards it to the laboratory for analysis. There the nickel first undergoes spectrographic analysis where concentrations of only a few hundredths of a percent of other metals present in the base nickel are determined. Since cathode performance is affected by the presence of minute quantities of several other metals in the base nickel, exact measurements are obtained through the use of a recording microphotometer. The strip is then taken to a conductometric carbon analyzer where a determination is made of the amount of carbon and sulfur present in the metal. Concentrations as low as 0.002% carbon or sulphur are readily detected.

All metals contain many microscopic inclusions of oxides, silicates, or sulfides distributed at random throughout the mass. It is often necessary to identify these inclusions to determine whether they will have an adverse effect on the life of the finished tube. By the use of an electron probe analyzer, particles as small as one-hundredth the width of a human hair can be examined and identified.

Shadow Mask

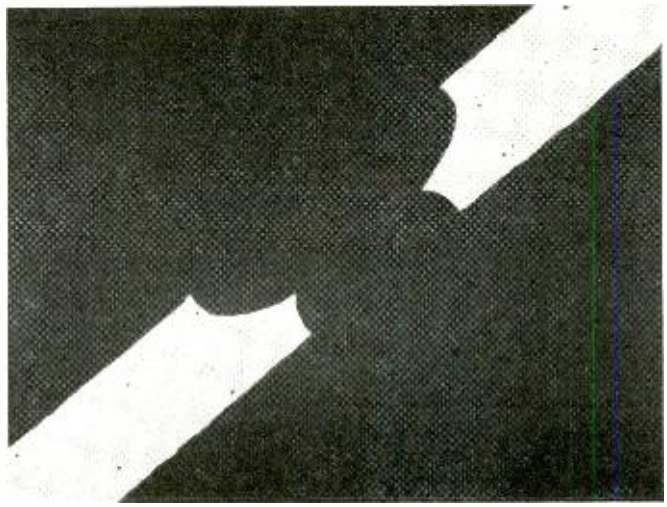
The shadow mask is manufactured by a combination of chemical, mechanical, and photographic techniques that are closely akin to photoengraving. In this process, 1000-pound coils of cold-rolled steel 0.006-inch thick (about the thickness of the cover of this magazine) and 21⅝ inches wide are first fed into a machine which chemically cleans all traces of oil, oxide, and other soil from the surface of the metal. Both sides of the strip are then coated with a thin layer of fish-glue solution which has been made light-sensitive by the addition of certain chemicals. This coating is quite similar to a photographic film in that exposure to light will produce an image. The coating applied in this machine is dried and the coated strip is recoiled on spools.

Following recoiling, the strips are fed through a manually indexed machine in which the coated strip is first sandwiched tightly between two glass sheets containing photographic patterns of about 400,000 dots. These two patterns are held in intimate contact with the coated metal by the action of vacuum, and must be perfectly aligned (from one side of the metal strip to the other) within a fraction of a thousandth of an inch. After alignment, the sensitized coating is exposed to the light emitted by two high-intensity arc lamps, and the dot pattern is reproduced on each side of the metal.

Once again the strip is recoiled and then fed into a machine where sprays of water remove the unexposed areas of coating which have remained water-soluble, then through an oven which bakes the remaining coating to a hard, chemically resistant finish. In the final processing step, the metal with its pattern of uncoated dots is fed through sprays of acid which chemically eat through the uncoated areas from both sides of the metal simultaneously to produce holes having the characteristic cross-section shown in Fig. 3.

This "tapered hole" feature improves the saturation of an individual color field and the contrast when the three fields

Fig. 3. Photomicrograph of a typical shadow-mask hole shows tapered hole that is produced to reduce electron scatter.



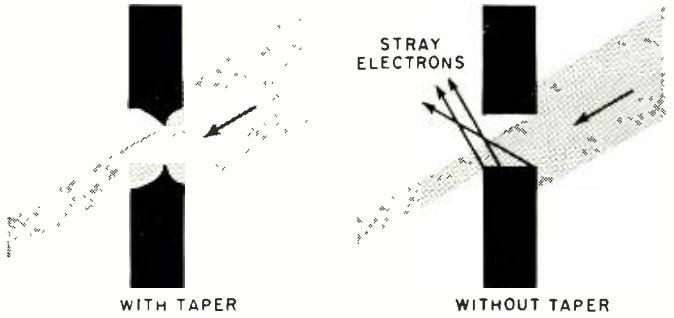


Fig. 4. Tapering the holes in a shadow mask reduces electron scatter, increases beam intensity, and achieves increased light output as well as better contrast and color saturation.

are used together to produce white. As shown in Fig. 4, tapering permits the electron beam to be transmitted through the mask without striking the side wall of the aperture. The degree of hole taper in the mask is not the same over its entire area, but maximum at the edge and gradually reduced toward the center. This gradation provides maximum taper where it is needed; that is, near the edge of the mask where the electron beam approaches at the greatest incident angle. Another advantage of the tapered holes is the fact that more of the beam is allowed to pass through the aperture, whereas the wall of the straight-sided aperture blocked upwards of 20% of the beam. Thus, tapering achieves increased light output as well as improved contrast and color saturation.

Light output is also substantially increased by grading the size of the holes over the area of the shadow mask. Holes gradually increase in diameter from the edges to the center; consequently, the central portion of the color hole feature effectively exploits the tendency of the human eye to take its impression of over-all brightness from the center of the screen it is viewing. The viewer is aware not of the variation, but only of the increased brightness of the picture.

After etching and removal of the protective coating, the mask is formed into its final spherical contour, blackened, and precision welded to a rigid frame. It is then subjected to several critical inspections for size and perfection of the apertures. Each mask is checked on a light table for defects that could produce objectionable spots, streaks, or bars in the color picture. In this inspection, irregularities in the size of adjacent holes so minute as to be virtually unmeasurable can be visually detected. In addition, before forming, the masks are checked in statistically determined areas for proper hole size. The measuring instrument is a photoelectric cell device which can measure tolerance of hole size to less than 0.0001 inch. The mask is now ready for installation.

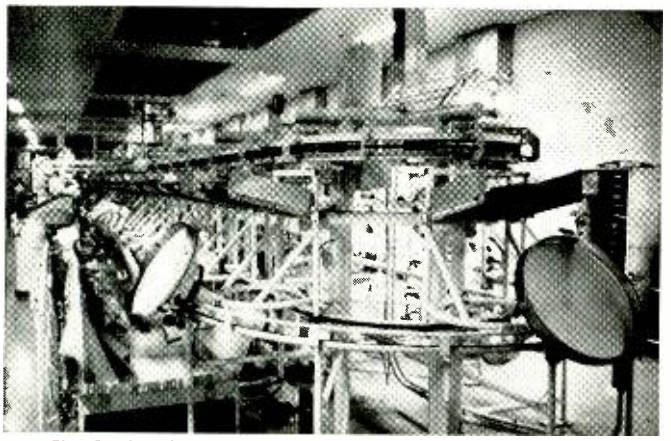


Fig. 5. Phosphor processing takes place on this semi-automatic machine. The trolley moves the CRT panels to each position.

Fig. 6. The phosphor dispensing station deposits an exact amount of phosphor on the spinning panel for uniform spread.

Phosphor Screening

(Editor's Note: It should be pointed out that the following discussion on phosphor screening applies to the author's company (RCA). *Other color-CRT manufacturers use different techniques for laying down the phosphors.)*

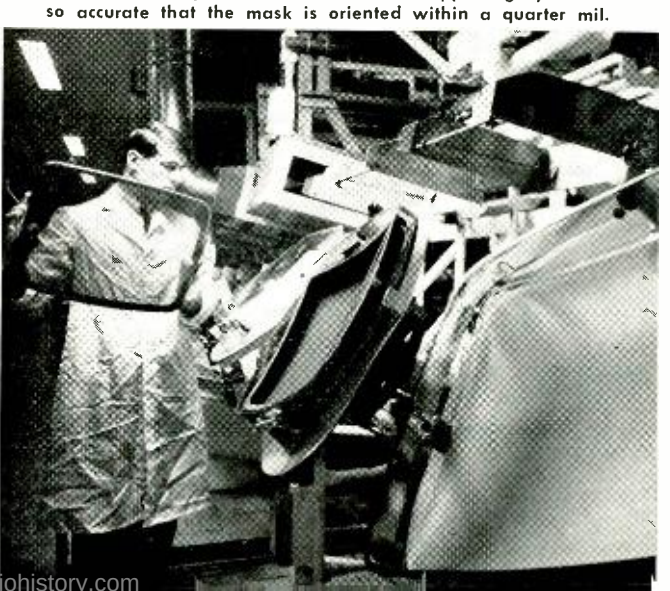
Application of the phosphor screen to the glass panel is perhaps the most critical of all manufacturing steps. Added to the usual problems of dimension control is the tendency of phosphors to behave erratically when contaminated by even trace (minute) amounts of impurities. Airborne particles of copper, for example, will make blue phosphors glow green and green phosphors glow red. As a result, screening is carried out in a very clean environment.

Each of the three dot arrays is formed in a "photo deposition" process similar to that used for the shadow mask. All processing steps are accomplished on a semi-automatic machine, such as the one shown in Fig. 5. The trolley moves the panels from position to position around the machine in an indexing manner.

At the dispensing station, shown in Fig. 6, a carefully metered amount of phosphor in the form of slurry is deposited into a spinning panel so that it spreads uniformly over the panel surface in a solid layer. At the time of dispensing, the slurry material looks much like pancake batter and contains a photosensitive additive as well as the fluorescent material. The phosphor layer is then dried at subsequent stations on the machine, and a shadow mask is installed in the panel. As shown in Fig. 7, the mask is supported by specially designed leaf springs and is readily inserted and removed. Furthermore, the supporting system is so precise that it places the mask within 0.00025 inch of the same position within the panel each time it is inserted.

The panel with its shadow mask is then placed on a device called a "lighthouse." In the lighthouse, a point source of light is properly placed with respect to the panel and mask so that the angle of (*Continued on page* 56)

Fig. 7. Installing a shadow mask. The supporting system is so accurate that the mask is oriented within a quarter mil.



There are two types of ghosts that annoy color-TV viewers. One is a simple reflection that can be easily remedied. The other is an elusive phase error that requires some thought in curing.

By WALTER H. BUCHSBAUM / Contributing Editor

ONE of the most persistent and annoying troubles in TV reception is the appearance of multiple images (ghosts). In the majority of cases, a ghost is due to a reflection of the television signal between the station and the receiving antenna. However, reflected signals can also be due to impedance mismatch between antenna and transmission line, or between the transmission line and the receiver.

In both color-TV and black-and-white reception, the ghost problem is caused by reflections, but a new type of ghost, effective only on the colors themselves, can also occur and the presence of ghosts is much more objectionable in color than it is in black-and-white. For this reason, many viewers who accept a slight ghost on black-and-white receivers without complaint will object violently to the same amount of reflected signal appearing on their color sets. This article will look into the causes and possible remedies of two types of ghosts which can occur in color-TV receivers. Before leading the reader to believe that a positive cure-all can be prescribed, however, it must be admitted that in some locations it may be totally impossible to receive perfect color-TV.

Color-TV Ghosts

Just as in black-and-white reception, signals which arrive at the receiving antenna by a reflected path, and are therefore slightly delayed, will cause a ghost in color-TV receivers. The reason why such ghosts are more objectionable in color than in black-and-white is best demonstrated by Fig. 1. It is assumed that the screen shows three color bars and Fig. 1A illustrates the combined video signal that creates this particular pattern, with the related amplitudes of these bars. If another, reflected, signal is received with a slight delay as indicated in Fig. 1B, the two signals will overlap at the borders of the red, green, and blue vertical bars. At this overlap, a mixture of the two adjacent signals will occur as shown. In a black-and-white picture, it may not be too objectionable to see a vertical line slightly displaced and repeated much weaker. In color pictures, however, when the displacement area assumes another color, as between the red and green in Fig. 1B, this immediately calls loud attention to the ghosting effect.

As indicated above, this type of ghost effect is due to the same cause as its black-and-white counterpart, and we shall call it a type-1 ghost for the rest of this article. Although delayed signals can be obtained by standing waves or an impedance mismatch among the antenna, transmission line, and receiver, the most frequent cause of type-1 ghosts is a reflection from a natural or man-made structure. Misadjusted horizontal convergence can give the same appearance on color pictures, but a type-1 ghost can be identified by the fact that it appears also during black-and-white reception. If convergence is misadjusted, color fringing also occurs in black-and-white reception. In a later paragraph, we shall indicate how some of these type-1 ghosts can be eliminated, but for the moment let us consider the type-2 ghost, a phenomenon limited solely to color-TV.

Most readers are familiar with the frequency *vs* amplitude relationship of a typical television channel. Fig. 2 illustrates the frequency arrangement for channel 4 and shows the relative amplitudes of the transmission channel and, superimposed, a typical receiver r.f. response. The color subcarrier is transmitted 3.58 mc. above the video carrier and contains color information in sidebands which are between 0.5 and 0.7 mc. away from the color subcarrier. The amplitude response of Fig. 2 tells the whole story for black-and-white performance; but for color reception, Fig. 3, which contains both amplitude and phase response for channel 4, must be considered. At the left side, relative amplitude in db is indicated, while at the right side, phase delay in electrical degrees is shown.

The problem of phase delay may not be too familiar and it may be worthwhile to recapitulate the basic characteristics of a tuned circuit. A single *LC* tuned circuit has zero phase delay at the center frequency with the phase of the signal shifting above and below, in electrical degrees, as frequency is varied above and below the center frequency. Tuned circuits are used in the receiver tuner, i.f., etc., and even the antenna consists

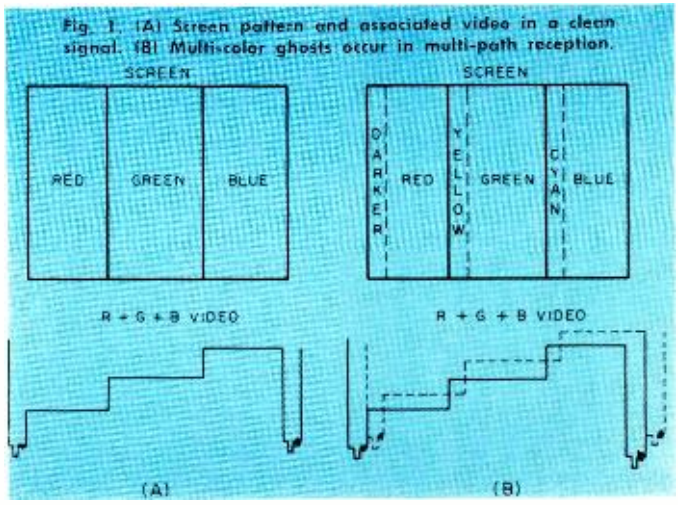


Fig. 1. (A) Screen pattern and associated video in a clean signal. (B) Multi-color ghosts occur in multi-path reception.

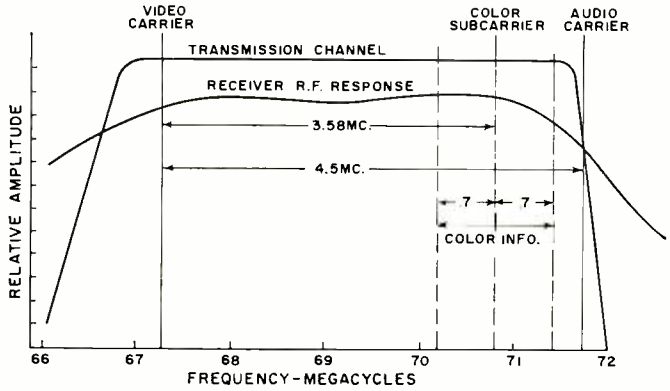


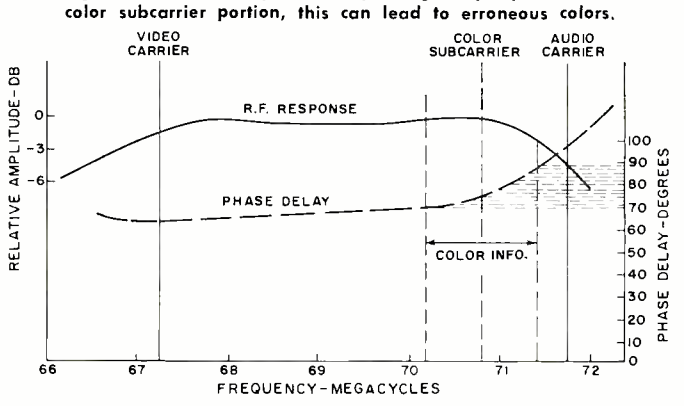
Fig. 2. Relative amplitudes for transmitter and receiver for Ch. 4. Placement and bandwidth of color subcarrier is shown.

essentially of tuned circuits. When several of these circuits are tuned broadly due to mutual coupling and loading, the phase angle changes more gradually. To present a typical example, a two-stage network, with a center frequency of 67 ±3 mc. at 3 db and a "Q" of 11, will produce as much as 60° phase shift at the 3-db points. This is based on a coupling coefficient of 2. If a coupling coefficient of 4 is used for the same frequency response, the phase shift at the 3-db points will be 35°.

When these figures are applied to a typical receiver r.f. response, the phase shift may be uneven at either end of the chromatic bandpass as shown in Fig. 3. Here, the phase shift changes from 70° to about 90°. If the r.f. amplitude response were completely flat over this bandpass area, the phase delay (theoretically) would be uniform. Because the over-all specifications require that the r.f. response be approximately 3 to 6 db down at the audio carrier, it is almost impossible to achieve a completely flat r.f. response over the color-subcarrier bandpass. Note that the phase delay over the lower portion of the color-subcarrier sideband is much less, about 7°, as opposed to 13° on the high portion of the sideband. This inequality adds to the phase-delay problem.

The real cause of type-2 ghosts is not the phenomenon of phase delay itself but the fact that this phase delay is sometimes unequal over the range of color information that the receiver uses. Remember that the basic hue or chroma information is encoded in the form of phase difference from the reference phase. The reference phase is fixed by the eight-cycle 3.58-mc. burst transmitted during each horizontal sync-pulse interval and against which the local color oscillator is adjusted. The problem of phase delay within the color subcarrier and its sideband will be discussed later in more detail, together with possible remedies, but the reason for it should be recognized clearly. Unlike the ghosts that are caused by two signals arriving with a slight time difference, type-2 ghosts result in certain wrong colors always appearing in place of the correct hues. This means that it may be impossible to obtain correct flesh tones and at the same time receive the correct hues for scenes other than the human face. Many complaints of unnatural colors, regardless of adjustment of the color controls, can be traced directly to type-2 ghosts.

Fig. 3. If the receiver phase delay changes rapidly across the color subcarrier portion, this can lead to erroneous colors.



Eliminating Type-1 Ghosts

Most of the type-1 ghosts are due to reflections between the transmitter and the receiver. These reflections invariably reach the receiver antenna from the side or rear and can be eliminated by using an antenna having a relatively narrow beam and a very high front-to-back ratio. Where only one channel is received, a narrow-band-type antenna can be used, but where a number of television channels must be received the problem becomes more complex. Antenna research in connection with some of our space projects has recently turned up a new technique for obtaining narrow beams and high front-to-back ratios all over a broad frequency band. Marketed under different trade names, the basic principle of the log-periodic antenna structure is that the individual elements are tuned and spaced with respect to their neighbors according to logarithmic scaling factors. In a way, the log-periodic type of antenna is a one-plane equivalent of a spiral antenna, such as that used in high-performance space communication systems. In metropolitan areas, less gain is required, but the directivity should be high to reduce multi-path reception.

Directional antennas will eliminate type-1 ghosts, but unless the phase delay is uniform over at least the color-subcarrier sidebands, type-2 ghosts could be caused by the antenna. This will be covered in more detail when the elimination of type-2 ghosts is discussed.

Many homes having a color-TV set also contain a black-and-white set, and often an FM receiver as well. Operation of all three receivers from a single antenna is accomplished by means of antenna couplers or signal splitters. In some instances, usually in the fringe areas, amplifiers are employed. These devices all contain tuned networks and, therefore, all present the possibility of an impedance mismatch and type-1 ghost, as well as the chance for unequal phase delay and a type-2 ghost. While the resistive antenna couplers or signal splitters can be counted on to have uniform phase delay, most well-designed devices using *LC* circuits keep the phase delay uniform at least over the color-subcarrier sidebands. It should be pointed out that poor installation itself can cause impedance mismatch and therefore either, or both, of the two types of ghosts.

Recognizing that transmission lines are often the culprits in type-1 ghosts, one manufacturer strongly recommends the use of coaxial transmission lines. 300- to 50-ohm baluns are available to convert from balanced to unbalanced terminations.

A shielded cable protects against pickup on the transmission line and is not likely to cause mismatch due to adjacent grounds, bends, etc. Shielded cable is especially recommended in areas where the signal is very weak and antenna preamplifiers are employed, as well as in metropolitan areas where excessively strong signals cause interference to be picked up directly by the transmission line.

Elimination of Type-2 Ghosts

A type-2 ghost usually appears as poor color fidelity. It seems to the viewer that some particular colors are always of the wrong hue. Referring back to Figs. 2 and 3, note that the drop-off in frequency brings with it a non-uniform phase delay. The type-2 ghost is caused by the non-uniform phase delay of the color subcarrier and its sidebands.

As shown in Fig. 3, the sidebands extend to approximately .7 mc. above and below the color subcarrier in most sets. Individual hues are specified by the phase difference between the reference burst (3.58 mc.) and the actual phase of the color subcarrier at any given instant. Fig. 4A shows, in vector-diagram form, the phase relationships of the reference burst, the red, blue, and green color difference signals, and the internal reference signals *X* and *Z*.

Earlier color receivers used the *I* and *Q* vectors, but most recent models use the *X* and Z vectors as illustrated in Fig. 4A. In a properly operating color demodulator, the *X* and Z vectors are 62.1 degrees apart. To produce a given shade of magenta, a certain amplitude negative *X* and negative Z vectors are decoded and, by vector addition, provide the magenta color on the screen as illustrated in Fig. 4B. If the phase of the *X* and Z vectors were shifted with respect to the reference burst, the resulting color would also be different. Fig. 4C shows the effect of an uneven phase shift. The $-X$ vector is shifted by 10° while the $-Z$ vector is shifted by 15°, resulting in an entirely different shade, a bluish-purple.

If the *X* and Z vectors were both phase-shifted by the same amount, adjustment of the hue control on the front of the TV receiver would produce correct colors. With the condition shown in Fig. 4C, however, it is possible to bring either the Z or *X* vector into its correct position with respect to the reference burst, but never both. Although a type-2 ghost can affect all colors, it will appear as though only certain distinct tones are "off color" while the rest are tolerably correct. This is due to the color-sensitivity characteristic of the human eye. The viewer's tendency will be to set the hue control for the best flesh tones, regardless of how unnatural the scenery may look. This is unavoidable since the viewer has no way of comparing colors during a color-TV telecast.

The technician can verify the type-2 ghost by connecting a color-bar generator to the TV receiver itself. With proper adjustment of the receiver and application of the signal directly to the receiver antenna terminal, all colors should be correct. If an antenna coupler is suspected, the output of the color-bar generator should be connected to the antenna input terminals of the coupler. A wrong color bar would now indicate the origin of the type-2 ghost to be in the coupler.

To check the antenna and transmission line, the color-bar signal can be radiated from a simple antenna into the color-TV reception antenna. This procedure may not always be practical, and therefore we are dependent on the signals received from a TV station. One useful reference in such a situation is to know the exact colors of a station sign or test pattern of some kind. The famous *NBC* peacock serves such a purpose, but the technician will have to time his diagnosis to catch it during the short time before each color program. Many stations transmit color-test patterns during non-broadcast hours.

Even without definite evidence pointing to the antenna and transmission line, a brief inspection of this installation should always be made. It is a safe bet that a narrow-band antenna, corroded and in place for a long time, will cause trouble in color-TV reception. Good color antennas should have a frequency response so that the change in amplitude is very gradual over a range of not more than 2 db over as many as six channels. Within any given channel, the amplitude response should be flat within one db, meaning that for a portion of the color-carrier sidebands, the flatness is better than 0.2 db. This, in turn, means a relatively uniform phase delay.

Where couplers, signal splitters, or amplifiers are used, it is important to know the bandpass response quite accurately. One very good color coupler is guaranteed to have a ±0.25-db flat response within any 6-mc. band. Another indication of phase delay is the v.s.w.r. In the case of one good color coupler, this is 1.15:1 for the input and 1.4:1 for the output, absolute maximum. Since theoretical perfection would require only a v.s.w.r. of 1.1:1, the over-all performance of color couplers is sufficiently good to minimize the chance of any type-2 ghosts. The reader should be cautioned against using older versions of couplers and signal splitters which were intended for black-and-white use.

Having chosen the best antenna, transmission line, and coupler available, it still happens occasionally that type-2 ghosts persist. When the color-TV receiver is properly aligned for a uniform phase delay over the color-carrier sidebands, it is possible to misalign certain tuned circuits to compensate,

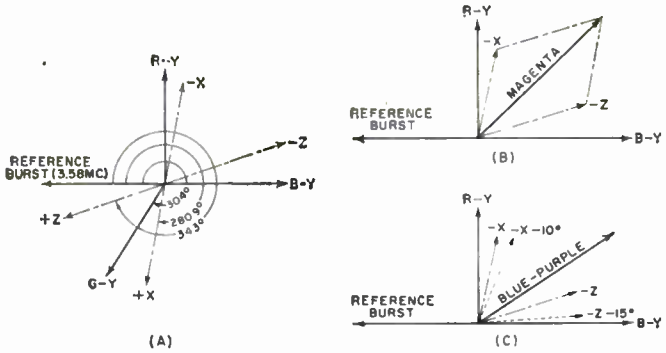


Fig. 4. (A) Vector relationships among the various coordinates. (B) How magenta is produced. (C) A slight change in axes phase can produce a different color than the magenta shown in (B).

at least partially, for a type-2 ghost. It is important to know beforehand which particular colors seem to be most affected by the type-2 ghost, and it will be noticed that these colors lie within a particular range of the color spectrum. In other words, it will be either the yellows and greens or the reds and yellows, etc. The next step is to use the color-bar generator at the input of the color set and check that the set is aligned for the correct colors of each color bar. In determining which colors are wrong, concentrate only on red, green, blue, and yellow, and do not consider pastels. If it is possible to use the color-bar generator to radiate a signal into the antenna, then the following adjustments can be made.

In every color receiver, there is usually a coil or a transformer that determines the frequency and phase response of the color signal going to the *X* and Z demodulators. Assuming that the type-2 ghost has caused the yellow shades to look more greenish, misadjust the coil slowly until the yellow color bar gets a slight orange cast. This means that the angle between the *X* and Z color signal is shifted in the opposite direction to that caused by the type-2 ghosts. Since this is usually a trial-and-error method, only a very slight adjustment can be done at any one time, and then the color-bar generator should be disconnected and a transmitted color signal should be examined. This entire procedure can be recommended to only those having a thorough understanding of color-television receiver circuitry.

One limitation of the above remedy is the fact that type-2 ghosts are usually limited to a particular channel, and misadjustment of the color decoders for that channel can result in the appearance of a type-2 ghost on other channels. For this reason, the above remedy is limited to situations where only a single color channel is received. ▲

EDITOR'S NOTE: *There is another ghost possibility within a color-TV set. An improperly terminated delay line results in the reflection of energy back and forth from the ends of the delay line. A poor termination can result from an open terminating network at the output end of the line, or from an ungrounded shield on the delay line. The symptoms are multiple, evenly spaced ghosts or reflections in the picture. The condition looks exactly like ghosts, but the clue to delay-line trouble is that there are several ghosts—all evenly spaced.*

While on the subject of delay lines, it should be mentioned that chromatic misregistry can be introduced into the chrominance channel by improper delay in the line. A change in bandwidth of the chrominance channel, due to severe misalignment, can result in a change in over-all time delay. One of the symptoms might be a right or left shift in color information with respect to the monochrome components of the picture. Other symptoms will accompany this condition. These are poor color resolution (color does not "fill in" small colored objects in the picture) and crosstalk between the color-difference signals. Crosstalk appears as incorrect colors at vertical edges of colored objects.

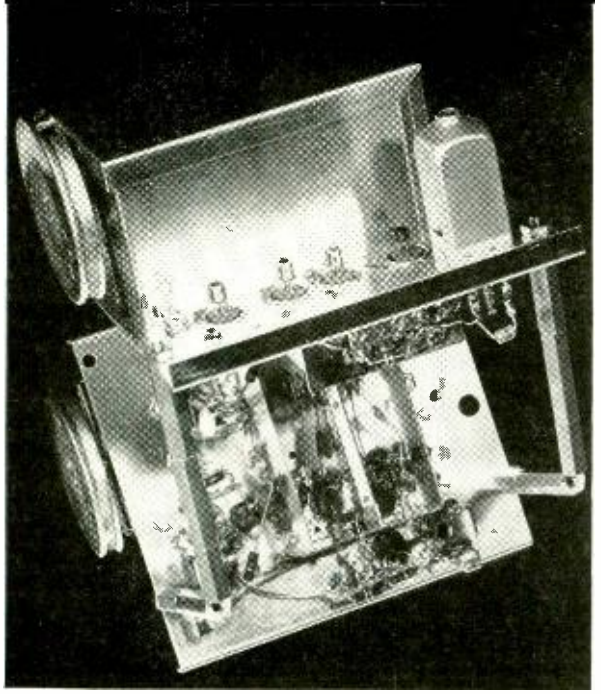


Photo of FET front-end taken with the unit placed on a mirror to show the underside. The three FET's are at the left, while the oscillator transistor is at the right beside the i.f. can.

FIELD-EFFECT TRANSISTORS for FM FRONT-ENDS

By DANIEL R. von RECKLINGHAUSEN
Chief Research Engineer, H. H. Scott, Inc.

Use of FET's with their almost perfect square-law characteristic results in high-fidelity tuner with no spurious response nor cross-modulation problems.

APPROXIMATELY ten years ago the inventor of the transistor described a new type of amplifying device which he called the "field-effect transistor," now known by its initials, FET. It was not until a few years ago that the very first field-effect transistors began to appear, costing more than $30.00 each and being treated more or less as curiosities. Within a short time, a few of the beneficial aspects of these transistors were realized and occasionally they found their way into military equipment. The first advantage was that FET's had a very high input impedance but circuit designers who had experience only with transistors found that they had to apply unfamiliar vacuum-tube circuit techniques.

In a conventional transistor, more properly described as a "bi-polar transistor," internal operation takes place by the movement of electrons and holes. In a field-effect transistor, only one type of carrier moves; for example, electrons only. This can be illustrated by the schematic representation of an FET as shown in Fig. 1. Here the field-effect transistor is just a bar of semiconductor material, such as *n*-type, with electrodes attached at both ends. When a voltage is applied, the electrons move between the two electrodes marked "drain" and "source" and move the same way as they do in an ordinary resistor. If two electrodes are attached to the sides of the semiconductor material, these electrodes, again being a semiconductor material but of the opposite type as the bar (here *p*-type), and a reverse voltage is applied to these electrodes (known as the "gate"), the effective width of the bar through which the electrons can travel is now reduced and the current through the bar decreases. It is the electric field from the gate electrodes which suppresses or restricts current flow in the main channel (much as does the grid in a vacuum tube); hence the name "field-effect transistor." Since only one type of carrier is moving in this transistor, field-effect transistors are also known as "uni-polar transistors."

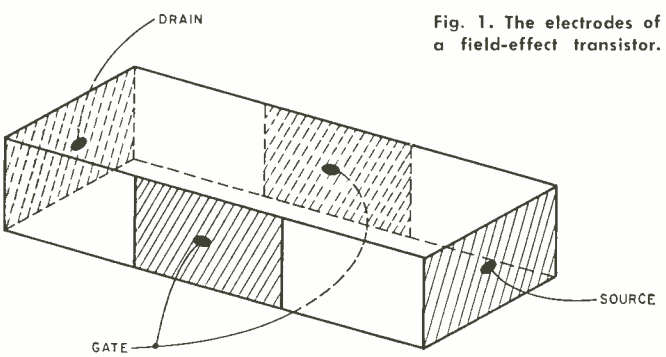


Fig. 1. The electrodes of a field-effect transistor.

Today, several makes of FET's are available and the price has dropped from many tens of dollars to only a few dollars. Also, today there exist various types of field-effect transistors, such as insulated-gate transistors, metal-oxide field-effect transistors, and even thin-film field-effect transistors. In particular, the insulated-gate FET's have extremely high input impedances. They are, however, also extremely fragile because electrostatic charges generated as the transistor is pulled out of a plastic package can build up a high enough voltage so that the insulation of this gate can break down. FET's without insulated gates do not suffer from this problem, are rugged, and yet have very high input impedance.

Square-Law Characteristics

The characteristics of an FET that interest the circuit designer most are, of course, how well these transistors behave in a circuit and what advantages they offer. As far as high-frequency operation is concerned, high input impedance is of little consequence. The major advantage of field-effect transistors is that the drain current is approximately proportional to the square of the bias voltage applied to the gate.

What is the advantage of such "square-law" behavior?

If a transistor, or any other device, has a pure square-law characteristic, the following effects take place. If only one frequency is applied to the input, this input frequency will also appear at the output along with some d.c. and the second harmonic of the input frequency. No other harmonic is created. In tuned amplifiers, the second harmonic is of no consequence because it is outside of the frequency range allowed to pass through the tuned circuit.

If *two* frequencies are fed to such an amplifier, the fundamental and the second harmonic of each of the two frequencies, as well as the sum and difference of the two frequencies, appear in the output. Again no other frequencies

are created. If these two original frequencies are close together, the only two frequencies which will then appear in the output tuned to one of these frequencies will be the two original input frequencies. Since the sum of the two frequencies and second harmonics of both are too high and the difference too low, all except the original frequencies are rejected by the tuned circuit. In other words, a square-law device is a very good tuned r.f. amplifier.

A square-law device also becomes a very good mixer if the output circuit is tuned to the difference between the two high input frequencies. Furthermore, if one of the two "frequencies" is just d.c., the output will still be that of the one frequency and the gain at this one frequency will then be controlled by the amount of d.c. Hence, a square-law device is also excellent for automatic gain control purposes.

Theory indicates that a field-effect transistor should be an ideal square-law device. Practically, it is only a few percent deficient. In contrast to this, tubes operate with a "three-halves power" characteristic thereby generating not only the second but also substantial higher harmonics and intermodulation products. Normal transistors have a diode characteristic, and a great number more harmonics and IM products of higher amplitude are created than in a tube. Hence, the normal transistor creates more undesirable distortion than a field-effect transistor for r.f. front-end applications.

Some Practical FM Problems

Let us look at some of the practical problems with FM. Within the last year, the Federal Communications Commission has authorized higher power for FM stations and has also issued an assignment table for FM stations. The result is that more strong stations are on the air, presently in excess of 1300 in the United States. The FCC Assignment Table specifies that stations in any general locality be spaced 800-kc. apart. For example, in the New York City area the FM band between 88 and 108 mc. has room for 25 stations spaced 800-kc. apart. All 25 channels are in use by educational and commercial stations in New York City and in Paterson and Newark, New Jersey, with the exception of one channel at 89.1 mc., which is reserved for the United Nations. Most of these stations are very powerful and r.f. signals of several tens of microvolts per meter to several volts per meter are not at all uncommon in the New York City area. Furthermore, many of these stations broadcast from antennas in the midtown area, so directional receiving antennas are of no use in reducing the unwanted input signals.

A high-quality FM tuner capable of high spurious response rejection can receive these signals with little spurious response and cross-modulation problems. These, if present, would show up as audio distortion on some stations due to r.f. intermodulation products, and as spurious signals on unoccupied portions of the FM band.

However, some transistorized FM tuners and even many of the earlier low-cost tube-type FM radios show evidence of spurious signal reception with field strengths of as low as 3 to 7 mv. per meter. Tube tuners in general are considerably better and this is why tubes, or nuvistors, have been in the front-ends of high-quality frequency-modulated tuners which were otherwise completely transistorized.

Advent of the FET

The advent of field-effect transistors has now given the circuit engineer an opportunity to design high-frequency circuits with the transistors without any sacrifice in performance, and an improvement in performance in many respects. However, as with any new device, there are a number of factors which have to be recognized.

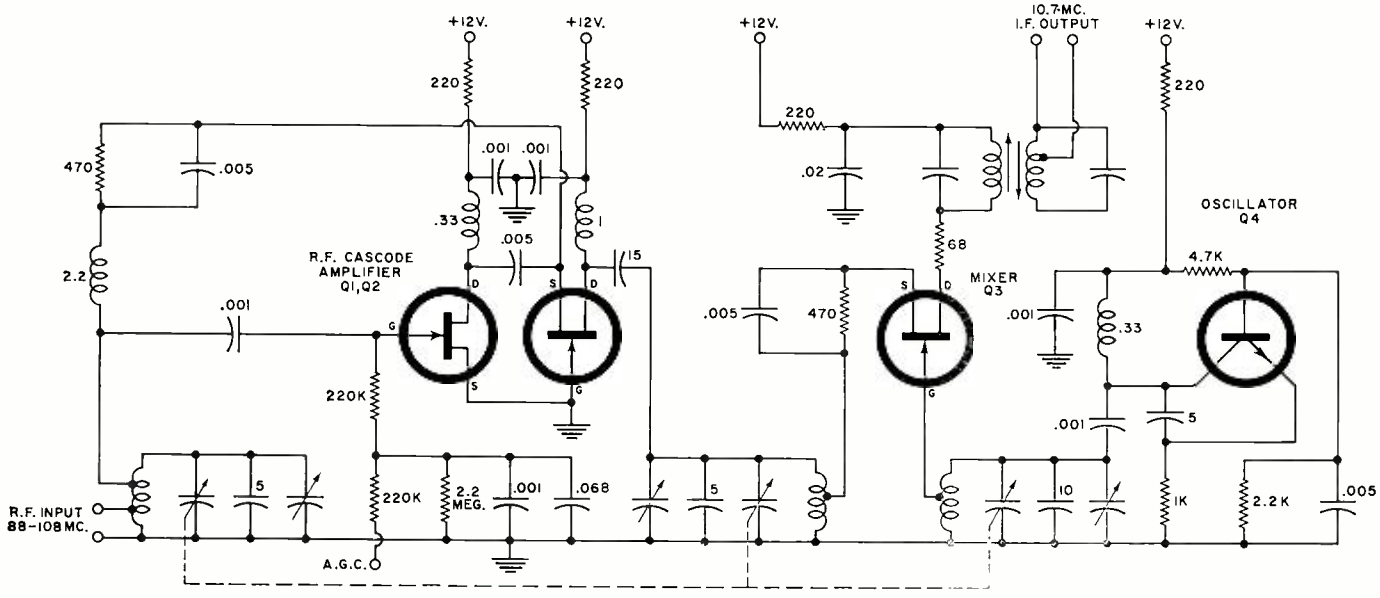
For example, the parameter variations in FET's are quite large. The drain current (equivalent to plate current of a tube) at zero volts bias can vary over a range of 30 to 1 or more. For this reason, a substantial amount of d.c. stabilization must be used in order to maintain the proper operating current. Fortunately, once a field-effect transistor of a particular type has been adjusted to a particular drain current, the gain of any transistor of the same type varies only ±25%. Further compensation will reduce this variation to still lower values.

Field-effect transistors have a poorer gain-bandwidth product than presently existing bi-polar transistors. In order to use FET's at high frequencies, the circuit has to be neutralized—more so than when using bi-polar transistors. As a result, the gain achievable is lower. However, the transconductance is quite constant with frequency and, therefore, field-effect transistors make good tuned amplifiers.

Fortunately, the noise created by field-effect transistors is very low. In tubes, the figure most often mentioned as a figure of merit is the equivalent noise resistance. The lower the equivalent noise resistance, the lower the noise of the tube. For a triode tube, the equivalent noise resistance is approximately equal to 2.5 divided by its transconductance. In a field-effect transistor, the equivalent noise resistance is only 1 divided by its transconductance. Therefore, field-effect transistors with considerably lower transconductance than customary in tubes can still be used for low-noise amplifiers.

Field-effect transistors are available with either *n*-channel (equivalent to *p-n-p transistors*), (*Continued on page* 64)

Fig. 2. Circuit diagram of the FM tuner front-end which employs three field-effect and one conventional transistor.



1966 Color-TV Set Chassis Directory

Although each of the color-TV set manufacturers listed in the following directory makes available a large variety of finished models, these are usually built around a series of basic chassis and color CRT's. Besides including important characteristics of these chassis, each company has supplied a brief description of its entire 1966 line of color receivers.

ANDREA RADIO CORP., 27-01 Bridge Plaza North, Long Island City 1, New York

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 2. Trans. UHF	Tuner 2. Trans. VHF	Tuner 1. Tube	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
VCV 325	25AP22A	2	25	90	295	1	1, 2	2	1		1	2	25	2, 3

Andrea's line, one of the oldest in this industry, incorporates seven color-TV models to serve every discriminating taste and market requirements. There are two 21-inch consoles and four 25-inch consoles, and one 25-inch color chassis for wall and custom cabinet installations.

The VCV 325 chassis uses a "Tru-Hue" 25-inch, rectangular, rare earth, short-neck, color CRT. The v.h.f. tuner uses a low-noise neutrode tube, while the u.h.f. tuner uses a low-noise transistor with continuous two-speed tuning drive. A factory preset fine tuning control and an illuminated channel selector window offers ease of tuning. A separate sound detector output jack is provided for hi-fi audio systems.

ADMIRAL CORP., 3800 Cortland Street, Chicago, Illinois 60647

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 2. Trans. UHF	Tuner 2. Trans. VHF	Tuner 1. Tube	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
1G11	21FBP22A	1	21	70	267	1	—	2	1		3	2	26	4
2G11	21FJP22A	1	21	70	267	1	1, 2	2	1		1	1, 2	26	4
3G11	21FBP22A	1	21	70	267	1	2	2	1		1	2	26	4
3G11	21FJP22A	1	21	70	267	1	1, 2	2	1		1	2	26	4
G13	25AP22A	2	25	89	295	1	1, 2	2	1		1	1, 2	26	4
G13 and 1G13	23EGP22	2	23	92	274	2	1, 2	2	1		1	1, 2	26	4

Admiral's 1966 color-TV line is highlighted by 21-, 23-, and 25-inch models. All sets have 26 kv. picture power, automatic degaussing, Admiral's exclusive color fidelity control, and transistor u.h.f. tuner. Another feature is the illuminated tilt-out control center that centralizes all tuning and preference controls in one convenient panel that slips back into the cabinet after the set is tuned or is not in use. Suggested list prices range from $349.95 for a 21-inch table model to $895 for a 23-inch color stereo theater with solid-state FM-AM tuner and 80-watt stereo amplifier.

CURTIS MATHES, 2220 Young Street, Dallas, Texas

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 2. Trans. UHF	Tuner 2. Trans. VHF	Tuner 1. Tube	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
CMC20	21FJP22	1	21	70	265	1	1, 2	2	1		1	2	25	2, 3
CMC22	25AP22A	2	25	90	295	1	1, 2	2	1		1	2	25	2, 3
CMC21—Same as CMC20 with "Instant On"														

Curtis Mathes color chassis feature "Instant On", automatic degaussing, automatic color control, and a no-glare picture tube. Each CM set is subjected to a continuous 24-hour "life test" under arduous conditions before being shipped.

DU MONT DIVISION OF EMERSON RADIO & PHONOGRAPH CORP., Jersey City, New Jersey 07302

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 2. Trans. UHF	Tuner 2. Trans. VHF	Tuner 1. Tube	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
120808	—	1	21	70	265	1	1, 2	2	1		1	2	24	2, 3
120809	—	2	25	90	296	1	1, 2	2	1		1	2	25	2, 3
120818	—	2	19	90	180	1	1, 2	2	1		1	2	25	2, 3

(See Emerson Radio & Phonograph Corp.)

EMERSON RADIO & PHONOGRAPH CORP., Jersey City, New Jersey 07302

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 2. Trans. UHF	Tuner 2. Trans. VHF	Tuner 1. Tube	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
120808	—	1	21	70	265	1	1, 2	2	1		1	2	24	2, 3
120809	—	2	25	90	296	1	1, 2	2	1		1	2	25	2, 3
120818	—	2	19	90	180	1	1, 2	2	1		1	2	25	2, 3

Emerson's new micromatic triple-alignment and convergence process achieves clarity of image and vividness of color. Color "Vivid 3" features: aluminized bonded-shield color CRT using rare-earth phosphors to produce brighter, more realistic colors with truer reds; "Magic Color Monitor" that purifies color image by automatic degaussing, even if set is moved; factory-adjusted noise-immune color circuit that eliminates color blotches from monochrome reception; "Magic Contrast" that sharpens color and monochrome contrast; and full-power transformer chassis.

Chassis No.	Type No.	Picture Tube: Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
GENERAL ELECTRIC COMPANY, Consumer Electronics Division, Electronics Park, Syracuse, New York													
M920BWD	21FJP22A	1	21	70	260	1	—	2	1	3	2	25	2, 3
M960BWD[a]	25AP22A	2	25	90	295	1	1, 2	2	1	1	2	25	2, 3
Porta-Color	11SP22	2	11	70	60	1	[b]	2	1	2	2	15.5	2, 3
M938BWD	21FJP22A	1	21	70	260	1	1, 2	2	1	1	2	25	2, 3
M930BWD[c]	21FBP22A	1	21	70	260	1	1, 2	2	1	1	2	25	2, 3

[a]Also chassis CC9531 and M961BCD; [b]Fiber glass bonded. [c]Also chassis M931BMD, M932BMP, M940BWD, M941BMP, M942BCL, M950BWD, M951BMP, M952BCL, CC9731, and CC9931

A 17-model color-TV line, led by "Porta-Color," the first U.S. portable color-TV set, has been announced by G-E.

Key features of the line include "Magic Memory" color reference tuning system for simplified color tuning, improved v.h.f./u.h.f. tuner using silver contacts for optimum signal conductivity, coaxial antenna system provision for highest picture quality, and color CRT's using "super phosphor" for greatest color fidelity and brightness.

An exclusive feature on the 25-inch models is the "Hide and See" drop-down door system having a hinge-slide mounting that removes the door completely from view when the set is being used. Porta-Color chassis is #M213BWD

HEATH COMPANY, Benton Harbor, Michigan 49023

GR-53A	21FJP22	1	21	70	265	1	1, 2	2	1	2	2	24	2, 3
GR-25	25AP22	2	25	90	295	1	1, 2	2	1	1, 2	2	25	2, 3

Heath now offers two color-TV kits. One uses a 25-inch rectangular tube, the other has a 21-inch round tube. Both feature an exclusive built-in dot generator for convergence adjustments. Both mount in a wall, custom cabinet, or preassembled Heath cabinets. The 25-inch set features exclusive "magna-shield" covering entire CRT and chassis for improved color purity, extra "B+" boost for improved picture definition, front-panel-mounted tilt-out convergence controls, automatic color control, automatic degaussing, hi-fi sound output, and a swing-out vertical chassis.

THE MAGNAVOX COMPANY, Fort Wayne, Indiana

U45-372B[a]	RE21FP22	1	21	70	265	1	2	2	1	1	2	25	2, 3
T904-14FB	23EGP22	2	23	90	275	2	1	2	1	1	1	25	2, 3
T904-16FB	23EGP22	2	23	90	275	2	1	2	1	1	1	25	2, 3
T904-12FB	25AP22	2	25	90	295	1	1	2	1	1	1	25	2, 3

[a]Also chassis U45-441B, U45-451B, U45-41FB, and U45-431B

1966 Magnavox color-TV models include the exclusive "Automatic Color" feature which assures optimum picture quality by eliminating critical and difficult manual adjustments. Inaccurately tuned channels degrade picture quality. The new line features "Chromatone" circuitry which provides depth to color pictures and warm sepia tones to monochrome, and "Quick On" which eliminates the bothersome wait for the picture to appear.

The Magnavox line of consoles and stereo theater combinations in a wide variety of furniture styles ranging in price from $399.90 up to $1195 bring the color-TV viewer the most advanced color-TV receivers available.

MOTOROLA INC., 9401 West Grand Avenue, Franklin Park, Illinois 60131

TS-914	23EGP22	2	23	92	274	2	1, 2	2	1	2	2	24	2, 4
TS-908	23EGP22	2	23	92	274	2	1, 2	2	1	2	2	24	2, 3
TS-917	25AP22A	2	25	90	295	1	1, 2	2	1	2	2	24	2, 3

Motorola introduced the first mass-produced, rectangular CRT color-TV receiver in 1963 and continues its 1966 line placing emphasis on the slim-trim cabinetry made possible by this tube. The firm has two groups of 23-inch rectangular color receivers, a "compact" cabinet chassis group, and a "slim silhouette" chassis category. Included in the latter group is a collection of cabinets by Drexel Furniture, with whom Motorola has an exclusive arrangement. The rectangular compact color series starts with a manufacturer's suggested list price, optional to dealer, of $479.95.

OLYMPIC RADIO & TV, Division of Lear Siegler, Inc., 34-01 38th Avenue, Long Island City, New York 11101

CTC-16	21FBP22	1	21	70	261	1	2	2	1	1	2	25	3
CTC-17	23EGP22	2	23	90	282	1	2	2	1	1	2	25	3
CTC-17	25AP22	2	25	90	295	1	2	2	1	1	2	25	3

Olympic offers a variety of 21-, 23-, and 25-inch color combinations, and 21- and 23-inch consoles in various furniture styles. Color combinations have an exclusive "Sound Control Center" that lets you play TV, radio, and phono at the same time in three separate rooms. 25-inch combinations have AM-FM/FM "Stereoplex" radio with 70-watt (peak) solid-state amplifier, along with a deluxe stereo record changer with low-mass tubular arm, featherweight cartridge, diamond stylus, and professional-size turntable. Color sets have automatic picture purifier and instant "Color On" indicator.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
PACKARD BELL CO., 12333 West Olympic Boulevard, Los Angeles 64, California													
—	—	1	21	70	261	1	1, 2	2	1	2	1	25	1
98	—	2	23	90	282	1	1, 2	2	1	2	1	25	1
—	—	2	25	90	295	1	1, 2	2	1	2	1	25	1

Packard Bell's 40th anniversary color-TV ranges from table models to combinations in all-hardwood handcrafted cabinets in a variety of styles. Customers may select models with 21-inch round color tubes at lower prices, or models with new rectangular tubes for larger pictures and slimmer cabinets.

Every Packard Bell color-TV includes "Instant Color Purity" (patent pending) which removes magnetic interference and clears the picture at the touch of a button.

The exclusive Packard Bell "Remote Control Ready" system offers a choice of four remote controls at any time, when set is purchased or later. Every chassis is 100% hand wired and handcrafted with power transformer protection.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
PHILCO CORP., Tioga and "C" Streets, Philadelphia, Pennsylvania 19134													
17KT50	19FXP22	2	19	90	180	1	1, 2	2	2	1	2	24	2, 3
16M91	21FBP22	1	21	70	295	1	[a]	2	1	1	2	24	2, 3
16M91	21FJP22	1	21	70	295	1	1, 2	2	1	1[b]	2	24	2, 3
16NT82	23EGP22	2	23	92	282	2	1, 2	2	2	1	2	24	2, 3
16QT85	25AP22A	2	25	90	295	1	1, 2	2	2	1	2	24	2, 3
16QT85A	25AP22A	2	25	90	295	1	1, 2	2	2	1	2	24	2, 3

[a]Separate safety winding; [b]Not in all models

The new 27-model line includes a 19-inch portable, featuring a Philco-built "Super M Spectro" color tube, and 19-, 21-, 23-, and 25-inch tube sizes. Many models feature a solid-state power-gated signal system which requires ⅓ less tubes, sustains signal power better, and lasts much longer.

Manufacturer's suggested retail prices begin at $369.95 for a 21-inch table model in a metal cabinet and range to $1195 for a home theater combination which includes 25-inch rectangular TV, solid-state hi-fi record player, and a solid-state FM-stereo/FM-AM radio. The company offers 16 models in the $400 to $600 price range where most color-TV business is presently being done.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
RCA SALES CORP., 600 North Sherman Drive, Indianapolis 1, Indiana													
CTC-16X	21FJP22A	1	21	70	265	1	1, 2[a]	2	1	1[b]	1[c]	25	2, 3
CTC-17X	25AP22A	2	25	90	295	1	1, 2	2	1	1	1[c]	25	2, 3
CTC-19	19EYP22	2	19	90	180	1	1, 2	2	1	1	1[c]	24	2, 3

[a]Price-leading model is uncapped; [b]Price-leading models have no degausser; [c]Some models only

The largest RCA Victor color television line in history, optionally priced from $349.95 to $1400 features thirty-nine 19-, 21-, and 25-inch receivers. Highlights include the industry's first "Automatic Color Purifier," a brighter "Hi Lite" picture tube, and new compact styling. The majority of RCA's new color line is priced below $600. A growing segment of RCA Victor color-television sales includes high-performance home-entertainment centers. Eleven of these combinations, including eight 25-inch sets, are featured in the current line, starting at a new low optional retail price of $650. Mobility is started with an all-wood swivel consolette and two console models with casters. One-knob tuning for both v.h.f. and u.h.f. reception is a feature of all new RCA Victor models above the price leader, while a tone control is used throughout the entire line of the latest RCA color-television receivers. RCA also hopes to make a 15-inch rectangular color tube available in 1966.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
SETCHELL-CARLSON, INC., New Brighton, St. Paul, Minnesota 55112													
U802	23EGP22	2	23	92	282	2	1	2	1	1	2	24.5	2, 3
U802	25AP22A	2	25	90	295	1	1	2	1	1	2	24.5	2, 3

The advanced design of Setchell-Carlson "Unit-Ized" color television is special throughout, accenting outstanding picture and sound performance along with beauty, dependability, and long life.

The exclusive "Unit-Ized" modular chassis construction permits on-the-spot determination of service problems. By removing a suspected module and plugging in a known working one, the technician can test the set immediately.

Precious hardwood fine furniture cabinets, in selected veneers and solids, are hand assembled and finished to complement the finest decor. Setchell-Carlson color sets are available in a choice of 23- and 25-inch CRT sizes.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
SYLVANIA ENTERTAINMENT PRODUCTS CORP., 700 Ellicott Street, Batavia, New York 14021													
D01	21FBP22	1	21	70	260	1	—	2	1	1	2	24	3
D02	25CP22	2	25	90	295	1	1	2	1	1	2	25	3
D03	19FMP22	2	19	90	180	1	1	2	1	1	2	24	4

The 1966 Sylvania color-TV line offers 19- and 25-inch rectangular and 21-inch round tube sets. Each has automatic degaussing and "Color Bright 85" CRT's. Suggested list prices range from $369.50 to $419.50 for the 19-inch sets; $599.50 to $819.50 for 25-inch consoles; $349.50 to $399.50 for 21-inch table models; and $409.50 to $529.50 for 21-inch consoles. Eight 25-inch rectangular color-TV home entertainment centers are available. Prices range from $875 to $1400. These units also contain the "Color Bright 85" tube. All sets are available in a variety of finishes and styles.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner: 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
WESTINGHOUSE ELECTRIC CORP., TV-Radio Division, Metuchen, New Jersey													
V-2488-1	21FBP22A	1	21	70	265	1	—	2	1	1	2	25	1, 4
V-2488-2	21FBP22A	1	21	70	265	1	1, 2	2	1	1	2	25	1, 4
V-2488-3	21FJP22A	1	21	70	265	1	1, 2	2	1	1	2	25	1, 4
V-2489-1[a]	23EGP22	2	23	90	278	1	1, 2	2	1	1	2	25	1, 4
V-2650-1	21FBP22A	1	21	70	265	1	—	2	1	1	2	25	1, 4
V-2650-2	21FBP22A	1	21	70	265	1	—	2	1	1	2	25	1, 4
V-2650-3	21FJP22A	1	21	70	265	1	1, 2	2	1	1	2	25	1, 4
V-2650-8	23EGP22	2	23	90	278	1	1, 2	2	1	1	2	25	1, 4
V-2650-8	25CP22A	2	25	90	300	1	1, 2	2	1	1	2	25	1, 4

[a]Some models use a 25CP22A

"Instant On," a Westinghouse innovation in TV, gives sound and picture within six seconds. It also guards against humidity damage to components, and tube filaments are protected from sudden initial power surges for longer life.

Up to 25 kv. of picture power combined with newly discovered phosphors produce more intense reds, more natural blues and greens. Instant color fidelity automatically cancels magnetism when the set is turned on, preventing color distortion on color pictures and unwanted color in monochrome reception. Memory fine tuning automatically returns to the correct setting when channels are changed so as to produce the best sound and picture.

Chassis No.	Picture Tube: Type No.	Shape 1. Round 2. Rect.	Tube Size (in.)	Defl. Angle (deg.)	Screen Area (in.²)	Phosphor 1. Rare earth 2. All sulphide	Faceplate 1. Bonded 2. Etched	Tuner: 1. Tube 2. Trans. UHF	Tuner VHF	Degauss. 1. Auto 2. Man. 3. None	Remote Control 1. Yes 2. No	Pix Tube Volts kv.	Chroma Ckts. 1. I & Q 2. R & B 3. Lo-level 4. Hi-level
ZENITH RADIO CORP., 1900 North Austin Avenue, Chicago, Illinois 60639													
24MC32 and 24MC42	21FBP22 or 21FJP22	1	21	70	265	1	[a]	2	1	3[b]	1[c]	25	—
24NC31	21FJP22	1	21	70	265	1	1, 2	2	1	1	1[d]	25	—
25MC36 and 25MC46	25GP22 or 25AP22	2	25	90	295	1	1, 2	2	1	1	1[e]	25	—

[a]Taped; [b]In four models; auto in others; [c]In one model, none in others; [d]In two models, none in others; [e]In four models, none in others

Zenith's 1966 color-TV highlights a new low-priced $349.95 (manufacturer's suggested retail price) table model, eleven different 21-inch receivers under $500, and a series of 25-inch rectangular screen sets starting at $625 (manufacturer's suggested retail price).

All consoles and combinations come in a popular furniture styling, many of fine veneers combined with selected hardwood solids. These apply to both 21- and 25-inch models.

Built better and handcrafted to last longer, each Zenith color set has a horizontal chassis with no printed circuits; advanced color demodulator; handcrafted 82-channel tuning system; new "Sunshine" picture tube for more brilliant color and black-and-white pictures; and very convenient operating controls. ▲

SOME FURTHER NOTES ON COLOR RECEIVERS

IN the area of small-screen color sets, **General Electric** recently made available details of its "Porta-Color" 11-inch color set. (This set will be covered fully in a forthcoming issue of this magazine.)

The new 11-inch rectangular tube (11SP22) has a 60-square-inch viewing area, uses rare-earth phosphor, and like its big brothers, employs the shadow-mask principle. Unlike them, however, the three guns are arranged in a horizontal line with the green gun in the center. A simple magnet arrangement causes the three beams to impinge on the shadow mask in the conventional triangle pattern. Unlike the large-screen sets, the new 11-incher does not have a separate dynamic convergence system. The color circuitry used with this set has been reduced to the absolute essentials.

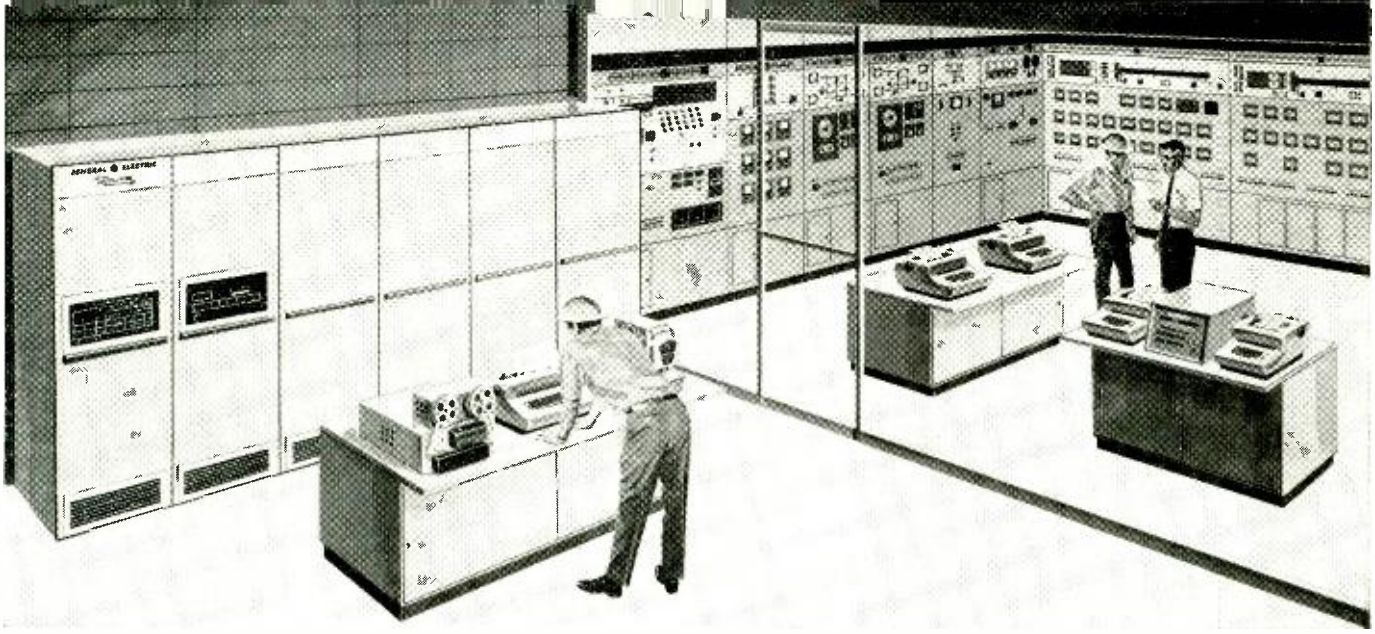
Another major manufacturer (**RCA**) has announced imminent production of a 15-inch rectangular color tube also using the three-gun, shadow-mask principle and rare-earth phosphor. The company hopes to demonstrate a set in the very near future.

While on the subject of small-screen color sets, visitors to the Japan Pavilion at the New York World's Fair may have noticed a number of small (6- to 9-inch) screen color sets. Several of these use a form of one-gun CRT while others use reduced versions of the three-gun system. Talks with company representatives brought out that these sets will not be imported to the U.S. until their relatively high prices can be brought down considerably.

Besides color sets, antennas for color reception are also in the news. According to one source, one West Coast store reported returns as high as 20% of newly bought color sets due to inadequate antenna installations. In Salt Lake City, it was discovered that 50% of complaints on new color sets were due to the lack of an adequate antenna. Most complaints were cleared up with the installation of a good antenna system.

There are many electronic innovations in the 1966 line of color sets. However, cabinet styles, another great area of customer appeal, have changed drastically this year. With the introduction of the short-neck rectangular color CRT, cabinet designers are able to create very appealing cabinets in a great variety of styles, and no longer must the customer be limited to the boxy look of past years.

According to one industry source, buyers of 1966 color sets will have more than 100 additional models to choose from over the 1965 models. This is a gain of almost 200 models over those available in the 1964 color line.



The powerful new G-E PAC computer is designed specifically for industrial process control. It can be used to provide set points for the conventional types of controllers or it can directly actuate process valves and motors.

COMPUTER CONTROL *of* INDUSTRIAL PROCESSES

By ED BUKSTEIN / Northwestern TV & Electronics Institute

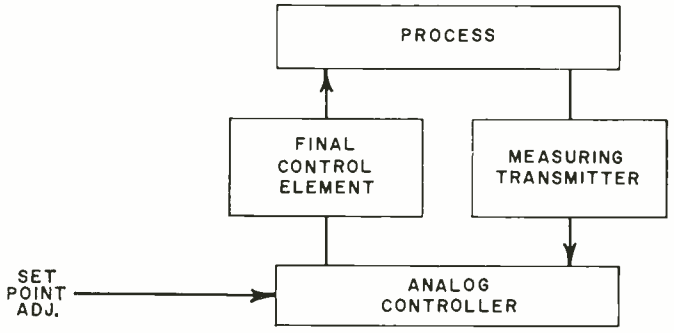
With special computers controlling industrial processes, costs are reduced and higher product quality is obtained.

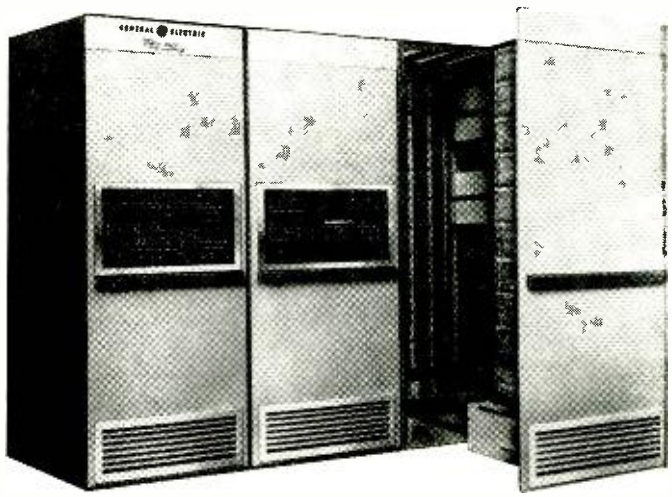
HAVING earned a respected place in the business world and in science, the digital computer is now establishing itself as an industrial worker *par excellence*. Computer control of industrial plants leads to reduced operating costs and to products of consistently higher quality.

Typically, industrial process control involves the regulation of hundreds of variables, such as temperature, pressure, humidity, viscosity, thickness, liquid level, flow rate, position, and others. Analog controllers in error-correcting feedback loops have been widely employed for control of these variables. Digital computers, however, are now entering the picture to aid or replace the analog-type controllers.

A conventional configuration for an analog controller is shown in Fig. 1. The transmitter is a measuring device whose output is proportional to the temperature, pressure, flow rate, or other process variable to be controlled. This output may be either electrical or pneumatic. Pneumatic transmitters produce output pressure in the range of 3 to 15 pounds per square inch. This pressure signal, representing the value of the process variable, is transmitted through a hollow line to the controller. *Electrical* transmitters produce either current output in the range of 4 to 20 ma. or voltage output in the range of 0 to 50 mv. As in the case of the pneumatic signal, the electrical signal is a representation (analog) of the process variable to be controlled.

Fig. 1. Typical analog control loop. Process variable, such as temperature or pressure, is held constant to a set amount.





Computer features roll-out construction to simplify maintenance.

In the controller, the signal from the transmitter is compared to the *set-point*. Set-point is a manual control adjusted by the operator to represent the desired value of the process variable. If there is a difference between the desired value (set-point) and the actual value (transmitter output), the controller produces a corrective signal. This signal is applied to the *final control element*: a valve in the flow line, for ex-

ample. Controller output, like transmitter output, may be either electrical or pneumatic. In either case, the final control element adjusts the process variable to the desired value.

Fig. 1 represents a single *loop;* dozens or even hundreds of such loops may be required to control an industrial plant. The many set-points are adjusted by experienced operators who presumably can predict the effect of each set-point on the final product quality. In actuality, human reaction time is not always adequate to cope with sudden disturbances in the process and with the complex interactions of one variable on the others. It is to deal with this problem of set-point adjustment that the digital computer has entered the picture.

Open-Loop Digital Controller

An open-loop configuration employing a digital computer is shown in Fig. 2. The analog portion functions as a closed-loop system as in Fig. 1, but the digital computer operates in an open-loop mode. A signal from the measuring transmitter keeps the computer informed about the status of the process. This is an analog signal (pneumatic pressure, voltage or current proportional to the value of the process variable) and is

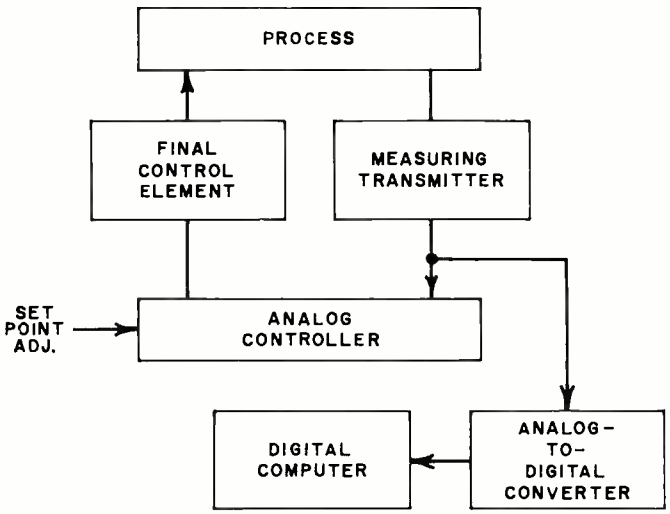


Fig. 2. Open-loop digital controller. Operator adjusts set-point in accordance with indications provided by computer.

not directly acceptable by the computer. An analog-to-digital converter is therefore employed to produce a digital equivalent of the analog signal.

The primary purpose of the computer in Fig. 1 is to tell the operator when to readjust the set-point. Programmed with equations representing the process characteristics, the computer calculates the optimum setting. Because of its high speed, the computer can indicate corrective action before the process has deviated significantly from the desired value. In addition to actuating an alarm when an off-limit condition occurs, the computer may also serve as a data logger. Using a typewriter or other output device, it produces a record of process behavior and variations. Such records are analyzed in order to obtain more accurate formulas and improved mathematical models of the process.

Closed-Loop Digital Controller

After a sufficiently accurate mathematical model of the process has been obtained, the digital loop can be closed. A configuration of this type is shown in Fig. 3. Here, the computer not only calculates the optimum set-point but actually adjusts it. As shown, the output of the digital computer is applied to a digital-to-analog converter to produce an analog type set-point signal. The human operator is now out of the picture except that a manual override feature is available for emergency use in case of computer failure. By using time-sharing techniques (multiplexing), the computer in Fig. 3

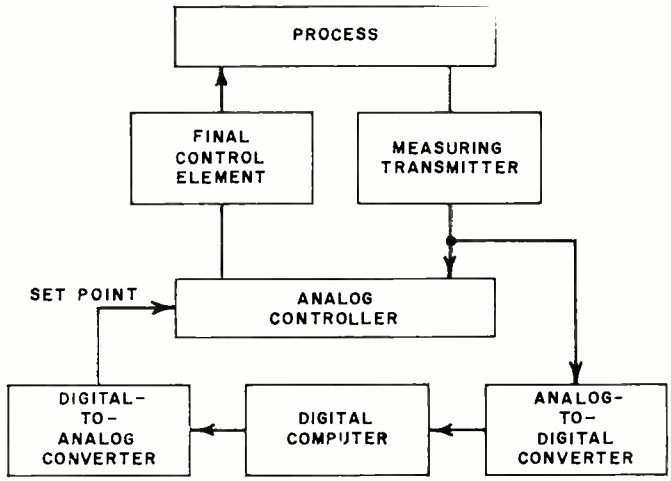


Fig. 3. Closed-loop digital controller. The computer not only calculates the set-point value but also adjusts it.

can perform the computations and adjust the set-points for hundreds of control loops employed in an industrial process.

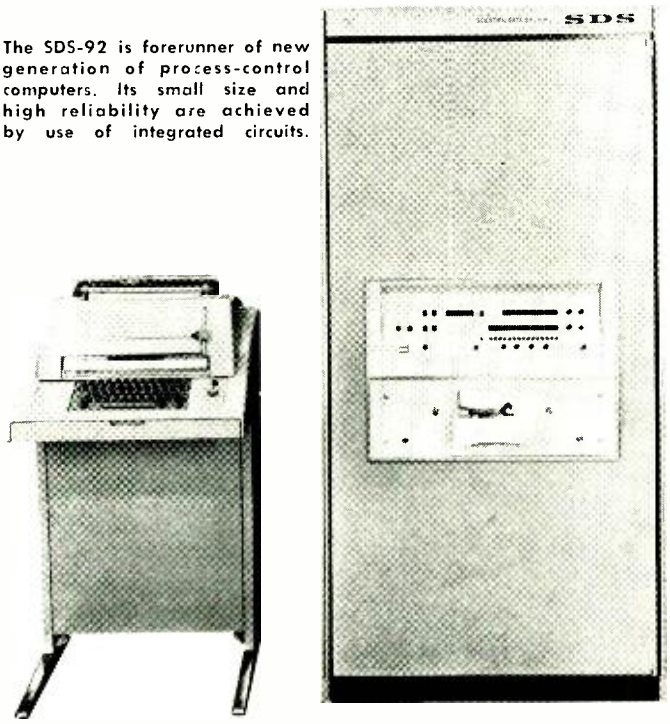
Two important advantages of closed-loop digital control are (1) faster and more effective response to uncontrollable process disturbances, such as changes of ambient temperature and variations of quality of raw materials, and (2) the computer can be programmed according to a profitability expression so that the system tends toward maximum profit rather than just maintaining constant values of system parameters.

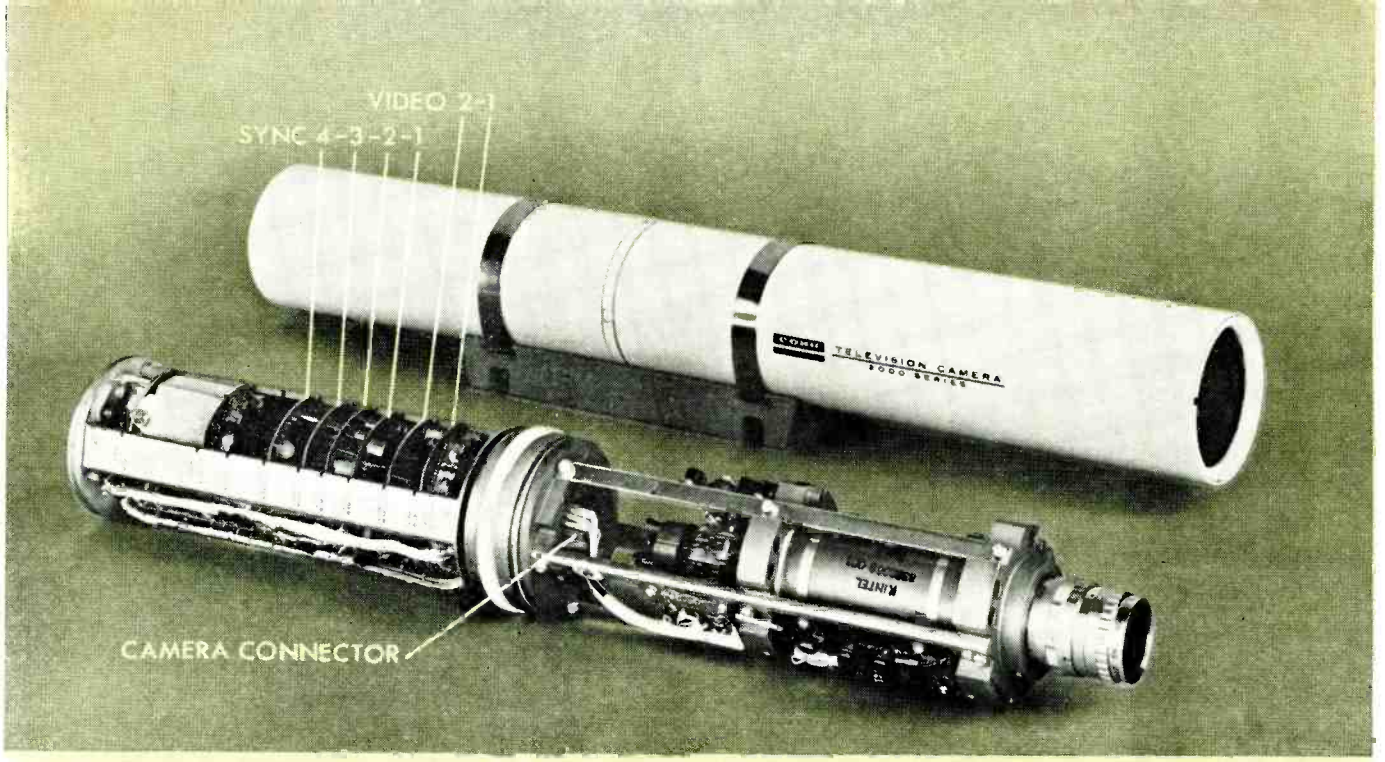
Direct Digital Control

One of the brightest stars on the industrial horizon is direct digital control (DDC). The techniques illustrated in Figs. 2 and 3 employ the digital computer as an "added attraction" to conventional analog control systems. DDC attacks the problem at a more fundamental level, employing the computer as a *replacement* for the analog controller.

A typical configuration for DDC is shown in Fig. 4. By means of appropriate transducers, process variables such as pressure, flow rate, are converted to corresponding electrical signals. These signals are sampled one at a time in rapid succession by the input scanner. Typically, the scanner is an array of relays whose contacts connect the input signals in succession to the analog-to-digital converter. The digital signals are then processed in the computer, whose memory includes the allowable limits for (*Continued on page* 75)

The SDS-92 is forerunner of new generation of process-control computers. Its small size and high reliability are achieved by use of integrated circuits.





OPERATION OF A HIGH-QUALITY CCTV CAMERA

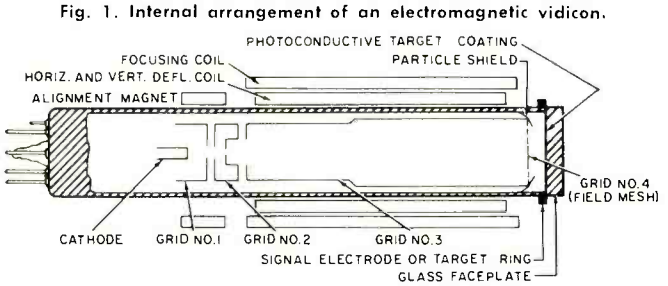
By GERALD L. HANSEN, Cohu Electronics, Inc.

Electromagnetically scanned vidicon, broadcast-type interlaced sync, automatic vidicon target control, and digital-type techniques make this approach much more sophisticated than those usually encountered.

SINCE the advent of the transistor and subsequent miniaturization of associated components, a constant revolution has been taking place in the field of closed-circuit television (CCTV). In the past, cabinets bulged at the seams with power supplies, cumbersome amplifiers, and sync generators, while cooling fans desperately tried to maintain a reasonable temperature. High-quality CCTV units are available today that can be held comfortably in one hand and outperform their predecessors in almost every respect. A typical unit may contain deflection circuitry, video amplifiers, broadcast-type interlaced sync generators, power supplies, and perhaps an r.f. modulator, yet may require less power than a standard 10-watt light bulb.

Units of this type are being utilized increasingly in industry and business and are in fact finding such widespread use that the average technician may suddenly find himself confronted with the rather awesome task of servicing one. These systems are also creating employment opportunities for technicians in areas considered—until now—highly unlikely. The range of applications is broad—mining and drilling operations, research laboratories, churches, schools, hospitals, prisons, factories, and homes. The prediction that a television camera and TV tape recorder will some day replace the home movie camera seems close to realization.

Fig. 1. Internal arrangement of an electromagnetic vidicon.



However, there is surprisingly little information available through normal channels for those who would like to become familiar with these latest CCTV systems.

Vidicon

The vidicon (Fig. 1) might be called the "heart" of a CCTV system. It has the important function of converting the image focused upon it into electrical signals that can be amplified and processed for final use in the monitor or receiver. Directly behind the glass faceplate of the vidicon is a transparent electrode coated with a layer of photoconductive material. This layer is called the "target." The target material varies in resistance in proportion to the amount of light falling upon it. When the beam emitted from the cathode strikes the target material, the brilliantly illuminated portions offer less resistance and pass the electrons more readily than do the dark areas. A positive voltage applied to the target electrode drains these electrons through a resistor, causing a signal to be developed. Therefore, when the beam is scanned across the target (exactly as is done on a TV picture tube), a video signal is developed that contains all the information necessary to reproduce the scene focused upon the target.

The vidicon can be thought of as a miniature picture tube operating in reverse (converting light into signals rather than signals into light). As shown in Fig. 1, grid #1 controls the amount of electron beam allowed to pass from the cathode to the target, accelerating grid #2 speeds up the electron flow,

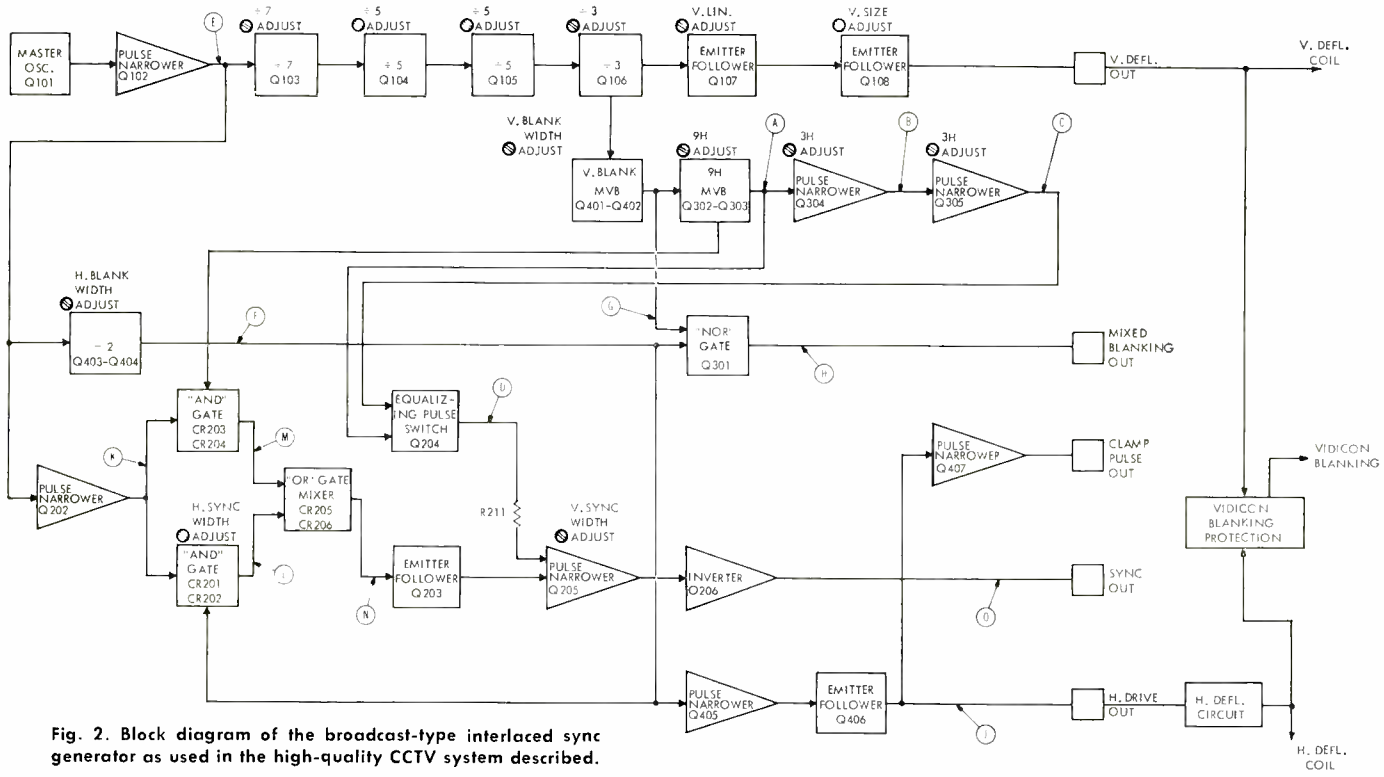


Fig. 2. Block diagram of the broadcast-type interlaced sync generator as used in the high-quality CCTV system described.

while focusing grid #3 controls the spot size. Beam deflection is accomplished electromagnetically by placing a yoke around the tube. An electromagnetic focus coil is also incorporated in the yoke. An alignment magnet completes the setup.

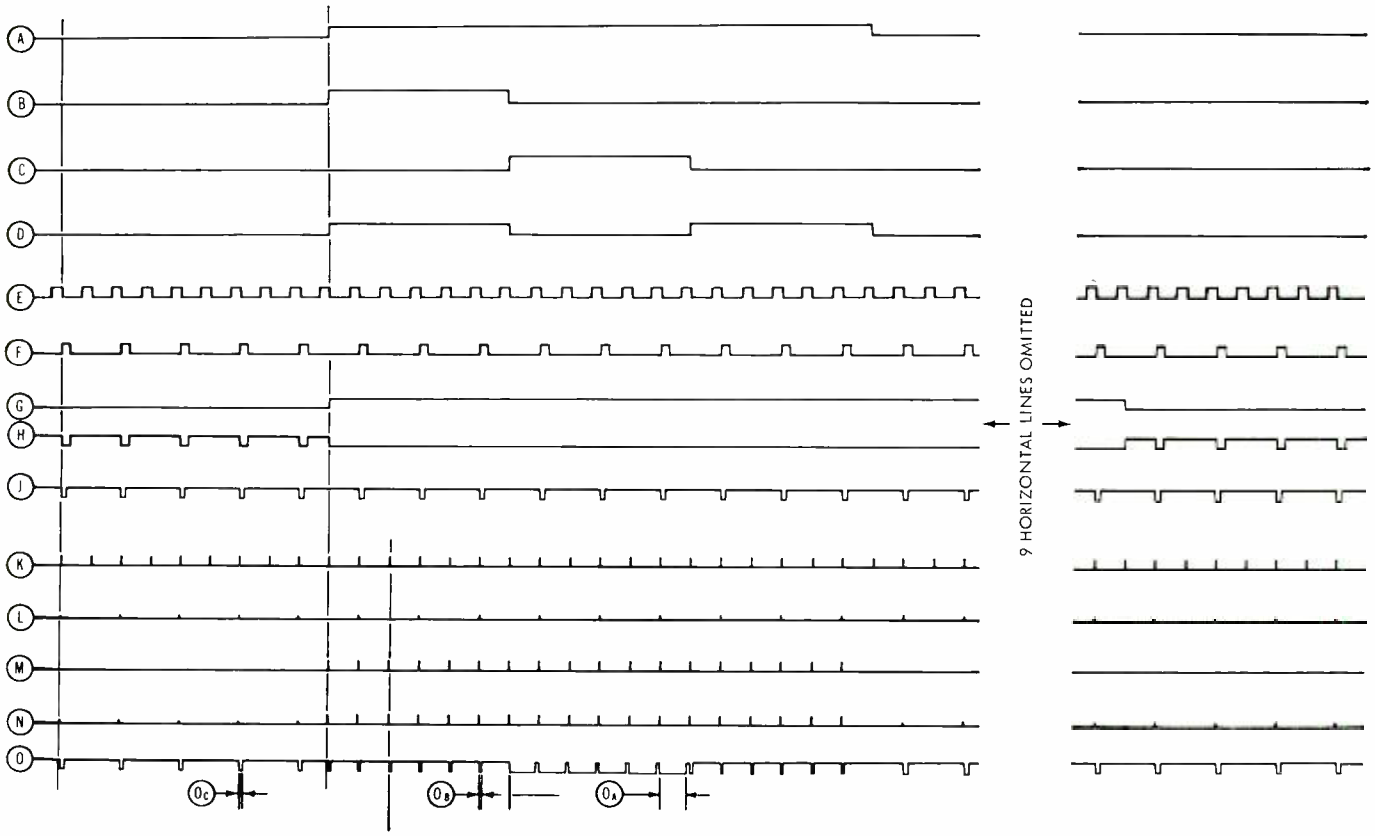
Circuit Operation

Fig. 2 is a functional block diagram showing one method of obtaining the necessary deflection signals for the vidicon yoke while also providing the broadcast-type sync which is necessary for a stable 2:1 interlace of the horizontal lines in the raster on the monitor picture tube. Fig. 3 illustrates the waveforms found in that circuit. The characteristic reliability and stability of this system are such that it has been accepted for use in commercial broadcast TV.

Operation is timed by master oscillator Q101, operating at a frequency of 31.5 kc. Its output supplies succeeding stages to provide the necessary horizontal, vertical, blanking, and clamp signals.

Several pulse narrower circuits are utilized to shape and control the duration of various pulses throughout the circuitry.

Fig. 3. Waveforms present in the sync generator. Letter identifications are keyed to block diagram of Fig. 2.



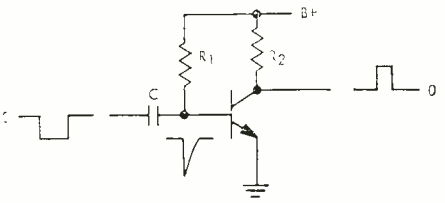


Fig. 4. Operation of a pulse narrower.

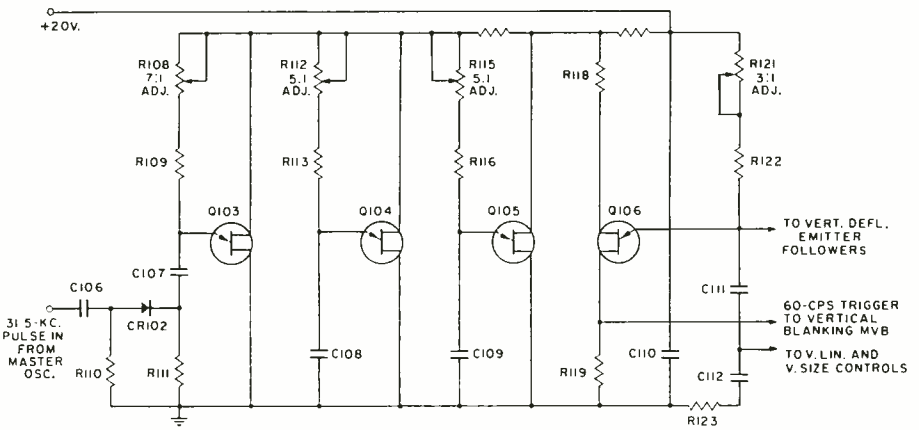


Fig. 5. Unijunction countdown circuit divides by 525 to generate 60-cps pulse.

Fig. 4 shows the basic pulse narrower. Under no-signal conditions, *R*1 supplies the bias current to saturate the *n-p-n* transistor, reducing the collector voltage to approximately ground potential. Negative-going pulses are differentiated by the *RC* network while the emitter-base diode action clips the positive transition. The negative input drives the transistor out of saturation, producing a positive pulse at the collector. Pulse width is determined by the values of *R*1, *C*, and the input pulse amplitude. All *n-p-n* narrowers operate in the same manner, but the *p-n-p* narrower differs only in input and output polarity. If *R*1 is made variable, output pulse width may be varied.

The master oscillator output is fed through pulse narrower Q102 (Fig. 2) into frequency-dividing network Q103, Q104, Q105, and Q106 (shown schematically in Fig. 5) that provides a total division of 525 for an output frequency of 60 cps. Unijunction relaxation oscillators are used for the dividers and are triggered in the following manner. The positive output from pulse narrower Q102 is applied through *CR*102 and *C*107 to the emitter of Q103. Resistor *R*108 is adjusted so that the circuit's natural period of oscillation (determined by the *RC* time constant in the emitter circuit) allows Q103 to fire on every seventh input pulse. The resulting conduction through Q103 produces a negative pulse across the "B+" series resistors. The negative pulses thus derived are felt at base #2 of Q104 as triggering, and this stage is adjusted to divide by a factor of five. Q105 and Q106 are each triggered in the same manner by the stage immediately preceding each one and are adjusted to divide by five and three respectively.

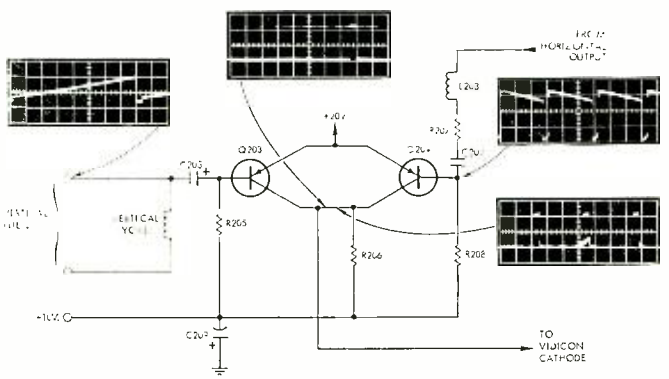
Since the waveform at the emitter of Q106 is a sawtooth, it may be utilized as a source of vertical deflection. It is linearized by a feedback arrangement in emitter follower Q107 (Fig. 2) and applied to emitter follower Q108 where a simple amplitude adjustment allows control over vertical size. The linearized, shaped, and amplified sawtooth is applied directly to the yoke for vertical deflection.

It should be noted that Q106 also provides an output at its base 1 terminal. In Fig. 2, it can be seen that this output is fed into the vertical blanking multivibrator, Q401-Q402. This is a one-shot or monostable multivibrator with a variable-width output used to obtain a positive pulse of the width needed for vertical blanking. This pulse, in turn, is fed into a *nor* gate (Q301) to be inverted and mixed with horizontal blanking. It later will be superimposed on the video waveform and used for blanking information in the monitor.

Horizontal blanking is obtained by dividing the master oscillator frequency by two and shaping the output into a pulse of the required width. This is accomplished by transistors Q403-Q404 which constitute an astable multivibrator having a natural frequency of approximately 15,750 cps. Triggering of this circuit is accomplished by feeding it the 31.5 kc. from pulse narrower Q102. Due to the time constants inherent in the circuit and the input pulse amplitude, the circuit uses every second pulse as a trigger and changes state accordingly, giving a variable-width pulse output to be combined with the vertical blanking in *nor* gate Q301. The multivibrator output is also routed to pulse narrower Q405 and emitter follower Q406 to shape a horizontal drive pulse used to develop the horizontal deflection component for the vidicon yoke.

The trailing edge of the horizontal drive pulse from emitter follower Q406 is used by pulse narrower Q407 to develop a clamp pulse which is routed to the video amplifier to maintain the black reference level during vidicon retrace.

Fig. 6. Vidicon protection circuit operates if pulses fail.



Vidicon Blanking

Circuit configuration for the vidicon protection and blanking function is shown in simplified form in Fig. 6. The collectors of Q203 and Q204 (*not* sync transistors Q203, Q204) are common to each other, and connection is made to the vidicon. Normally, the vidicon cathode is slightly negative in potential to assure proper emission of electrons. However, during the negative-going retrace portion of the horizontal and vertical deflection waveforms, either Q203 or Q204 will be driven into saturation. This causes the +20 volts applied at the emitter of the conducting transistor to be felt at the vidicon cathode, forcing it into cut-off. Thus, the vidicon will be blanked during retrace time.

We now have derived all of the drive and blanking pulses that are necessary for proper operation of a CCTV system. The final requirement is a synchronizing signal that can be added to the video output so that the monitor deflection oscillators will operate synchronously with deflection oscillators of the camera system.

Probably the easiest way to understand the operation of the sync circuitry is to refer to the waveform diagram shown in Fig. 3, keyed to the block diagram of Fig. 2.

The output pulse width of narrower Q202 determines the delay of the sync pulses (*O*) with respect to the blanking pulses (*H*). This produces the familiar front porch. The output from narrower Q202 is fed to two *and* gates. For *and* gate 1 (*CR*201-*CR*202) to conduct, there must be a pulse present from the horizontal blanking multivibrator. Therefore, the 31.5-kc. signal has every second pulse blocked, and the output

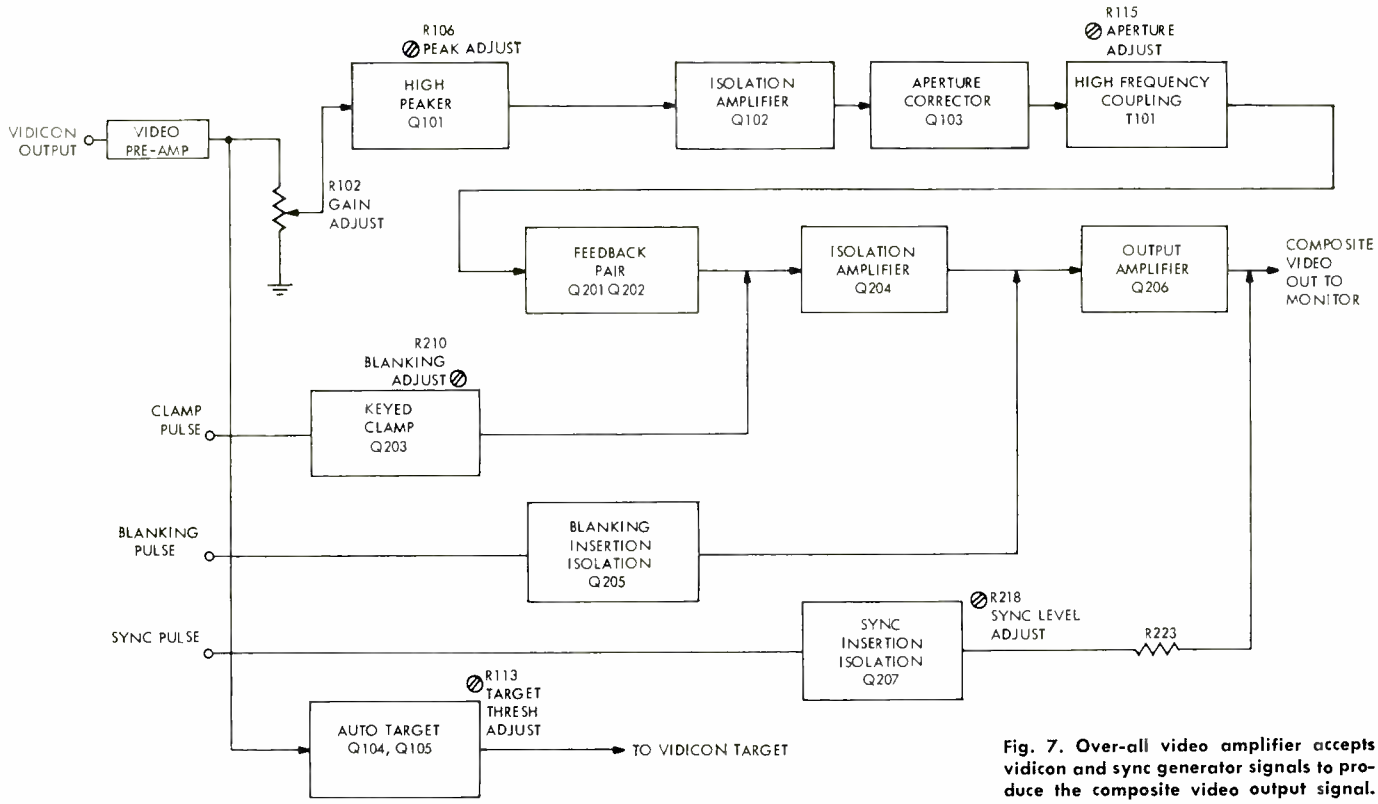


Fig. 7. Over-all video amplifier accepts vidicon and sync generator signals to produce the composite video output signal.

from this gate is at the rate of 15,750 cps (L). An adjustable resistor provides control over horizontal sync width by setting the amplitude of the pulse (L) felt at the following *or* gate. *And* gate 2. ($CR203$-$CR204$) conducts only during the 9H pulse (A). (This pulse-width duration is nine times that of one complete cycle of the horizontal frequency and is keyed by the vertical blanking multivibrator.) Output of *and* gate 1 is mixed in the *or* gate with the output of *and* gate 2. The output (N) of the *or* gate is fed through emitter follower $Q203$ to sync pulse narrower $Q205$. Because the sync pulse narrower uses the trailing edge of its input pulses, a time delay is achieved which determines front porch width.

The RC time constant of sync pulse narrower $Q205$ circuit is adjusted to provide the pulse width (O_A). However, during equalizing-pulse time (O_B), switch $Q204$ is turned on, connecting $R211$ in parallel with the sync width control. This changes the output-pulse width of narrower $Q205$ to that of equalizing pulses.

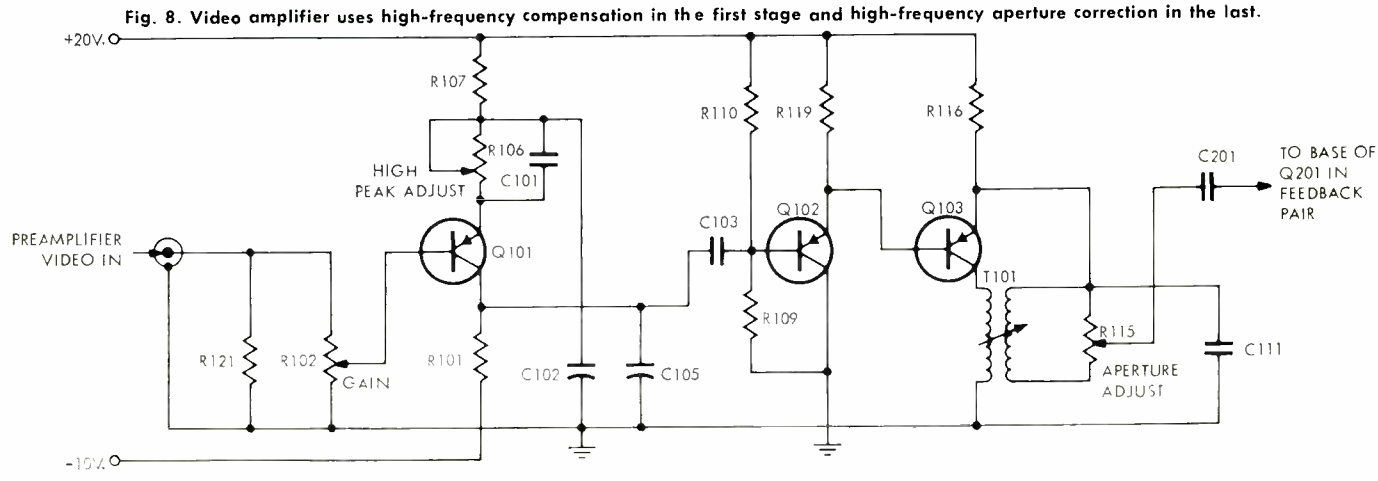
The sync-equalizing interval-pulse switch $Q204$ is operated by pulses from the 9H multivibrator $Q302$-$Q303$ and the second 3H pulse narrower $Q305$. It can be seen from the waveforms that the equalizing-pulse switch conducts during the 9H interval but is interrupted for a period of 3H by the output of pulse narrower $Q305$ as shown in Fig. 3 (D).

Video Signal

Fig. 7 is the functional diagram of a typical video chain. Output from the vidicon is amplified initially by a video preamplifier consisting of an emitter-follower input stage to match the high-impedance output of the vidicon to the lower impedance of the following transistorized amplifier circuitry. Gain of the circuit is approximately 30 db and is accomplished by a feedback pair arrangement that tends to flatten the over-all frequency response of the preamplifier. An emitter follower provides isolation and impedance matching.

The output from the preamplifier is routed into the main amplifier through "Gain Adjust" $R102$. Fig. 8 shows this control and the three interesting stages that follow it. $Q101$ has a variable resistor and capacitor network in its emitter circuit to provide frequency-selective amplification, thus compensating for attenuation of higher frequency components which occurs in the preamp input stage as a necessary adjunct to maximum signal-to-noise ratio. If this resistance ($R106$) is set too low, trailing whites will be observed behind black information on the monitor. If it is set too high, trailing blacks will be in evidence. Proper adjustment gives sharp, (*Continued on page* 00)

Fig. 8. Video amplifier uses high-frequency compensation in the first stage and high-frequency aperture correction in the last.



RARE-EARTH PHOSPHORS FOR COLOR-TV TUBES

By R. C. MILLER, Engineering Manager
and T. V. RYCHLEWSKI, Development Engineer
Electron Tube Div., Sylvania Electric Products Inc.

A new red phosphor which improves brightness by 43 percent is being used in color-TV picture tubes.

A BREAK-THROUGH in color-television picture tubes was announced by *Sylvania Electric Products Inc.* in June, 1964—a new red phosphor for use in making color-television screens. Since that time, the company has been using the new red rare-earth phosphor. With the utilization of the new phosphor, an improvement of 43% in brightness gain over the existing industry standard tubes was realized. The use of the new red allowed using the green phosphor to its fullest brightness capabilities instead of subduing it because of balance requirements with the previous red. To some extent this applies to the blue phosphor as well. Opening up the green along with the brighter red led to the new brighter color tube.

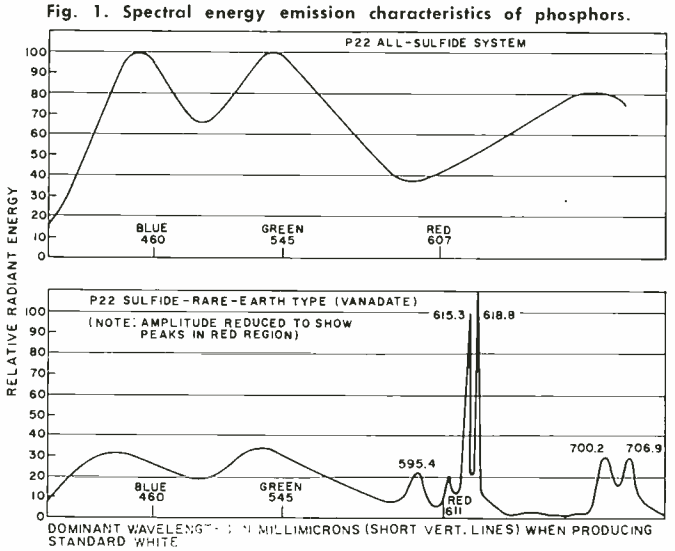
Although the brightness gain is important, still another equally important advantage is realized. The new red phosphor is a richer red; and unlike the color of the previous red phosphor, the new red color remains a rich red even when made considerably brighter by using higher gun-current density. The previous red phosphor shifted to orange under these same conditions.

Other manufacturers of color tubes are also obtaining the necessary rare-earth raw materials so that they too can make the new red phosphor. The whole industry has swung into the rare-earth camp and set manufacturers are employing the new rare-earth color-television picture tube types.

One of the four elements used in making the new red phosphor, europium, is of the rare-earth series and yttrium is similar to the rare-earth series of elements. The remaining two are oxygen and vanadium. The phosphor is actually yttrium vanadate activated by europium ($YVO_4:Eu$). See Fig. 1 for the spectral energy characteristics of the all-sulfide and rare-earth phosphors.

For true color rendition, it is important that each of the primary colors, *i.e.*, red, green, and blue, stay the same color throughout the various conditions of light mixing so that small amounts, or large, as needed, will result in truer representation. Since the new red phosphor color stays the same whether a low 100-μa. beam current or a high 2000-μa. beam current excites it (a ratio of 20 to 1), a truer color representation results over the various ranges of brightness called for in color-television pictures. (See Figs. 2 and 3 for details).

Fig. 1. Spectral energy emission characteristics of phosphors.



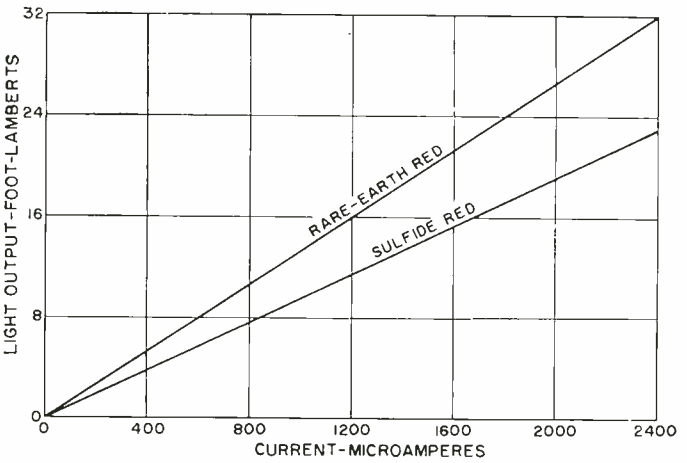


Fig. 2. Brightness comparison for various beam currents.

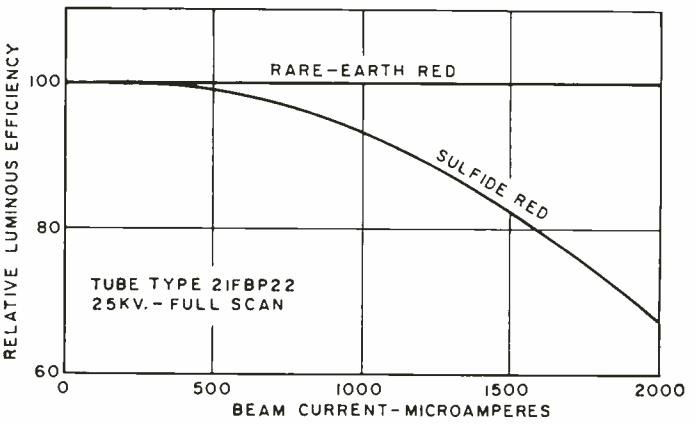


Fig. 3. Luminous efficiency for the red-emitting phosphors.

Viewing resolution, crispness of picture, and color fidelity in the high-brightness areas of a TV scene have all been improved by the rare-earth screen system. Specifically, the necessity for driving the red electron gun current to high levels compared to the green and blue to obtain white has been eliminated. Previously, the increased red gun electron beam size at the higher current (high brightness) condition degraded resolution and resulted in color fringing in dark areas surrounding high light areas.

An additional fact about the new rare-earth phosphor is that its unexcited appearance as a powder is white, like table salt. As a result, the new color-television screens do not have the yellowish look of the older types. Instead, they are much whiter in appearance with only the green sulfide phosphor having a very faint tint of color.

Color-tube manufacturers also find some processing improvements in making the new rare-earth red screen. Since it transmits ultraviolet light in the 3650 Å range instead of absorbing most of it, as did the sulfide red, this action of the new red in the photoresist exposure step is used in making the color phosphor dot patterns. ▲

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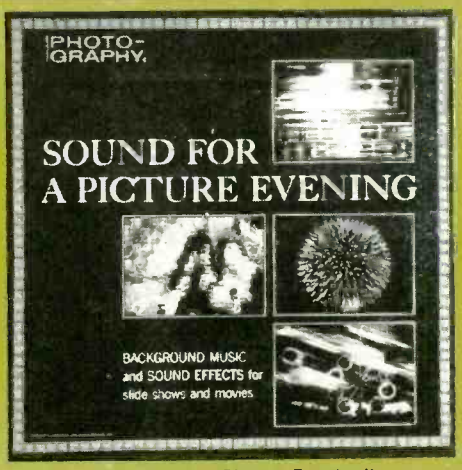

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Essential to the technician's safety is a thoroughgoing knowledge of the potential dangers of electric current.

ELECTRIC SHOCK

"BET you can't guess where I was last night," Barney said to his employer. "I'd probably do better predicting the course of a Mexican jumping bean," Mac growled without looking up from the TV set he was aligning.

"I was at a Red Cross class learning how to apply artificial respiration to a victim of drowning or shock."

"Fine, but what brought this on?"

"I may as well tell you. Last week when I was servicing that photoelectric counter at the spring factory, I darned near electrocuted myself. I'm not used to working on a wet cement floor, and I carelessly got hold of the hot 120-volt lead. For the first time in my life I couldn't let go, but fortunately I staggered backward and broke the connection. See what it did to my finger?"

His extended forefinger revealed a narrow, deep burn edged with whitened, blistered skin.

"Still smells like a butcher-shop incinerator," Barney said, sniffing the wound and wrinkling his nose in distaste; "but I decided that if I were going to spend the rest of my life working in a snake house, I'd better learn the poisonous and the harmless snakes and provide myself with some snake-bite serum. That's why I've really been boning up on just how electric shock injures or kills a human being. Also, when I found out that artificial respiration is the best method of reviving a victim of shock, I went to the Red Cross to learn the modern methods of restoring breathing."

"You know you're busting to tell me what you've learned," Mac said, laying down his soldering gun and reaching for his pipe; "so why don't you sound off?"

"I thought you'd never ask!" Barney exclaimed, heaving himself up on the workbench. "In the first place, it's the electric current that does the damage. Of course, we know current is a function of both voltage and resistance, but the resistance of the human body varies so widely it's impossible to tag one voltage as 'dangerous' and another as 'safe.' People have been killed by less than 50 volts and have survived contact with several thousand volts.

"The resistance of the human body to electric current is divided between internal resistance, such as would be measured between two flayed areas of the body, and skin resistance. Internal resistance varies from about 100 ohms between the ears—and no cracks about the vacuum between *my* ears increasing this value—to about 500 ohms from a hand to a foot. Skin resistance varies from about 1000 ohms for wet skin to more than 500,000 ohms for dry skin. The skin area in contact with the voltage also affects this skin resistance. For example, a man sitting in a grounded tub of water with one hand on the hot side of the a.c. line may present no more than 500 ohms total resistance to the voltage present between the hot wire and ground.

"Electricity damages the body in at least three ways: (1) it harms or interferes with proper functioning of the nervous system and heart; (2) it subjects the body to intense heat; and (3) it causes the muscles to contract. The first effect probably accounts for the most deaths. Normally, the heart contracts at a rate of about 65 beats per minute at the dictation of a built-in pacemaker. Electric current interferes with this pacemaking activity in two possible ways. The current may produce 'ventricular tachycardia' in which the heart beats very rapidly with greatly reduced efficiency that cannot sustain life for long. At currents between 100 and 200 ma., 'ventricular fibrillation' is induced in which the heart produces weak, random contractions that render it nearly useless for circulation of the blood."

"What happens with still more current than 200 ma.?"

"Oddly enough, the victim's chances may be better with the higher current because it causes clamping of the heart muscles and prevents the deadly fibrillation. One writer says that if the heart is exposed to this 100- to 200-ma. current, no power on earth can save him from the resulting fibrillation and death, but I think this needs some qualifying. I know that in certain types of heart surgery ventricular fibrillation has been deliberately induced for a certain length of time so that the quiet heart can be operated upon; then, another shock of a different sort has been used to restore the heart to normal operation. If this 'de-fibrillation' equipment could be used quickly enough on a shock victim, his life might be saved.

"But let's go back to the effect of rising current. At 1 ma., the victim may feel no more than a tingling of the skin. Higher current can cause muscular contractions severe enough to break bones, and it produces a loss of voluntary control over the muscles that freezes a victim to the source of current. A man normally can free himself from a current of 9 ma. or less; a woman, from 6 ma. or less.

"The electric current deadens the center in the brain that controls breathing. At 30 ma., breathing becomes labored and it finally ceases completely at values approaching 75 ma. At or about 100 ma., ventricular fibrillation begins. Beyond 200 ma. the heart muscles are clamped."

"What about really heavy currents measured in amperes?"

"We know about the effect of these from autopsies performed on criminals executed in the electric chair. In a typical execution, 2000 volts single-phase a.c. is applied to moistened sponge-lined electrodes fastened to the shaved head and one leg. Immediately the voltage is dropped to 500 volts and then raised and lowered at 30-second intervals for a total application of two minutes, during which period the current varies from 4 to 8 amperes. There is little doubt circulation and respiration cease at the first contact, and it is believed consciousness is blotted out instantly. The temperature of the body rises abruptly. A temperature of 128°F has been measured at the site of the leg electrode 15 minutes after the execution. The blood is profoundly altered biochemically."

"Let's change the subject," Mac said with a little shiver. "I imagine the path through the body has lots to do with the shock danger."

"And you're right. A current passing from finger to elbow through the arm may produce only a painful shock, but that same current passing from hand to hand or hand to foot may well be fatal. That's why the practice of keeping one hand in your pocket while working on high-voltage circuits and

standing on an insulating material is a good one.

"A.c. is said to be four to five times more dangerous than d.c. For one thing, a.c. causes more severe muscular contractions. For another, it stimulates sweating that lowers the skin resistance. Along that line, it is important to note that resistance goes down rapidly with continued contact. The sweating and the burning away of the skin oils and even the skin itself account for this. That's why it's extremely important to free the victim from contact with the current as quickly as possible before the climbing current reaches the fibrillation-inducing level.

"The frequency of the a.c. has lots to do with the effect on the human body. Unfortunately, 60 cycles is in the most harmful range. At the house-current frequency, as little as 25 volts can kill. On the other hand, people have withstood 40,000 volts at a frequency of a million cycles or so without fatal effects."

"Well, now that we have the victim thoroughly shocked, what can we do to revive him?"

"Apply artificial respiration at the earliest possible minute and keep applying it until a doctor pronounces the victim dead. In one study, about three out of four who received artificial respiration within *three* minutes of the shock lived; but of those who got it *four* minutes after the shock, only 14% survived. In another study involving 700 victims, 479 had stopped breathing, 323 of those were saved by artificial respiration. Most recovered in 20 minutes, but some took as long as four hours to start breathing on their own. It may even take as long as eight hours to revive a victim, and during this period no pulse may be discernible and a limb-stiffening condition similar to rigor mortis may be present. These are manifestations of shock and are not to be taken as evidence the victim has died."

"Well, this has been a most illuminating conversation," Mac said, knocking the ashes from his pipe against the heel of his hand. "Let's see if I can recapitulate your major points:

"1. A very little current can produce a lethal electric shock. Any current over 10 ma. will result in a painful and serious shock.

"2. Voltage is not a reliable indication of danger because the body's resistance varies so widely it's impossible to predict how much current will be made to flow through the body by a given voltage.

"3. The current range of 100- to 200-ma. is particularly dangerous because it is almost certain to result in lethal ventricular fibrillation. Victims of high-voltage shock usually respond better to artificial respiration than do victims of low-voltage shock, probably because the higher voltage and current clamps the heart and hence prevents fibrillation.

"4. A.c. is more dangerous than d.c., and 60-cycle current is more dangerous than high-frequency current.

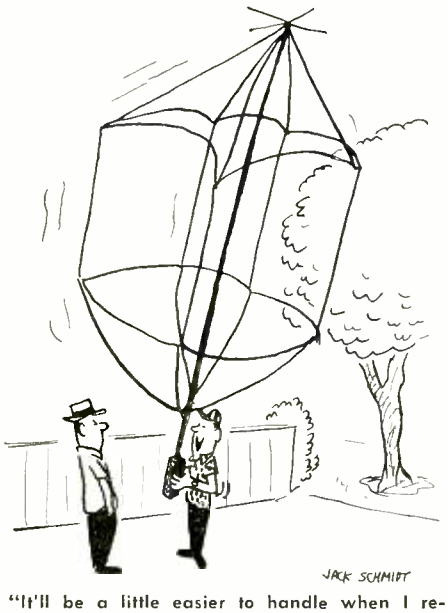
"5. Skin resistance decreases when the skin is wet or when the skin area in contact with a voltage source increases. It also decreases rapidly with continued exposure to electric current.

"6. Prevention is the best medicine for electric shock. That means having a healthy respect for all voltage, always following safety procedures when working on electrical equipment, and constantly keeping in mind that you don't need to take hold of *both* 120-volt wires to kill yourself. Touching the hot wire while in contact with a good ground will fry you just as quickly.

"7. In case a person does suffer a severe shock, it is important to free him from the current as quickly as can be done safely and to apply artificial respiration *immediately*. The difference of a few seconds in starting this may spell life or death to the victim. And keep up the artificial respiration until a physician pronounces the victim dead."

"Hey! That's excellent," Barney applauded. "I didn't know you were such a good listener. I thought you were just a talker. I might conclude by saying that about 750 persons died from electric shock in industry last year, as did 150 who were electrocuted in the home. Considering that we who work with electricity are supposed to be well informed of its danger, that's not very encouraging."

"No, but I think it's the old story of familiarity breeding contempt," Mac said. "Working with electricity day after day, we tend to get careless until an experience such as you had in the spring factory wakes us up. It could well be that shock will save your life." ▲



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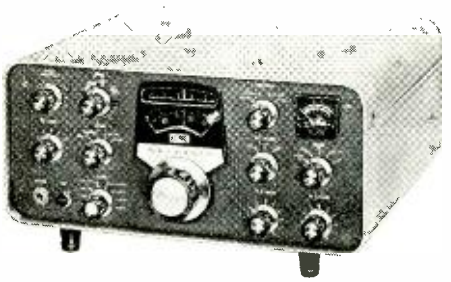

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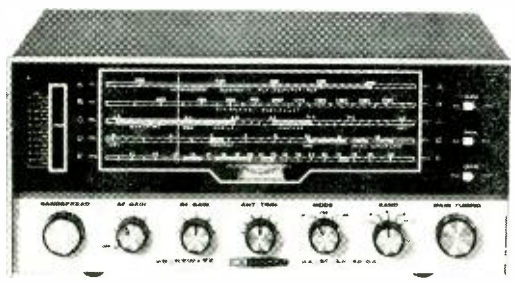

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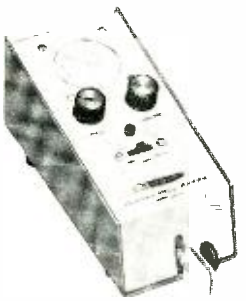

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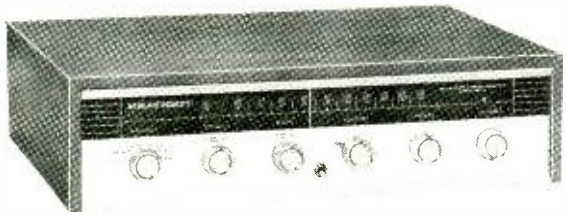

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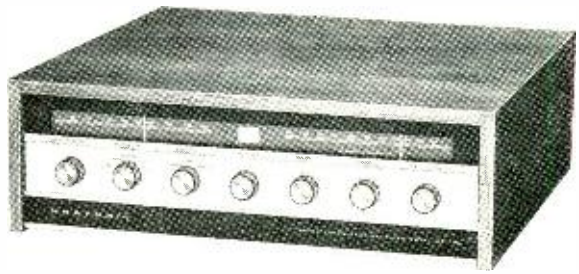

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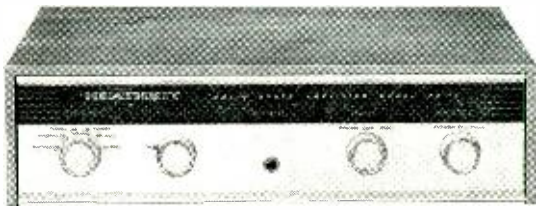

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Cryogenics in Electronics

(*Continued from page 29*)

ficient operation. In addition, considerable reductions in size and weight are very important for these devices in countless applications in industry and science.

In other electronic applications, superconducting magnets can be used for such devices as image-amplifier tubes and electronic microscopes for increased resolution and for traveling-wave tubes where the high magnetic fields will reduce noise. Microwave amplifiers can be designed to work in the gigacycle frequency range by application of cryogenic refrigeration. On the same principle, microwave dewars are used for the evaluation and measurement of K-band (about 30 gigacycles), microwaves, optical and X-radiation.

In a like manner, superconductivity can be instrumental in making possible high-performance computers, microwave radar and communications systems, scientific instruments, high-current storage batteries and magnetohydrodynamic power supplies.

A superconductive gyro takes advantage of the fact that, when the resistivity of a superconductor approaches zero, magnetic induction also disappears. As a result, the superconductor will expel a magnetic field. It creates, in effect, a magnetic cushion so that the gyro rotor can float in space. The loss of resistivity keeps power requirements very low and makes for very stable gyro operation.

Quenching Superconductivity

Most superconductors, however, are *quenched* when placed in a magnetic field, that is to say, their resistive properties are restored in a magnetic field of even low intensity. The self-bias produced in a solenoid will thereby destroy the desirable superconducting properties.

Superconductivity can thus be controlled by magnetic force as well as temperature. This dual property makes an important tool of superconductivity. By this means it is possible to design switches, rectifiers, and flip-flops that are compact and fast-acting, while consuming almost no power.

Superconducting rectifiers, for example, are designed so that quenching of the superconductivity in a magnetic field performs the same action as a conventional rectifier. It offers a large impedance to current flow in one direction, with relatively little opposition in the reverse direction.

This magnetic quenching has, until recently, limited the application of superconducting solenoids to the production of magnetic fields of only a few kilogauss intensity. The recent discovery of new alloys which remain superconducting in very intense magnetic fields (while carrying currents up to 100,000 amps per square centimeter and above) has relieved this situation. These new alloys lead to the production of magnetic fields that may be in excess of 200 kilogauss.

Making use of these new alloys, a new type of power supply depends for its operation on the properties of field strength. Operation of the power supply continues even after the power supply is disconnected from the source of power.

Superconductivity does not provide "free" power, however, instead it merely eliminates dissipation of the power so that the maximum amount of work can be performed by it. This absence of dissipation makes it possible for an electrical current to continue to flow almost indefinitely without loss.

Interaction Between Superconductors

The interaction between superconductors and non-superconductors also promises to pave the way toward new thermal devices such as switches and flip-flops. When copper or another non-superconducting wire is soldered to a superconductor such as tin, thermal resistance at the interface is much greater when the tin is superconducting than when both metals are at ambient temperature. This high junction resistance can be reduced by a factor of 10 to 1 when a magnetic field is applied to the junction. Thermal switches such as this are very sensitive and fast acting.

When a coil of superconductive wire is wrapped around a rod of non-superconductive metal whose resistivity is much larger or smaller than the superconductor, current in the wire can be made to control the resistivity of the rod (or *vice versa*). Switching can thereby be accomplished to switch from a zero resistance to a finite value and back. Upon this action is based fast-acting switches which find extensive application in computer memory circuits.

For use in a memory circuit, the device is immersed in liquid helium, the container (dewar) is vacuum sealed and pressure reduced until the ultra-low temperature (in the vicinity of −452°F) is achieved. Circuit wires introduced into the dewar through vacuum inlet tubes are connected to computing equipment operating at ambient temperature.

Cryogenic's Future

Future developments will allow fast and efficient superconducting materials to be used in countless electronics applications. Superconductivity provides the means for designing new devices having greater efficiency than with any previously known electronics techniques. In addition, it brings about new knowledge that will improve the design of conventional equipment. ▲

RADIO & TV NEWS

SPURRED by continuous advances in consumer demand for electronic home entertainment products, factory shipments of electronic components by U.S. producers in the fourth quarter of 1964 set an all-time quarterly high, advancing more than 14% in value over the preceding quarter and 12% over the same quarter of 1963, according to the U.S. Dept. of Commerce.

An unprecedented demand for color- and monochrome-TV receivers was largely responsible for the new quarterly mark. Shipments of electronic components for defense end use leveled off after a decline starting in 1963.

Major gains included: transformers up 19%, capacitors up 16%, semiconductors up 15%, relays up 14%, and connectors and resistors up 12%. Moderate increases of power and special-purpose tubes, quartz crystals, and TV picture tubes were also reported.

Price declines continued in all major product categories of the semiconductor industry, reflecting the stiffer competition from the producers of integrated circuit packages and the increasing output of low-cost, commercial-grade transistors that are now beginning to find volume markets in TV receivers and other consumer products.

Antenna Farm

Twelve hundred feet above the streets of New York is the former dirigible mast of the Empire State Building. Since the lighter-than-air craft passed into history, this mast has been converted into the world's highest antenna farm. At the present moment, there are nine TV transmitting antennas and several other service antennas sharing this mast.

In the near future, an antenna system mounting 32 dipoles will be installed above and below the observation windows located on the 102nd floor of this building and will go into operation as the world's first master FM transmitting antenna. This complex antenna system will be capable of transmitting the signals of 17 FM stations simultaneously.

It is hoped that the 1250-ft. height of this new FM antenna will eliminate interference from surrounding skyscrapers, enabling participating stations to reach a greater number of people.

Gemini Radio Audience

Probably the largest radio audience in history listened to broadcasts of the eight-day flight of Gemini 5. Besides the millions listening in the U.S. and Canada, the Voice of America world-wide English Service used a special global network of 51 transmitters with a cumulative power total of 8,741,000 watts.

In addition to English, there were broadcasts of the space flight in 37 different languages to reach an audience estimated at better than half a billion.

Woofer Sharks?

Electronic observation of feeding sharks has prompted Florida-based marine biologists to suggest that it is very likely that sharks are attracted to a target through the low-frequency sounds made by an injured fish or animal floundering on the surface. ▲

Manufacture of Color Tubes

(*Continued from page 32*)

approach of the light rays at the mask aperture is the same as that which will exist for the electron beam when the tube is completed. In effect, the shadow mask acts as a "negative" in the exposing process. The areas struck by the light rays passing through the shadow mask are rendered insoluble in water by virtue of the photosensitive agent which was included in the slurry mixture.

After exposure, the panel is removed from the lighthouse, the shadow mask removed, and the panel replaced on the slurry machine for development of the first color array. Development is simply a washing operation. Those areas exposed to light are not washed away and remain on the glass; all of the water-soluble, non-exposed material is removed to leave a uniform array of phosphor dots. Final drying completes the screening of the first color field.

It is then only necessary to repeat the same process for the other two colors, each time using a different phosphor slurry, and placing the light source at a different predetermined point to represent the position of the particular electron beam activating each color.

Final Manufacturing Steps

Panels passing the screen inspection are transported by conveyor to the aluminizing operation. Here they are loaded onto cars which evaporate a 4000-angstrom layer of aluminum on the inside of each panel. The aluminum layer acts as a mirror and insures that all the light produced by the phosphors will be directed outwards toward the viewer. Because the phosphor dots are porous, direct application of aluminum would result in severe aluminum penetration of the dots and little, if any, mirror effect. Consequently, an organic buffering film is laid down to temporarily provide a mirror-like, smooth base for deposit of the aluminum layer.

Following aluminizing of the screened and filmed panel, the shadow mask is inserted and electron shields are secured to the outer rim of the shadow mask frame. These shields intercept electrons that ricochet around the outside of the mask frame and prevent them from reaching the face of the tube. The entire assembly is then baked out to remove the layer of film as well as any other organic materials.

The panel is joined to a coated funnel by means of a special sealing glass called frit. As shown in Fig. 8, the frit, made up of powdered glass mixed with the organic binder and vehicle, is dispensed on the sealing surface of the coated funnel. The funnel and panel are then loaded onto a fixture which holds the

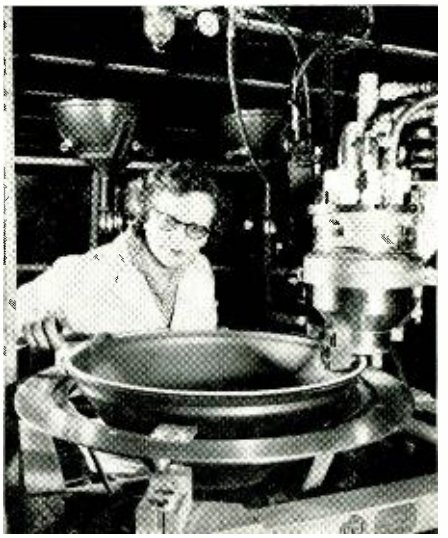


Fig. 8. The phosphor panel and shadow mask are joined to tube funnel with a soft glass called frit. Heating the junction makes permanent, strong seal.

parts in accurate orientation by means of built-in locating devices. The bulb and fixture are belt-fed through a large oven in which the frit devitrifies or crystallizes to provide a vacuum-tight seal of high mechanical strength. The sealed bulb is then mated with its three-element electron gun and put through the final manufacturing steps and tests necessary to produce a finished tube.

The author gratefully acknowledges the assistance of A.E. Hardy, T.A. Saulnier, A.M. Morrell, and D.J. Ransom, who provided source material for this article. ▲

Color-TV Set-up Problems

(*Continued from page 25*)

brightness levels). Simply set the drive controls to about midrange and turn the brightness to a low light level. If the screen looks grey, leave the screen controls alone. If the screen has a red cast, decrease the red screen; or if the screen has a purple cast (reddish-blue), increase the green screen.

After the low-level color is set satisfactorily, advance the brightness control to a high light level, short of blooming or defocussing. If the screen takes on a colored appearance, the drive controls should be adjusted in the same manner as the screen controls. Note, however, that most sets have only two drive controls: blue and green. Consequently, if too much red is apparent both the green and blue drive controls must be advanced.

This procedure should be repeated until no change in the raster color is noticed as the brightness control is turned from its minimum to its maximum setting.

Difference Amplifiers

The color difference amplifiers are the last stages before the picture tube and

just after the demodulators. They are directly coupled to the picture-tube control grids so their conduction affects the black-and-white as well as color reproduction. The three amplifiers take the two demodulator outputs and matrix them to obtain the third color.

If a difference amplifier fails, both color and black-and-white pictures will be affected. Generally, the tubes "open" and cause the associated gun to run at a higher beam current. Thus, if the *R-Y* tube filament opens, the screen would turn red. Conversely, if the coupling capacitor on the *R-Y* amplifier were to short, the tube would conduct heavily and lower the grid voltage on the red gun. Of course, this would cause a blue-green screen presentation.

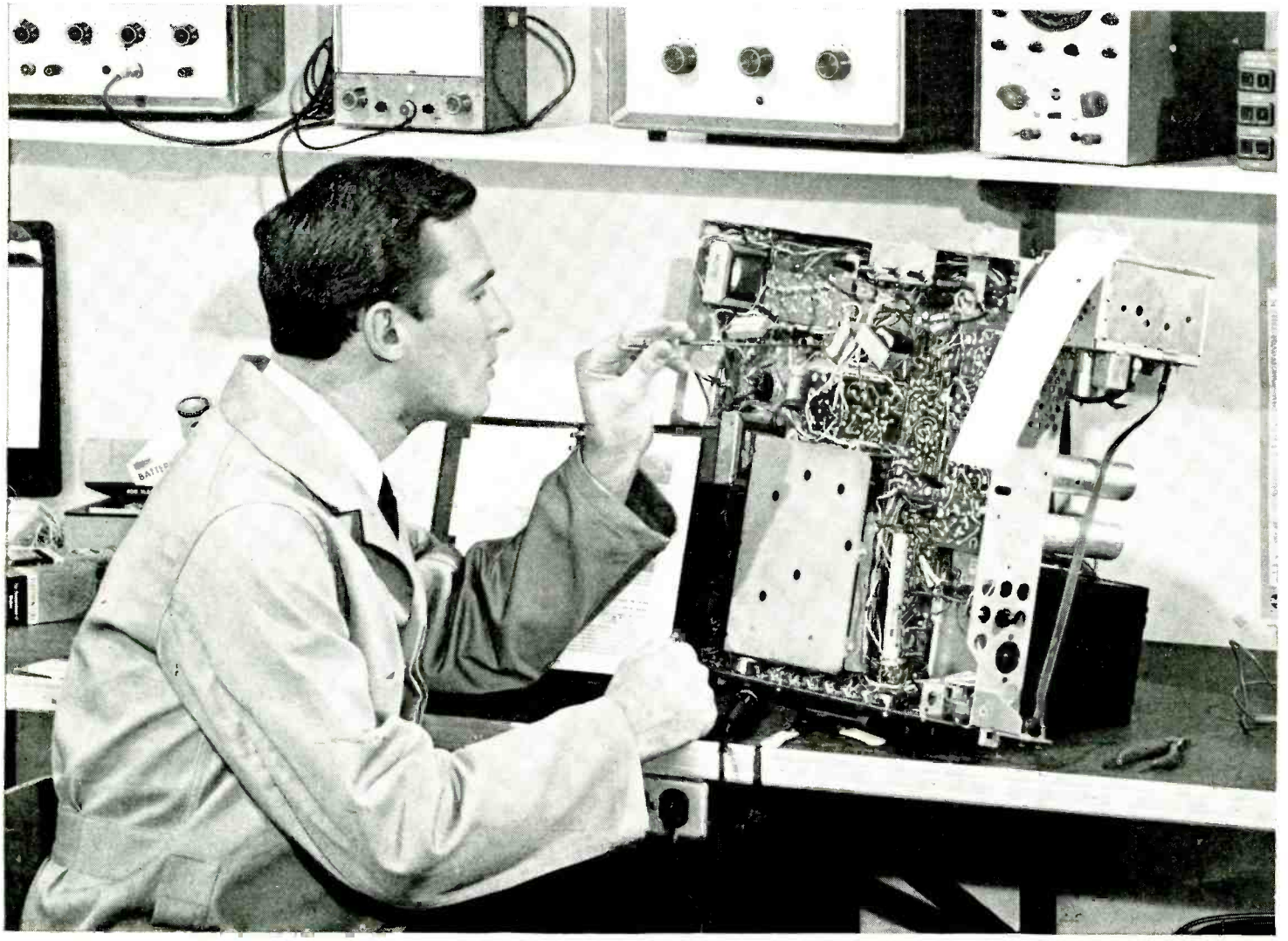
It is important to recognize a difference-amplifier function because the resultant black-and-white screen temperature can be adjusted to counteract it. The result would be a near-normal black-and-white picture (it would not track too well) but a color picture with one color completely missing.

This by no means completes the list of common problems encountered during initial color set-up but it should get you through more than half of them. You will find that the customary problems encountered in black-and-white installations are magnified many times with color installations. For example, if it is necessary to change the linearity, height, width, or picture position, purity and convergence may suffer. Be sure these items are checked first on a set-up.

You will also find that new-set convergence may shift slightly for a week or a month after installation. If this happens, wait until it stops drifting and set it up again.

High-voltage problems occur in color sets since the high voltage is normally 25 kv. Depending on the humidity, most new sets will exhibit a corona discharge when first turned on. A little anti-corona spray around the ultor button will often help and in others it may be necessary for the moisture to "cook out." Always check corona symptoms out since the arcing could be much more serious and involve potential flyback trouble.

Experienced technicians will tell you that one of the biggest callback problems is the horizontal section. When working in this section be sure that the efficiency coil and high voltage are set properly. Failure to do this can cause multiple output and high-voltage tube replacements. The efficiency coil should be adjusted for minimum current in the cathode of the horizontal output tube. Old timers usually use a #44 pilot lamp in series with the plate cap and adjust for minimum brightness. Remember, too, that the high voltage is normally adjusted with the brightness control set to minimum. ▲



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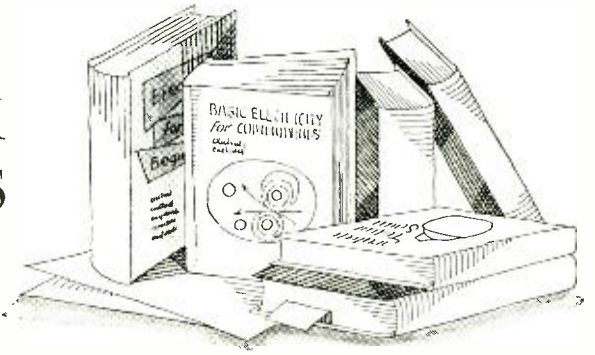

"FUNDAMENTALS OF RADIO" by Murray P. Rosenthal. Published by *John F. Rider Publisher, Inc.*, New York. 309 pages. Price $8.95.

As the title implies, this is an introductory text designed for radio students and hobbyists. Written by a member of the Technical Staff of *RCA Communications Systems Division*, the author has covered a variety of pertinent material in eleven chapters dealing with electricity, magnetism and electromagnetism, electric circuits, vacuum tubes, semiconductors and transistors, power supplies, amplifiers, oscillators, radio transmission, antennas, and radio reception. Included in this last chapter is a full discussion of FM-stereo operation as well as AM-FM equipment.

Two separate sections cover the mathematics needed in radio work for those whose math is deficient in this respect and troubleshooting—which also includes information on the use of various items of test equipment.

The book is well illustrated with photos, line drawings, schematics, and block diagrams. It can be used as a home-study text as well as a classroom manual.

* * *

"MATHEMATICS FOR ELECTRONICS" prepared by *Federal Electric Corporation.* Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 598 pages. Price $15.00.

This is a programmed text for the "do-it-yourself" student of mathematics. It can be used to extend or upgrade your knowledge of mathematics as used in electronics.

Both theory and practice in classical algebra, analytical geometry, trigonometry, and complex algebra (as related to electronics) are covered in this book. Prerequisite is a knowledge of secondary school mathematics. The programmed format permits the student to proceed at his own pace and to double-check his understanding before going on to the next topic.

* * *

"ELECTRONIC COMPUTERS" by S. H. Hollingdale & G. C. Tootill. Published by *Penguin Books Inc.*, Baltimore, Maryland. 325 pages. Price $1.65. Soft cover.

This is another of the "Pelican Originals" being issued by this publisher and, like the earlier volumes, is addressed to the layman. In 13 chapters, the authors cover the development and history of the computer, the different kinds of computers, computer programming, hybrid computers, and they speculate on computers of the future. They have also appended a list of books for those who wish to pursue the subject further but since most of these are of British origin, the list may not be too helpful to U.S. readers.

On the whole, though, the book is delightfully readable and a good background text for a basic understanding of computer operation.

* * *

"SEMICONDUCTOR DATA MANUAL" compiled and published by *Motorola Semiconductor Products Inc.*, Phoenix 1, Arizona, 900 plus pages. Price $3.50. Soft cover.

This handy manual provides complete technical information on a broad range of semiconductor devices and represents a gathering together of much data which was heretofore available only in loose-leaf form or as miscellaneous publications. Some 2600 semiconductor devices are covered in this reference work with complete specs on silicon zeners; silicon rectifiers; silicon rectifier assemblies; SCR's; power transistors; low-frequency, low-power transistors; high-frequency transistors; special and multiple transistors; special-purpose silicon diodes; and integrated circuits.

* * *

"DIODE REFERENCE BOOK" by David G. Kilpatrick & William A. Dittrich. Published by *International Resistance Company*, 414 N. 13th St., Philadelphia, Pa. 19108. 261 pages. Price $3.95. Soft cover.

This "Datadex" features functional coding of diodes to facilitate the location and identification of such components. The book describes characteristics by indicating the type and number of junctions, average forward current, peak operating voltage, and recovery time.

More than 3000 diodes are cross-indexed by JEDEC and "Datadex" numbers. Relative price information on each unit is also included. A special 25-page section carries the actual size outlines of each diode type while over 260 pages are devoted to useful information includ-

ing theory, circuits, and testing procedures for signal diodes, tunnel diodes, variable capacity diodes, and microwave diodes.

* * *

"HANDBOOK FOR ELECTRONIC ENGINEERS AND TECHNICIANS" by Harry E. Thomas. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 421 pages. Price $15.00.

This is a compilation of a variety of miscellaneous data needed by design engineers and their supporting technicians. The material ranges from prints and drawings, through electronic components, chassis assembly and wiring, mathematics for electronic applications, to testing and measurement of a wide range of equipment, power supplies and filter circuits, design data, and finally mathematical tables and formulas.

This is not intended to be a classroom text but rather a ready-reference source for verifying a whole host of points likely to be encountered when working with all types of commercial and military electronic hardware.

* * *

"PRINCIPLES OF TELEVISION ENGINEERING" by Roy C. Whitehead. Published by *Iliffe Books Ltd.*, Stamford Street, London SE1. Two volumes 25s/9d. & 36 s. (by mail).

These books are designed as classroom texts to prepare students whose aim is a career in TV broadcasting, servicing, or operating for the British exams.

Prerequisites include an elementary knowledge of physics and mathematics and a basic knowledge of sound broadcasting. The treatment is thorough and no-nonsense, with mathematics introduced as required. The material is based on BBC television standards and operating procedures, but the U.S. student will be able to derive considerable benefit from the text.

* * *

"INTRODUCTION TO ELECTRIC CIRCUITS" by Herbert W. Jackson. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 542 pages. Price $14.00.

This is a second edition of a popular handbook for practicing and aspiring electrical/electronic technicians. The book is written at a technical school level. Students with adequate mathematical background could use this volume as a home-study text since there are problems appended to each chapter for checking the student's grasp of the subject matter. The text is amplified with line drawings and schematics while the appendices carry a number of tables useful to the student.

* * *

"WAVEFORMS" and "VACUUM-TUBE AMPLIFIERS" published by *Dover Publications, Inc.*, New York, N.Y. Price $3.25 and $3.00 respectively. Soft cover.

These volumes are two more in the excellent series of works originally published by *McGraw-Hill Book Co.* as part of the Massachusetts Institute of Technology Radiation Laboratory Series. By making these definitive works available to a wide audience in low cost editions, the publisher is rendering a genuine service to the technical community.

Despite their low cost, both volumes are complete and unabridged and carry all of the illustrations and supplementary material included in the originals.

* * *

"PHOTOELECTRONIC MATERIALS AND DEVICES" edited by Simon Larach. Published by *D. Van Nostrand Company, Inc.*, Princeton, N.J. 424 pages. Price $12.00.

This is a joint effort by some fourteen engineers and specialists from *RCA Laboratories, Hewlett Packard,* and Stanford University, and is based on a series of inter-disciplinary papers in the general area of photoelectronics which appeared in the *"RCA Review"* in 1959. Nine chapters deal with the luminescence of solids, photoconductors, infrared-sensitive extrinsic germanium and germanium-silicon alloy photoconductors, photoelectric emission, noise currents, photovoltaic effect, solid-state optoelectronics, solid-state image intensifiers, and a review of Electrofax behavior. ▲

FET's for FM Front-Ends

(*Continued from page 37*)

or p-channel (equivalent to n-p-n transistors). Of these two types, the n-channel type is the better high-frequency transistor because of a better ratio of transconductance to stray capacitances.

A bonus with field-effect transistors is that their capacitances change very little with temperature. This minimizes detuning and insures stable circuits.

Two major disadvantages of field-effect transistors for this application should be mentioned. They are very high in impedance and cost. Their high impedance causes no difficulty in high-frequency circuits, but in audio and video circuits large amounts of mismatch will have to be tolerated in matching to normal transistor circuits. With continuing improvement in techniques, the cost of field-effect transistors has been reduced considerably and should continue to drop.

A number of FET FM front-ends have been developed at the *H. H. Scott* laboratories and the circuit of one of these is shown in Fig. 2. The input signal from the antenna is first selected by a tuned circuit and then amplified in a field-effect transistor cascode circuit operated in parallel for d.c. The first stage is neutralized with a 2.2-μhy. coil. The cascode stage produces a power gain of approximately 25 db.

The output of this stage is applied to a second tuned circuit and the amplified signal is injected into the "source" of the converter stage, which is also a field-effect transistor.

The "drain" is connected to a conventional tube-type i.f. transformer tuned to 10.7 mc. The mixer transistor operates as an attenuator for the r.f. signal controlled by the instantaneous oscillator voltage. The oscillator is a conventional common-base transistor oscillator and the output voltage from the oscillator is applied to the gate of the field-effect transistor mixer.

With a large variety of field-effect transistors, IHF sensitivities of 1.6 to 2 microvolts were obtained with a spurious response rejection (or cross-modulation rejection) of 96 db to over 100 db. Two strong signals, equivalent to more than 50 mv./meter separated by 800 kc. can be fed to the input of this front-end without any spurious intermodulation products being generated. This performance is as good, if not better, than the performance of the best tube front-ends and is at least 20 db better than the performance of the best transistorized front-ends using the best available bi-polar transistors we have checked.

This circuit is not designed for home construction. These transistors are manufactured specifically for *H. H. Scott* and are not available from distributors. ▲

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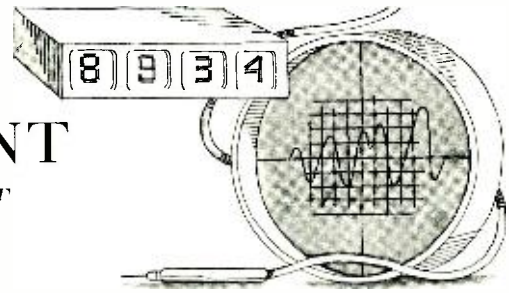
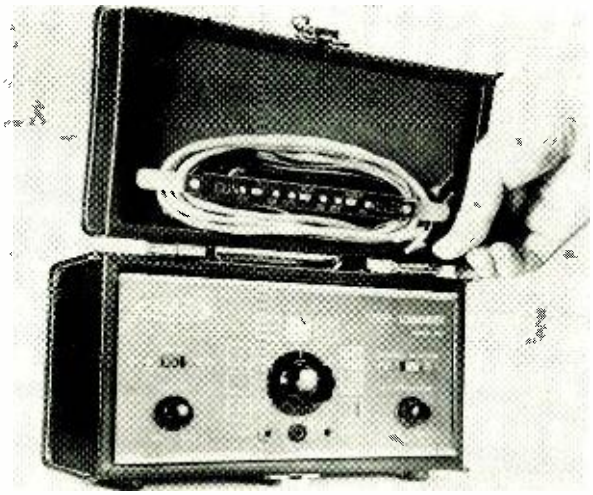
PRODUCT REPORT



Amphenol Model 860 Color Generator

For a copy of manufacturer's brochure, circle No. 26 on Reader Service Card.



TO his normal burden of tube caddy, toolbox, and v.t.v.m. or v.o.m., the up-to-date TV service technician must now add a comprehensive instrument to generate the patterns required for aligning and troubleshooting increasingly popular color receivers. Many present generators are heavy and require 117 volts a.c. for power. *Amphenol Corporation's* answer to the technician's need for a compact color generator is its new Model 860 "Color Commander," a completely transistorized battery-powered unit with a good many special features which reduce routine alignment time.

Measuring only 9″ x 5″ x 4″, the generator offers four conventional patterns plus five completely new ones which speed convergence. With these nine patterns, a technician should be able to completely converge and adjust the chroma of a television receiver in about 20 minutes.

The heart of this generator is the crystal-controlled 315-kc. timer (see block diagram). Its extreme stability results from the use of silicon unijunction transistors in all circuits. Frequency stability of a unijunction oscillator is largely dependent on the external *RC* timing circuits, and if high-quality resistors and capacitors are employed, extreme frequency stability is readily achieved.

The complete composite video signal is fed to the video output jack where it can be used for signal injection or monitoring purposes. The complete composite is also fed to a modulator where it is used to modulate a carrier from the channel oscillator. The channel oscillator carrier is adjustable to channels 3 or 4 through the use of a channel switch located on the front panel.

One of the new patterns displays single horizontal and vertical cross-bars (see A below) which enable the service technician to accurately center the raster before starting convergence alignment. This saves the extensive time normally spent later in correcting misconvergence resulting from initial errors in the centering.

Another new pattern is a single-dot type (B), making it possible to set a receiver's static convergence with great accuracy. In addition, any resetting of static convergence during alignment is readily accomplished since the three color guns can easily be focused on a single spot on the screen.

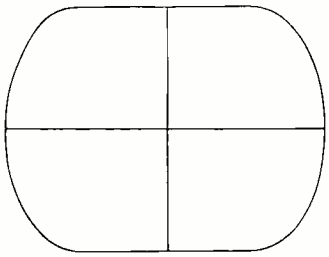
The color-bar pattern is designed to provide easy alignment of color demodulators and to insure proper hue relationships. Three color bars are reproduced on the screen; R−Y, B-Y, and −(R-Y) in 90°, 180°, and 270° color phases, respectively (C). Color adjustments can be made with or without an oscilloscope, thus reducing occasions when a color-TV set must be taken to the shop for alignment.

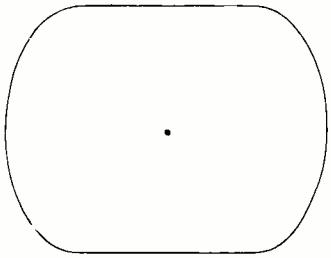
Other patterns available on the new generator include the following: (1) single horizontal and vertical line patterns for individual convergence; (2) thirteen horizontal bars for dynamic convergence and linearity; (3) twenty vertical bars for dynamic convergence and linearity; (4) 20 × 15 crosshatch for dynamic convergence; and (5) 300 multiple dots for critical inspection of convergence.

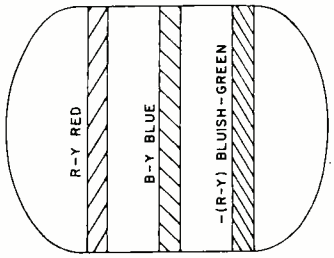
Although the crosshatch pattern (D) is not new, the one generated here has many desirable features. With its four to three aspect ratio, which contains 20 vertical and 15 horizontal lines (4 to 3), the service technician can easily make linearity, height, and width adjustments. The operator merely adjusts the controls for perfect squares over the entire screen.

Color sync circuits, hue control ranges, color demodulators, and color-killer circuits can be tested with the generator, as well as the ability of the set to display color values. What is more, any phase shift or trouble in the r.f. and i.f. stages can be traced by using the r.f. output of the generator. Built-in color-killer switches are an added convenience feature.

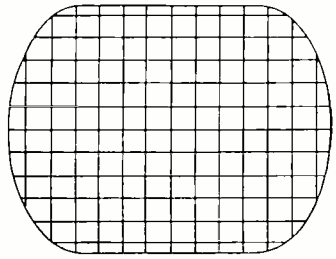
The "Color Commander" normally operates on battery power but can be operated from an optional a.c. supply which fits into the battery holder. Nine mercury cells will give approximately 120 hours of service, alkaline cells ap-

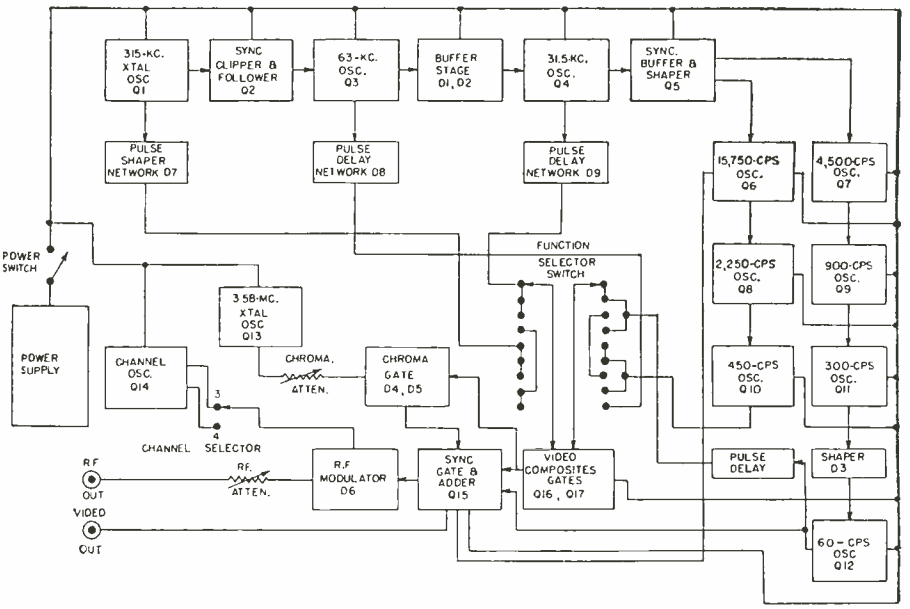

SINGLE CROSS-BARS PATTERN
(A)


SINGLE-DOT PATTERN
(B)



COLOR BARS
(C)


CROSSHATCH
(D)



proximately 40 hours, and carbon penlite cells will be useful for about 25 hours.

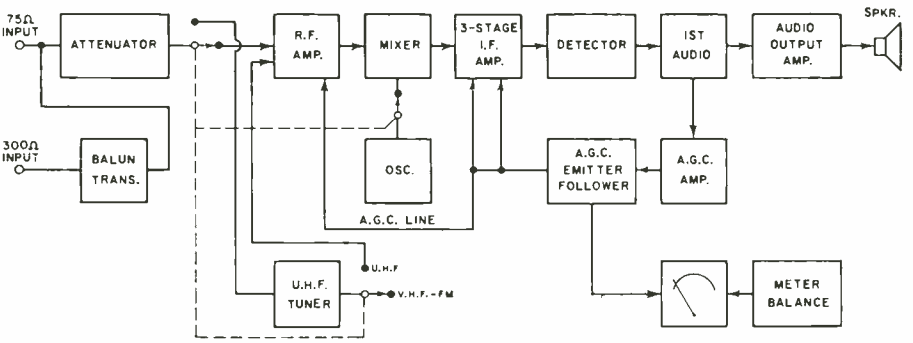
The unit weighs only 3½ pounds in its fitted leatherette carrying case.

"Color Commanders" are available from *Amphenol* distributors at a list price of $149.95. ▲

Sencore FS134 Field-Strength Meter

For copy of manufacturer's brochure, circle No. 27 on Reader Service Card.

WITH the increase in FM-stereo broadcasting, the u.h.f. and color-TV boom, and the expanding use of distribution systems, the field-strength meter has become an important tool for the service industry. The *Sencore* FS134, a completely solid-state instrument of this type, is compact, portable, lightweight, and battery-operated. It covers the standard v.h.f. television band, the



u.h.f. television band, and the FM band. It has been designed for all-around use and can be employed to aid in the installation of master and home-type antenna systems, to set up distribution systems, to make field-intensity surveys, and to aid in tracking down of distribution-systems problems such as weak signal, sync clipping, overloading, noise, and many others.

The FS134 is extremely easy to operate. Merely set the frequency dial to the station or frequency whose field strength you desire to measure, turn the instrument to "Cal," and calibrate. Then turn to "On" and tune for maximum reading. If a 75-ohm coaxial cable lead-in is used, just plug it into the coax connector on the front panel. If the lead-in is 300-ohm twin-lead, use the 300-ohm input with the built-in balun to match to 75 ohms. The attenuators are to control high-level signals such as those found in distribution systems. The audio portion of a TV program or the audio of an FM station can be heard on the built-in speaker. The field strength can be read directly off the meter in both microvolts and db. The zero-db reference equals 1000 microvolts across 75 ohms, a standard reference in the industry.

The instrument uses separate v.h.f. and u.h.f. tuners for best stability and lowest losses. These are followed by a three-stage, 42.8-mc., high-gain i.f. system controlled by amplified a.g.c. The large four-inch meter reads the amplified a.g.c. voltage and produces an indication of field strength that can be easily read from several feet away. The meter's extended logarithmic range from 30 to 30,000 microvolts permits different antennas to be installed and tried out without constantly changing the sensitivity range. Signals can be heard in the speaker at levels as low as 5 microvolts so that weak fringe-area signals can be located and built up with proper antenna orientation to a level that can be read on the meter.

The very good shielding of the instrument prevents strong signals from being picked up directly by the instrument itself; they must be fed to the unit by the antenna (not supplied). In this way, the effect of antenna placement and orientation can be easily seen.

Nine standard "C" cells are used as the entire power source. Since the total current drain is only around 25 to 35 ma. with no signal, these should last a long time. A single 12-volt rechargeable nickel-cadmium battery (which sells for around $12) can also be used in conjunction with an optional battery charger. With this arrangement, the unit can be operated off the a.c. line for bench use.

The price of the Model FS134 is $199.50. ▲

CCTV Camera

(*Continued from page 47*)

clearly defined lines and edges to a televised test pattern. It effectively compensates for amplifier input capacity. Q102 is an emitter follower for isolation and impedance matching.

Q103, *T*101, and *R*115 form an aperture-correcting circuit. This is necessary because the finite size of the scanning-beam spot in the vidicon smears the sharp transitions between whites and blacks. *T*101 has a resonant frequency at the upper end of the bandwidth curve, in this case 9 mc. It can be seen that with *R*115 set at its extreme end toward the emitter, *T*101's secondary is effectively shorted out and no aperture correction will be in evidence. However, as the arm of the pot is advanced, the high frequencies coupled through *T*101 will be felt in the following amplifier stages. Thus, the amplitude of the higher frequencies has been increased with respect to the lower frequencies, providing greater contrast of detail in the high-frequency portion of the televised scene.

As shown in Fig. 7, this circuit is followed by more amplification and isolation stages to the final output amplifier Q206. Note that the drive, blanking, sync, and clamp pulses previously described are finally put to use by simply adding them to the video signals.

The final block remaining on Fig. 7 is labeled "Auto Target." It is the function of this circuit to automatically adjust the vidicon target voltage to compensate for any change in light level on the scene that is being viewed. This is done by feeding the video from the preamplifier into a detector circuit. The detector output (a d.c. voltage) is then amplified to provide a target voltage dependent upon the preamplifier output. Increasing scene illumination results in a decrease of target voltage. Target voltage thus derived has an advantage over the simple photocell method sometimes used in that it is a function of the image focused on the vidicon rather than the integrated incident light from a broad area. Various lenses may thus be used without affecting operation.

Power Supplies

The system under discussion requires a +22 to +30 volts d.c. and draws approximately 400 ma. of current. The input voltage is reduced to a regulated +20 volts and is utilized in various parts of the system to supply circuit requirements. It is also used to power a converter which has outputs of −10, +450, and −225 volts. Since a CCTV system constitutes a stable load (no significant changing of parameters to vary the current drawn), all voltages are regulated by regulation of the +20 volts. ▲

ELECTRONIC CROSSWORDS

By JAMES R. KIMSEY

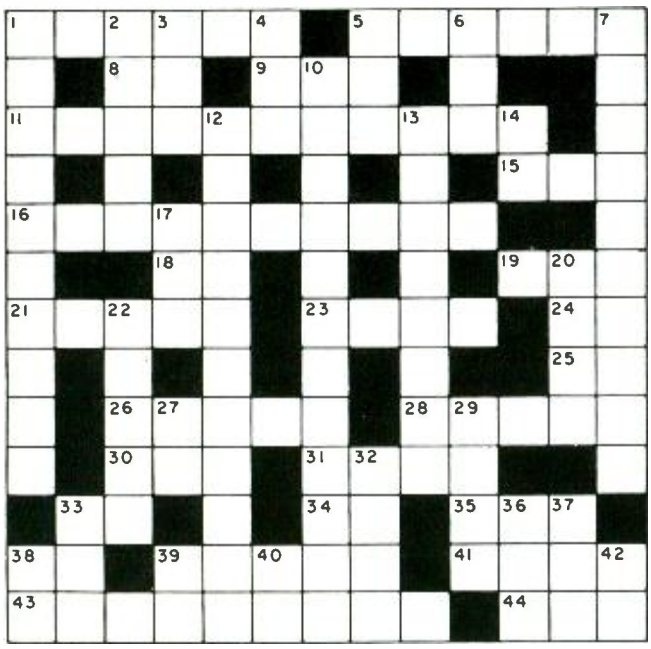
(*Answers on page 83*)

ACROSS

1. In television, the light-sensitive surface of an iconoscope or other TV camera tube.
5. A mechanical device that converts some form of intelligence into a corresponding electrical signal.
8. A switch position.
9. Consumed.
11. A device for converting a.f. current into sound waves.
15. To move a television camera to keep it on the subject.
16. That property of a coil or other radio part which tends to prevent any change in current flow.
18. As shown or described.
19. The absolute c.g.s. unit of energy and work.
21. The unit of luminous flux.
23. A device which produces amplification, oscillation, rectification, or other useful results by controlling the flow of electrons in a circuit.
24. Either.
25. A unit of current equal to one-thousandth of an ampere (abbr.).
26. Jargon.
28. A type of variable frequency oscillator noted for its very low drift characteristics.
30. Period of time.
31. Long-handled tool with teeth at one end.
33. Electronic antenna switch (abbr.).
34. Chemical suffix indicating that the compound includes alcohol.
35. A bow of flame formed between two electrodes.
38. A network of three impedances.
39. To make suitable, especially by changing.
41. Any segment of a whole.
43. A storage tube.
44. Covering for 5 down.

DOWN

1. A resistor used in series with a voltage to increase the range of the meter.
2. A vibration which may be heard by human ears.
3. Also.
4. A metal ..... placed on top of some vacuum tubes and connected to one of the electrodes.
5. Green vegetable.
6. A hint.
7. A device for converting mechanical vibrations into sound waves.
10. A device which converts handwriting into electrical impulses at the transmitting position, and back to handwriting at the receiving position.
12. The electrode in a cathode-ray tube that is maintained at a constant positive potential and is used to accelerate the beam (2 words).
13. The back e.m.f. produced in a coil when the current flow through it is stopped and the magnetic field collapses.
14. Schematic symbol for the plate resistance of a tube.
17. Put into service.
20. To play in a boisterous, lively way.
22. A circuit operating at microwave frequencies, in which radiation from atoms is stimulated.
27. Look!
29. Jump.
32. Voice range.
33. Bind.
36. Knock.
37. Test instrument (abbr.).
38. Afternoon.
39. Chemical abbreviation.
40. Type of current (abbr.).
42. Football score (slang).



Colorimetry

(*Continued from page 23*)

chromaticity of the spectrum color just considered (green at 520 millimicrons) may be represented in a two-dimensional rectangular coordinate system by a point whose coordinates are $x = .0633/.8515 = .0743$ and $y = .7100/.8515 = .8338$.

Fig. 4A shows how the colors of all spectral lines, the most saturated of real light sources, plot as an inverted horseshoe curve having its open end closed by the non-spectral magenta. The entire figure is known as a *chromaticity diagram,* and the curve is known as the *spectrum locus.* The CIE standard primaries are represented by a point $x = 0$, $y = 1$ for the green; $x = 0$, $y = 0$ for the blue, and $x = 1$, $y = 0$ for the red. The numbers spotted along the horseshoe are wavelengths in millimicrons. Each point in the chromaticity diagram specifies the chromaticity (hue and saturation) of a color independent of its luminance.

Ideal incandescent radiators (black bodies) are plotted as an arched curve across the middle of the horseshoe for various values of radiator temperature in degrees Kelvin. "White" is a general term for a light which evokes an achromatic, or colorless, sensation. Points located in the central region of the chromaticity diagram, including the segment of the black-body locus between 2500°K and 12,000°K, are recognized as "white" depending upon particular adaptation conditions of the observer.

For any specified value of "white," the hue of any color can be related to its dominant wavelength through the angular position of the point representing that color on the chromaticity diagram about the chosen white as a center. Similarly, the saturation sensation given by any color is related to its purity; in other words, to the distance along the radius from the white point to the dominant wavelength point, measured as a fraction of the total distance out to spectrum locus along that same radius. To appreciate the dependence of hue upon the point in the chromaticity diagram considered as white, note that it is possible for a given point on the diagram to be specified by a dominant wavelength of 583 millimicrons when referred to sunlight "white," or by a dominant wavelength of 484 millimicrons when referred to incandescent "white."

This dominant wavelength-purity system represents a second method of specifying chromaticity. Of greatest use in color printing and photography, where colors are viewed by reflected light under a given illumination source, it is less applicable to color television, in which the viewed colors (fluorescing phosphors) are self-luminous. Nonetheless, it does provide some basis for comparing the range of colors obtainable by different color-reproducing systems.

Color Gamuts

The toned area in Fig. 4B covers the color range or gamut of the best modern pigments, dyes, and inks for "daylight" illumination (6770°K). The superimposed triangle shows the gamut of a color picture tube using the latest phosphors, the x and y coordinates of which form the apexes of the triangle. The area not enclosed by the triangle or printing gamut represents colors not reproducible by either system, but because these colors are mostly the heavily saturated greens and blues that rarely occur in nature, the compromise has been relatively unimportant.

Editor's Note. The chromaticity diagram illustrated on the cover shows a much larger color phosphor triangle than that shown in Figs. 4B and 4C.

The triangle on the cover was based on the performance of one of the first color tubes (21CYP22) that closely approximated the three color coordinates specified by the FCC. The chromaticity diagram shown in Fig. 4 is that of modern high-efficiency phosphors presently being used.

Because the heavily saturated green found in the area between the two triangles is almost never found in nature, there is no need to transmit it. It then becomes possible to reduce the triangle size, and by using a more efficient green phosphor, produce a brighter picture.

It should be noted that both phosphor triangles show that color-TV chromatic limits are still greater than color by conventional printing techniques.

Perhaps a more meaningful approach to the evaluation of the color television gamut is shown in Fig. 4C, which gives positions on the chromaticity diagram of a number of familiar objects.

Because the colors of most natural objects are not highly saturated, phosphors are often chosen not only for their degree of saturation but for their brightness capability as well. Even though the color television gamut is already slightly superior to that obtainable from the best modern printing inks and dyes (37.8% of the area under the spectrum locus *vs* 35.5%), it could easily be made substantially larger if color range were the only consideration. Because the eye is far more tolerant of slight color errors than of low light output levels, however, the phosphors used in current television picture tubes represent a realistic balance of both color gamut and brightness.

The author gratefully acknowledges the assistance of A. E. Hardy, T. A. Saulnier, and A. M. Morrell, who provided source material for this article and reviewed the final text for technical accuracy. ▲

LOW-NOISE R.F. AMPLIFIERS

By JIM KYLE

Special techniques including masers, parametric amplifiers, tunnel diodes, and low-noise transistors are used to reduce receiver noise so that low-level signals can be detected.

THE absolute limitation on the usefulness of any communications system is the electrical noise present in the system. Whether information is transmitted by wire or radio wave, the signals suffer loss along the path from transmitter to receiver—and when this loss makes the signal weaker than the inherent noise at the receiving end of the system, the signal is lost for good.

Because of this, "signal-to-noise ratio" (usually abbreviated S/N) is used as a key parameter of performance in such widely divergent areas of communication as tape recording, telephone engineering, and radio.

And, also because of this, the object of virtually every technical improvement in radio communications is to increase the signal-to-noise ratio.

The all-important S/N ratio can be increased in many ways. The most obvious way is to increase transmitter power. If all other system parameters remain unchanged, the S/N ratio will increase in a direct relationship as the transmitter power increases. Conversely, a specified S/N ratio may be maintained at a greater range from the transmitter.

However, the route of increasing power rapidly runs into limitations. One is legal in nature—regulatory bodies limit the maximum power permitted in various radio services; the other is physical—transmitting tubes capable of handling more than a couple of million watts or so on a sustained basis simply aren't available. So the engineer uses other techniques.

One of the favorites is the gain antenna. This can provide dramatic improvements at first but then rapidly runs into physical limitations.

The technique which appears to offer the most promise at this time, and which has already resulted in a tenfold or greater improvement in capabilities for some types of communications, involves reducing the receiver's inherent noise.

Though the noise is present in every stage of the receiver, it is controlled primarily by the amount of noise in the first r.f. amplifier stage alone. Only in this stage is the raw incoming signal competing with the inherent noise; after this stage, the signal has been amplified and will have a better chance of being stronger than the noise of subsequent stages.

However, the inherent noise of the first r.f. stage is amplified just as much as the signal, so that for any significant reduction in over-all receiver-noise level, the noise level of the first r.f. amplifier must be reduced to the lowest possible figure.

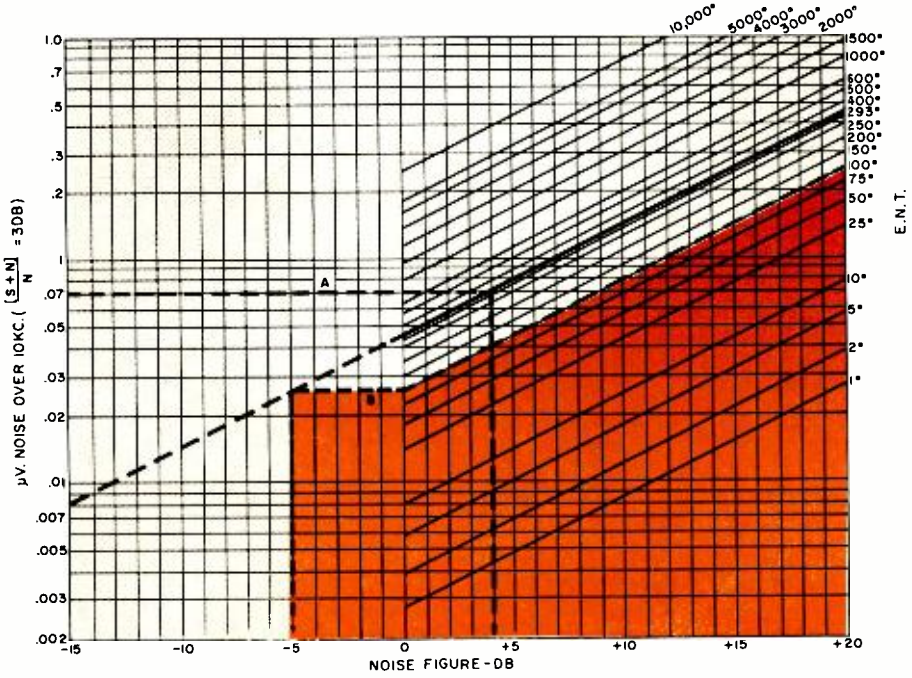
"Low-noise" r.f. amplifiers have been on the scene for decades. However, a number of relatively recent developments have lent new dimensions of meaning to the almost hackneyed phrase. Where formerly an r.f. amplifier with a 3-db noise figure was considered good, amplifiers are now available which boast noise figures in the *negative* db range when measured by conventional techniques.

Noise Figure

Before examining these newer techniques, it would be well to clarify some of the terms used in discussing low-noise r.f. amplifiers. The foremost of these terms is "noise figure."

"Noise figure" is a measurement of the relative amount of noise inherent in an amplifier or a receiver. One of several definitions commonly accepted is that this figure is the ratio of the S/N ratio existing at the input of the amplifier, to the S/N ratio at the amplifier's output. Since no amplifier can actually *improve* the signal-to-noise ratio of the original re-

Fig. 1. Comparison among conventional "microvolts sensitivity" amplifier ratings, noise figure, and effective noise temperature (E.N.T.). Example A shows conversion of microvolt sensitivity to noise figure at room temperature (293°K). Example B shows conversion of 100°K E.N.T. to noise figure. Intersection of 100° curve and 0 db point is extended to 293° line. The noise figure, as read below, is —5 db.



ceived signal, the noise figure obtained by this approach will always be some value greater than unity.

Actually, two terms are in wide use in referring to receiver noise measurements, and since the two are often used interchangeably, the resulting confusion is intense. These terms are "noise figure" and "noise factor."

No clear-cut separation between their meanings exists. The consensus of usage appears to be that noise *factor* is the ratio defined above, of input S/N to output S/N, while noise *figure* is the same ratio but expressed in decibels rather than as a dimensionless ratio. Thus, a "perfect" amplifier would have a noise factor of 1, or a noise figure of 0 db. Since the important thing about noise is *power* rather than voltage or current, the ratios convert to db by the power-decibel equation; a ratio of 2 equals 3 db.

Both noise factor and noise figure must be dealt with, since the equations used in determining noise levels and their effects most usually cannot employ logarithmic numbers, while the pure ratio expressed by the noise factor is not nearly so meaningful when examining a complete system.

The major reason for employing noise figure at all as a measure of amplifier performance is that it is a more direct indicator of actual performance than is a "microvolt-sensitivity" rating. The amount (measured in millimicrovolts) of noise present in an amplifier depends to a large degree upon the bandwidth of the amplifier. Thus, to use microvolt-sensitivity ratings, the noise bandwidth of the amplifier must also be known. However, due to the manner in which noise figure is measured, the bandwidth is almost immaterial; the noise figure yields a direct indication of the amount by which the S/N ratio of the incoming signal will be degraded by the amplifier's inherent noise.

It cannot be overemphasized that noise figure alone is not an adequate measurement. A straight piece of hookup wire a couple of inches long has a noise figure of 0 db. However, it is useless as an amplifier. When using noise figure as the parameter of performance, *gain* must also be specified.

The fact that several of the newer devices yield noise figures in the negative db range (noise factors less than unity) implies better-than-perfect performance. This is not so, and the newer devices do *not* improve the S/N ratio of the incoming signal. The apparent contradiction is due to the fact that the noise-figure equations usually employed to calibrate measuring instruments include an assumption that all parts of the amplifier are effectively at room temperature (293°K is the usual assumed temperature), since the amount of noise present depends largely upon the temperature of the components. Noise of the newer devices is so low that the effective temperature is far lower than that assumed, yielding "incorrect" results (which are, however, meaningful because they have consistent error—a "−4 db" amplifier is still 10 db better than a "+6 db" amplifier).

To escape this built-in error, neither noise factor nor noise figure is used to evaluate many of the newer devices. Instead, "effective noise temperature" is employed as the parameter. Although not directly interchangeable with "noise figure," it can be roughly compared. Fig. 1 shows such a comparison among microvolt ratings (10-kc. bandwidth), noise figure, and effective noise temperature.

Maser

Probably the most spectacular of the newer devices, as well as the one which has received the widest publicity, is the *maser*. This is a device for *m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation and operates on principles more closely akin to nuclear physics than to conventional radio circuitry.

Briefly, the operating principle is this. Certain materials have their molecules arranged in such a manner that some electrons in the atomic shell can be "lifted" to a higher-than-normal energy level by interaction with a magnetic field. When the lifted electrons absorb an amount of energy determined both by the material and by the strength of the magnetic field, they "fall back" to the original level, and in so doing release their stored energy in the form of radiation. The frequency at which this radiation is emitted is determined primarily by the magnetic-field strength.

In the maser, things are arranged in such a way that the energy absorbed by the electrons is provided by a local "pump" oscillator, while the energy released by radiation is applied to the r.f. signal instead. Thus, energy is added to the signal, and this is (by definition) amplification.

Actually, two basically different types of solid-state masers are in use. The one described most frequently is the "cavity maser" in which the active material (usually a ruby crystal) is placed in a resonant cavity, tuned so as to be resonant at both the pump and signal frequencies. The one more widely used, however, is the "traveling-wave maser" in which the active material is placed in a waveguide to form a slow-wave structure, so that the r.f. signal will be exposed to the maser action for a longer period of time, allowing the maximum possible field interaction to take place.

Both the cavity and the traveling-wave masers are capable of extremely low-noise operation. Effective noise temperature of either type of maser can approach 1°K, which corresponds to a noise figure of between − 15 and − 25 db (depending upon which reference book is consulted for the conversion factors and techniques).

The cavity maser, however, has rather limited bandwidth and so is dropping out of general use. The traveling-wave maser's bandwidth is much greater. The Telestar satellite uses a traveling-wave maser, with signal-to-noise ratio better than 70 db over a 30-mc. bandwidth, operating with a received signal power of only about one-millionth of one microwatt. This calculates to a "noise figure" of − 7.8 db.

Both types of masers are limited to the microwave region and above; they do not function successfully below about 1 gc. Maser action, in addition, occurs only at exceptionally low temperatures. Operating units are cooled with liquid nitrogen or liquid helium. Hence, masers are physically rather complex devices as well.

Thus, while the maser appears to be the nearest thing to a perfect amplifier yet developed, it is too complex to enjoy wide use with portable equipment. In addition, it offers no help at all in the lower u.h.f. region and below.

Parametric Amplification

One of the most popular of the other new techniques is that of parametric amplification. Like the maser, it utilizes a local pump oscillator, and power is transferred from the pump to the signal. However, unlike the maser, the parametric amplifier operates at room temperature and requires no exotic precious-gem components.

The principles of parametric amplification are best explained by use of an analogy. Consider a conventional variable capacitor electrically in series with a transmission line and mechanically coupled to a high-speed electric motor. As the motor rotates the capacitor shaft, the capacitance varies from maximum to minimum and back again.

If this capacitor is connected in series with a transmission line carrying a signal, at the instant the capacitor shaft is turned to maximum-capacitance position, the voltage across the line will charge the capacitor. As the shaft rotates toward lower capacitance positions, the charge on the capacitor must remain constant since it has no place to be dissipated. However, the capacitance is decreasing, and since the charge remains constant the voltage across the capacitor must *increase* to compensate.

It is true that if the capacitor is charged at minimum capacitance, its voltage will decrease as the shaft turns toward higher capacitance positions. However, if the rate of capacitance change is much faster than the rate of change of voltage

in the signal, the net result will be a transfer of energy from the rotational force driving the capacitor to the signal-output channel, and amplification will occur. Since no resistances are involved, the action is theoretically free from all noise.

This electro-mechanical version cannot be made to operate at useful frequencies because the capacitor cannot be turned rapidly enough. By substituting a voltage-variable capacitor for the mechanically variable one and applying an a.c. voltage to the capacitor instead of using a motor, the amplifier can be made to function well into the microwave region.

The circuit of such an amplifier appears in Fig. 2. Many variations are possible, and most of them have been used at one time or another. The first working paramp (*para*metric *amp*lifier) used a single resonant cavity, with pump frequency chosen to be twice signal frequency so that the cavity could be made simultaneously resonant at pump, signal, and idler frequencies. Later models have used individually tuned tank circuits and have combined pump with idler, signal with pump, and signal with idler, to obtain two-tank operation.

This "idler" frequency which was mentioned in the preceding paragraph is unique to parametric amplification. It has many of the characteristics of the "sum" or "difference" frequencies found in mixer circuits, but in the paramp it is not actually used. Although unused, it cannot be ignored, however. Unless it is properly disposed of through a tank circuit that allows it to circulate and keeps it away from the rest of the circuit, no amplification will be obtained.

Noise performance of the paramp depends primarily upon the ratio of pump frequency to signal frequency. The greater this ratio, the lower the noise. Some configurations of paramps appear to have no lower noise limit (could this ratio be raised to a figure approaching infinity), while others seem to reach a "floor" in the neighborhood of "−1 db" noise figures. In terms of effective noise temperature, performance in the 20°K region has been reported at a signal frequency of 6 gc., with the paramp refrigerated to a temperature of 90°K. With room-temperature components, 55°K effective noise temperatures have been recorded at 6 gc. Noise performance appears to be relatively independent of frequency between 400 mc. and 6 gc. where the majority of work with paramps has occurred.

In comparison with the maser, the paramp has the advantage of greater simplicity but suffers the disadvantage of slightly poorer performance. Its commercial and military applications are primarily in the area of portable and mobile equipment; fixed stations which are not intended to be moved at any time tend to use the maser where possible because of its better performance. Complexity of operation is about equal for both types of amplifiers.

Tunnel Diodes

A simpler approach to low-noise amplification than either of the methods already discussed and which yields performance approaching but not equaling the maser and the paramp, involves the Esaki or tunnel diode.

This device is a specially treated semiconductor diode which exhibits a "quantum mechanical tunneling" effect and which, under proper circuit conditions, is effectively a negative resistance.

By connecting this negative resistance into a tuned circuit low-noise amplification may be obtained.

A 100-mc. tunnel-diode amplifier circuit, designed to be inserted in a 50-ohm transmission line, is shown in Fig. 3. This circuit was intended for high gain over a wide bandwidth, rather than for lowest noise, and so the designers (*G-E*) did not specify noise performance. Calculated noise figure from published constants appears to be approximately 8 db.

Lower noise figure would be obtained by reducing the source impedance seen by the amplifier (through tuned-transformer techniques) and by reducing current flow, but this would require complete redesign to avoid circuit oscillation.

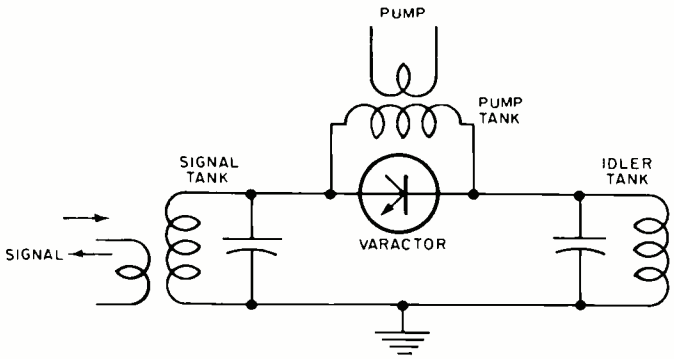


Fig. 2. Basic circuit of a low-noise parametric amplifier.

The tunnel-diode amplifier is the simplest of all low-noise r.f. amplifier circuits, both in arrangement of parts and in the number of components, but suffers one serious disadvantage at the present state of the art. The diode itself is capable of amplification at an infinite number of frequencies simultaneously and can also oscillate at a near-infinite number of frequencies while amplifying at all the rest. This makes the stabilization of such an amplifier a most tedious process. Regardless of the frequency at which a tunnel-diode amplifier is to operate, u.h.f. construction facilities must be employed in order to suppress parasitic oscillations.

Despite this disadvantage, designers are presently conducting intensive study of the tunnel diode for use in u.h.f.-TV circuitry; it can be expected to appear in mass-produced consumer equipment within the next few years.

Transistors & Special Tubes

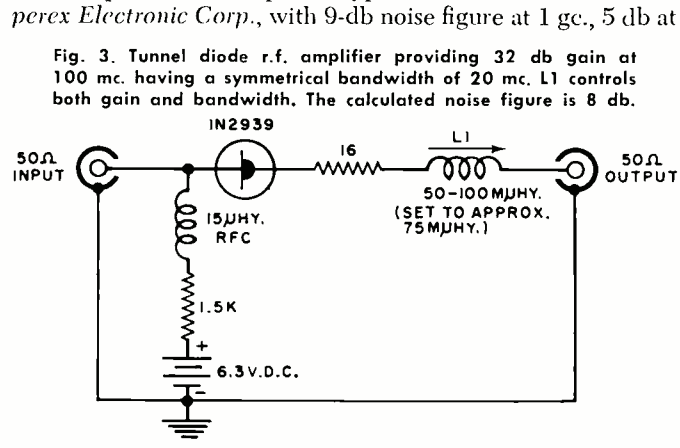
All of the low-noise techniques discussed heretofore have involved either radically different concepts, or specialized new components, or both. However, transistors and vacuum tubes have also made recent strides forward in low-noise performance to the point that the more exotic techniques are proving to be less and less necessary for all but the most exacting applications.

For instance, transistors are now in production which have guaranteed maximum noise figure of 4.5 db at signal frequencies up to 500 mc., with noise figure of 2 db or less at lower frequencies. This, while not as spectacular as the performance of the maser or the paramp, still represents a notable achievement when compared with the low-noise amplifiers of only a few years ago.

Circuitry for low-noise amplifiers using these newer transistors is virtually identical to established, standard transistor r.f. amplifier circuits and is not shown here.

One of the best performers among transistors in the noise arena is the 2N2857, produced by *RCA* and by *Kmc Semiconductor Corporation*. This one is guaranteed to have a noise figure below 4.5 db at 500 mc. and below 2 db at 200 mc. A runner-up is the development type number A1243 from *Amperex Electronic Corp.*, with 9-db noise figure at 1 gc., 5 db at

Fig. 3. Tunnel diode r.f. amplifier providing 32 db gain at 100 mc. having a symmetrical bandwidth of 20 mc. L1 controls both gain and bandwidth. The calculated noise figure is 8 db.



500 mc., and 3.5 db at 70 mc. The 2N2495 from *Amperex* exhibits a 2-db noise figure in the range from 150 kc. up to 25 mc., increasing to 5 db at 200 mc. Similar low-noise transistors are also produced by *Philco*, *Sprague*, and others.

Advances in noise performance of vacuum tubes are due primarily to new manufacturing techniques developed by a number of firms which allow closer control of tube characteristics and permit virtually microscopic tube structures.

Most widely publicized of these advances is probably *RCA's* nuvistor, which has been thoroughly described in the electronic press since its introduction. This thimble-sized ceramic-and-metal tube features coaxial construction with multiple supports for each element. The resulting structure is so rigid that the tubes are almost immune to damage.

Most widely known of the nuvistors are the types 6CW4 and 6DS4, both triodes intended for v.h.f. amplifier service in TV tuners. However, many other types are also available under industrial (four-digit) type numbers. Among these are the 8058, which features double-ended construction and automatic grid grounding, and the 8056, a low-plate-voltage triode. The construction of the 8058 is especially designed for u.h.f. use, and it may be employed well into the microwaves, thus extending the advantages of nuvistors into u.h.f. (lead inductance limits the 6CW4 and 6DS4 above 200 mc.).

The nuvistor is not, however, the only new type of tubes providing low-noise performance. An equally important advance is that known as "frame-grid" construction, which apparently originated with *Philips* of the Netherlands and is now employed by most major tube manufacturers the world over for certain types of tubes.

The frame grid is a special construction technique for maintaining absolute precision in the spacing of the grid wire which, in turn, allows the tube to be designed for much greater transconductance. This leads to low noise.

One of the first of the frame-grid tubes was the type 6ES8, which can be substituted for the 6BQ7 series of cascode-design tubes in most existing r.f. amplifiers with slight modification of supply voltages and in some cases of neutralization networks; it provides a dramatic reduction in the receiver noise.

Later models include the 6HA5 single triode and the 7788 pentode. The 7788 is unique in that, although a pentode, it provided lower noise than most high-quality triodes. When triode-connected, its noise figure is virtually the lowest obtainable with vacuum tubes, being bettered only by the next group of vacuum tubes to be discussed.

Both frame-grid and nuvistor tubes are classified as normal receiving types. Another type of low-noise tube, the ceramic planar triode, falls into the special-purpose category. Used mostly in critical military and space applications, this type of tube offers the best noise performance available from conventional vacuum-tube circuitry.

These tubes physically resemble small shirt buttons more than they do vacuum tubes. Designed especially for grounded-grid circuits, they are constructed specifically to be inserted in coaxial-line cavities and are intended for the u.h.f. and lower microwave-frequency ranges. The cathode connection is at one end (with the heater connections coaxial to it) and the grid is in the middle, with the plate connection at the other end.

As the name implies, construction of these tubes is *planar* rather than *coaxial*. The cathode is a flat surface, with the grid parallel to it and only a few thousandths of an inch away. The plate is a third plane surface, also parallel.

Noise figures of these tubes range from 3 to 8 db depending upon frequency and tube type. This surpasses both the frame-grid tube and the nuvistor in the upper u.h.f. and lower microwave regions. At lower frequencies, noise figure of the planar triode drops toward the vanishing point.

Major disadvantages of the ceramic planar triode are its cost and its low availability. ▲

Computer Control

(*Continued from page 43*)

each. If an off-limit condition occurs, the computer actuates an alarm. The computer memory also contains the values obtained during previous scans of each variable, and the computer can therefore predict trends and initiate corrective action.

Using appropriate formulas and mathematical models of the process, the computer calculates optimum value for each variable according to previous and present error. Computer output is then applied to the digital-to-analog converter. The analog signals are applied to final control elements to adjust the process variables. An output scanner assures that each output signal is applied to the cor-

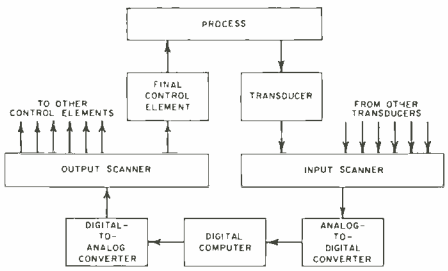


Fig. 4. The direct digital controller employs a computer in place of a more conventional analog controller unit.

rect control element according to which input signal produced that output. The computer directly controls the process rather than merely adjusting the set-point of an analog controller, hence the name *direct* digital control.

Although DDC is so new that many people, even in the computer industry, haven't yet heard of it, its promise is so great that several manufacturers are designing computers specifically for this usage. Considerable research effort is also being directed toward the development of transducers which produce digital-type outputs, eliminating the need for the analog-to-digital conversion process. Similarly, manufacturers of final control elements are busy developing devices that will respond directly to digital signals. For the user, DDC offers superior control at lower cost because it eliminates hundreds of analog controllers. ▲

THIRD HAND

ONE answer to the need for a third hand when working on electronic equipment is to use a large alligator clip, of the type used as a battery jumper for automobiles. File down the teeth to blunt them, then secure one of the handles to the workbench with a bolt or woodscrew. Because of the size of these clips and the excellent spring tension, small items can be clamped within the jaws, and work can progress with the conventional two hands. ▲

EW Lab Tested

(*Continued from page* 14)

Shure Brothers has introduced an unusual amplifier designed solely for headphone use. The Model SA-1 "Solo-Phone" is a very low-powered stereo amplifier, with inputs for tuner and magnetic cartridge and jacks for driving one or two pairs of stereo phones. It has a concentric volume control with a slip-clutch coupling for adjusting channel balance. The complete amplifier, with its integral power supply, comes in a walnut finished cabinet measuring only 10¼" wide by 3½" high by 3⅞" deep, and weighing only 2½ pounds.

The fully transistorized SA-1, although intended primarily for private listening to high-fidelity records, FM broadcasts, and tape recordings has many applications in other areas.

In our lab tests, the SA-1 delivered 30 milliwatts into a 4-ohm load, 40 milliwatts into 8 ohms, and 55 milliwatts into 16 ohms. It can be driven to comfortable listening levels by any magnetic cartridge, or from any high-level source of 0.1 volt or more. The stereo channel separation was 42 db and the hum was −50 dbm at maximum gain (completely inaudible in our phones). Some hum could be induced by touching the input selector switch, but this was not heard in ordinary use.

The basic frequency response was smooth and flat, except for a broad rise of about 5 db in the region below 150 cps. This boost is not mentioned in the amplifier specifications, but is quite beneficial in compensating for the normal loss of bass in headphones. The RIAA phono equalization was accurate, with only a gradual 2.5 db rise around 60 cps.

The listening quality of the unit was excellent and was limited only by the quality of the headphones we used. *Shure* rates its distortion at 1% for 100 millivolts output into 8 ohms. Our distortion analyzer does not operate with this low voltage, but in our listening tests we never heard any distortion at any tolerable listening level. The over-all subjective effect is definitely cleaner than we are accustomed to hearing from speakers.

This excellent little amplifier, which has a switched convenience outlet for powering a record player, tape recorder, or FM tuner, can be the basis for a personal high-fidelity system of high quality. Not only can it drive phones, but any moderately efficient speaker will deliver comfortable room volume (in a small room) with only a few milliwatts of drive. Using the SA-1 with speakers also guarantees that one's neighbors will not be disturbed.

The *Shure* SA-1 "Solo-Phone" sells for $45.00. ▲

AUDIO POWER WATTMETER

By SOL DAVIS/Philco Corp.

THE audio power wattmeter shown in Fig. 1 will measure sine-wave audio outputs up to 50 watts with its output indicator calibrated directly in watts.

Selector switch S1 is used to choose either a 4- or 8-ohm resistive load (if desired, a 16-ohm load may be added). Potentiometer *R3* is connected across the 8-ohm load resistor (*R2*) so that bridge rectifier *BR1* will see the same voltage at both switch settings. Diode *D1* is used because the bridge rectifier does conduct slightly in the negative direction and *D1* will remove this unwanted voltage. Resistor *R4* loads the bridge rectifier so that its output will be fairly linear.

Resistors *R5* and *R6* are series limiters for the low-power range, while *R7* and *R8* serve the same purpose for the high-power setting. The current flowing through *M1* must be limited to 50 μa. for full-scale meter deflection.

The circuit should be wired in accordance with good workshop practice with all wiring as short and direct as possible. The two load resistors (*R1* and *R2*) should be mounted on the exterior of the case and should be provided with proper ventilation space.

Capacitors *C1* and *C2* may be necessary for some transistor amplifiers where there may be a d.c. voltage present at the amplifier loudspeaker output terminals.

Calibration

Temporarily disconnect *R1* and place *R5* at maximum resistance. Place S1 in the 4-ohm position and S2 to the "×.1" setting.

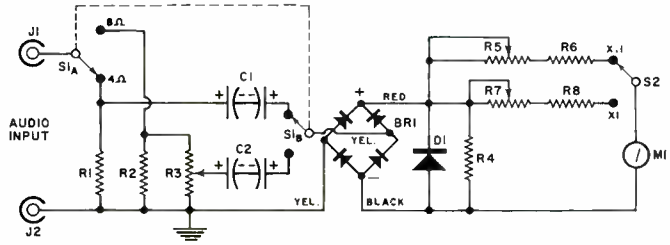
Apply 4.46-v. r.m.s. of any available sine-wave audio voltage to *J1*. Power-line frequency (60 cps) will do. Adjust *R5* until the meter indicates full scale. This is 5 watts. Reduce the input voltage to 4.0-v. The meter should be marked as 4 watts. Reduce the applied voltage to 3.46-v., 2.83-v., and 2.0-v. The meter should be marked as 3, 2, and 1 watt respectively. If the applied voltage is reduced to 1.41-v., the meter can be calibrated as ½-w.

Set *R7* to maximum resistance, place S2 in the "×1" position and apply 14.1-v. r.m.s. to the input. Adjust *R7* for full-scale (50-w.) indication. Reconnect *R1* to the circuit.

Place S1 in the 8-ohm position and increase the applied voltage to 20-v. r.m.s. Adjust *R3* until the meter indicates full scale. A high wattage source may be required to do this.

Either a v.t.v.m. or a v.o.m. better than 1000 ohms/volt may be used to set the applied voltages. ▲

Fig. 1. Audio wattmeter can be calibrated to 50 watts output.



R1—4 ohm, 50 w. res. ±1%
R2—8 ohm, 50 w. res. ±1%
R3—1000 ohm, 4 w. wirewound pot
R4—680 ohm, 1 w. res.
R5—100,000 ohm, 2 w. pot
R6—47,000 ohm, ½ w. res.
R7—500,000 ohm, 2 w. pot
R8—120,000 ohm, ½ w. res.

C1,C2—100 μf., 50 v. elec. capacitor
D1—Any general-purpose diode
BR1—Bridge rectifier (Conant Type B or equiv.)
M1—0-50 μa. meter (Weston 301 or equiv.)
J1,J2—Insulated jack
S1—D.p.d.t. switch
S2—D.p.s.t. switch

NEW V. L. F. TRANSMISSIONS

FOLLOWING the adoption by the 12th General Conference of Weights and Measures of a supplementary definition of the second based on the invariant transition of the cesium atom, the National Bureau of Standards has begun transmission of the new international unit of time from its Fort Collins, Colorado low-frequency station WWVB on 60 kc., effective January 1, 1965.

The standard carrier broadcasts from WWVB will be maintained without offset with respect to the U.S. Frequency Standard within a tolerance limit of $\pm 2 \times 10^{-11}$. Time pulses will be produced by amplitude modulation of the carrier. Each pulse is initiated at the same relative phase of a cycle of the carrier and will be repeated at one-second intervals (the international or atomic second). Thus, the new international unit of time will be made directly available to listeners for the first time.

The phase of these periodic time pulses relative to the carrier phase will be shifted by a step adjustment of 200 milliseconds, or exactly 12,000 whole cycles of the carrier, about once every three months or so in order to remain within approximately 100 milliseconds of the UT2 scale that is broadcast by the other NBS stations. Adjustment will always be carried out at 0000 UT on the first of each month. The first such adjustment was made Jan. 1, 1965.

Morse code announcements which provide the time difference, UT2 minus time of pulse, will be broadcast in the same manner as for WWV and WWVH. The difference in milliseconds will be broadcast during the identification period on the hour and every 20 minutes thereafter in International Morse code. The code, UT2 AD (for add), or UT2 SU (for subtract), is followed by a three-digit number. Added or subtracted to the time indicated by the time pulse, the correction will give the UT2 scale. Corrections will be revised daily, the new value appearing for the first time during the day after 0000 UT, and will be repeated for the ensuing 24-hour period.

Because of changes in the speed of rotation of the earth on which UT2 is based, on January 1, 1965 the clock at NBS station WWVB was retarded 200 milliseconds at 0000 hours UT (7:00 p.m. EST, December 31, 1964). The phase adjustments insure that the time pulses will remain within about 100 milliseconds of the variable UT2 scale. Thus, navigators who need the UT2 scale to determine their positions can use the new time pulses with just as much confidence as they have for those from WWV or WWVH. ▲

MOVING?

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If you've recently changed your address or plan to in the near future, be sure to notify us at once. Affix address label showing old address here, and print new address below.

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city state

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Notify us of your address change as far in advance as possible—it takes about 2 months for a change to become effective. (Eg. A notice received in **May** becomes effective with the **July** issue.)

Mail to: ELECTRONICS WORLD
1255 Portland Pl., Boulder, Colo. 80311

NEW PRODUCTS & LITERATURE

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

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

HARNESS FABRICATION SYSTEM

A new harness fabrication technique which is said to improve the costs and methods of harness tying and to overcome the problem of what to do with harness boards which have been built for a specific application after the job is finished, has been recently demonstrated.

The new "pop-up" harness board consists of a perforated aluminum work surface below which is located a movable panel to which the pins are fastened. In the "up" position, the pins are elevated sufficiently to contain all wires as they are routed. When it is time to tie the harness, the pins can be lowered to a preset height so that they do not interfere with the tying operation. When the harness has been completely tied, the retracted position of the pins facilitates removal of the harness. Moving the pins again to the "up" position readies the board for fabrication of the next harness.

In conjunction with the new board, the company has developed a "Ty-Rap" hand tool which is lightweight and has a pistol-type grip. The tool is operated by squeezing the handle-length trigger which automatically tightens the cable tie around the wire bundle and, at the proper degree of tension preset on the tool, twists and cuts off the excess. Thomas & Betts

Circle No. 126 on Reader Service Card

MIL-SPEC SUBMINIATURE SWITCHES

Three new toggle switches, which measure just 1 9/32" over-all, are designed to save valuable panel space in aerospace applications. Designed to conform to MIL-S-3950, the new units have been designated MS18150, a s.p.d.t. two-circuit switch rated 5 amps resistive at 28 volts d.c. or 120 volts a.c.; the MS18151, a s.p.d.t. single-break switch rated 3 amps resistive at the same voltages; and the MS18152, a d.p.d.t. two-circuit switch rated 2 amps resistive.

All switches are sealed and moisture-proofed. Housed in space-saving anodized aluminum cases as small as 5/16" diameter, the units mount in 1/4" panel holes. Full specification on this line will be supplied on request. Controls Company of America

Circle No. 127 on Reader Service Card

MULTITURN 1/4" TRIMMERS

Two new, humidity-proof multiturn trimming pots, only 1/4" square, for use in difficult packaging situations are now in production.

Model 15 is a circuit board flush-mounting unit measuring .250" x .250" x .185". Model 16 is a circuit board stand-off unit providing under-unit access for through circuit board cleaning. It measures .250" x .250" x .215". Standard 0.1" PC board pin spacing makes the new models interchangeable with larger trimmers and practical for use in existing designs.

Rated at 1/2 watt at 50°C, the trimmers are available in resistances ranging from 100 to 25,000 ohms at 5% tolerance. The temperature coefficient is 20 PPM/°C for the operating temperature range of −65°C to 175°C.

The 25-turn continuous rotation trimmers meet all applicable MIL-Spec requirements. Techno-Components

Circle No. 128 on Reader Service Card

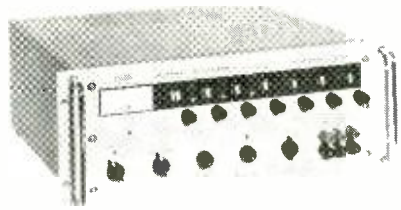
PRECISION VOLTAGE CALIBRATOR

A solid-state voltage standard for use as precision calibrator or voltage reference source is available as the Model 332A.

The new instrument will deliver any desired output voltage up to 1111 volts with an accuracy of 0.003%. Line and load regulation is 0.0005% of setting. Output current is 0 to 50 ma. at any output voltage.

Seven in-line decade switches provide 0.1 ppm resolution on each voltage range. The d.c. common mode error is less than 2 nanovolts per volt of common mode voltage (174 db CMR). Overcurrent protection automatically limits output current at any preset level between 1 and 60 ma. Overvoltage protection automatically disables the output voltage if the level exceeds the front-panel control setting.

Stability is ± 0.0015% per week or ± 0.0025% per month. The temperature coefficient is 0.0002% of setting per °C from +20 to 40 C. Ripple and



noise is less than 20 μv. r.m.s. on the 10-volt range and less than 40 μv. r.m.s. on the 1000-volt range. John Fluke Mfg.

Circle No. 129 on Reader Service Card

READOUT TUBE WITH DECIMAL POINT

The NL-809 is a new rectangular readout tube featuring a decimal point. This long life, neon-glow tube displays 0.6" high characters 0-9 and a decimal point. The decimal point is an integral part of the tube. The rectangular shape and the decimal point permit close spacing of characters with the decimal point correctly located with respect to the numerals. Use of two or more of these tubes permits switching the decimal point without wide spacing of the numerals.

The NL-809 has an ionization of 170 volts d.c., requiring a minimum supply voltage of 170 volts d.c. Higher anode voltage may be used with a proper resistor. Anode current ranges are from 1.5 to 3 ma. d.c., with a typical value of 2.5 ma. National Electronics

Circle No. 130 on Reader Service Card

COAX CABLE PLUG FOR TV

A new TV accessory, the C-59 coaxial cable plug, is designed specifically for use in conjunction with RG-59/U 72-ohm coax in television installations. At somewhat reduced efficiency, the plug can be used with polyfoam RG-59/U and RG-58/U cable.

The plug comes complete with three pins arranged for mating with the company's wall plates. For effective performance, polarization of the plug with the wall plate should be observed—shield-to-shield and center conductor-to-center conductor. Soldering is unnecessary. Mosley

Circle No. 1 on Reader Service Card

10-TURN PRECISION POTS

An exclusive film element for precision pots which produces essentially infinite resolution and provides vastly longer life, has been developed. The technique is being incorporated in the new "Infinitron" precision pots now being marketed

as the Model 3501 (bushing-mount) and Model 3551 (servo-mount) 7/8" diameter, 10-turn units.

The noise specification of 100 ohms or 1% is comparable to wirewound types. Maximum resistance change in any environment is only 5% throughout a life of 4 million shaft revolutions for the Model 3501 and 10 million shaft revolutions for the Model 3551.

Both models meet the cycling humidity requirements of MIL-STD-202, Method 103. Optional models are available which meet the moisture resistance requirements of MIL-STD-202, Method 106. Full details on the line are available on request. Trimpot Div., Bourns

Circle No. 131 on Reader Service Card

HIGH-POWER SILICON RECTIFIER

The 400VB is a 400-ampere silicon power rectifier incorporating a large-area alloyed junction combined with hard solder construction in order to eliminate the thermal fatigue problem normally encountered in such units.

The new line offers 50 to 1000 volt p.r.v. and is engineered and manufactured to withstand operating and storage temperatures of −40 C to +190 C. The units are supplied in standard or reverse polarity for design flexibility. Bulletin SR-158-X contains complete technical information. International Rectifier

Circle No. 132 on Reader Service Card

WIRE STRIPPING COMPOUND

The rapid removal of such high-temperature insulation as DuPont ML or REL Magnet Isonel No. 200 can be accomplished by means of a new compound called PT-5-ML wire stripper. The stripping action takes place in approximately three minutes at 110°C and is accomplished by dissolving the insulation film. Speedier action can be obtained with higher temperatures. The vapor arising from the heated solution is completely neutral.

Parts are completely stripped preparatory to soldering and a water rinse leaves the surfaces clean and ready for soldering. London Chemical

Circle No. 133 on Reader Service Card

SOLDERABLE PAINT

A new electrically conductive polymer alloy with outstanding adhesive properties is now being marketed as Type 350, a silver-filled paint which adheres readily to conventional solders, metals, plastic, glass, rubber, and ceramic surfaces.

Anticipated usages including coatings for tantalum anodes, electrostatic shielding, and component grounding. Maximum volume resistivity is reported to be .001 ohm-cm.

The product requires no formulating and can be applied directly from the container by dip, brush, or roller coating, in addition to silk screening. Dynaloy

Circle No. 134 on Reader Service Card

MICROMINIATURE TRIMMERS

An improved line of microminiature trimming pots, completely redesigned to utilize a new production process called "Weld-Fast," is now on the market. The 2600 line trimmers are only ¾ inch long, 5/16 inch high, and 5/32 inch wide. Resolution is said to be 53 percent better than comparable units because the mandrel runs the full length of the trimmer. Unnecessary mounting holes have been eliminated.

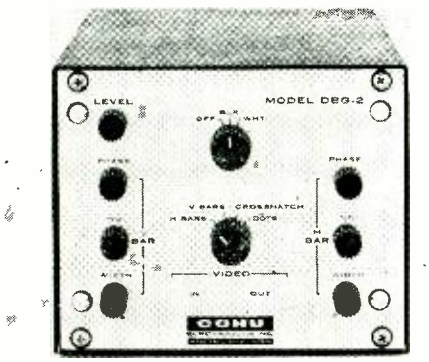
The standard trimmers exceed MIL-STD-202A, steady-state, for humidity while the humidity-proof 2610 versions exceed MIL-STD-202B. Resistance values range from 10 ohms to 20,000 ohms and have a power rating of one watt at 40°C. Amphenol Controls

Circle No. 135 on Reader Service Card

DOT-BAR GENERATOR

A new dot-bar generator that provides test patterns for TV systems having scan rates from 525 to 1029 horizontal lines is now on the market as the Model DBG-2.

The new instrument is designed to measure the linearity of the television system and its component equipment, as defined by EIA Standard RS-170. Four test patterns may be selected



for modulating the incoming video signal: horizontal bars, vertical bars, crosshatch or grating, and dots. The dot pattern is useful for convergence of color-TV receivers.

A polarity control provides either a white or black pattern on the monitor. This all-solid-state dot-bar generator operates with either composite video or external sync pulses, and patterns are adjustable for width, number, and position.

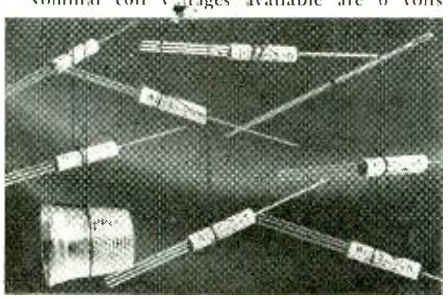
The instrument measures 9" x 6" x 5" and weighs just 3 pounds. Cohu

Circle No. 2 on Reader Service Card

ULTRAMINIATURE NEEDLE RELAY

What is billed as the world's smallest glass reed relay is now available as the Series 370. It occupies a volume of 0.02 cubic inch and is only 0.19 inch in diameter. The small size of the new needle relay permits a packaging density exceeding that of semiconductors and provides the advantages of hard contact switching.

Nominal coil voltages available are 6 volts and 12 volts with nominal rated coil power of 50 or 60 mw., respectively. Contacts are rated at 125 ma., 4 watts and 10×10^6 operations at rated load can be expected. Maximum operate time is .40 m-sec. and weight is only 1.1 grams.



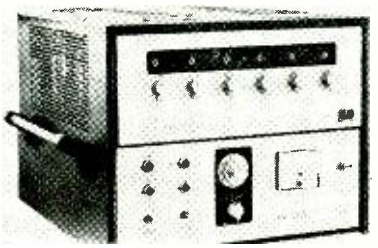
The low profile of the relay permits close stacking of PC boards. Application areas include aerospace, integrated circuits, and miniaturized instrumentation circuits. Wheelock Signals

Circle No. 136 on Reader Service Card

A.C. VOLTAGE STANDARD

A true absolute a.c. voltage standard featuring an internal, continuously variable oscillator is now on the market as the Model 146-AV10.

The new instrument provides a precision voltage in six fully switched decades from 0 to 511.110 volts r.m.s. and continuous frequency selection from 38 to 11,100 cps. The true absolute accuracy is 0.025%, including the algebraic sum of all calibration uncertainties, 1 year stability, and temperature effects from 15° to 35°. Total harmonic distortion is 0.01% from zero to full load.



The circuit features all-solid-state, modular construction and is completely short-circuit-proof. Convection cooling is provided. Weston-Rotek

Circle No. 137 on Reader Service Card

½-INCH-SQUARE POT

A new ½-inch-square, worm-gear-actuated adjustment potentiometer designed specifically for industrial and commercial use has been designated the Model 3257 "Trimit."

Features include an idling mechanism which prevents damage from forced adjustment at the end of wiper travel, a temperature range from −65 to +105°C, fused "Silverweld" termination, and shock and vibration capabilities of 20 g and 100 g, 2000 cps respectively.

Resistance range of the new pot is 10 to 20,000 ohms ± 10%. Power rating is .25 watt at 25°C. Actual dimensions are ½" x ½" x 0.22". Trimpot Div., Bourns

Circle No. 138 on Reader Service Card

TRANSFER TYPE FOR PC'S

A number of electronics manufacturers, seeking to improve their printed circuits, are using transfer type to insure the permanency of letters, codes, or symbols on their products.

The type comes in sheets measuring 10" x 13" in 300 different type faces in 10 pt. to 188 pt. sizes. Stock colors are opaque black, white, and red. Custom-printed alphabets, codes, or symbols are available on special order in these colors or any other color required.

The letters can be applied to practically any smooth surface and if they do not come in contact with an abrasive will last indefinitely. The letters are heat-resistant and can be used for blueprint, ozalid, or other heat-producing reproduction machines. Cello-Tak

Circle No. 139 on Reader Service Card

COMMERCIAL TRIMMERS

Two new models of a low-cost 5/16" "Squaretrim" pot have been added to the firm's line of commercial trimmers as the Models 501 and 502.

The Model 501 (back pins) and the Model 502 (side pins) require space totaling only 0.07 cubic inch in volume. They have a wide range covering 10 to 30,000 ohms with a precision tolerance of ± 5% and a resolution better than .124%. Adjustability is 15 mechanical turns and a slip-clutch eliminates mechanical damage to the wiper.

Other features include high power of 0.5 watt at 70 C and low noise of 100 ohms maximum. Operating temperature range is −55° to +150°C, with a low temperature coefficient of ± 70 PPM C maximum. Weston

Circle No. 140 on Reader Service Card

COAX CUTTER AND STRIPPER

A compact, efficient stripper designed specifically for cutting and stripping RG-59 U is now on the market. The tool is also adjustable to other sizes. It has two stripping holes; the larger one is for removing outer insulation and braid while the smaller stripping hole easily removes the inner insulation.

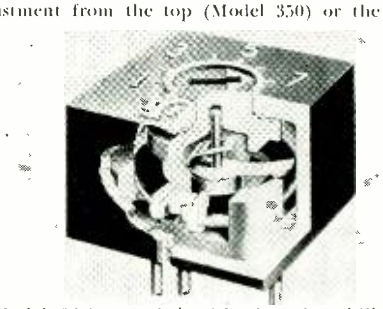
The tool is manufactured from high-quality spring steel and the cutting edges are honed and heat-treated to give long service life. The handles have cushion grips for comfort. Hunter Tools.

Circle No. 3 on Reader Service Card

HIGH-RESISTANCE MINIATURE TRIMMER

The resistance limit of its popular 5/16" cube trimmer has been increased by using an exclusive metal glaze for the resistance element. The new unit provides a virtually infinite resolution output in standard ranges from 50 to 50,000 ohms. Particularly suited to high-density packaging, it is rated at 0.3 watt at 70 C and conforms to all applicable environmental specifications of MIL-R-22097.

Positive stops and single-turn screwdriver adjustment from the top (Model 350) or the side



(Model 360), coupled with the adaptability to high-frequency circuits, make these trimmers of interest to both the design and the packaging engineer. International Resistance

Circle No. 141 on Reader Service Card

HI-FI—AUDIO PRODUCTS

STEREO TAPE CARTRIDGES

The initial release of 175 of the firm's best-selling disc titles on "Stereo 8" tape cartridges has been announced. Designed specifically for use with new 8-track stereo players designed for moving vehicles as well as the home, the new "Stereo 8" cartridges are backed by a one-year warranty.

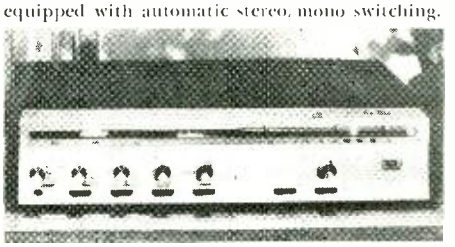
The library includes popular, original cast and sound track, jazz, classical, and light classical selections. RCA Victor

Circle No. 4 on Reader Service Card

SOLID-STATE STEREO LINE

The Series 1100 line of solid-state components includes the Model 1144 50-watt amplifier, the Model 1155 FM-stereo tuner, the Model 1156 AM-FM-stereo tuner, the Model 1177 FM-stereo receiver, and the Model 1178 50-watt AM-FM-stereo receiver (photo).

The 50-watt amplifier has computer-type program lights on the front panel to indicate input source while the direct-coupled output eliminates transformer and capacitor limitations. The solid-state circuitry is virtually heat-free. The tuners are styled to match the amplifier. Both are equipped with automatic stereo, mono switching.



A full-time stereo indicator light shows the presence of a stereo broadcast irrespective of the position of the stereo/mono switch. Dial locations of favorite FM stations can be marked by means of movable station markers located just above the tuning dial.

The receivers combine the features and specifications of the amplifier and tuner in one compact unit. A recessed terminal panel conceals all connectors, assuring neat installation anywhere. Electro-Voice

Circle No. 5 on Reader Service Card

THREE-WAY SPEAKER SYSTEM

A recently released, 3-way speaker system combines high-fashion furniture design with hi-fi performance as the "Mediterranean."

The system features an exclusive all-electric,

tri-sectional sonic control for adjusting the speaker performance to room acoustics. This feature eliminates amplifier adjustment which would affect over-all response.

The acoustical loading chamber for the speaker-system components has been integrated into a decorator-styled commode which is usable as a lamp or occasional table. The cabinet stands 22½" high and is 24⅜" in diameter. The acoustically correct grille cloth is neutral and blends with any decorating scheme.

Power handling capacity is 50 watts integrated program material and frequency response is from 25 to 20,000 cps with crossovers at 800 and 5000 cycles. University

Circle No. 6 on Reader Service Card

COMPATIBLE STEREO PICKUPS

To insure compatibility with all types of stereo equipment, four different V-15 pickups, each designed for a specific application, have been developed.

The V-15/AC-2 is for conventional record changers where high output and heavier tracking forces are required. The V-15/AT-2 is for lighter tracking and high-quality automatic turntables. The even more compliant V-15/AM-1 is designed for professional-type manual turntables while the elliptical stylus V-15/AME-1 is designed for the technical sophisticate.

The cartridge is subminiature and weighs 5 grams in order to take full advantage of low-mass tonearm systems. It is equipped with the company's floating stylus and patented replaceable "V-Guard" stylus assembly. Additional styli for mono and 78 rpm use are available and are simply plugged into the cartridge. Pickering

Circle No. 7 on Reader Service Card

TRANSISTORIZED TAPE RECORDER

The Model 1020 high-fidelity tape recorder/reproducer offers a number of professional features of interest to the audiophile. The unit is fully transistorized and includes a professional-quality hysteresis synchronous capstan drive motor, two permanent split-capacitor reel drive motors, two vu meters, and a sturdy die-cast mainplate.

The unit will accept reels up to 8¼" in diameter which boosts playing time by 50 percent. A

digital counter with push-button reset and dual headphone jacks on the front panel are exclusive with the Model 1020.

A decorator-styled base of polished walnut is available as an accessory. Magnecord

Circle No. 8 on Reader Service Card

WIRELESS INTERCOM

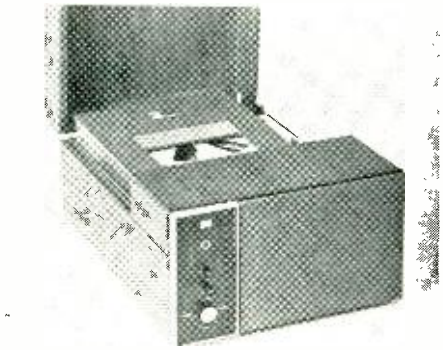
A solid-state wireless intercom designed for use in the home, office, or factory is now available as the No. 99-1373M. It will connect any two locations fed by the same electric company power-line transformer. Each unit is merely plugged into the a.c. outlet and is ready to operate. Each unit is a "master" with a volume/on-off control, push-to-talk bar with "lock-bar" feature for continuous operation, and measures 6½" x 5" x 2½".

Housed in a two-tone grey plastic case, these transistorized units will operate from 110-120 volts, 60 cps a.c. Lafayette

Circle No. 9 on Reader Service Card

BACKGROUND MUSIC SYSTEM

A self-contained, on-location background music system which plays 700 musical selections and is designed primarily for small business, commercial, and industrial locations is being marketed as the "Cantata 700."



Playing music from its own stored sound tape library, the "Cantata" does not depend upon a central studio and does not require external phone lines or complex antenna systems. The unit is compatible with any existing sound system and can be used with a wide range of accessory amplifiers, microphones, and speaker systems to cover virtually any location.

The unit is being offered for outright purchase, including the tape library, rather than on a rental basis as is usually the case with such systems. 3M Company

Circle No. 10 on Reader Service Card

MINIATURE AUDIO TRANSFORMERS

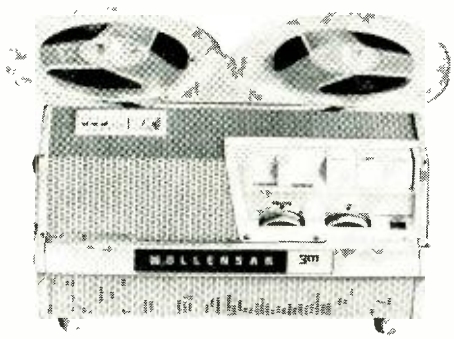
The smallest available audio transformer—the PIL-50 measuring 5/16" in diameter by 5/16" high and weighing only 1/50 ounce—is now being offered as a stock item. The transformer is metal encased, hermetically sealed, and manufactured and guaranteed to MIL-T-27B by full environmental testing.

The DO-T type structure used overcomes inherently poor electrical characteristics usually found in miniature audio transformers. Electrical parameters include 500 ohms c.t. primary impedance, 30 ma. unbalanced d.c. in the primary, secondary impedance 500 ohms c.t. and a maximum level of 100 mw. Frequency range at 1 mw. is 800-250,000 cps ±3 db. UTC

Circle No. 142 on Reader Service Card

AUDIOVISUAL TAPE RECORDER

A new solid-state, all-transistor monophonic tape recorder, designed exclusively for the audiovisual field, is now available as the Wollensak Model 1500 AV. The recorder features 10-watt, all-transistor circuitry; automatic shut-off; a vu



meter; reset circuit breaker; three-wire grounded power cord with conventional two-wire adapter; two recording speeds; and two inputs for microphone or radio/phono.

The unit weighs 18 pounds and is being handled exclusively by audiovisual dealers. 3M Company

Circle No. 11 on Reader Service Card

CONTEMPORARY SPEAKER SYSTEM

Styled in a contemporary upright walnut cabinet with a Spanish wood fretwork grille, the 847A "Seville" requires less than 2 square feet of floor space, making it ideal for use in a small room or apartment. Inside the cabinet are a 414-type 12" bass speaker, an exponential horn, and a compression high-frequency driver. A special two-section 3000-cycle crossover network is also provided.

The "Seville" is designed to operate from 8 or 16 ohms, is rated at 20 watts, and has a frequency response of 40-22,000 cps. Dimensions are 26" high x 19" wide x 14" deep. Altec Lansing

Circle No. 12 on Reader Service Card

BATTERY-OPERATED RECORDER

A compact, low-cost, battery-operated tape recorder, designed for voice applications, is being marketed as the Model F-20 "Sound Camera."

The unit comes with a remote-control microphone, solid-state circuitry, a new peripheral drive system, precision tape transport mechanism, and flux-field head for improved response at slow tape speeds. A standard 2 3/8" reel will provide 30 minutes of recording time.

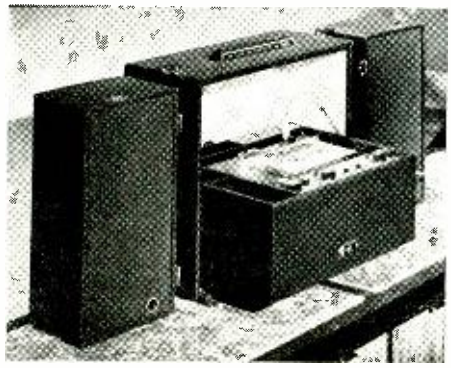
The recorder measures 6 3/8" x 2 1/4" x 4 1/2" and weighs 2 pounds. Concord

Circle No. 13 on Reader Service Card

NEW TAPE-RECORDER LINE

A complete line of fully transistorized, printed-circuit tape recorders, which are available for reel-to-reel as well as cartridge operation, has just reached the market.

Typical of the machines in the new line is the "Relay III" (photo) a 4-track portable stereo tape recorder which handles cartridges. The detachable speaker wings contain two 9" oval



speakers and two 3 1/2" tweeters and can be separated up to 24 feet. A tilt-down tape deck makes for easy access to all controls.

The four-track, two-speed cartridge operation provides up to one hour of stereo at 3 3/4 ips while up to four hours of monophonic voice recording is obtainable at 1 7/8 ips. RCA Victor

Circle No. 14 on Reader Service Card

AUTOMATIC TURNTABLE

Continuously variable anti-skating compensation, silicone-damped automatic cueing, and a single-play spindle that rotates with the record are among the major features of the new "Dual 1019" auto/professional turntable.

Anti-skating is applied within the tonearm system, around the pivot and in the horizontal plane, directly counter to the direction of skating. A direct-reading numerical dial, located in the base of the tonearm, enables the user to induce the proper anti-skating compensation for any stylus, according to stylus radius and tracking force applied.

The 1019 also features automatic start in both single play and changer operation, ½-gram tracking, 6% variable speed for all four speeds, direct-dial stylus force adjust, tonearm dynamically balanced in all planes, a 7½-pound dynamically balanced non-ferrous turntable platter, soft spring-mounted footings, and built-in provision for shutting off the amplifier automatically at the end of play.

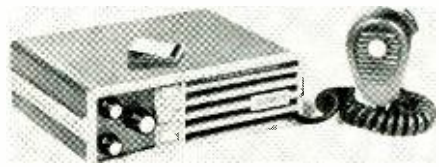
The unit measures 12 3/4" x 11 1/2" with just 6" required above base and 3" below. United Audio

Circle No. 15 on Reader Service Card

CB-HAM-COMMUNICATIONS

ALL-SOLID-STATE CB UNIT

An 11-channel, all-solid-state CB radio, the "Escort II," features a special mono-crystal "Hetro-Sync" circuit which provides additional channels with the installation of a single crystal for each



new channel. The new circuitry effects considerable savings since most CB units require two crystals for each channel. In addition, the circuit utilizes a zener diode in the input circuit for stability and special close-tolerance crystals to provide a frequency tolerance of ± .003%.

Features include low power drain (0.4 amp receive, 1.5 amps transmit), special high-gain audio power amplifier, negative peak clipping and high-level saturation limiting to prevent overmodulation and provide extra talk power.

It also has an external speaker jack, collector-current metering jack, and a pi-network output circuit with TVI filter. Over-all dimensions are 8 1/2" wide x 2 3/4" high x 8 1/2" deep. The unit weighs 5 pounds. Pearce-Simpson

Circle No. 16 on Reader Service Card

WIRELESS MICROPHONE SYSTEM

The new wireless system recently put on the market consists of a crystal-controlled receiver as well as transmitter. The Model 50 FM transmitter is FCC-approved in the Business Radio Service. It is frequency modulated, uses solid-state circuitry, and will operate on a single 9-volt mercury battery having a life of 25 continuous hours. Range of the transmitter is up to 5000 feet, depending on conditions. The unit measures 2 1/2" x 3 1/2" x 1 1/8" and weighs only 8 ounces with battery and mic.

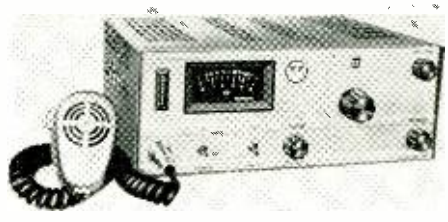
The Model 300 FM receiver has a sensitivity of 1/4 mv. for 20 db quieting. The receiver has both high- and low-Z outputs which can be connected to any p.a. system. Alan I. W. Frank

Circle No. 17 on Reader Service Card

MOBILE CB UNIT

A self-contained, mobile CB transceiver, called "The Raven," is a compact unit measuring only 4" high x 10 3/4" wide x 8" deep.

Special features of this new unit include opto-



electronic automatic compressor, two-nuvistor cascode front-end, 12 tubes with 19 functions; 2 transistors, and 5 diodes. There are no synthesized circuits.

The complete unit, including speaker and transistorized 12-volt power supply, is constructed on a single chassis. An "S" meter with special regulated bridge circuit and an r.f. indicator meter showing relative power are built in.

The transmitter has 100% peak limited plate modulation while the receiver has sensitivity of 0.2 μv. for 10 db of quieting. The unit features all 23-channel crystal-controlled transmit and receive. Adjacent-channel rejection is 80 db down. Browning Labs

Circle No. 18 on Reader Service Card

MANUFACTURERS' LITERATURE

LAB CHART & CATALOGUE

A reference chart of standard formulas and tables designed for use by electronic technicians with laboratory test equipment is now available. Featured are typical test set-ups for determining return loss and response, amplitude response, and u.h.f. converter performance.

Also offered is a new catalogue of test instruments covering sweep generators, field-strength meters, delay lines, fixed attenuators, and high-output detectors. Blonder-Tongue

Circle No. 143 on Reader Service Card

POTENTIOMETERS

The latest information on trimming, precision, and non-linear potentiometers and miniature switches and turns-counting dials is presented in a new 8 page short-form catalogue.

Included in the booklet are design details, photos, and prices. Spectrol

Circle No. 144 on Reader Service Card

PHOTOELECTRIC CONTROLS

A complete line of transistorized photoelectric controls is presented in a new 20-page, fully illustrated catalogue. Discussed in detail are plug-in logic modules, counters, scanning assemblies, self-contained controls, and accessories.

Featured is a special 2-page section of design notes. Farmer Electric

Circle No. 145 on Reader Service Card

INDICATOR LIGHTS

A new 8-page illustrated catalogue (L-200D) presenting a complete line of neon and incandescent oil-tight pilot lights for heavy-duty industrial applications is now available. Dialight

Circle No. 146 on Reader Service Card

PLUGS & PATCH CORDS

A wide variety of phone, flat, miniature, and double-pronged plugs and patch and replacement cords for electronic, broadcasting, and military applications is described in a new 12-page, fully illustrated catalogue, No. P-202.

Of special interest is a "Silent Plug" which features a built-in circuit device that prevents annoying "squeals" if the plug is accidentally touched, making it ideal for use with musical instruments. Switchcraft

Circle No. 19 on Reader Service Card

COILS & TRANSFORMERS

A new 16-page cross-reference guide to the coils and transformers manufactured by five companies has been issued. Prepared in handy chart form, the guide (Form 715) is a listing of all competitive units for which there is an equivalent in the line of the issuing firm. Merit

Circle No. 20 on Reader Service Card

WIRING DEVICES

A complete line of wiring devices for commercial, industrial, and residential use is presented in a new 132-page catalogue (No. 5A-153). More than 100 new products introduced during the past year are included.

Wiring diagrams, dimensional drawings, and suggested engineer's specifications are contained in a technical section. General Electric

Circle No. 21 on Reader Service Card

POWER SUPPLIES

A comprehensive 48-page catalogue containing complete specifications on voltage and current-regulated power supplies is now available. The fully illustrated brochure (B-657) features a special 4-page glossary of power-supply terms and also includes a 6-page section of application notes covering measurements, dynamic impedance, and constant-current operation. Kepco

Circle No. 147 on Reader Service Card

METER CATALOGUE

Forty different types of meters, such as taut-band, aircraft, subminiature, wattmeters, frequency meters, and portable laboratory-standard units, are fully illustrated and described in a new 12-page quick-reference guide (M865). Hickok

Circle No. 148 on Reader Service Card

PANEL METERS

A new 16-page, fully illustrated bulletin (No. 47) on panel meters and pyrometers is currently available. Covered in the booklet are units with black phenolic and clear plastic cases, ruggedized-sealed devices, portable and bench pyrometers, and a king-sized meter for distant viewing.

Complete specifications including physical dimensions and prices are provided. API Instruments

Circle No. 149 on Reader Service Card

ELECTRONIC COMPONENTS

Complete technical information on various types of capacitors, RFI filters, rectifiers, diodes, and integrated networks is provided in a new 28-page illustrated catalogue (No. 66). Erie Technological

Circle No. 150 on Reader Service Card

RESISTANCE ELEMENT

A combined data sheet and designer's order form for custom hot-molded carbon resistance elements has been made available. The data sheet contains applications, a table of specifications, and a temperature coefficient curve.

The postage-paid, self-mailing order form allows the engineer to sketch the mechanical design of the custom resistance element he would like to order and fill in its electrical specifications, such as resistance, tolerance, dissipation, mechanical life cycle requirement, and special requirements. Clarostat

Circle No. 151 on Reader Service Card

SEMICONDUCTORS

More than 600 types of silicon rectifiers for industrial, military, and commercial applications are listed in a new 16-page catalogue. Also included is a 2-page section showing case dimensions for all types. Semicon

Circle No. 152 on Reader Service Card

ZENER DIODES

A new, updated selection guide covering more than 4000 different zener and reference diodes is now available. Suitable for wall or desk, the guide lists zeners with nominal voltages from 2.4 to 200 volts in ±5%, 10%, and 20% tolerances. Motorola Semiconductor

Circle No. 153 on Reader Service Card

PHOTOELECTRIC CELLS

Technical information on a complete line of cadmium sulfide photoelectric cells, ranging in size from ¼" to 1", is offered in a new brochure, No. 67-473. Included are current-voltage curves, spectral response, and cell resistance vs illumination. Pioneer Electric

Circle No. 154 on Reader Service Card

SILICON RECTIFIERS

A new selection guide listing about 200 silicon rectifiers capable of replacing more than 1000 devices is currently available. Convenient for wall or desk, the guide covers rectifiers in current ratings to 1000 amperes and in voltage ranges from 50 to 1000 volts. Motorola Semiconductor

Circle No. 22 on Reader Service Card

THYRATRONS

Complete information on the principle of operation, construction, applications, characteristics, and ratings of hydrogen thyratrons is contained in a new 15-page brochure and selection guide. General Electric

Circle No. 155 on Reader Service Card

TRANSISTOR DATA SHEETS

Three new engineering bulletins are offered describing a number of new silicon epitaxial planar transistors. Bulletin No. 32201 discusses types 2N2368 and 2N2369, bulletin No. 32202 covers type 2N2369A, and bulletin No. 32204 gives details on type 2N914. All four transistors are designed for high-speed switching applications, and complete electrical and mechanical specifications are provided. Sprague

Circle No. 156 on Reader Service Card

TESTS ON WROUGHT IRON

A special 12-page report entitled "Attenuation of Electromagnetic Fields Using Wrought Iron" has been released. The booklet describes how wrought iron was tested to determine its shielding ability from magnetic energy and radio frequencies in the 30-cps to 10-billion-cps range. Complete information on measurement equipment and techniques is supplied, as well as a number of graphs and charts. A. M. Byers.

Circle No. 157 on Reader Service Card

PLASTICS CHART

A new 4-page chart (CDX-2A) comparing a new engineering plastic "PPO" (polyphenylene oxide) with other plastics has been published. Materials covered include polycarbonate, acetal, nylon (6/6), polypropylene, and PTE and FEP fluorocarbons.

Physical, mechanical, thermal, and electrical properties are compared in both tabular and graphic form. General Electric

Circle No. 158 on Reader Service Card

MOBILE POWER SUPPLY

A technical data sheet listing all physical and electrical specifications on the Model R28-45 power supply has just been published. The power supply operates at 28 volts d.c. and delivers up to 45 amps. It is fully regulated at ± 1% over line and load changes of up to ± 10% and employs silicon controlled rectifiers in the regulator circuit.

Principal application for the new unit is for mobile operation in vehicles or trailers. Full details to permit determination of suitability are included in the data sheet. Chatham Electronics

Circle No. 23 on Reader Service Card

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65	Amphenol-Borg
66	Sencore

Answer to Crossword Puzzle appearing on page 69

M	O	S	A	I	C	■	P	I	C	K	U	P
U	■	O	N	■	A	T	E	■	U	■	■	H
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P	I	■	A	D	A	P	T	■	P	A	R	T
M	E	T	R	E	C	H	O	N	■	P	O	D

1965 INDEX
VOLUMES 73-74

As a service to our readers we are again presenting a complete listing of all feature articles which appeared in ELECTRONICS WORLD during 1965. We suggest you keep this for reference.

NOMOGRAMS & DESIGN CHARTS

TELEVISION & RADIO

TEST EQUIPMENT & MEASUREMENTS

PRODUCT REPORTS

TUBES & SEMICONDUCTORS

ELECTRONICS MARKET PLACE

COMMERCIAL RATE: For firms or individuals offering commercial products or services. 70¢ per word (including name and address). Minimum order $7.00. Payment must accompany copy except when ads are placed by accredited advertising agencies. Frequency discount: 5% for 6 months; 10% for 12 months paid in advance. READER RATE: For individuals with a personal item to buy or sell. 40¢ per word (including name and address). No Minimum! Payment must accompany copy. GENERAL INFORMATION: First word in all ads set in bold caps at no extra charge. Additional words may be set in bold caps at 10¢ extra per word. All copy subject to publisher's approval. **Closing Date:** 1st of the 2nd preceding month (for example, March issue closes January 1st.) **Send order and remittance to:** Hal Cymes ELECTRONICS WORLD, One Park Avenue. New York. New York 10016

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INVESTIGATORS, free brochure, latest subminiature electronic surveillance equipment. Ace Electronics, 11500-J NW 7th Ave.. Miami 50. Fla.

CANADIANS—Giant Surplus Bargain Packed Catalogs. Electronics. Hi-Fi. Shortwave. Amateur. Citizens Radio. Rush $1.00 (Refunded). ETCO. Dept. Z, Box 741, Montreal. Canada.

RESISTORS precision carbon-deposit. Guaranteed 1% accuracy, ½ watt 8¢. 1 watt 12¢. 2 watt 15¢. Rock Distributing Co., 902 Corwin Road. Rochester 10, N.Y.

NEW supersensitive transistor locators detect buried gold, silver, coins. Kits, assembled models. $19.95 up. Free catalog. Relco-A22, Box 10563, Houston 18, Texas.

JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266. Spokane, Washington 99207.

ELECTRONIC Ignition Kits, Components. Free Diagrams. Anderson Engineering, Epsom, New Hampshire 03239.

DIAGRAMS for repairing Radios $1.00. Television $2.50. Give make model. Diagram Service, Box 1151 E. Manchester, Connecticut 06042.

TV CAMERAS, transmitters, converters, etc. Lowest factory prices. Catalog 10¢. Vanguard, 190-48 99th Ave., Hollis. N.Y. 11423.

WEBBER Labs. Transistorized converter kit $5.00. Two models using car radio 30-50Mc or 100-200Mc, one Mc spread. Easily constructed. Webber. 40 Morris, Lynn, Mass.

ACHTUNG! Das machine is nicht fur Gerfingerpoken und mittengraben. Is easy schnappen der Springenwerk, blowenfusen und poppencorken mit spitzensparken. Ist nicht fur gewerken by das Dummkopfen. Das rubbernecken sightseeren keepen hands in das pockets. Relaxen und watch das Blinkenlights. This attractive, brass metal plaque only $2.00 ea. ppd. Southwest Agents. Dept. E, 8331 Hwy. 80 West, Fort Worth, Texas 76116.

CANADIANS. transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics (Dept. EW), P.O. Box 1437 Winnipeg. Manitoba, Canada.

CONVERT any television to sensitive, big-screen oscilloscope. Only minor changes required. No electronic experience necessary. Illustrated plans, $2.00. Relco, Box 10563. Houston 18, Texas.

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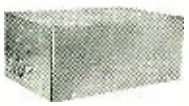

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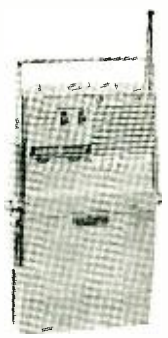

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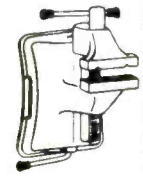

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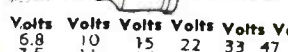

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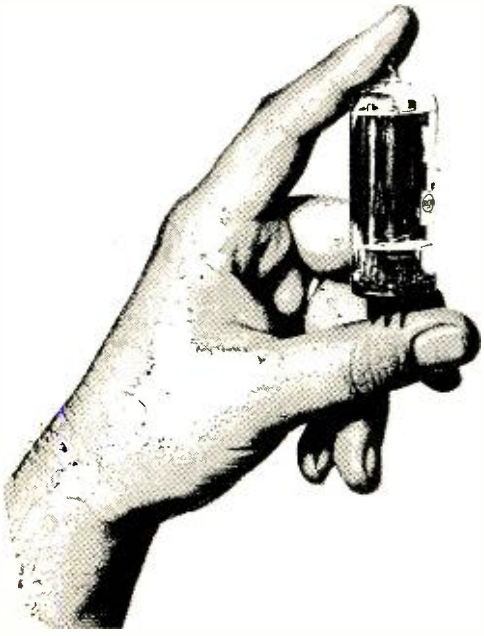

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