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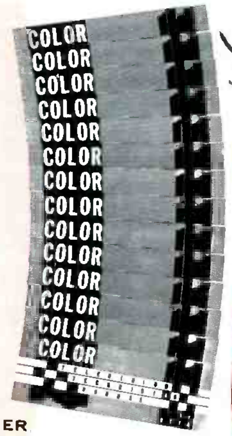
5 PICTURE TUBES FOR COLOR TELEVISION RECEIVERS — PART I
6 PICTURE TUBES FOR COLOR TELEVISION RECEIVERS — PART II
7 DETAILED OPERATION OF THE COLOR TELEVISION RECEIVER
8 THE CHROMINANCE CHANNEL
9 COLOR TELEVISION CIRCUITS — PART I
10 COLOR TELEVISION CIRCUITS — PART II
11 ADJUSTING THE COLOR TV RECEIVER
12 COLOR TV TEST EQUIPMENT
13 TROUBLESHOOTING THE COLOR TV RECEIVER
14 SERVICING PROCEDURE



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A selection
of articles
from

RADIO & TELEVISION NEWS

ZIFF-DAVIS PUBLISHING COMPANY
WILLIAM B. ZIFF (1898-1953) FOUNDER
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INTRODUCTION

Years ago it was common to hear that color television was "just around the corner." Many people believe that when it came we would be presented with a full-grown, matured accomplishment—a color television receiver with a large screen displaying resplendent natural-color programs. If this has been the goal then color television has arrived.

Color television receivers are available at a price that middle-income families can afford. From here on, steady development will improve the quality of the color display and serviceability of the receivers much the same way as this was accomplished for black-and-white sets over a period of ten years. There may be some major changes such as the use of a single-gun picture tube instead of the three-gun type now in common use. But, today's receivers are in every way worth their price. Ordinary black-and-white programs are very often transformed by breathtaking and exciting displays of lively color.

Now that color television is definitely here, the editors feel that this book is needed. It is a guide to the layman who wants to know more about color television and who wants to know whether to buy a set now. It is also a handbook for service technicians; analyzing the receivers and presenting the best known methods for installation and service. Included is a complete course in the fundamentals of color television. Also, experimenters are shown how to build a color converter for black-and-white sets.

The subject matter is divided into six chapters. The first describes the new sets now on the market and gives information about the service and installation policies of the manufacturers. It also includes a Buyers' Guide. The second chapter offers a complete course in the fundamentals of color television. Chapter 3 describes the picture tubes now in use and those that may possibly be used in the near future, as well as other specialized components that are used for color TV. How to install and service color TV receivers are covered in Chapter 4 at the television service technicians' level. Test instruments specifically designed for color television are described in Chapter 5. Chapter 6 includes material for experimenters interested in building their own color TV converters and information on studio techniques.

The articles contained herein are the best of those published on the subject in RADIO & TELEVISION NEWS. The editors have compiled this material in an easy-to-read format, based on their long experience in publishing RADIO & TELEVISION NEWS each month.

The Editors

CHAPTER 1

THE NEW COLOR SETS

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Buyer's Guide

These are the color TV sets now available. They can be seen at the larger retail stores and at distributors' showrooms. Use this guide to check prices and styles.

Company	Color TV Models (Name & Number)	Style, Period, Finish	Suggested List Price
ADMIRAL Corporation	Regent — C322C2	Consolette — Grained Mahogany	$499.95
	Regent — C322C3	Consolette — Grained Blonde	519.95
	Barcelona — C322C6/C222C6	Console — Grained Mahogany	699.95
	Barcelona — C322C7/C222C7	Console — Grained Blonde	719.95
	Ambassador — C322C16	Console — Mahogany	595.00
	Ambassador — C322C17	Console — Blonde	615.00
	President — C322C26	Console — Grained Mahogany	699.95
	President — C322C27	Console — Grained Blonde	719.95
	Patrician — LC322C36	Console — Lo-Boy — Wood Mahogany	799.95
	Patrician — LC322C37	Console — Lo-Boy — Wood Blonde Oak	819.95
	Patrician — LC322C39	Console — Lo-Boy — Sierra	829.95
EMERSON Radio & Phonograph Corporation	Model C-506	Consolette — Wood Cabinet, Mahogany, Walnut and Blonde	$678.00
	Model C-507 (u.h.f.-v.h.f.)	Consolette — Wood Cabinet, Mahogany, Walnut and Blonde	698.00
GENERAL ELECTRIC Company	21 T 500	Consolette—(Detachable Legs) Mahogany Veneer — Contemporary	$499.95
	21 C 700	Open Face Console — Traditional Mahogany Veneer	No List Price *(To be determined by Retailer and Distributor)*
	21 C 701	Open Face Console — Contemporary Walnut Veneer	No List Price *(To be determined by Retailer and Distributor)*
HOFFMAN Electronics Corporation	The Commodore — M2021	21-inch Table Model — Mahogany	$595.00
	The Commodore — B2021	21-inch Table Model — Limed Oak	615.00
	The Commodore — P2021	21-inch Table Model — Salem Maple	615.00
	The General — M4041	21-inch Console — Mahogany	695.00
	The General — B4041	21-inch Console — Limed Oak	715.00
	The General — P4041	21-inch Console — Salem Maple	715.00
	The Ambassador — M4061	21-inch Lowboy — Mahogany	775.00
	The Ambassador — B4061	21-inch Lowboy — Limed Oak	795.00
	The Ambassador — P4061	21-inch Lowboy — Salem Maple	795.00
	The President — M4021	21-inch Console — Mahogany	795.00
	The President — B4021	21-inch Console — Limed Oak	815.00
	The President — P4021	21-inch Console — Salem Maple	815.00

Company	Color TV Models (Name & Number)	Style, Period, Finish	Suggested List Price
MAGNAVOX Company	Cmud — 477	Console — Mahogany or Blonde Oak	$695.00
MOTOROLA Inc.	21 CT2M	Console — Contemporary Design, Dawn Mahogany	No List Price *(Price determined by Retailer and Distributor)*
	21CT2B	Console — Contemporary Design, Swedish Oak	
PHILCO Corporation	Model 5100	Consolette — Modern — African Mahogany Veneer, Panels of Printed "Charcoal Tweed" Above And Below The Picture Area.	$795.00 *(Including Tax)*
	Model 5102	Console — Modern — Genuine Stripe African Mahogany Veneers Fronted With Luxurious Picture Frame Moulding of Solid Mahogany.	$895.00 *(Including Tax)*
	Model 5102-L	Console — Modern — Blonde Oak Veneers And Oak Solids.	$895.00 *(Including Tax)*
RCA VICTOR	Aldrich — 21CS781	Mahogany and Grained Limed Oak Table Model	$495.00
	Stanwyck — 21CT783	Mahogany and Grained Limed Oak Consolette	550.00
	Westcott — 21CT785	Mahogany and Grained Limed Oak Console	595.00
	Dartmouth — 21CT786	Mahogany, Walnut and Grained Limed Oak Consolette	650.00
	Chandler — 21CD793	Mahogany and Natural Walnut Veneers and Solids, Door Console	795.00
	Strathmore — 21CD795	French Walnut and Bleached Birch Veneers and Solids, Door Console	795.00
	Whitby — 21CD789	Mahogany and Blonde Tropical Veneers and Solids, Console	695.00
	Asbury — 21CD791	Mahogany, Natural Walnut and Blonde Tropical Hardwood, Console	750.00
	Arliss — 21CD797	Mahogany Veneers and Solids, Door Console	850.00
	Wingate — 21CD799	Maple and French Walnut Veneers and Solids, Door Console	850.00
SYLVANIA Electric Products Inc.	The Granada — 31T304	Table Model — Contemporary, Complete Hardwood, Mahogany or Blonde Korina	$595.00 *($605.00 for Blonde)*
	The Saratoga — 31C606	Console — Contemporary, Complete Hardwood, Mahogany or Blonde Korina	695.00 *($715.00 for Blonde)*

The suggested list price includes the manufacturer's federal excise tax in many cases. Also included is a one year warranty on the color picture tube and a 90 day warranty on parts. The prices are subject to change without notice.

Hoffman "Colorcasters" for 1957

By
WALTER H. BUCHSBAUM
Television Consultant
RADIO & TELEVISION NEWS

The "Commodore," a table model, is the lowest priced set in the Hoffman line.

Owner appeal, convenient operation, and quality performance are the goals of this manufacturer.

ONE enthusiastic manufacturer of color TV receivers, *Hoffman Electronics Corp.*, is now featuring its third series of color models. The first two were the 15- and 19-inch shadow-mask tube versions of several years ago; the latest series of receivers uses the 21AXP22 exclusively. This tube is the round metal envelope improved shadow-mask version used in *RCA*, *Emerson*, and many other late-model color sets. In all *Hoffman* "Colorcasters" the picture tube is mounted in the cabinet and shipped in place.

Four basic receiver models comprise the new "Colorcaster" line, each available in mahogany, limed oak, and Salem maple veneers with prices varying according to the type of finish. Basically equipped with a v.h.f. tuner, each receiver is also furnished for full 82-channel reception at a slight increase in price. When a u.h.f. tuner is included, the model number remains the same but with the letter "U" added.

The lowest priced model is the "Commodore," a table model costing from $595 to $645, depending on the finish and whether or not it includes a u.h.f. tuner. The "General" is an open-faced console with the speaker panel below the screen; while the "Ambassador" is a lowboy style cabinet with the speaker mounted alongside the picture tube. An elaborate three-speaker sound system is used in the most expensive model, the "President." Table 1 lists the recommended retail prices on the *Hoffman* color line.

Operating Controls

Like some of the new *RCA* color receivers, the *Hoffman* "Colorcasters," with the exception of the "President" model, have the station selector and "on-off"-volume control at the upper side panel. The "President" has all controls on a vertical front panel alongside the screen. An unusual and novel feature is the addition of color dials to the hue and chroma-gain controls. As indicated in Fig. 1, the hue control background dial has a red and green section at the sides with a flesh color setting in the center. This helps the customer to ,remember that, by turning the knob to the right, greenish hues will predominate, while turning it to the left will increase the emphasis on the reds. The correct position of the hue control is indicated in the viewed picture by the naturalness of the flesh colors. When the flesh tones in the picture appear too reddish, the customer will have no difficulty in deciding in which direction the hue control should be turned.

The action of the chroma gain or "color brilliance" control is made graphic as well. Three color stripes, which taper from the weakest chroma gain to the saturation point where the stripes are thickest, are shown in Fig. 1. This clever use of human engineering in illustrating the purpose and action of the hue and chroma controls should avoid many of those service calls which are due to customer misunderstanding.

Another control that is not found in many other color receivers is the "Town and Country" switch included in every model. The action ,of this switch is basically the same as the "local-distance" switch used in many familiar monochrome TV receivers. Its presence in a color set, however, is new and will be a considerable help in locations of either excessive signal strength or in fringe areas.

In the "President" model, the chassis is mounted on its side, with the tubes pointing toward the picture tube and the bottom of the chassis accessible when the side panel of the cabinet is removed. The other three models have the chassis mounted underneath the picture tube, but with the feature that the entire chassis slides out at the rear for easy servicing. In addition to the customer-operated controls, almost all of the other adjustments are located under the removable small subpanel below the screen. These controls, together with some adjustments accessible from the rear of the receiver, permit the service technician to adjust for optimum monochrome and color performance.

Service and Installation

Hoffman's policy is that TV receiver installation and all service is the function of its distributors and dealers. Detailed service bulletins, as well as con-

NAME	MODEL NO.	TYPE	SCREEN SIZE*	FINISH	PRICE**
Commodore	M2021	Table	21"	Mahogany	$595.00
	B2021	Table	21"	Limed Oak	615.00
	P2021	Table	21"	Salem Maple	615.00
General	M4041	Console	21"	Mahogany	695.00
	B4041	Console	21"	Limed Oak	715.00
	P4041	Console	21"	Salem Maple	715.00
Ambassador	M4061	Lowboy	21"	Mahogany	775.00
	B4061	Lowboy	21"	Limed Oak	795.00
	P4061	Lowboy	21"	Salem Maple	795.00
President	M4021	"Soundorama" Console	21"	Mahogany	795.00
	B4021	"Soundorama" Console	21"	Limed Oak	815.00
	P4021	"Soundorama" Console	21"	Salem Maple	815.00

*Diagonal measurement.

**Price is suggested retail for manufacturer's local zone (with tax) on v.h.f. models. The u.h.f. models are from $20 to $30 higher.

Table 1. The current line of Hoffman "Colorcasters" includes four basic models, available in a choice of three different wood finishes, from $595 to over $800.

siderable basic instruction in color TV, have been furnished by the factory and, in addition, each receiver is supplied with a diagram (complete with frequencies, voltages, and waveforms) fastened on the inside of the cabinet.

The standard warranty for one full year on the picture tube and 90 days on all parts is provided by the manufacturer. Regular installation and service contracts are available from local dealers. Prices of these service contracts depend on the individual store and local labor charges.

Each "Colorcaster" is shipped complete and ready to operate but the average purchaser will still require an expert to install the set. Aside from the availability of a usable antenna, the color purity, convergence, and synchronizing controls almost invariably require adjustment.

Circuit Features

All of the *Hoffman* color receivers use basically the same receiver chassis with only minor modifications, usually involving the number of speakers, u.h.f. tuner, etc. This chassis employs circuitry described in detail in the article on pages 108 and 109 in this collection and is quite similar to the *RCA Victor* receiver described on page 52. One of the outstanding differences is in the action of the contrast and chroma-gain controls. By coupling these two controls together and by some modifications in the video circuitry, the usual problem of balancing out contrast with chroma gain is eliminated. Whenever the contrast control setting is changed, a corresponding change takes place in the chroma section with the result that color and *Y*-signal gain track closely.

Other features include the use of a synchroguide horizontal oscillator and a.f.c. stage, instead of the familiar multivibrator circuit. Also, in the interests of producing a quality image, there have been alterations in the color producing portions of the receiver circuit.

Revisions in the latter direction are concerned mainly with providing wider bandpass in the color-signal circuits. As an example, two stages of bandpass amplification now precede the color demodulator circuits, where one was used before.

Also, the widely adopted high-level narrow-band triode demodulators have been abandoned in favor of low-level wide-band stages. The receivers use a pair of color detector stages identified as the *X* demodulator and the *Z* demodulator. The *X* demodulator feeds to the grid of the *R-Y* amplifier, while output from the *Z* demodulator is applied to the *B-Y* amplifier. The *G-Y* signal is produced from the mixed *R-Y* and *B-Y* signals.

Another alteration is intended to facilitate balancing out the outputs of the three guns in the picture tube. In earlier receivers, separate controls were provided for the blue and green guns, but none for the red gun. Balance was achieved by manipulating the blue and green controls along with the master brilliance control, which affected output of all three guns simultaneously. The present arrangement is easier to adjust: there are separate controls for the red, green, and blue guns on the latest "Colorcasters."

For the rest, circuit design and layout do not present any radical departures from the color sets of other manufacturers.

Since installation and service are not under direct control of the manufacturer, with policy being determined locally by distributors, there is no set pattern as to whether the distributor's service personnel or that of the dealer will be responsible for the receivers after they are in the hands of their owners. Nor is there any pattern evident as to whether the receivers will be serviced on an individual-call or contract basis and, if the latter policy is to prevail, what the cost of the contracts will be. With this uncertainly, the set maker has apparently felt obligated to make available the best possible data for use by whomever will be called on to work on the sets. The well-illustrated service booklets on the "Colorcaster" chassis give complete and detailed instructions on procedure and adjustment.

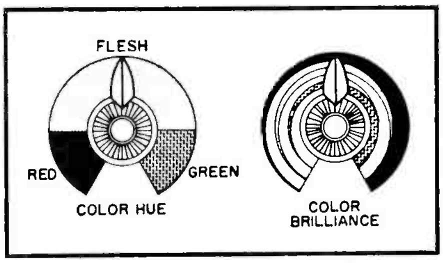

Fig. 1. Use of actual colors on the color hue and color brilliance controls is to make their functions graphic to the technically uninitiated. Note taper of the three color stripes around the color brilliance knob, to indicate range from pastel shades to saturated shades.

At the time this article was prepared, *Hoffman* had scheduled full production of all the models discussed here. Plans call for the marketing of this color line throughout the 1956-57 business year. Additional models may be released as required but the main line has been planned for current availability. —30—

The "Ambassador," lowboy model available in choice of three finishes, is made to sell for under $800. Note station selector and on-off-volume control on upper side panel, while other controls are under the picture tube, located on the horizontal chassis.

1957 ADMIRAL COLOR SETS

Fig. 1. The Model C322C27 retails in the East for about $719.95. The Model C322C26 is similar in appearance but in mahogany.

Color TV has broken through the $500 barrier with sets from many makers. Here are Admiral's sets and policies.

WITH the introduction of color receivers priced at less than $500, color is here for many; not just a select few. All signs point to an ever-growing production of color receivers and increased color programming. Thus, now is the time to consider the practical aspect of buying, selling, installing, and servicing color receivers if this has not already been done.

As with any new product, color television demands specialized knowledge at all levels of the industry—from manufacturer to consumer. Before and since the adoption of the present NTSC color standards on December 17, 1953, manufacturers have gained their knowledge by producing comparatively small quantities of receivers and watching the results very closely. Field experience gained with these first receivers, combined with extensive research and development programs, has now made it possible to mass-produce practical color receivers with realistic prices.

Admiral's 1956-1957 line of color receivers presently includes Models C322C2, C322C3, C322C16 (Fig. 2), C322C17, C322C26, C322C27 (shown in Fig. 1), LC322C36, LC322C37, and LC322C39. This is in addition to Models C222C6 and C222C7 introduced at the beginning of the year. Models C322C2, C322C3, C322C16 and C322C17 are consolettes with prices starting at $499.95. Equivalent models with built-in all-channel u.h.f. tuners are also available. There are actually four basic models, the other numbers represent cabinet finishes.

The prototype 28Y1 chassis was first produced at the beginning of the year, while the 27Z1 and 29Z1 chassis have only recently been introduced. All three of these chassis are similar, using the three-gun magnetically converged 21AXP22A color picture tube, and triode high-level demodulators.

The use of high-level demodulators allows the color signal to be coupled directly to the picture tube and eliminates the complex and costly circuits (matrix circuits) needed to add the color to the black-and-white signal, the multiple video output amplifiers, and the d.c. restorer circuits required by most low-level color demodulator circuits. Not only is circuitry simplified, but the stability of color balance is improved, for the output of the high level demodulator is practically independent of tube characteristic variations over a wide range and is not affected by changes in color signal strength or power line voltages as much as most low-level demodulator circuits.

The use of high-level demodulators and more dual-function tubes, and intensive development work based on field experience have resulted in receivers that are more efficient, reliable, easier to sell, install, and operate.

There are only six tubes in *Admiral's* new color receiver in addition to those normally used in an equivalent black-and-white receiver. By simply observing the visual symptoms, a trained color service technician can most often eliminate all but one or two of these tubes and their associated circuits as a possible cause of color trouble. Troubles in the balance of the receiver generally produce the same familiar visual symptoms presented by black-and-white receivers.

As many of the installation and service adjustments as possible are mounted on the front of the chassis behind a readily removable cabinet panel beneath the picture tube. This feature allows making convergence adjustments while directly viewing the screen. In the 29Z1 chassis, all convergence controls, including those for

By
FRANK HADRICK*
and
HUGH S. WYETH*

*Service Division, Admiral Corporation

static convergence, are located on the front of the chassis.

Since some stations transmit a color stripe signal during black-and-white programs, a color stripe test point is provided on the rear apron of the chassis. Merely shorting this test point to chassis ground permits the service technician to correctly tune in the color stripe signal and determine if the receiver will pick up a color program, reproduce the picture in correct colors with adequate range of color intensity and hue, and have stable color sync.

All *Admiral* color receivers feature only two additional operating controls for ease of operation. These are the "Color Fidelity" and "Color Intensity" controls. The fidelity control varies the phase of the 3.58 mc. oscillator within the receiver so the desired color hues will be reproduced. The intensity control varies the chroma amplifier gain and thus, as its name implies, the intensity or saturation of the colors.

Additional safety features have been incorporated in models using the later color chassis. Besides the usual a.c. power interlock which disconnects the receiver power supply when the cabinet back is removed, there are two other safety interlocks. One immediately shorts the high voltage supply if the cabinet back is removed, and thus eliminates the shock hazard presented by residual charges in the 25,000-volt supply.

The picture window safety glass is removable from the front for cleaning the glass and the face of the picture tube. Many customers perform this service, so to provide an additional safety factor, an interlock has been added which will disable the horizontal output amplifier, and thus the high voltage, should the picture window be removed with the receiver turned on.

Circuitwise, there are similarities between many of the large-screen color receivers introduced within the past months. These similarities necessarily follow from the widespread common use of a 21-inch, three-gun magnetically converged picture tube and a common trend towards high-level color demodulation of one sort or another.

In black-and-white receivers, the use of aluminized picture tubes, tinted picture tubes and picture windows, and higher video drive, makes it possible to view the black-and-white picture in a very well lighted room. This is *not* true of color receivers which should always be viewed in a room with a low light level to prevent color wash-out. For this reason, greater care must be taken in choosing the installation location for the color receiver.

Moving the receiver will affect color purity and convergence to some extent although not as much as it did previous color receivers. The customer must be made to understand this. Some technicians even go to the extent of marking the floor with strips of masking tape so that the receiver can be returned to its exact position after it has been moved for cleaning purposes.

Don't count on the existing antenna installation being satisfactory for color reception. Chances are that it will be, but even though the customer was satisfied with the black-and-white picture, the antenna may require re-orienting, repair, or replacement, to produce good color pictures.

Admiral's warranty on color receivers to the consumer is the same as for black-and-white receivers; 90 days on parts and one year on the color picture tube. Because of the higher costs of color picture tubes and other color receiver components, this warranty has a considerable monetary value. Thus, the customer should be urged to promptly register his or her receiver with the factory by mailing the postcard packed with each set.

Initially, service costs will be somewhat higher for color receivers. That color receiver service costs are higher follows from the more extensive and complex circuitry, higher costs of picture tubes and other color components, and the additional test equipment investment required of service dealers. Then, too, the very qualities that enhance the value of a color picture also mean that poor operation will be more apparent. For instance, many customers have learned to tolerate minor black-and-white ghosts. Will the same customer be as tolerant of multi-hued ghosts?

To illustrate the color service costs anticipated by at least one large service organization, consider their service contract prices. The cost of a one-year contract providing unlimited service, one-year warranty on all parts including the picture tube, and installation to an *existing* antenna is $99.50. The same service organization offers a service contract providing 90 days of unlimited service and flat-rate service calls at $7.50 each for the next nine months. The cost of this contract, which also provides a one year warranty on all parts including the picture tube, and installation to an existing antenna, is $69.50.

The differences between color and black-and-white offer a challenge not only to the service technician, but to the dealer, dealer salesman, and installation man. The seller must know the aspects of color that affect the customer, for consumer education will minimize potential service problems and increase customer satisfaction. Success in color hinges on the sale being backed with a source of good service by qualified technicians, just as is the case in the automobile industry.

—30—

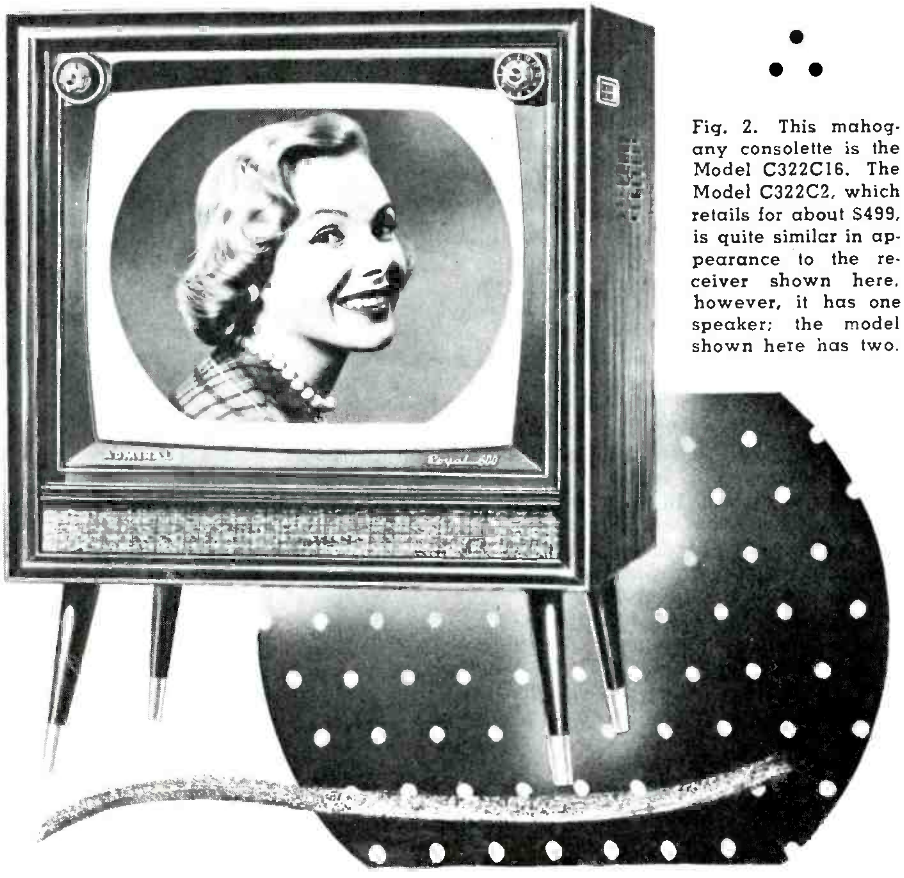

Fig. 2. This mahogany consolette is the Model C322C16. The Model C322C2, which retails for about $499, is quite similar in appearance to the receiver shown here, however, it has one speaker; the model shown here has two.

1957 RCA Color Sets

A $500 color TV set and 9 other models plus complete service contracts may make this the first big color year.

By

WALTER H. BUCHSBAUM

Television Consultant

RADIO & TELEVISION NEWS

Mr. David Sarnoff, Chairman of the Board, RCA, shown here presenting a $500 "Aldrich" color TV with 21" tube.

AN INDICATION that 1957 may be a big year for color TV can be seen in the fact that the new line of *RCA* color sets includes a total of ten different models, grouped into three basic series, "Special," "Super," and "Deluxe."

All *RCA* color receivers use the 21-inch round, three-gun, shadow-mask type color picture tube with a viewing area of 254 square inches. They are all automatically usable for either color or monochrome broadcasts and while the basic models feature a v.h.f. tuner, a u.h.f. tuner is optional in areas where both types of reception are available. The inclusion of the u.h.f. tuner is indicated if the receiver model number is followed by the letter "U."

Lowest priced of the *RCA* sets is the "Special" series which actually contains only the "Aldrich," Model 21CS-781, with a nationally advertised list price of $495. This is a table model available in mahogany or limed oak with a matching stand provided at extra cost. The "Super" series is the medium-priced line with three sets from $550 for the "Stanwyck" consolette to the "Dartmouth" consolette at $650. For the higher-priced market, a total of six models are offered ranging from the "Whitby" open console priced at $695 to the "Wingate" at $850. The latter is a colonial style full-door console and is made of maple and French walnut veneers and solids.

All *RCA* color receivers are now being shipped with the picture tube in place and should, in theory, be very simple to install. In practice there are several problems which are likely to crop up and *RCA* discourages the average customer from installing the receiver himself. One of the problems is the misadjustment of various color controls which may occur in transit. Another is the frequent limitation which an apparently good antenna shows when a color receiver is connected to it. Ghosts, smearing, and limited bandwidth or detuning are sometimes tolerable in black-and-white sets but are quite objectionable when color transmissions are received.

Still another problem is the occasional magnetization of certain components of the receiver due to transportation. This occurs when any ferric metal is moved across the magnetic lines of the earth, and may result in color impurities and/or poor convergence. A special demagnetizing coil is used to remove this defect.

Service

The *RCA Service Company* offers several plans for the installation and service of color sets. For installation alone their regular charge is $25. This applies in cases where a usable antenna already exists and where no special couplers or divider networks are required. Installation of the receiver and final adjustments on both color and monochrome transmission only are included in this price.

All components in the color set are guaranteed for 90 days. The color picture tube is guaranteed for a full year like new black-and-white picture tubes. In addition, most dealers recommend that one of three *RCA Service Co.* service contract plans be taken at the time a color set is purchased. One plan provides installation to an existing antenna and a full year of unlimited service at a cost of $99.50. This contract includes both labor and materials for any defect or trouble that might occur within the first year. The black-and-white set 1-year service contract with this company costs $59.

Optimistic customers may feel that the first three months are the most critical and for them, *RCA* offers a 90-day service policy which also includes installation to an existing antenna and unlimited service for the period stated. This 90-day policy costs $39.95.

Still another plan provides installation, 90-day service, and one year parts guarantee. The price of this contract is $69.50 with a flat charge of $7.50 for each service call after the 90-day period.

All of the preceding service and installation charges are based on the presence of a usable antenna. Installing a roof or window antenna in the New York metropolitan area, for example, costs a flat $35. Special installations requiring more elaborate equipment naturally run higher.

Recent experiences of many TV service technicians seem to indicate that antennas which have been up for five years or more should be replaced when a color TV set is installed. The mechanical mounting as well as electrical connections are often so badly corroded that the replacement might as well be made. —30—

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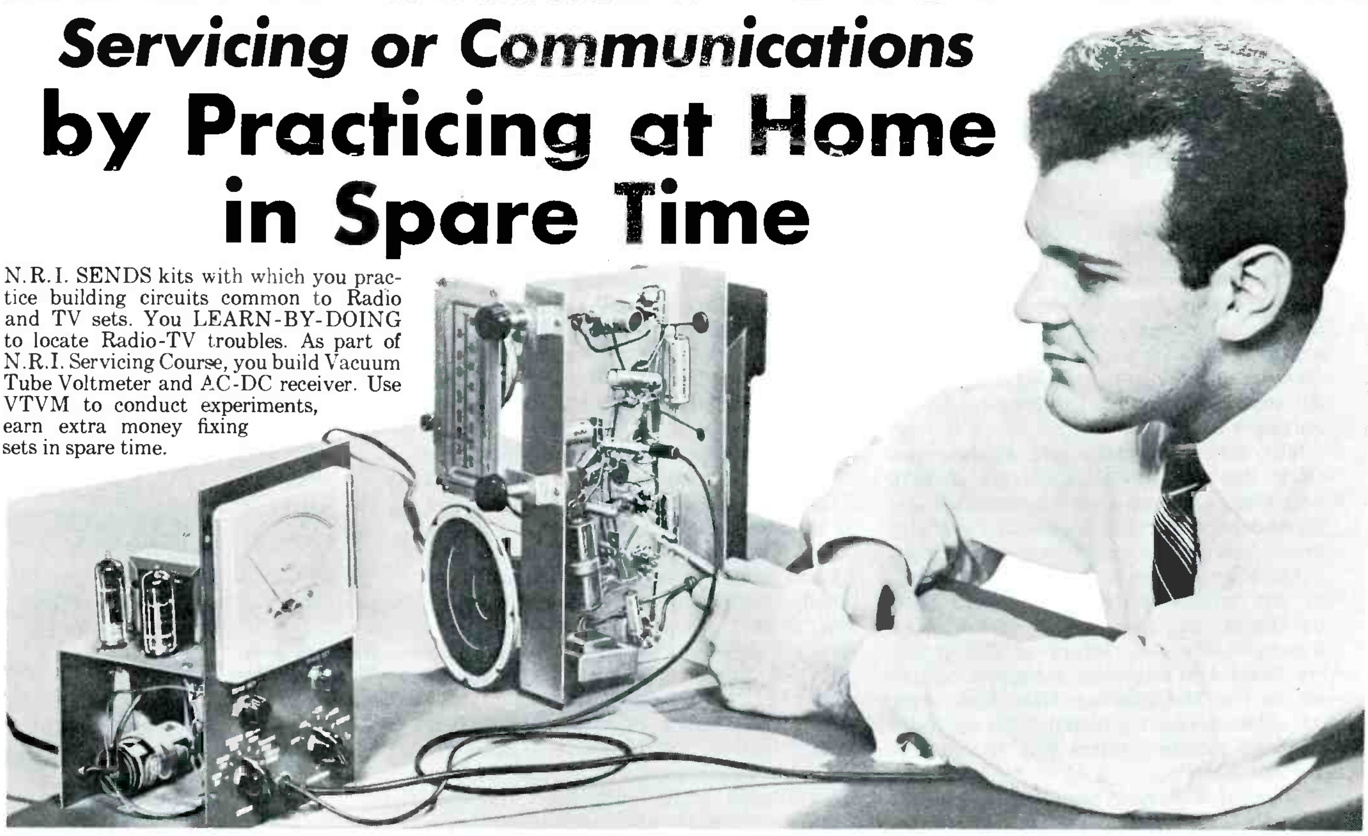

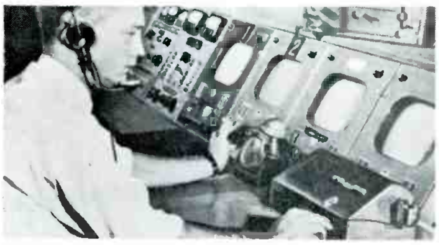

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COLOR Set Roundup

Survey of the color TV receiver market—who is selling sets and what the servicing policies are.

Almost all television receiver manufacturers now have color TV sets on the market. Previous pages described those of *Hoffman, Admiral,* and *RCA*. The other major manufacturers with sets available are *Emerson, Motorola, Sylvania, General-Electric, Philco,* and *Magnavox*. All sets are listed in the Buyers' Guide on pages 6 and 7.

The *Emerson Radio and Phonograph Corp.* has two models available at $678 and $698. *Emerson* has experimented independently in color television for many years and while their receivers are in many ways similar to those of *RCA*, many of the circuit modifications have been developed in their own laboratories. *Emerson* offers a factory service policy for those who buy color television receivers in the Metropolitan New York area. In other areas, its distributors or independent service dealers will handle the servicing.

General-Electric has three models available. One carries an advertised list price of $499.95. The list price for each of the other two models is determined by individual *G-E* distributors and retailers. Service policies for the *General-Electric* color sets are available from the retailer or distributor.

Until this year the *Philco Corp.* did not have available a color TV receiver for the market. *Philco* was developing, under great secrecy in its laboratories, a new color television system which uses a single-gun tube (see page 65). *Philco* is still doing intensive development work on this system, however, it is also marketing three color television receiver models using the *RCA* type three-gun picture tube.

All *Philco* distributors have service departments with service contracts available. In addition, *Philco* has an extensive network of factory-authorized service depots capable of servicing its receivers.

The *Motorola Corp.* was an early starter in commercial color television. It marketed the first large-screen color television receiver using the 19-inch *CBS* Colortron tube. This set was the first selling for under $1000. In 1956 *Motorola* introduced the model 19CT1 at $695. A new receiver with a 21-inch screen, the model 21CT2, is being sold at a price determined by the individual retailer.

The *Magnavox Co.* is retailing one color TV set available either in mahogany or blonde at $695. The basic color chassis for this receiver is supplied by the *RCA Victor Company*—the cabinet is by Magnavox. Service for these sets is available from the *RCA Service Company*.

Sylvania Electric Products, Inc. is now selling two color TV receivers. Both are available in mahogany or blonde. Service is available from authorized factory-trained distributor and independent service personnel.

The *Westinghouse Corp.* is presently preparing for the market a color television receiver with a 22-inch rectangular picture tube. The *Westinghouse* set promises to be competitive in price with those by the other manufacturers. Although the *Allen B. DuMont Laboratories, Inc.* does not have any commercial color television sets available for sale, it is intensively developing a set using the Lawrence-type single-gun Chromatic picture tube. This tube is described on page 68.

Other television manufacturers will, of course, market color television sets as soon as they are able to produce them at a fair profit to themselves and when they are certain that there is a great demand for such receivers. —30—

Sylvania color Model 31T304

Hoffman color Model M2021

Westinghouse 22″ color set

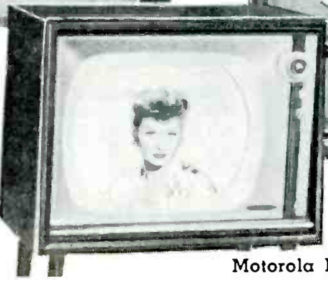
▼ Emerson Model C506

Philco Model 5102L

Admiral Model C322C2

RCA Model 21CS781

▲G-E Model 21C701



Motorola Model 21CT2M

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FUNDAMENTALS OF COLOR TV

By
MILTON S. KIVER

Part 1. Color fundamentals and their application in color television for radio and TV service technicians.

COLOR forms one of the most intimate contacts in our everyday life—we wear colored clothes, we use colored objects, we live in colored houses, and we eat colored food. Yet, in spite of this close contact with color, most people have only a casual knowledge of the nature of color or of color mixing. To the television technician, color possesses added significance because of its application in color television. Such terms as color primaries, hue, saturation, chromaticity, and luminance will be commonly used in any description of a color television receiver, both from the standpoint of operation and of service. What do these words mean? How do they tie in with color television? These are some of the questions the service technician will be confronted with and now, while the art is still young, is as good a time as any to learn about them.

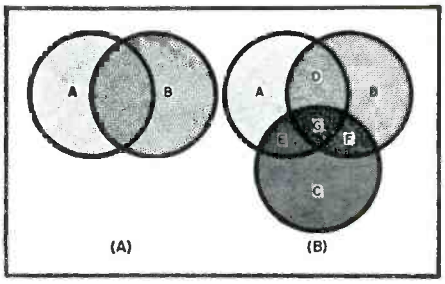
Let us start off with color primaries. Anyone who has ever experimented with projector lamps has discovered that when different colored lights from several projectors are combined, the resultant color seen by an observer will differ from the color of any of the projected beams. Thus, for example, yellow can be formed by combining red and green light; white light can be produced by combining red, green, and blue. The color of the light formed will appear to the eye as a complete color and the eye will be unable to distinguish the various components of the mixture that united to form the new color.

This method of color formation is illustrated in Fig. 1A. Two circles of colored light are projected onto a screen and positioned so that they overlap to some extent. Within the overlapping region, a new color will be produced by the addition of color "A" and color "B." Where the circles of light do not overlap, each light will retain its original color. If a third circle of light is added, as shown in Fig. 1B, then a maximum of seven colors can be obtained. These would be: color "A," color "B," color "C," color "D" (formed from "A" and "B"), color "E" (formed from "A" and "C,"), color "F" (formed from "B" and "C"), and color "G" (formed from "A," "B," and "C")—and each would differ from the other. In the areas where the circles of light overlapped, the eye would not be able to distinguish each of the colors forming the mixture, but instead would see the final color produced. Thus, color "A" and "B" would not appear to the eye as color "A" and color "B," but as some new color which we can call color "D." The same would be true of each of the other combinations.

The number of different colors that can be formed by the use of three colored lights, as shown in Fig. 1B, will depend upon the colors chosen. Experience has indicated that the colors red, blue, and green, when combined with each other in various proportions, will produce a wider range (or gamut) of colors than any other combination of three colors. Note, however, that if we used four different colors in our mixing process, we could produce an even greater number of different colors. With the addition of more and more colors to our mixing scheme, the reproducible range would widen somewhat. Obviously, however, a line must be drawn and the use of three colors has been standardized. The three colors chosen, red, green, and blue, are thus referred to as the "primary" colors although, as we shall see, the use of the word primary has been widely misinterpreted to mean that red, green, and blue will, in various combinations, reproduce *all* colors. This is only in a special instance.

It may be confusing to learn that the primary colors used in color light projection are red, green, and blue, when it is known that the primary colors used in painting and printing are red, yellow and blue. Why the difference? Printing uses a subtractive color system, i.e., as the colors are laid down on a sheet, each succeeding color filters the light from the color below it and subtracts something from it. Projected light, however, is an additive system whereby all the colors projected add together to form the final result. This difference requires different primary colors.

Fig. 1. (A) A new color is formed between color "A" and color "B" as a result of mixing color "A" and color "B". (B) Adding three original colors, "A", "B", and "C", results in four new ones.



The reason why three primaries were chosen, in preference to say four, probably stems from the belief that the eye behaves as though it contains three sets of nerves, with each set of nerves responsive to a different portion of the visible spectrum. Thus, one set of nerves has its greatest sensitivity in the blue region; another set is most sensitive in the green region; and the third set is most sensitive to red. Whether or not three sets of nerves actually exist has never been absolutely established. However, since the eye reacts as though such a condition does exist, it is reasonable to work on the assumption that it does.

The theory which serves to explain the ability of the human eye to distinguish various colors can also be employed to explain color blindness. In the eyes of a color-blind person, all of the color sensitive nerves or retinal cones react in the same way to all colors. Hence, when colored light is viewed by these people, all three sets of nerves are similarly stimulated and the same result is obtained as though equal amounts of red, green, and blue light were intermixed. The color seen would be white, or some intermediate shade of grey. These people can distinguish between dark and light, but no more.

There are also people whose retinal cones differ sufficiently to see some of the colors, but not all. These people are known as partially color blind. Perhaps the best known instance of this is green and red color blindness. In the eyes of these people green or red appears grey. Fortunately, however, over 90 per-cent of the population have normal vision, which means

COLOR ANALYSIS

that they are able to distinguish between all of the spectrum colors.

A diagram which is very convenient to use for color mixing is the tongue-shaped (or horseshoe-shaped) curve shown in Fig. 2. (Another name for this curve is chromaticity diagram.)

Around the perimeter of this curve are listed numbers that range from 400 at the lower left-hand corner to 740 at the farthest point to the right. These figures represent the wavelength of various spectrum colors in millimicrons. Thus, purple (violet) extends from approximately 400 to 450, blue extends from 450 to 500 millimicrons, green extends from 500 to 570 millimicrons, yellow extends from 570 to 590 millimicrons, orange extends from 590 to 610 millimicrons, and red extends from 610 to 740 millimicrons.

Any point not actually on the solid-line curve but within the diagram represents not a pure spectrum color but some mixture of spectrum colors. Since white is such a mixture, it, too, lies within this diagram; specifically, at point "C." This particular point was chosen at an international convention in England and is generally referred to as "illuminant C." Actually, of course, there is no specific white light, since sunlight, skylight, and daylight are all forms of white light and yet the components of each differ considerably. The color quality of a conventional black-and-white television receiver tube is represented by some point in the central region of the diagram about point "C."

The chromaticity chart lends itself readily to color mixing because a straight line joining any two points on the curve will indicate all the different color variations that can be obtained by combining these two colors additively. Thus, consider a line drawn connecting points "R" and "G" representing certain shades of red and green respectively. See Fig. 3. If there is more red light than green light, the exact point representing the new color will lie on the line, but be closer to "R" than "G." Point "R^1" might be such a color. On the other hand, if a greater percentage of green light is employed, the color will still lie on the line connecting "R" and "G," but now, it will be closer to "G" than "R." Point "G^1" might be such a color. This same line of reasoning can be carried out for any two colors on the chart.

(On the screen of a three-gun tri-color picture tube we can carry out the same experiment by turning off the blue gun and permitting only the electron beams from the green and red guns to reach the phosphor-dot screen. As one beam, say that from the red gun, is made more intense, the resultant color on the screen shifts closer to red. On the other hand, if the red gun is turned down and the green gun beam is turned up, the resultant color takes on more and more of a greenish cast. When both guns are producing beams of equal intensity, yellow will be seen.)

Point "C," in the central region of this diagram, is taken to represent white or daylight. If we draw a line between point "C" and any point around the curve, we have a mixture of white light and a particular spectrum color. Thus, in Fig. 4, a line connects point "C" and green at 545 millimicrons (point "A"), indicating a mixture of white light and spectrum green. If the amount of white light is zero, then the pure spectrum green will be produced. As white light is added, the hue of the green changes and the point representing this mixture moves along the line toward point "C." We might consider this as diluting the green, causing it to become lighter and lighter.

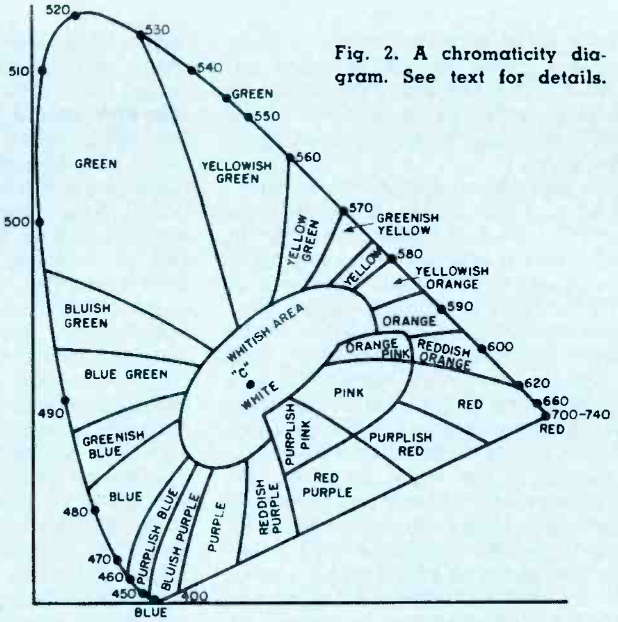


Fig. 2. A chromaticity diagram. See text for details.

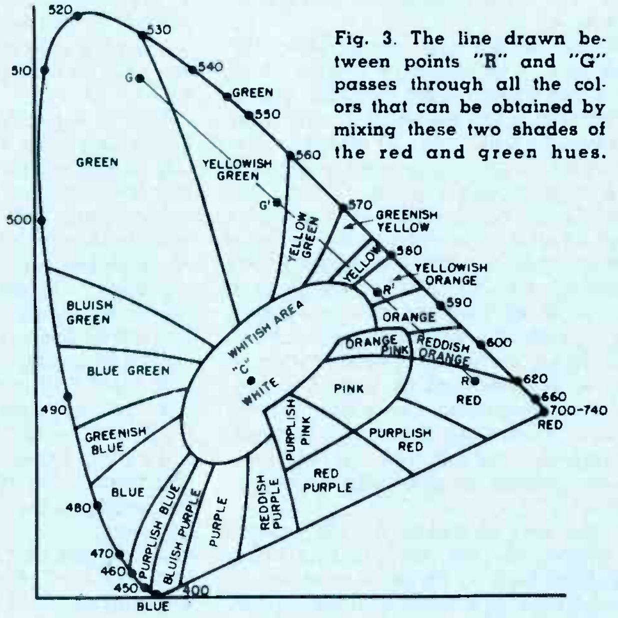


Fig. 3. The line drawn between points "R" and "G" passes through all the colors that can be obtained by mixing these two shades of the red and green hues.

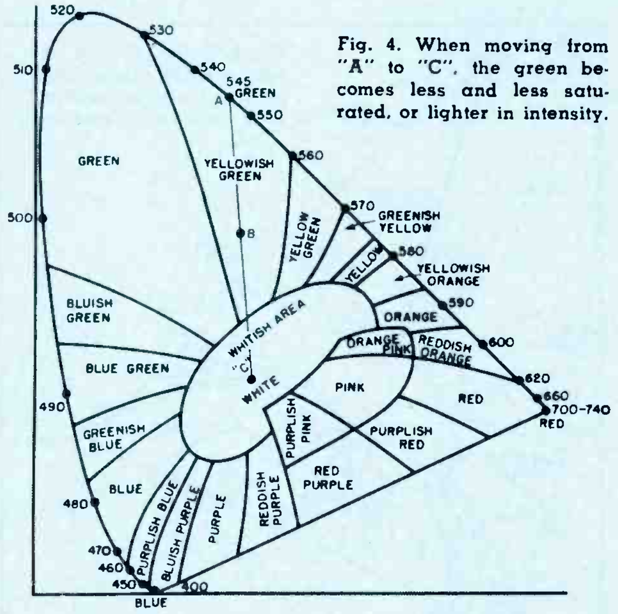


Fig. 4. When moving from "A" to "C", the green becomes less and less saturated, or lighter in intensity.

(In a color tube, we dilute a solid color, say green, by adding more red and blue. The red and blue combines with some of the green to form white, thereby reducing the intensity or depth of the green.)

It is possible to specify the saturation of a color by its distance from point "C." Thus, consider point "B" in Fig. 4. This is half way between point "C" and point "A" and represents a mixture of green diluted 50 per-cent with white light. The saturation of the green at point "B" is 50 per-cent. Had the distance between point "C" and point "B" been 75 per-cent of the total distance between point "C" and point "A," we would have stated that the saturation of the color at point "B" was 75 per-cent. By moving point "B" closer and closer to the spectrum curve, its purity increases until it becomes 100 per-cent at the curve—point "A." By moving point "B" closer to point "C," its saturation decreases. At point "C," the saturation is said to be zero.

In connection with saturation, the word hue is frequently heard. Hue represents colors such as red, green, orange, etc. It is associated with color wavelength and when we label a certain color as green, or orange, or red, we are specifying its hue. Thus, hue refers to the basic color as it appears to us, while saturation tells us how deep the color is. If the color is highly saturated we say that it is a deep color, such as deep red, or deep green. If it contains a considerable amount of white light, we say it appears faded or pale, as a faded red or a pale green. Hue and saturation are psychological terms representing the observer's impression of a color and hence they cannot be defined as precisely as wavelength.

At the bottom end of the chromaticity curve, on the line drawn from deep blue to red, there is a series of colors which are combinations of red and blue in various proportions. These range from bluish purple to purplish red. It can be seen that this line completes the curve of Fig. 2. However, this line should not be considered in the same sense as the rest of the curve. It does not contain any spectrum colors but only combinations obtained from mixing spectrum colors. Because of this, the region at the back end of this tongue-shaped curve is known as the region of non-spectral colors. The boundaries of this region are obtained by drawing dotted lines from point "C" to red at 700 millimicrons and from point "C" to blue at 450 millimicrons. The remainder of the diagram above these dotted lines is known as the region of spectral colors. The entire diagram is known as the domain of real colors.

One further term used in connection with this diagram is complementary color. Any two colors which can by themselves form white are known as complementary colors. Thus, in Fig. 5, the line connecting point "F" with point "G" passes through point "C" and hence, the colors at "F" and "G" are said to be complementary to each other.

We have previously seen that a line drawn between two points representing two different colors contains all of the combinations that can be derived using those two colors. If, now, we wish to determine what range or gamut of colors can be obtained from any three given colors (say "R_1," "G_1," and "B_1"), we would draw connecting lines to each of the colors. See Fig. 6. The result is a triangle. We can produce any color within this triangle by various combinations of the three colors, "R_1," "G_1," and "B_1."

The wavelengths of "R_1," "G_1," and "B_1" chosen for television fall near 610 millimicrons for the red, near 540 millimicrons for the green, and near 470 millimicrons for the blue. These are actually the values used for the triangle drawn in Fig. 6 and by studying this diagram you can see the extent of the color range obtainable on a color television receiver. Note that colors not included within the triangle will not be reproduced by *any* combination of the three primary colors chosen.

This, of course, brings us back again to the statement made previously, that three primary colors cannot reproduce *all* colors simply by adding the three primary colors together. In color television, of course, only those colors which can be produced by adding the primaries together can be considered, this being the only practical approach possible.

The choice of suitable primary colors for television depends principally upon what type of color phosphors can be obtained for the receiver picture tube. Originally it was felt that the color picture would be traced out on a black-and-white screen and then the light passed through a color filter to present the observer with the "color" image. This was the method employed in the *CBS* system and in the early forms of the *RCA* system. However, with the development of a color tube, phosphors are employed which emit colored light directly, leading to a less cumbersome system physically and a more efficient system optically.

A considerable amount of research work is being done on evolving phosphors which will provide as wide a gamut of colors as possible. In recent tubes, a willemite phosphor (Zn_2SiO_4: Mn) was used for the green, a sulphide phosphor (ZnS:Ag:MgO) for the blue, and a third phosphor, $Zn_3(PO_4)_2$: Mn for the red. These primaries provide a fairly wide range of colors, as seen in Fig. 6. By comparison, the area covered by printing inks is much smaller. It may be that as the art advances, the color range of the phosphors will be extended, although the colors now obtainable are wholly satisfactory.

When the NTSC system of color television was under development, a considerable amount of research was done on how much color the average

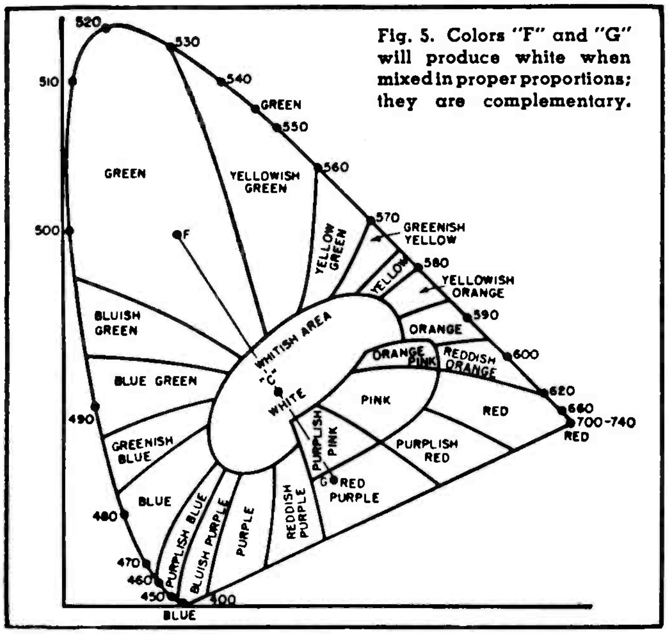


Fig. 5. Colors "F" and "G" will produce white when mixed in proper proportions; they are complementary.

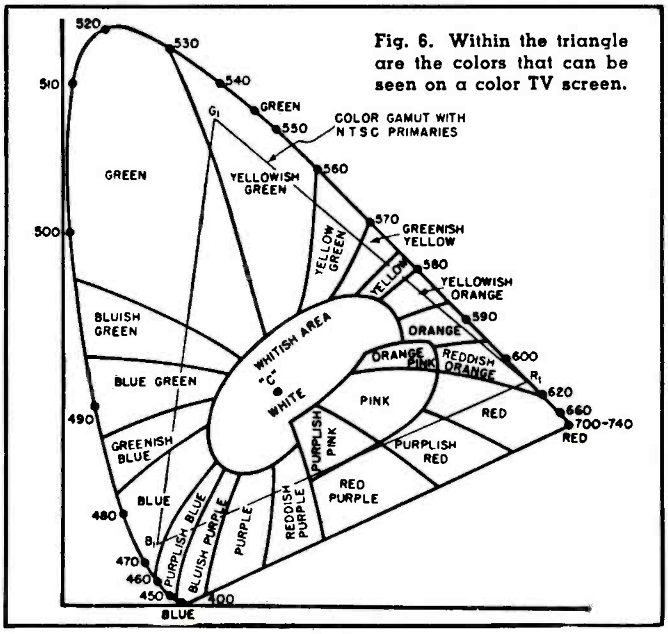


Fig. 6. Within the triangle are the colors that can be seen on a color TV screen.

human eye really sees. This work, in conjunction with other data which has appeared from time to time, brought forth several very interesting facts.

1. The theory that vision is a three-color process is true only when the object viewed is relatively large. On a television screen, this refers to objects which are produced by video frequencies from 0 to .5 mc.

2 For medium-sized objects, say those produced by .5 mc. to 1.5 mc. video frequencies on a television screen, only two primary colors are needed. Blues and yellows are among the first colors to lose their color and become indistinguishable from gray within this range.

3. For very fine detail, say those reproduced by video frequencies from 1.5 to 4.0 mc., all people with normal vision are color blind. In other words, all that is seen are shades of brightness.

The conclusion to be drawn from the foregoing is that 4 mc. color is not necessary. All we require is color up to 1.5 mc. And even within this range, we need all three colors only to .5 mc. and only two primaries for the color signal extending from .5 mc. to 1.5 mc. In the formation of the NTSC signal, these facts were put to use by employing one color signal, called the "Q" signal, with a range from 0 to .5 mc. and a second color signal, called the "I" signal, with a bandpass from 0 to 1.5 mc. The rest of the video picture, containing all of the fine detail, is reproduced in black-and-white by a monochrome signal and the eye is none the wiser. As a matter of fact, a full color television signal consists of a 0 to 4 mc. monochrome video signal (just as we have in black-and-white broadcasting) plus a color subcarrier containing the "I" and "Q" color signals mentioned previously. It has been truly said that the NTSC system is a "colored" television system.

The monochrome signal possesses such alternate names as brightness signal and luminance signal. The color portion is frequently referred to as the chrominance signal.

In the next article of this series we will see how the NTSC color signal is formed and of what it consists.

Part 2. Explanation of the NTSC color TV signal, how it was developed, and why it is compatible with black-and-white.

PERHAPS the most striking feature of the compatible color television system to the service technician is the fact that a high quality color television signal can be fitted into the same spectrum space now occupied by a black-and-white (or monochrome) signal. To make this feat even more astounding, we not only have the color signal, but we have in no way disturbed the existing monochrome signal.

How is all this possible? It is all possible because of the nature of a television signal. When we say that a television signal extends from 0 up to 4 mc., we do not mean that it occupies every cycle of that 4 mc. In other words, the energy is not spread continuously from one end of the band to the other; rather, it exists in the form of bundles of energy each separated from the group above and below it by a frequency of 15,750 cycles. This is illustrated in Fig. 1, where a section of the spectrum of a video signal is shown. Note that each bundle or cluster of energy is distinct from its neighbors, with relatively wide, empty spaces in between. It is into these empty spaces that the color signal is fitted. This process of fitting one video signal in among the empty spaces of another video signal is known as interleaving. The two signals thus can be said to occupy the same general band, although they never come in contact with each other and hence do not, within limits, interfere with each other.

The Monochrome Signal

The black-and-white or monochrome portion of the total color signal is equivalent in all respects to present black-and-white signals. It is formed by combining the red, green, and blue signals from their respective color cameras in the proportions of:

$$Y = .59G + .30R + .11B$$

where Y is a mathematical symbol representing the monochrome signal, G is the green signal, R is the red signal, and B is the blue signal.

This particular combination was chosen because it closely follows the color sensitivity of the human eye. That is, if you take an equal amount of green light, and an equal amount of red light, and an equal amount of blue light and superimpose the rays from these lights on a screen, you will see white. However, if you then look at each light separately, the green would appear to be twice as bright as the red, and six to ten times as bright as the blue. This is because the eye is more sensitive to green than to red, and more sensitive to red than to blue. It is in recognition of this fact that the proportions given in the formula were chosen.

Thus, the monochrome signal is composed of 59 per-cent green, 30 per-cent red, and 11 per-cent blue, and contains frequencies from 0 to 4 mc. (The use of the letter Y to denote the monochrome portion of the color signal is a common practice and should become familiar to the reader.)

Other names for this monochrome signal are luminance and brightness signal. The function of this signal is to reproduce, at the picture tube, the changes in brightness of the picture.

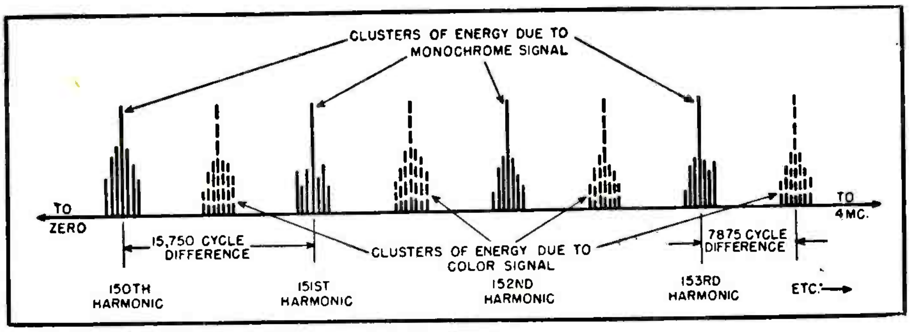
The Color Signal

The second component of the television signal is the color signal itself. This, we have just seen, is interleaved with the black-and-white signal. To determine what information this portion of the total signal must carry, let us first see how the eye reacts to color, since it is the eye, after all, for which the color image is formed.

A number of men have investigated the color characteristics of the human eye, and they found that to reproduce essentially all of the colors which the eye normally sees, we require only three so-called primary colors of light. These are red, blue, and green. The proportion in which these colors are mixed will determine the color produced; when all three are used, white will be produced.

The average human eye requires these three primaries only for relatively large colored areas or objects. When the size of the area or object decreases, several things happen. Probably the most important change that takes place is that it becomes more difficult for the eye to distinguish between various colors. For example, blue and green are often confused with each other, as are brown and crimson. Also, blue tends to look like grey and

Fig. 1. Representation of the signal energy distribution of a 4 mc. video signal showing how the color information is inserted in the gaps between the monochrome.



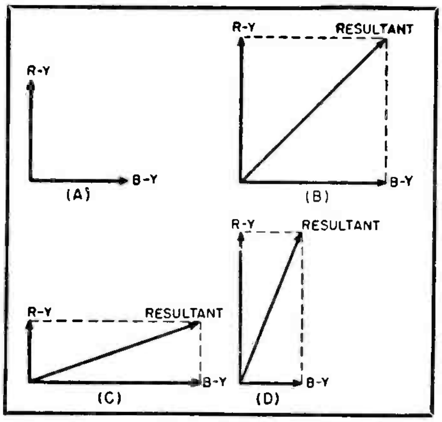


Fig. 2. The angular position and amplitude of the resultant carrier for various amplitudes of B-Y and R-Y. (A) The B-Y and R-Y vectors. (B) The resultant when B-Y and R-Y are equal, (C) when B-Y is stronger than R-Y, and (D) when the R-Y signal is stronger than B-Y signal.

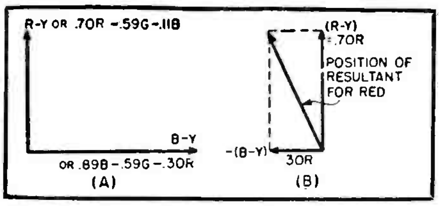


Fig. 3. How color determines the position of a resultant vector. (A) Equations showing compositions of B-Y and R-Y. (B) Position of resultant vector when red field only is being scanned. See text for details.

yellow likewise becomes indistinguishable from grey. Reds remain fairly distinct, but all colors tend to lose some of their vividness. Thus, where the eye formerly required three primary colors, now it finds that it can get by very well with only two. That is, these two will, in different combinations with each other, provide the range of colors that the eye needs or can see.

Finally, when the detail becomes very small, all that the eye can discern are changes in brightness; colors cannot be distinguished from grey and to all intents and purposes, the eye is color blind.

These properties of the eye are utilized in the NTSC color system. For example, only the larger detail is colored; the fine detail is rendered in black-and-white. Secondly, as we shall see later, even the color information sent is regulated according to bandwidth. That is, the larger objects receive more of the green, red, and blue than the medium sized objects.

The color signal takes the form of a subcarrier and an associated set of sidebands. The subcarrier frequency is approximately 3.58 mc. This represents a figure which is the product (approximately) of 7875 cycles multiplied by 455. 7875 is one half of 15,750, and if we use an odd multiple (*i.e.*, 1, 3, 5, etc.) of 7875 as a carrier, then it will fall midway between the harmonics of 15,750 cycles. If we used even multiples of 7875, we would end up with 15,750 or one of its harmonics and this would place the color signal at the same points (throughout the band) as those occupied by the black-and-white signal. Refer back to Fig. 1. By taking an *odd* multiple of 7875, we cause the second signal to fall in between the bundles of energy produced by the first signal, and the two do not interfere.

Now that we have a color carrier (or subcarrier, as it is known), the next step is to provide it with enough modulation to enable the receiver to develop a color picture. Ordinarily, the information required would consist of R, G, and B since these are the three primary colors of light from which all of the other colors are derived. This means modulating the color subcarrier with three different quantities. Actually, however, we can do exactly the same job using only two quantities if we resort to the following modification. Take the R, G, and B voltages and combine them with a portion of the monochrome signal after the latter has been inverted 180°. This produces $R—Y$, $G—Y$, and $B—Y$ signals. We can do this by taking a portion of the brightness signal (Y signal) and passing it first through a low-pass filter. This permits only the low-frequency components to get through which is satisfactory since the color signals are also concerned only with the low frequencies. Then the brightness signal is passed through an amplifier and inverted. If we call the brightness signal Y, then after the inversion it becomes $-Y$. This is then added to each of the three color signals or voltages to produce a $G—Y$, a $R—Y$, and a $B—Y$ signal.

At the receiver, the original R, G, and B can be re-obtained by adding Y to $G—Y$ to obtain G, by adding Y to $R—Y$ to get R, and by combining Y with $B—Y$ to get B.

Thus far, it would seem that we have only exchanged R, G, and B for $R—Y$, $G—Y$, and $B—Y$. However, once this is done, it turns out that instead of requiring all three color-difference signals, all we really need are two, say $R—Y$ and $B—Y$. This is so because G information is already present in the Y or brightness signal since the latter contains voltages from all three colors (*i.e.*, $Y = .59G + .30R + .11B$). Hence, if we send along only $R - Y$ and $B - Y$ in the color signal to the receiver, we can use these to obtain the $G—Y$ information we need. For those who would like to see proof of this, a simple analysis is given at the end of the article.

Thus, we now have only two pieces of color information to send and somehow the 3.58 mc. color subcarrier must be modulated by $R - Y$ and $B - Y$ voltages without conflict to each other.

The best solution to this problem, designers found, was to take the $B—Y$ and $R—Y$ signals and apply each to a separate modulator. At the same time, 3.58 mc. carriers were also applied to each modulator, but with this difference. Their frequencies were the same, but one carrier was 90° out-of-phase with the other. After the carriers were amplitude modulated, they were then combined to form a resultant carrier. This is best illustrated by means of vectors. In Fig. 2A, the $B - Y$ vector represents the $B—Y$ modulated carrier; the $R—Y$ vector represents the carrier modulated by the $R—Y$ voltage. When these voltages or signals are combined, a resultant is formed. If the $R—Y$ and $B—Y$ signals are equally strong, the resultant will occupy the position shown in Fig. 2B. If the $B—Y$ signal is predominant, the resultant will be drawn closer to it. See Fig. 2C. On the other hand, if the $R—Y$ signal is the stronger, the position of the resultant vector will shift toward it. See Fig. 2D. Thus, we can see that the phase angle of the resultant will be governed by the coloring of the picture while the amplitude (or length) of the vector will determine how saturated the colors are.

This particular fact is of great importance in the receiver because if we somehow change the phase of the resultant with respect to $B—Y$ or $R—Y$, then the colors reproduced on the screen will be incorrect. Hence, present circuit designs incorporate a special phasing control which enables us to compensate for any phase shift that may occur. The position of this control in the circuit will be covered in a later article.

Note that the $B—Y$ and $R—Y$ signals amplitude modulate their separate carriers prior to the addition and so each modulated signal possesses a 3.58 mc. carrier and a series of sidebands (like every AM signal). When the resultant is formed, the sidebands are brought along with it.

If we were to pause now and reconstruct our total color signal, here is what we would find. First, there would be the Y or monochrome signal and it would extend over the entire video frequency range from 0 to 4 mc. Second, there would be a color subcarrier, with a frequency of 3.58 mc. This carrier is modulated by the $R—Y$ and $B—Y$ signals and the modulation intelligence is contained in a series of sidebands that stretch above and below 3.58 mc. Just how far above and below is dependent on the band of frequencies contained in the $R—Y$ and $B—Y$ modulating voltages. It was discovered that the eye is perfectly satisfied with the color image that is produced if we include color information only up to 1.5 mc., while the portion of the image from 1.5 mc. to 4 mc. is rendered in black-and-white. Hence, the sideband frequencies of the color modulating voltages (so far called $R—Y$ and $B—Y$) need extend only from 0 to 1.5 mc. Furthermore, we can even modify this set of conditions somewhat because the three primary colors are required only for large objects or areas, say those produced by video frequencies up to .5 mc. For medium sized objects, say those produced by video frequencies from .5 to 1.5 mc., only two primary colors need be employed.

In other words, to take advantage of this situation, we need two color signals, one of which has a bandpass only up to .5 mc., while the other has a bandpass from 0 to 1.5 mc. The next problem, then, is to determine what the composition of these two color signals is.

To appreciate the answer to this, let us return to the vector diagram showing the $R-Y$ and $B-Y$ signals. This is redrawn in Fig. 3A and to this diagram we have added the equivalent equation for Y, namely, $.59G+.30R+.11B$. For $R-Y$, then, we have $R-.59G-.30R-.11B$ or $.70R-.59G-.11B$ and, for $B-Y$ we obtain $B-.59G-.30R-.11B$ or $.89B-.59G-.30R$. This means that the $R-Y$ and $B-Y$ vectors contain R, G, and B voltages in the proportions shown.

Now, let us suppose that the color camera is scanning a scene containing only red. Then, no green or blue voltages would be present and the $R-Y$ signal becomes simply $.70R$, while the $B-Y$ signal is reduced to $-.30R$. This set of conditions is shown in Fig. 3B, with the position, too, of the resultant vector. In other words, this is the position the vector would occupy when red only was being sent.

By following the same process, we can obtain the position that the resultant vector occupies when only green is being sent, or blue, or any other color formed by uniting these three colors in any combination. A number of colors are shown in Fig. 4 and we see, perhaps more clearly than before, how the phase of the color subcarrier changes as the color to be transmitted varies. This, of course, brings us back to a statement previously made, namely: the phase angle of the resultant will be governed by the coloring of the picture while the amplitude (or length) of the vector will determine how intense (*i.e.,* saturated) the colors are.

The designers of the NTSC system found that while they could use $R-Y$ and $B-Y$ for the color signals, better system operation would result if they chose two other signals situated not far from the $R-Y$ and $B-Y$ signals. These two other signals were labeled I and Q signals and their position with respect to $R-Y$ and $B-Y$ is shown in Fig. 7.

Thus, where before we had $R-Y$ and $B-Y$ voltages modulating the 3.58 mc. color subcarrier, we now substitute I and Q signals. Furthermore, the Q signal possesses frequencies up to .5 mc. while the I signal is permitted to have signals up to 1.5 mc.

Now, what do we gain from this? For all color signal frequencies up to .5 mc., both I and Q are active and since they are 90° apart as were $R-Y$ and $B-Y$, they will act just the way $R-Y$ and $B-Y$ acted. That is, they will, in combination with each other, produce all of the colors shown in Fig. 4. Hence, whether we use I and Q or $R-Y$ and $B-Y$ as our modulating voltages for color frequencies up to .5 mc., we get precisely the same results.

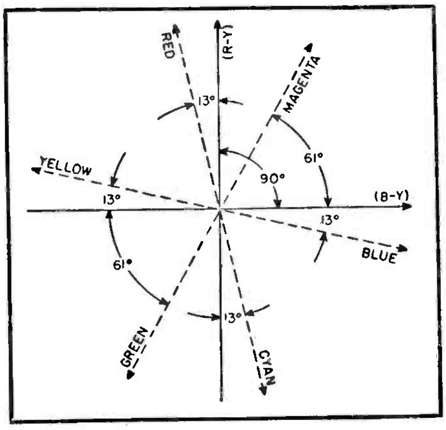
Now consider the situation for color frequencies from .5 mc. to 1.5 mc. The Q signal drops out and only the I signal remains to produce color on the picture tube screen. From Fig. 7 we see that positive values of the I signal will produce colors between yellow and red or actually a reddish orange. On the other hand, negative values of I will produce colors between blue and cyan or, in general, in the bluish-green range. Hence, when only the I signal is active, the colors produced on the screen will run the gamut from reddish-orange to bluish-green.

But why do we want this? If you go back to an earlier section of this article you will see that for medium-sized objects (say those produced by video signals from .5 mc. to 1.5 mc.) the eye is sensitive only to bluish-green or reddish-orange. Since this is so, the NTSC signal (*via* its I component) is fashioned to take advantage of this fact.

We are now in a position to consider the color signal in all its aspects.

1. There is a monochrome signal with components that extend from 0 to 4 mc. This is the Y signal.
2. The color subcarrier frequency is set at 3.58 mc. (actually it is 3.579545 mc.).
3. This color subcarrier is modulated by two color signals called the I and Q signals.
4. The Q signal has color frequencies that extend from 0 to 500 kc. or .5 mc. This means that the upper Q sideband extends from 3.58 mc. up to 3.58 + .5 or 4.08 mc. The lower Q sideband goes from 3.58 mc. down to 3.58 − .5 or 3.08 mc.
5. The I signal has color frequencies that extend from 0 to 1.5 mc. When this modulates the color subcarrier, upper and lower sidebands are formed. The lower sideband extends from 3.58 mc. down to 3.58 − 1.5 or 2.08 mc. If the full upper sideband were permitted to exist, it would extend all the way up to 3.58 + 1.5 or 5.08 mc. Obviously this would prevent the use of a 6 mc. overall band for the television signal (video and sound). To avoid this spilling over beyond the limits of the already established channels, the upper sideband of the I signal is limited to about .6 of a megacycle. This brings the upper sideband of the I signal to 4.2 mc. The video passband then ends rather sharply at 4.5 mc. See Fig. 5.

Fig. 4. The phase of the color subcarrier depends upon the color to be sent.



There is one further fact that is of importance in the make-up of a color television signal and this concerns the color subcarrier. We know that the 3.58 mc. carrier is modulated by the two I and Q color signals. Now, in conventional modulation methods, both the carrier and the sidebands are present when the signal is finally sent out over the air. The intelligence (or modulation) is contained in the sidebands and that is actually all that we are interested in. However, the carrier is

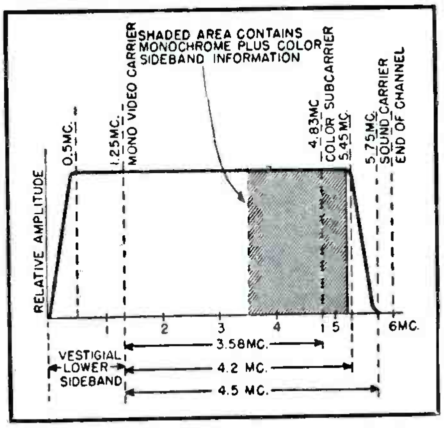


Fig. 5. The distribution of the full color signal within its allotted band.

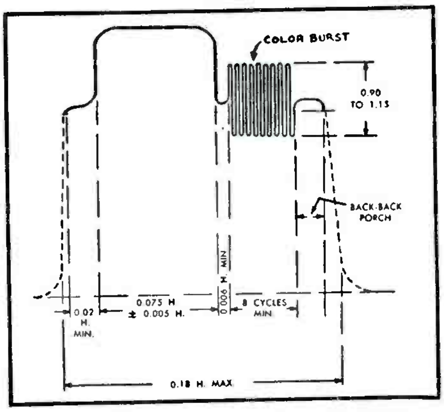
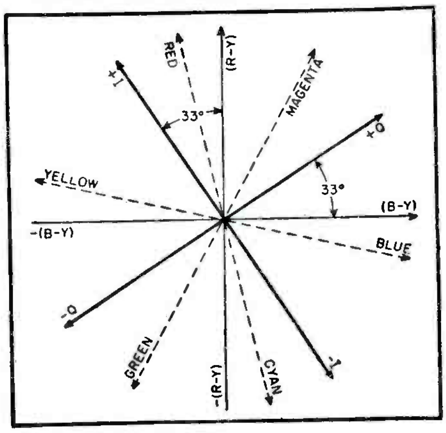


Fig. 6. The position of the color burst for subcarrier oscillator sync on the back porch of a horizontal sync pulse.

Fig. 7. The positions of the I and Q signals with respect to R-Y and B-Y.



sent along because it is required in the receiver to reverse the modulation process and recreate the original modulating voltages.

In the NTSC color system, the color subcarrier is not sent along with its sidebands (after the latter have been formed). Instead, it is suppressed by using a balanced modulator. This particular practice is followed for two reasons. First, by suppressing the color subcarrier, we reduce the formation of a 920 kc. beat note between it and the 4.5 mc. sound carrier which is also part of every television broadcast. This 920 kc. note would appear as a series of interference lines on the face of the picture tube. Now, it is true that the color sidebands are present and that they can (and do) beat with the 4.5 mc. sound carrier to produce similar low frequency beat notes. However, in any signal, the carrier usually contains far more energy than any of its sidebands and so, when we suppress the carrier, we are, in effect, suppressing the chief source of this interference. Whatever other interference may be produced by some of the stronger sidebands near 3.58 mc. can be more easily dealt with using traps in the i.f. system. This will be seen when we examine the circuitry of a receiver.

The second reason for using this suppressed carrier method is that it leads to an automatic removal of the entire color signal when the scene that is televised is to be sent wholly as a black-and-white signal. For when this occurs, I and Q drop down to zero and since the balanced modulators suppress the carrier, no color signal at all is developed. After all, why have a useless color carrier when no color information is to be sent?

With these advantages of carrier suppression comes one disadvantage. When the color sidebands reach the color section of the receiver, a carrier must be reinserted in order to permit detection to take place. Off hand, one might suppose that all we needed to do this is to employ an oscillator operating at 3.58 mc. This is one requirement. A second and vitally important consideration is the phase of this reinserted carrier. Remember that back at the transmitter, attention was given to the phase of I and Q as they were introduced into the modulator. If the same relative phase were not maintained in the reinserted carrier, the colors obtained at the output of the color circuits would not possess the proper hue.

To provide information concerning the frequency and phase of the missing color subcarrier, a color burst is sent along with the signal. This burst follows each horizontal pulse and is located on the back porch of each blanking pedestal. See Fig. 6. It contains a minimum of 8 cycles of the subcarrier and it is phased in step with the color subcarrier used at the station. In the receiver, this burst is used to lock in the frequency and phase of a 3.58 mc. oscillator, and thus, we are assured at all times that the reinserted carrier will correctly do its job when it recombines with the color sidebands.

The position of the color burst on the back porch of each horizontal sync pulse insures that it will not be seen on the screen of either color or monochrome television receivers since the screen is ordinarily blacked out during this retrace interval. If the burst were to be placed at a lower level, it would produce undesirable spurious picture tube light, especially on those sets which did not contain special horizontal blanking signals.

The burst does not appear during the vertical serrated pulses or after the equalizing pulses. It was found that the 3.58 mc. oscillator in the receiver remains in synchronism during this brief interval when no burst signal is being received. Upon the reappearance of the horizontal sync pulses and the accompanying color burst at the end of the vertical pulse interval, control of the 3.58 mc. receiver oscillator is smoothly resumed.

Following is the proof, mentioned earlier in the article, that we need only $R-Y$ and $B-Y$ to give us $R-Y$, $B-Y$, and $G-Y$.

Y, the monochrome signal, consists of 59 per-cent green, 30 per-cent red, and 11 per-cent blue. Or, mathematically:

$$Y=.59G+.30R+.11B$$

With this in mind, an $R-Y$ signal is:

$$R-Y=R-(.59G+.30R+.11B)$$

or:

$$R-Y=.70R-.59G-.11B$$

By the same method, a $B-Y$ signal is:

$$B-Y=B-(.59G+.30R+.11B)$$

or:

$$B-Y=.89B-.59G-.30R$$

Also, a $G-Y$ signal is:

$$G-Y=G-(.59G+.30R+.11B)$$

or:

$$G-Y=.41G-.30R-.11B$$

Now, if we take .51 $(R-Y)$, add it to .19 $(B-Y)$, and then invert the resultant signal, we will obtain $G-Y$. This will prove that with $R-Y$ and $B-Y$ we can get $G-Y$.

Thus,

$$\begin{aligned} .51\ (R-Y) &= .51\ (.70R-.59G-.11B) \\ &= .36R-.30G-.056B \end{aligned}$$

And,

$$\begin{aligned} .19\ (B-Y) &= .19\ (.89B-.30R-.59G) \\ &= .17B-.057R-.11G \end{aligned}$$

Adding the two equations together gives us:

$$.36R-.30G-.056B+.17B-.057R-.11G$$

or, combining like terms:

$$.30R-.41G+.11B.$$

This is equal to $-(G-Y)$ as shown above. Hence if we invert the equation, we obtain:

$$.41G-.30R-.11B$$

which is $G-Y$.

Part 3. A general analysis of a color receiver based on the NTSC system. Specific circuitry will be covered later.

IN the previous article we developed the principles of the NTSC color television system. In this and succeeding articles we will examine first the general form of a suitable receiver and then delve more deeply into it, replacing each of the block sections by specific circuits.

Much of the internal circuitry of color television receivers depends upon the type of picture tube used. Thus, you would find circuits in sets using the tri-gun picture tube that would not be found in receivers utilizing a single-gun tube. Of course, the reverse situation would also be true, *i.e.*, there would be stages in a single-gun receiver that have no actual counterpart in the tri-gun set. Since the tri-gun tube is the one that set manufacturers are turning to first, let us start our receiver analysis with it.

An over-all block diagram of an NTSC color television receiver using a tri-gun display device is shown in Fig. 1. The signals captured by the antenna are received by an r.f. tuner which is similar in all respects to the tuners employed in black-and-white receivers. That is, it is capable of receiving v.h.f. signals on channels 2 to 13 and perhaps u.h.f. signals from channels 14 to 82. In the v.h.f. band, an r.f. amplifier is present, together with an oscillator and mixer. For u.h.f. reception, the signal is either converted down to v.h.f. (and then treated as any other v.h.f. signal), or the video i.f. signal is produced directly.

The tuner is followed by a video i.f. system which is somewhat more extensive than the video i.f. systems of monochrome sets in that it usually contains more stages and its bandpass is somewhat wider. Also, more care must be taken in alignment to see that the response curve possesses the proper shape. However, the layout of the stages, their circuitry, and the use of traps follow the practice established in monochrome receivers.

An a.g.c. voltage is applied to the first few video i.f. amplifiers, as well as to the r.f. amplifier.

The sound take-off point in Fig. 1 is shown as coming from the end of the video i.f. system rather than from the second detector or beyond. This might lead you to believe that a split-sound system is employed rather than an intercarrier system. Such is not the case. An intercarrier system is employed and the reason for positioning the sound take-off in the video i.f. system stems from a desire to prevent undesirable interaction between the sound carrier and the color subcarrier. The two are separated by 920 kc. and unless the sound carrier is kept properly attenuated, a 920 kc. beat will appear on the picture tube screen. To minimize such interaction, the sound carrier is removed at the plate of the last video i.f. stage. This permits the set designer to adjust all of the following circuits so that the response to the sound carrier or to any 4.5 mc. beat which it may produce (after detection) is as low as possible.

In the sound system, the sound and monochrome video carriers are mixed in a germanium crystal diode, producing a 4.5-mc. beat note that contains the sound intelligence of the broadcast. This is followed by several sound i.f. amplifiers, an FM detector, and then the usual audio amplifiers. See Fig. 2. Again, this follows the practice established in monochrome receivers.

Returning to the video channel, both the black-and-white and the color signals are extracted from the picture carrier at the video detector. (Remember that while the color sidebands have their own subcarrier, they still form part of the over-all video signal. As far as the picture carrier is concerned, color signals occupy the same relative position as any monochrome frequency.) The combined signals, after the detector, are applied to a video amplifier. At the plate of this stage, portions of the signal are shunted to the sync and a.g.c. stages and to a color sync section. See Fig. 3. At the same time, another portion of the signal is taken from the cathode circuit of this tube and applied to the chrominance or color section of the receiver. Still remaining is the luminance or black-and-white signal and this is taken from the plate of the 1st video amplifier and applied to the grid of the 2nd video amplifier through a 1.0 microsecond time-delay network. This is done so that when the luminance and color signals meet again later in the adder or matrix section, they will be in time step with each other. The color signals pass through narrow bandpass filters in the chrominance system and this serves to delay them. By inserting an equivalent delay line in the path of the luminance signal, we keep all segments of the video signal in step with each other.

Two contrast controls are shown in Fig. 3, one in the cathode leg of the 1st video amplifier, the other at the input to the 2nd video amplifier. The units are mechanically ganged together so that the proper relationship is maintained between the monochrome and color signals for all settings of the contrast controls.

The video signal is amplified by the 2nd video amplifier and then fed to the adder (or matrix) section. Here it combines with the various *I* and *Q* (or color-minus-brightness) signals to produce the proper amounts of red, green, and blue voltages.

Chrominance Section

The function of the color or chrominance section is, first, to extract the color sidebands, second, to attenuate all the remaining sections of the signal and third, to demodulate the color signals so that the original color "intelligence" or voltages are obtained. Here is how this is accomplished. Refer to Fig. 4.

A portion of the total video signal is obtained from the cathode of the 1st video amplifier and fed to a bandpass amplifier. Beyond this stage is a bandpass filter which permits signals from approximately 2.1 to 5.0 mc. to pass, while other frequencies are attenuated. This tends to eliminate all monochrome signals below 2.1 mc. The color information, of course, lies between 2.1 mc. and 4.2 mc. of the video signal.

The bandpass amplifier receives other voltages in addition to the video signal. The screen grid of the tube, for example, receives a negative pulse from the horizontal deflection transformer. This is designed to key the tube off while the color burst signal (on the back porch of each horizontal sync pulse) is passing through the circuit. This prevents the color burst voltage from reaching the d.c. restorers at the output of the chrominance channel and incorrectly shading the background of the color picture. The color burst signal is designed principally for the color synchronization section of the receiver, as will be pointed out presently.

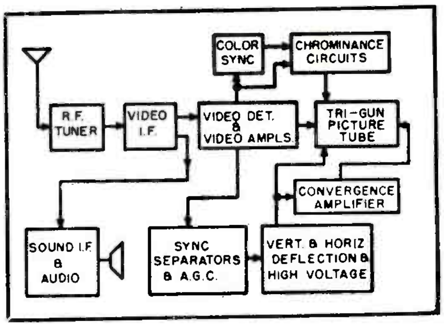


Fig. 1. Block diagram of a tri-gun color set.

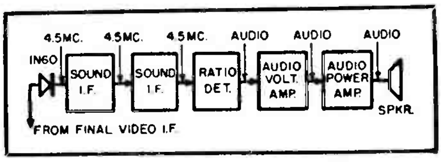


Fig. 2. Sound system of a color TV receiver.

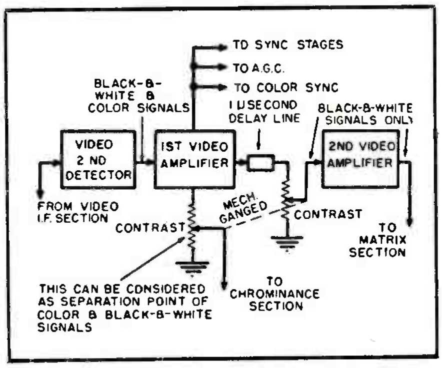
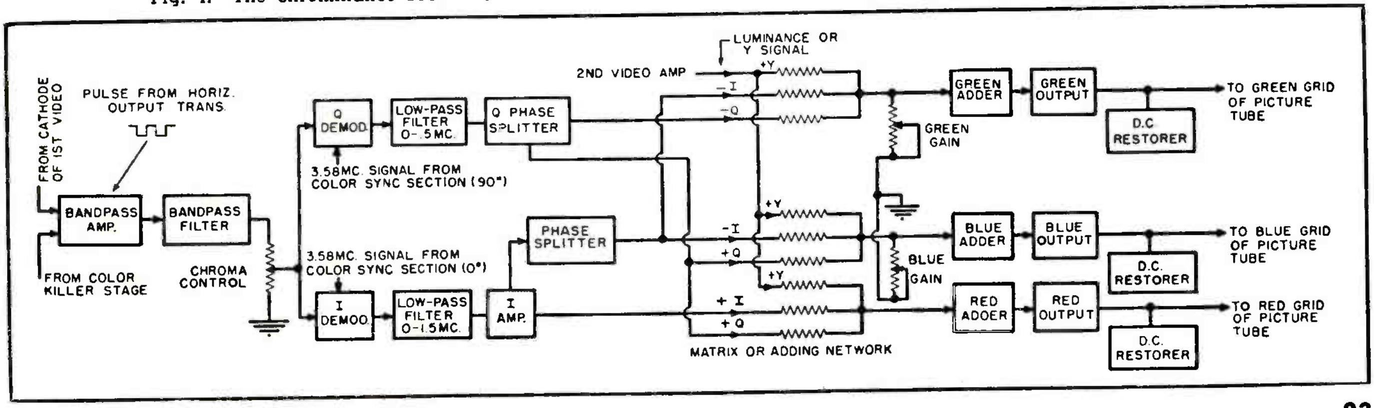


Fig. 3. Block diagram of the video section.

The control grid circuit of the bandpass amplifier also operates in conjunction with a color killer tube. This killer tube biases the bandpass amplifier to cut-off when a black-and-white signal alone is being received. However, when a color signal is present, the color burst just mentioned keeps the color killer tube cut off and this, in turn, releases the bandpass amplifier so that it will pass color signals to the following color demodulators.

The end of the bandpass filter is terminated in a chroma control potentiometer. This control regulates the amount of color signal reaching the picture tube and, hence, determines the saturation with which the colors will appear. In action it may be compared to the contrast control although there is a master contrast control that

Fig. 4. The chrominance section of a color television receiver. See text for an analysis of block functions.



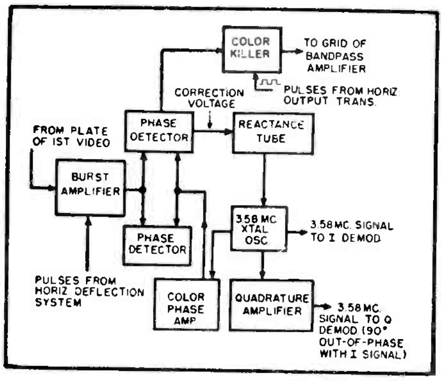


Fig. 5. Block diagram of color sync channel.

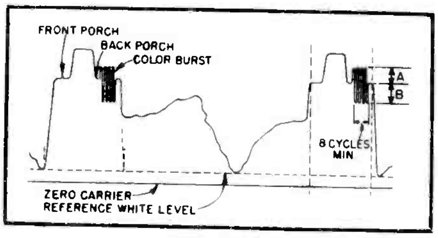


Fig. 6. The color burst on the back porch of each horizontal sync pulse. Refer to text.

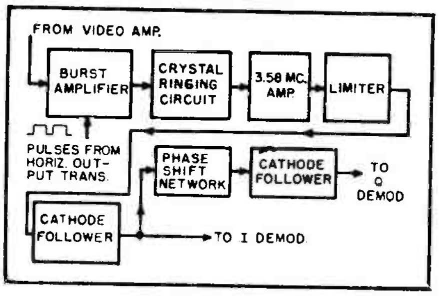


Fig. 7. A crystal ringing circuit for developing a 3.58 mc. signal for use in the I and Q demodulation steps in color receiver.

regulates the intensity of both the monochrome and color portions of the image simultaneously. The chroma control might be considered as an adjunct to the master contrast control, concerned only with the color portion of the picture.

Beyond the bandpass filter and chroma control, the color signal is fed in equal measure to two demodulators (*i.e.,* detectors). One is called the *Q* demodulator, the other the *I* demodulator. The incoming signal goes to the No. 1 grids of these tubes. At the same time, color subcarrier voltages of about 30 volts peak-to-peak are applied to the No. 3 grids (the suppressor grids). The color subcarrier voltages both possess the same frequency, but one is 90° out-of-phase with the other. This is in accordance with the formation of the *I* and *Q* signals at the transmitter. The beating of this inserted carrier with the *I* and *Q* sidebands recreates the original signals at the demodulator outputs.

The signals from the demodulators now pass through low-pass filters designed, first, to remove the color subcarrier frequency (3.579545 mc.) and the sideband frequencies and, second, to limit the *I* and *Q* signal bandwidths to the values assigned to them at the transmitter. Thus, the output of the *Q* demodulator goes through a 0-.5 mc. low-pass filter while the output of the *I* demodulator passes through a 0-1.5 mc. low-pass filter. The *Q* signal is applied to an amplifier from which positive and negative output voltages are available. The *I* signal goes first to one amplifier which provides one polarity output and then to a second amplifier from which the opposite polarity output voltage is obtained. (The reader will recognize that one tube could provide both positive and negative *I* voltages, if desired.)

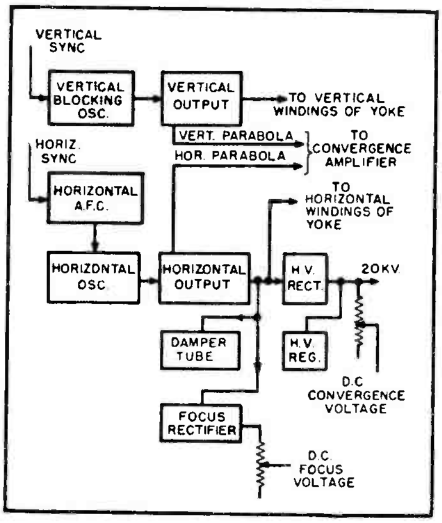
All the *I* and *Q* voltages, in proper amplitude and polarity, together with the luminance signal, combine in a series of fixed resistive networks to produce the desired red, green, and blue color signals. After this, each signal is passed through one more amplifier and then each is applied to a separate control grid of a tri-gun color tube. Included, too, in this final arrangement, are three d.c. restorers, one each for the red, green, and blue signals.

At the end of this article is a mathematical proof showing how the red, green, and blue signals are obtained by combining the *I, Q,* and *Y* (luminance) signals. We suggest at this point, that the reader simply accept the statements previously given.

Color Sync Section

A portion of the signal at the plate of the 1st video amplifier goes to a stage known as a burst amplifier. This stage is the input amplifier for a special section of the receiver known as the color synchronization section. See Fig. 5. The purpose of this section is to utilize the color burst, which is sent along with the horizontal sync pulses, to develop in the receiver a local subcarrier possessing the proper frequency and phase. This is necessary because the color signal, when broadcast from the transmitter, does not possess a color subcarrier. All it possesses are the color sidebands. To properly demodulate the color signal, the carrier must be reinserted and this is one of the principal functions of the color synchronization section.

Fig. 8. Arrangement of the vertical and horizontal stages and the high-voltage system.



In order to reinsert the missing carrier properly, the receiver must be given some information concerning the frequency and phase of the missing carrier. This information is provided in the form of a burst of approximately 8 cycles of the color subcarrier which appears on the back porch of each horizontal synchronizing pulse in the composite signal. See Fig. 6.

The burst amplifier is normally kept cut off except during horizontal retrace when it is keyed or triggered into conduction. In this way, all but the desired burst are prevented from passing through this tube. The signal at the output of the burst amplifier is fed to a phase detector. The phase detector also receives a sample of the signal generated by a 3.58 mc. crystal oscillator. The two signals are compared with each other and any difference in frequency and phase leads to the development of a correction voltage which is applied to a reactance tube. The latter stage, being connected across the oscillator tuning circuit, causes its frequency and phase to change enough to bring the oscillator in line with the received burst.

Output for the *I* demodulator is obtained directly from the oscillator while a succeeding quadrature amplifier supplies a signal 90° out-of-phase with the *I* signal. This is fed to the *Q* demodulator. This quadrature relationship is required because the *I* and *Q* signals were originally 90° out-of-phase with each other when the color subcarrier was modulated at the transmitter.

An alternate approach to the development of a suitable 3.58 mc. subcarrier can be achieved by means of a crystal ringing circuit. This system uses a quartz crystal which, when excited by the color burst at the start of each horizontal line, will continue to "ring" or oscillate at its natural frequency (here 3.58 mc.) for the duration of one horizontal line, at least. The burst from the burst amplifier activates the quartz crystal which, because of its extremely high "*Q*," continues to oscillate with very little decrease in amplitude until the next burst arrives. A trimmer condenser in series with the crystal can change its resonant frequency by several hundred cycles and thus compensate for normal crystal tolerances.

The stage following the crystal is an amplifier stage and the stage beyond that is generally a limiter to smooth out variations in output of the ringing circuit. See Fig. 7. Output from the limiter may be used as one of the 3.58 mc. driving voltages for the *I* or *Q* demodulators, while the same output passed through a 90° phase-shift network will provide the reference voltage for the other demodulator.

Note this distinction between these two circuits: In the crystal ringing circuit, no oscillations are generated when no color bursts are being received (*i.e.,* when a black-and-white signal is reaching the receiver). On the other hand, in the automatic phase detector system, a 3.58 mc. voltage is always being developed, even when the color burst is not present.

A color killer tube is included in both types of color sync systems. Its purpose is to prevent signals from passing through the chrominance section when no color signal is being received. This is done to prevent the appearance of spurious color specks on a black-and-white picture.

Much of the remaining section of the color television receiver is similar to the circuits in black-and-white television receivers. The a.g.c. stage, for example, is generally of the keyed variety, receiving a suitable video signal at its control grid and a positive triggering pulse from the horizontal output transformer. The a.g.c. voltage that develops, then, is governed by the amplitude of the sync pulses in the incoming signal.

The sync separator system receives a portion of the composite video signal and then acts to divorce the sync pulses from the rest of the signal. At the output of the sync separator section, the sync pulses are fed to the vertical and horizontal deflection systems through appropriate integrating and differentiating networks.

A block diagram of the two deflection systems and the high voltage section is shown in Fig. 8. For the most part the vertical and horizontal oscillators and output amplifiers follow established practice. Thus, the vertical system uses a blocking oscillator and an output amplifier. The horizontal system possesses an a.f.c. network, a controlled horizontal oscillator, an output amplifier, and a damper tube. A special focus rectifier operates off the horizontal output transformer to develop 4000 volts which are required by the focus electrode on the tri-gun color picture tube.

The accelerating voltage for the picture tube is 20,000 volts and this is obtained by employing one or more high-voltage rectifiers. In addition, regulation of this voltage is desirable to prevent variations in scanning linearity, brightness, and most important of all, picture color. A gaseous shunt regulator tube is one common method employed to stabilize the high voltage. During an all-black picture the regulator absorbs the entire load; during an all-white picture the picture tube takes the load and the regulator does very little.

There is one additional feature of this receiver that requires some explanation and that concerns the horizontal and vertical parabolic waveforms that are sent to a convergence amplifier. These voltages are combined and then placed in series with the d.c. focus and convergence voltages which are required by the tri-gun picture tube. The need for these additional voltages stems from the fact that the phosphor plate and the shadow mask of the picture tube are flat surfaces. Hence, if the three electron scanning beams are made to converge at the center of the screen, they will not converge at the screen at other points away from the center. The result would be a misregistered picture. To keep this from occurring, special parabolic waves are combined with the d.c. voltage on the convergence electrode of the color picture tube as the beams swing across the screen.

To maintain good focus over the entire screen, a similar parabolic voltage is inserted in series with the fixed d.c. focus voltage.

Following is the proof, mentioned earlier, showing how the red, green, and blue signals are obtained by combining I, Q, and Y signals.

The I signal, from NTSC specifications, is defined as:

$I = —.27(B\text{-}Y) + .74(R\text{-}Y)$ where B stands for blue, R stands for red, and Y stands for the monochrome signal.

The Q signal is similarly defined as consisting of:

$$Q = .41(B\text{-}Y) + .48(R\text{-}Y)$$

These may be looked upon as two simultaneous equations that we wish to solve for $(B\text{-}Y)$ and $(R\text{-}Y)$. To solve for $(R\text{-}Y)$, simply multiply the entire Q equation by .27 and multiply the entire I equation by .41, then add them together. Doing this gives us:

$$.27Q = (.27)(.41)(B\text{-}Y) + (.27)(.48)(R\text{-}Y)$$

plus

$$.41I = —(.27)(.41)(B\text{-}Y) + (.41)(.74)(R\text{-}Y)$$

or

$$.27Q + .41I = (.27)(.48)(R\text{-}Y) + (.41)(.74)(R\text{-}Y)$$

simplifying:

$$.27Q + .41I = (.13)(R\text{-}Y) + (.30)(R\text{-}Y) = .43(R\text{-}Y)$$

$$\text{Hence } (R\text{-}Y) = \frac{.27}{.43}Q + \frac{.41}{.43}I$$

$$\text{or } R\text{-}Y = .62Q + .96I$$

Thus, if we take .62 of the Q signal (with positive polarity) and .96 of the I signal (with positive polarity) and mix them together, we obtain a red-minus-brightness signal, $(R\text{-}Y)$.

By taking the same I and Q equations, and solving for $B\text{-}Y$ instead of $R\text{-}Y$, we obtain the following result:

$$B\text{-}Y = —1.1I + 1.7Q$$

Still to be obtained is a $G\text{-}Y$ signal and this was shown in the previous article to equal:

$$G\text{-}Y = —.51(R\text{-}Y) —.19(B\text{-}Y)$$

or, substituting the equivalent I and Q expressions just given,

$$G\text{-}Y = —.51(.62Q + .96I) — .19(—1.1I + 1.7Q)$$

or

$$G\text{-}Y = —.64Q — .28I$$

To each of these color-minus-brightness quantities ($R—Y$, $B—Y$, and $G—Y$) we add Y from the luminance channel (*i.e.*, the second video amplifier) to obtain R, B, and G. These are the three color signals we seek. These are then amplified and fed to their respective grids of the tri-gun picture tube.

Part 4. Tuner, video i.f., video amplifier, and sound circuits of typical color TV sets described in detail.

IN the previous article we examined in some detail the block diagram of a color television receiver designed to operate with a tri-gun color picture tube. Now we are ready to consider the actual circuits which each of the blocks represented.

R.F. Tuner. The introduction of color in no way alters or modifies the r.f. section of the television receiver. Thus, the r.f. amplifier should still possess high gain and low noise; the oscillator still provides a signal which, when mixed with the incoming signal, will produce the desired difference or video i.f. frequencies. For the reception of v.h.f. signals, either a turret tuner or a continuous arrangement is employed. For u.h.f. reception, continuous tuning is the most common method although there is also available an 82-channel turret tuner.

A typical v.h.f. turret tuner circuit is shown in Fig. 1. Cascode amplifiers are common in the r.f. stage, although some manufacturers favor single high-frequency miniature pentodes. The oscillator tube is invariably a triode, usually half of the mixer tube. The latter may be another triode (*i.e.*, ½ of a 6J6) or pentode (½ of a 6U8). This arrangement requires only two tubes for the entire tuner section.

In the tuner shown in Fig. 1, the cascode r.f. amplifier uses a 6BZ7 duo-triode. One section of a 6J6 serves as the mixer while the other section functions as the oscillator. Balanced 300-ohm and unbalanced 75-ohm (coaxial line) input impedances are provided by a center-tapped primary winding, L_{101A}. All signals must pass through a high-pass filter designed to attenuate all signals below channel 2.

The secondary winding, L_{101B}, is tuned by the input capacity (of the first triode unit) in series with alignment trimmer C_{105}. Loading of L_{101B} by R_{101} provides the required bandpass, particularly on the lower v.h.f. channels. The a.g.c. bias is applied to the first triode of V_{101} through decoupling resistor R_{102}.

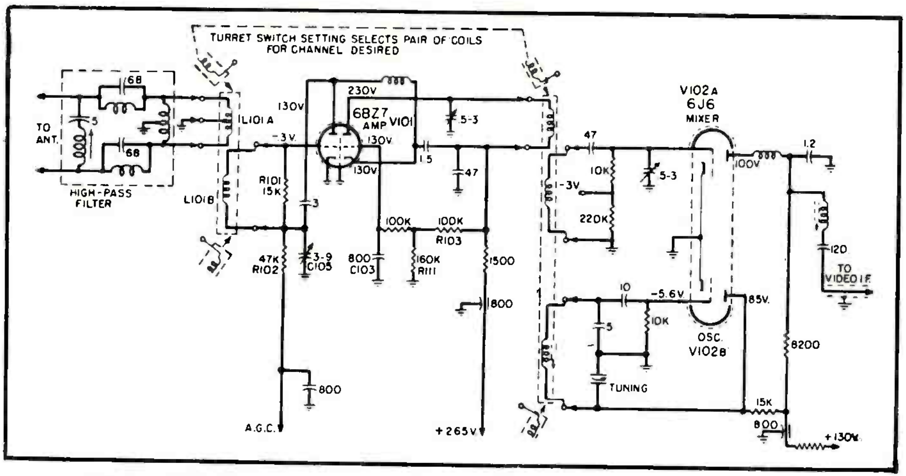


Fig. 1. Typical r.f. tuner used with color TV receiver. This is a turret-type unit for v.h.f. only, however combination v.h.f.-u.h.f. models are also used.

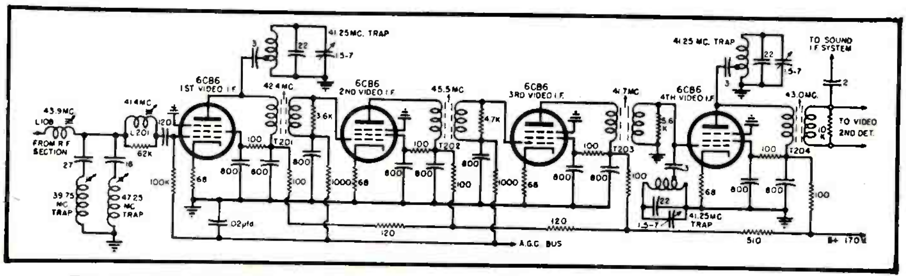


Fig. 2. The video i.f. circuits of one color TV receiver. Four stages are used here to assure a wider and more uniform bandpass than for black-and-white sets.

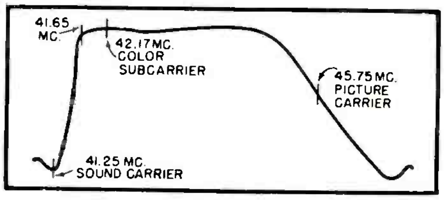


Fig. 3. Video i.f. response curve of a color TV receiver. Note the steep slope of the curve between 41.25 and 41.65 mc.

Direct coupling is used between the first triode plate and the second triode cathode. This is normal in cascode circuits. With cathode feed to the second triode, C_{103} is used to place the grid at r.f. ground potential. Since the two triode sections of V_{101} are in series across a common plate supply, the cathode of the second triode is positive with respect to chassis ground. A divider across the "B+," consisting of R_{103} and R_{111}, places the grid of the second triode at a sufficiently positive potential (with respect to its cathode) for proper operating bias.

The signal at the plate of the second triode of V_{101} is inductively coupled into the grid circuit of the mixer. At the same time, a voltage from the oscillator is similarly brought into the mixer circuit. The mixer combines both signals to produce the desired i.f. and then transfers this signal to the following i.f. stages.

The oscillator is of the ultraudion variety with a front panel fine-tuning control.

Video I.F. Section. The video i.f. system follows the r.f. tuner. This will consist, usually, of four and sometimes five separate stages. See Fig. 2. In the conventional black-and-white television receiver, three i.f. stages was the number most frequently used, although four stages were found in some sets. The increased number of i.f. stages in a color receiver stems, in part, from the wider bandpass required (4.2 mc.) and from the greater precautions that must be taken to insure that the response curve will possess the right form.

The desired response curve for the video i.f. section is shown in Fig. 3. Of particular interest is the care with which the low frequency end of the curve must be shaped so that it provides the proper amplification for the color subcarrier and its sidebands. Note that the curve is flat down to approximately 41.65 mc. and then the "roll-off" is quite steep. The steep decline is needed to prevent the sound carrier from receiving too much amplification, producing a 920-kc. beat note at the video second detector which would appear on the screen as an interference pattern. Furthermore, too much sound voltage at the detector will produce a fine-grained 4.5-mc. pattern on the screen and/or sound bars. The latter effect, of course, can occur in all television receivers, whether they be of the black-and-white or color variety. The 920-kc. interference, however, arises only when a color signal is being received.

Video i.f. systems in color receivers follow the same practice as for black-and-white receivers in so far as interstage coupling is concerned. Most common types of coupling are bifilar coils and/or single wound coils. For example, the circuit of Fig. 2 uses bifilar coils predominantly (T_{201}, T_{202}, T_{203}, and T_{204}), but two of the tuned circuits have single-wound coils (L_{108} and L_{201}). The interstage coils are stagger-tuned, ranging from a low frequency of 41.4 mc. to a high frequency of 45.5 mc. Also present are five shunt traps, three tuned to the sound i.f. signal of 41.25 mc., one to the video carrier frequency (39.75 mc.) of the adjacent higher channel, and one to the sound carrier frequency (47.25 mc.) of the adjacent lower channel.

A number of sets resort to complex coupling circuits in one or more i.f. stages in order to obtain the desired attenuation at certain trap frequencies, such as the adjacent-channel video carrier, adjacent-channel sound carrier, and the sound carrier of the channel being received.

In one *RCA* color receiver, a bridged-T circuit is inserted between the tuner and the first video i.f. amplifier. See Fig. 4. The network contains a trap tuned to the accompanying sound carrier, 41.25 mc. In order to reduce interference from this source (*i.e.,* cross modulation), the sound carrier is attenuated as soon as possible in the i.f. amplifier. (The signal is not removed completely, however, since enough must be available for the sound system. The latter ties into the video system at a subsequent point.)

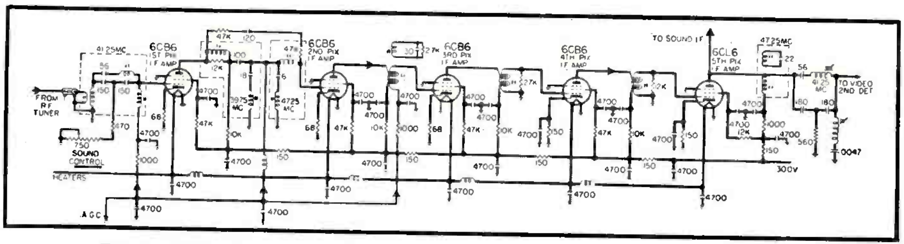


Fig. 4. Five stage video i.f. system employed by RCA in its color TV sets.

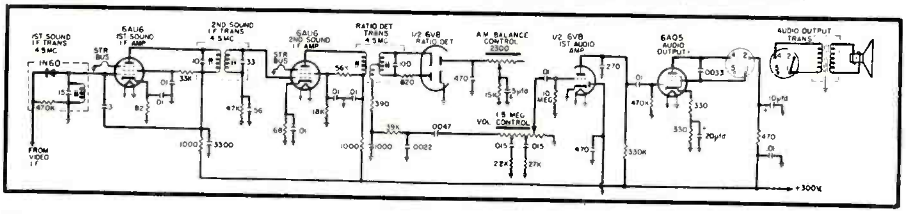


Fig. 5. Sound i.f. and audio circuits of a typical color television receiver.

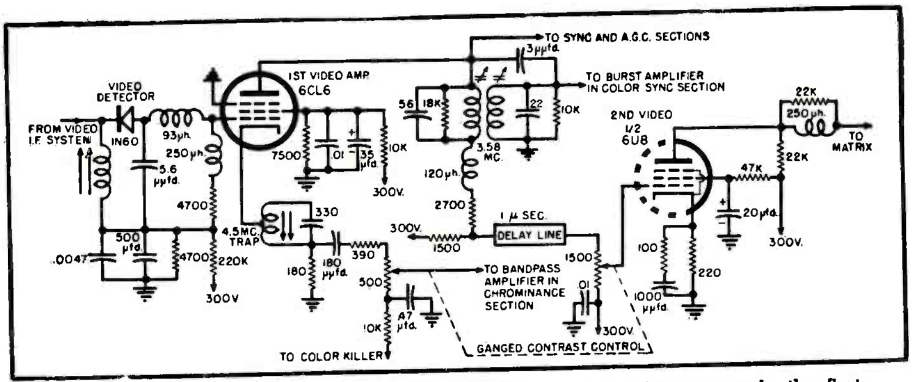


Fig. 6. Video amplifier circuit using two pentodes and a 3.58 mc. trap in the first video plate circuit for recovering the 3.58 mc. burst signal for color synchronizing.

A more elaborate bridged-T network, combined with an *m*-derived bandpass circuit, is employed between the first and second i.f. stages. This contains two rejection traps, one tuned to 39.75 mc. (video carrier of adjacent higher channel), the other tuned to 47.25 mc. (sound carrier of adjacent lower channel). A second such complex coupling network is found between the final i.f. stage and the video second detector. This, too, contains two traps, one for the accompanying sound carrier at 41.25 mc. and one for 47.25 mc.

It will be noted from Fig. 4 that the sound take-off occurs in the plate circuit of the final video i.f. amplifier. This does not necessarily denote a split-sound type of receiver, as mentioned earlier, but stems from a desire on the part of the set designer to avoid any interaction between the color subcarrier and the sound carrier that could produce (by mixing) a 920 kc. beat note. The sound carrier is permitted to travel with the video signal up to the plate of the final video i.f. amplifier and then it is diverted to a germanium crystal where it mixes with the video carrier to produce a 4.5 mc. signal. In the meantime, the monochrome and color subcarrier signals proceed to the video second detector for their demodulation. By this arrangement, the sound signal can be strongly attenuated in the video detector thereby minimizing the development of a 920 kc. beat signal.

Automatic gain control is applied to the first two or three video i.f. stages in the same manner, and for the same reason, that it is applied in monochrome receivers. The r.f. amplifier also receives all or a portion of the same a.g.c. voltage.

Sound Channel. As indicated previously, the sound signal is diverted from the video path in the plate circuit of the final video i.f. amplifier. This signal and a portion of the video carrier are then mixed in a germanium diode to produce the desired 4.5 mc. intercarrier sound signal. See Fig. 5. This is followed by several 4.5-mc. i.f. amplifiers and then the signal is applied to a ratio detector. Here the audio intelligence is recovered from the FM signal. Further amplification by audio voltage and power amplifiers raise the signal to the proper level for operating a loudspeaker. Just how extensive this portion of the audio system is will be governed by the price range of the receiver. If a high-fidelity system is desired, then the audio stages can be elaborated, perhaps by the addition of push-pull output, phase inversion, feedback networks, etc. The system shown in Fig. 5 is commonly found in most TV receivers where economy and good sound is desired.

Luminance Channel. The video signal is demodulated in the video detector (Fig. 7), providing an output 0 to 4 mc. monochrome signal plus the *I* and *Q* color sidebands. (The color subcarrier, it will be remembered, was deleted at the transmitter.) The detector itself may be either a germanium diode (1N60 or its equivalent) or one section of a vacuum tube. There appears to be a definite swing toward the germanium crystal but vacuum tubes are still widely used.

Beyond the detector, both the monochrome and color sideband signals are applied to at least one stage of amplification before they are separated In the circuit of Fig. 8, the output from the video second detector is applied first to the triode section of a 6U8, then to the pentode section. Both signals remain together only in the triode because at the grid of the pentode, a portion of the signal is fed to the bandpass amplifier, which is the input stage to the chrominance section of the receiver. Hence, separation of the monochrome and color signals might be said to occur at the output of the triode video amplifier.

The second video amplifier in Fig. 8 deals solely with the monochrome portion of the total color signal. This fact is further accentuated by the 3.58 mc. series trap which is present in the plate circuit of this stage. The trap attenuates any 3.58 mc. color subcarrier voltage which may be present here in order to prevent it from reaching the picture-tube screen and producing a visible interference pattern. The presence of the 3.58 mc. trap limits the response of the luminance or monochrome channel to a somewhat lower value, usually 3.0 or 3.2 mc. Since most present monochrome receivers operate within this bandwidth, both in their i.f. and video amplifier systems, any loss of detail will be no more apparent on color sets than on black-and-white sets.

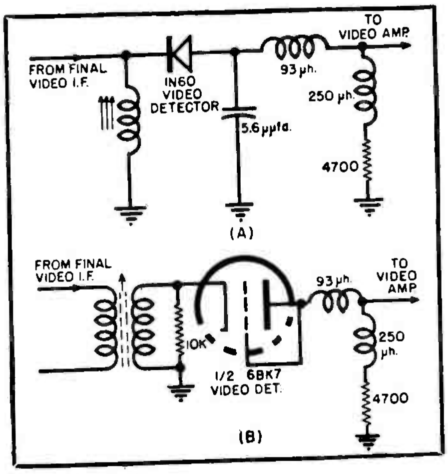


Fig. 7. Two types of video second detectors found in color TV sets. (A) Germanium diode; (B) triode vacuum tube with grid and plate connected to form a diode.

At this point the reader may wonder why a special 3.58 mc. trap is required when, in fact, no 3.58 mc. color subcarrier is being sent with the signal. The answer rests in the fact that while it is true that at no time is there any voltage at precisely the 3.58 mc. frequency, the phase excursions of the color signal cause the carrier to move back and forth from frequencies above 3.58 mc. to frequencies below 3.58 mc Furthermore, most of the color energy is concentrated in the sidebands around the 3.58 mc. frequency and if we re-

Fig. 8. Video amplifier circuit using a triode-pentode tube.

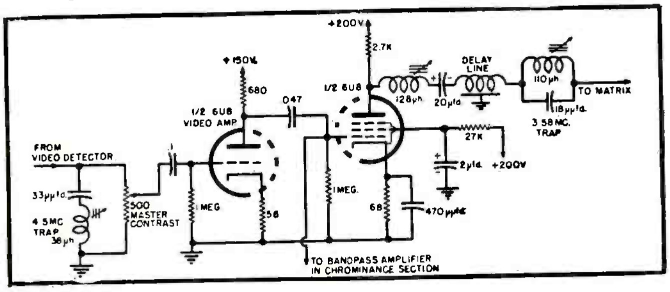
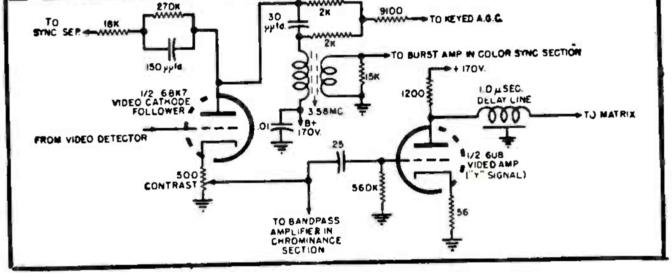


Fig. 9. Cathode follower video amplifier circuit for color TV.



move the bulk of this energy with a trap, we minimize any tendency of the color signal to produce interference patterns on the screen.

Another fact to note is this: The frequency of the color subcarrier (and hence, the frequency of its sidebands as well) was purposely chosen so that all this energy would fall midway between the clusters of energy of the monochrome signal. Any color signal reaching the screen of a monochrome receiver will tend to at least partially cancel itself out on successive frames so that its visibility is reduced. The same action occurs in a color set when the color signal reaches the screen *via* the luminance channel. Hence, the combination of the 3.58 mc. trap with the frequency interlace principle act to reduce the visibility of any interference pattern from this source to a considerable degree.

Returning to the circuit of Fig. 8, the luminance signal is finally applied to the matrix section where it combines with suitable *I* and *Q* signals to provide the original red, green, and blue voltages.

Two additional representative video amplifier systems are shown in Figs. 6 and 9. The circuit in Fig. 6 is taken from an *RCA* schematic and employs a 1N60 crystal diode as the video second detector. The output of this stage is fed to a 6CL6 video amplifier. Here both chroma and monochrome signals are amplified. The monochrome signal is then transferred to a second video amplifier and from this stage to the matrix network. The chroma signal is taken from the cathode circuit of the 1st video amplifier and transferred to the bandpass amplifier which stands at the head of the chrominance section.

There are a number of things to note about Fig. 6. A 3.58 mc. resonant circuit in the plate circuit of the 1st video amplifier transfers the 3.58 mc. signal to a burst amplifier for use in the color sync section of the receiver. The same arrangement also attenuates the amount of 3.58 mc. voltage reaching the second video amplifier. The response of this latter amplifier extends to approximately 3.2 mc., enabling it to impose additional attenuation on the color subcarrier.

Connection to the sync and a.g.c. circuits is made at the plate of the 1st video amplifier. Also, a 1.0 microsecond delay line is inserted in the path of the luminance signal between the 1st and 2nd video amplifiers. The delay line is terminated in a 1500-ohm potentiometer which serves as a contrast control for the luminance signal. A contrast control for the chrominance portion of the signal is mechanically ganged to the luminance contrast control, thereby insuring that both signals will be varied in equal amounts. This is required to maintain the proper voltage relationship between the two signals.

A 4.5 mc. trap in the cathode leg of the 1st video amplifier attenuates any 4.5 mc. voltage that may develop in the video detector through the beating of the video and sound carriers.

For the color TV video amplifier circuit shown in Fig. 9, the detector stage is formed by using one-half of a 6BK7 duo-triode. The grid and plate are tied together so the triode function as a diode. The second triode section of the 6BK7 is operated as a cathode follower, thereby permitting a number of circuits to obtain their signals from the detector without imposing any capacitive loading on this stage.

The plate circuit of the cathode follower provides signal voltages for the sync separator, a.g.c., and burst amplifiers. The cathode of the same tube contains a 500-ohm potentiometer which provides the signal for both a luminance amplifier and a bandpass amplifier and controls the contrast for both channels simultaneously.

The brightness or luminance signal is amplified by a single triode stage and then passed through a 1.0 microsecond delay line that is terminated in the matrix network. There are no special traps in this circuit, but response falls off rapidly beyond 3.2 mc., attenuating any color subcarrier and 4.5-mc. voltages that might be present.

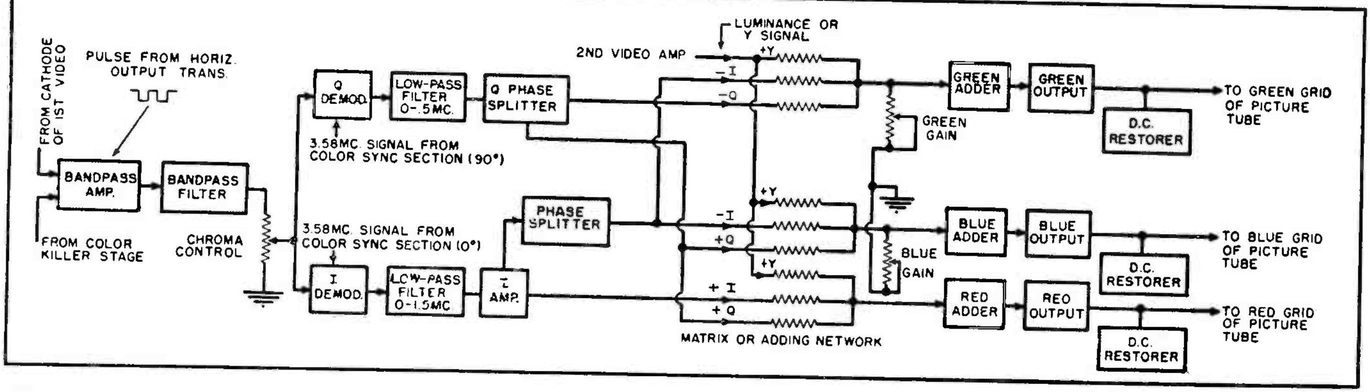
Part 5. Analysis of the chrominance circuits of three typical color TV receivers using the 3-gun color tube.

In the previous article we followed the full video signal (containing both black-and-white and color components) from the antenna to the video second detector. After detection, we had the 0 to 4 mc. black-and-white signal plus the color information. The latter was present as sidebands of the 3.58-mc. color subcarrier which meant that the color signal would require additional detection (or demodulation) before we could use it for application to the color picture tube. Thus, detection in a color receiver is a two-step process. First we remove the carrier which brought the full signal to the receiver. Then we must remove the color subcarrier so that the color video frequencies which it possesses may become available. It is important to keep this distinction in mind.

The black-and-white portion of the full signal is amplified by one or two video stages and then transferred to the matrix. While this is happening, the color subcarrier and its sidebands are diverted to the chrominance section of the receiver. See Fig. 1. This section is concerned only with the color portion of the signal and it consists basically of a bandpass amplifier, the *I* and *Q* demodulators, and *I* and *Q* amplifiers and phase splitters. The output of the system is fed to the matrix network where, in combination with the monochrome or *Y* signal, we reobtain red, green, and blue voltages which are then applied to the proper control grids of the tri-gun color tube.

The complete circuit of the chrominance section of a television receiver is shown in Fig. 2. The incoming signal, which contains both chrominance and luminance components, is applied to the grid of the bandpass amplifier.

Fig. 1. Block diagram of the chrominance section of a color television receiver. The exact circuitry varies from set to set.



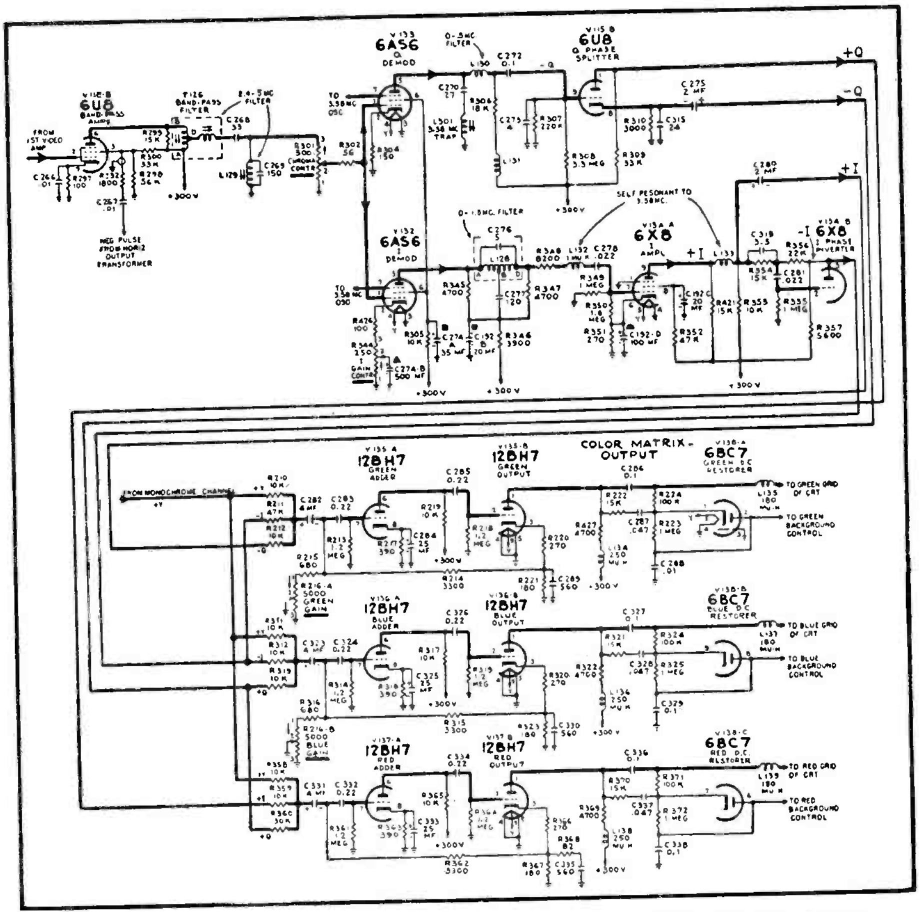


Fig. 2. Schematic diagram of the chrominance circuits of an RCA color TV receiver.

This tube will permit the signals to pass at all times except during the horizontal retrace period (including the color burst) when the tube is keyed to cut-off by a negative voltage pulse obtained from a winding on the horizontal output transformer. The pulse is applied to the screen grid of the bandpass amplifier through a .01 μfd. condenser. The tube is keyed out during the color burst interval in order to avoid unbalance in the color background due to the d.c. restorers clamping on the color burst rather than on the tips of the sync pulses.

The control grid of the bandpass amplifier also operates in conjunction with a color killer stage. This latter stage (not shown in the diagram) biases the bandpass amplifier to cut-off when no color signal is being received. However, when a color signal is active, the color killer stage removes its bias and the bandpass amplifier is able to function normally. In this way we avoid having spurious signals pass through the color system when it is inactive and produce random colors on the screen.

A filter in the plate circuit of the bandpass amplifier has a bandwidth of approximately 2.4 to 5.0 mc. See Fig. 3. This enables the circuit to pass only that portion of the total signal containing the color information. The rest of the signal, containing only monochrome or luminance voltage, is sharply attenuated.

A chroma control terminates the filter and with it the set viewer can adjust the depth of saturation of the colors in the picture. The need for such adjustment may arise because of the level of the surrounding light in the room, because of the personal preference of the viewer, or because of variations in the color circuits of the receiver. Whatever the reason, the control is not a particularly critical one and it may be varied over a considerable range without overly distorting the picture as far as its tonal values are concerned.

From the chroma control, the signal is fed in equal measure to the control grids of the *I* and *Q* demodulators. At the same time both tubes receive, at their suppressor grids, a 3.58-mc. signal. The latter represents the missing color subcarrier and is needed in the demodulator to properly reproduce the original *I* and *Q* color video signals. The 3.58-mc. signal which the *I* demodulator tube receives is 90° out-of-phase with the 3.58-mc. voltage applied to the *Q* demodulator. This is required since the *I* and *Q* sidebands themselves are 90° out-of-phase with each other.

The detected *Q* signal appears at the plate of V_{133} and is passed through a 0 to .5-mc. filter before being applied to a *Q* phase splitter. The latter stage then supplies negative (at its cathode) and positive (at its plate) *Q* signals necessary for the matrixing network into which the signals are fed.

The 3.58-mc. color subcarrier signal is not required beyond the demodulator and it is shunted away from the grid of the phase splitter by the series-resonant trap L_{301}, C_{270}.

In the *I* channel, the detected *I* signal is passed through a 0 to 1.5-mc. filter and then through an *I* amplifier and an *I* phase inverter before being applied to the same matrixing network. Positive *I* signals for the network are obtained at the plate of the *I* amplifier; negative *I* signals appear at the plate of the following phase inverter.

A .5 microsecond delay is designed into the *I* system and its purpose is to slow down all *I* signals so that they keep in step with the corresponding *Q* signals. The time it takes a signal to pass through a system is found to be inversely proportional to the bandpass of that system. That is, the narrower the bandpass, the longer it takes for signal passage. In a color receiver, the *Q* channel has the narrowest bandpass (0-.5 mc.) and its signals suffer the greatest amount of delay. The bandpass of the *I* channel extends from 0-1.5 mc. and so its signals are not slowed down as much as the *Q* signal. Finally, the *Y* or monochrome channel has the widest bandpass (0-3.2 mc.) and its signals are delayed the least in passage.

To insure that the *I*, *Q*, and *Y* signals arrive at the matrix at the same instant, it is necessary to artificially increase the delay time of the *Y* and *I* signals to that of the *Q* signal. In the *Y* channel, this is done by inserting a 1.0 microsecond delay line. In the *I* channel, the additional delay required is on the order of .5 microsecond. While no special delay line is employed in the *I* circuit of Fig. 2, the over-all characteristics of the system shown have been so fashioned that this added delay is actually present in distributed form. That is, each section of the circuitry contributes some share toward the delay and by the time the signal has arrived at the matrixing network, it has been moved back in step with the *Q* signal.

Note that the *I* channel has one amplifier stage more than the *Q* channel. This is due to the narrower bandpass of the *Q* channel. A narrower bandpass permits us to use higher load resistances, with a corresponding increase in gain. The difference in gain of the two demodulators is on the order of almost 7 to 1. For a 2-volt peak-to-peak signal input, the peak-to-peak value of the signal at the plate of the *Q* demodulator is 20 volts, while at the plate of the *I* demodulator it is only 3 volts.

The Matrix Section

The matrix or mixing section is the place where the *I*, *Q*, and *Y* signals combine to reproduce the original red, green, and blue signal voltages. There are a variety of mixing networks possible, but the most economical and straightforward is the resistive network. See Figs. 2 and 4. From the NTSC specifications, the *I* and *Q* signals have the following composition:

$I = -.27\ (B-Y) + .74\ (R-Y)$

$Q = .41\ (B-Y) + .48\ (R-Y)$

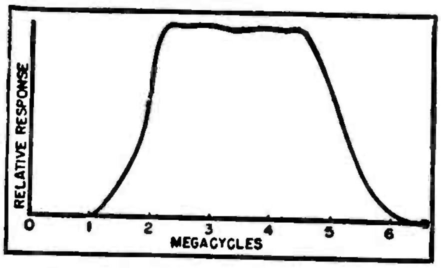


Fig. 3. Response of the bandpass filter in the plate circuit of the bandpass amplifier of the circuit in Fig. 2.

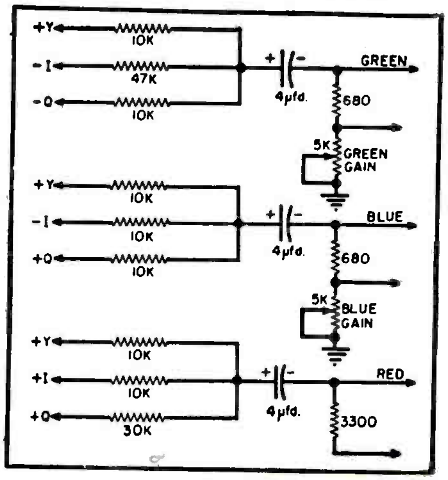


Fig. 4. The matrix network for combining the Y, I, and Q signals in the proper proportions to give red, green, and blue signals in circuit of Fig. 2.

These represent two equations and if we solve them simultaneously for *B-Y* and *R-Y* we obtain:

$B\text{-}Y = 1.72Q - 1.11I$

or $B = Y + 1.72Q - 1.11I$

and $R\text{-}Y = .62Q + .96I$

or $R = Y + .62Q + .96I$

Now, what do these equations tell us? They reveal that if we take 1 volt of signal from the *Y* channel, and 1.72 volts of positive *Q* voltage from the *Q* channel, and 1.11 volts of negative *I* voltage from the *I* channel, we obtain 1 volt of blue signal. Of course, we are not restricted to voltages this small; we may use much larger voltages, as long as we maintain the same relative relationship between the *I*, *Q*, and *Y* voltages taken from these three channels feeding into the matrix network.

The red signal is obtained by using different proportions (and polarities) of the *Y*, *I*, and *Q* voltages than were used for blue. This is indicated by the last equation and the red signal is then dealt with separately.

Still missing is a green voltage and this can be obtained from still another equation which is also derivable from the NTSC specifications. That is:

$$(G\text{-}Y) = -.51\ (R\text{-}Y) - .19\ (B\text{-}Y)$$

and from this, by a little mathematical manipulation,

$G\text{-}Y = -.64Q - .28I$

or

$G = Y - .64Q - .28I$

Hence, within the same matrix, we can obtain the desired green signal by combining 1 volt of *Y* signal with .64 volt of negative *Q* signal and .28 volt of negative *I* signal.

The foregoing equations make it evident why a resistive matrix network can work and also why positive and negative *I* and *Q* voltages are required, whereas from the *Y* channel only a single positive signal is needed.

Let us return now to Fig. 2 and briefly check the red, green, and blue amplifiers to make certain that the voltages they receive at least conform in polarity to the voltages indicated in these equations.

The green amplifier (or "adder" as it is labeled on the diagram) receives a *Y* voltage, a negative *I* voltage, and a negative *Q* voltage. The circuit, of course, is so designed that these signals are present in the ratio of 1 to 28 to .64.

The blue amplifier receives a *Y* voltage, a negative *I* voltage, and a positive *Q* voltage. Finally, the red amplifier receives a *Y* voltage, a positive *I* voltage, and a positive *Q* voltage.

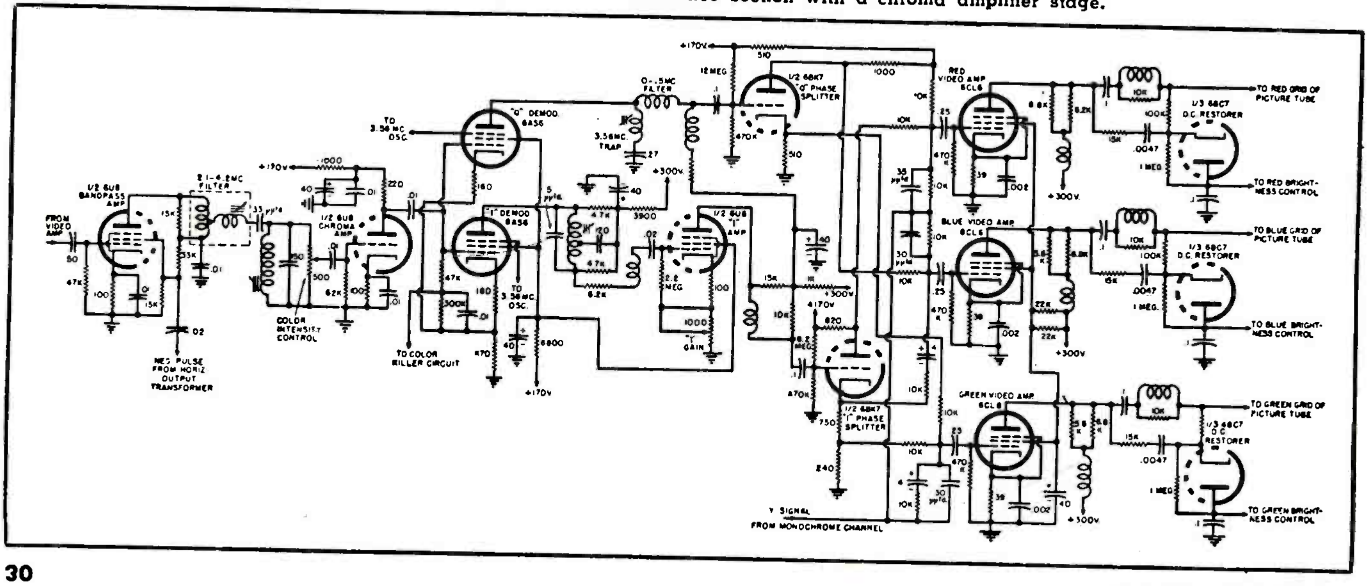
Each of these voltages is passed through two video voltage amplifiers and then applied to its respective control grid in the tri-gun picture tube. Bandpass of each system is on the order of 3.2 mc. Over-all gain controls for the green and blue channels are provided to permit the gains of these sections to be adjusted relative to the red channel. In the initial tri-gun picture tubes that were made, the efficiency of the red phosphor was lower than the efficiencies of the green and blue phosphors. To compensate for this, more drive was required at the red control grid, or what is the same thing, less drive for the green and blue grids. Adjustment of the two gain controls served to satisfy this condition. A d.c. restorer is included in each path to bring each color signal to the proper level before it is applied to the picture tube.

The chrominance channel of another color television receiver is shown in Fig. 5. The complete signal is brought to the grid of the bandpass amplifier from the master contrast control. The tube admits all of the signal except the color burst because during this interval it is keyed off by a negative pulse applied to the screen grid.

In the output circuit of the bandpass amplifier there is a 2.1 to 4.2 mc. bandpass filter terminating in a 500-ohm chroma control ("color intensity control"). As before, the chroma control governs the amount of color signal reaching the rest of the chrominance section and hence it regulates the intensity or saturation of the colors viewed on the picture tube screen. The color signal receives an additional stage of amplification beyond the chroma control and then it is fed in equal measure to both the *I* and *Q* demodulators.

The demodulators in this system are also the recipients of two additional voltages. One voltage, in the form of a negative biasing voltage, is obtained from a color killer tube. When a color signal is being received, this bias voltage drops to zero and both demodulators conduct. On the other hand, when no color signal (and hence, no color burst) is present, the negative voltage

Fig. 5. Schematic diagram of a chrominance section with a chroma amplifier stage.



from the color killer tube is high enough to cut both demodulators off. The over-all effect, then, is the same in this system as in the previous one, although the approach is slightly different.

The second voltage applied to the *I* and *Q* demodulators is provided by a 3.58-mc. generating section. This is the missing color subcarrier and is applied in equal measure but with a 90° phase difference to each demodulator. The tubes then mix this signal with the incoming color sidebands to provide the detected *I* and *Q* color signals at the output.

In the *I* channel, there is a 0-1.5 mc. low-pass filter, an amplifier and a phase splitter. Also, sufficient delay is incorporated in this circuit to force the *I* signal components to keep in step with the *Q* signal components. Positive and negative *I* signal voltages are available at the plate and cathode terminals, respectively, of the phase splitter for use in the matrix network.

The *Q* channel is somewhat less extensive, containing only a phase splitter and a 0-.5 mc. low-pass filter. The output from this section, too, is fed to appropriate points in the matrix network.

The remainder of the chrominance channel consists of three individual 6CL6 amplifiers, one for each of the three color signals, and three d.c. restorers. Action here is similar to that existing at the same point in the previous system and additional explanation is not required.

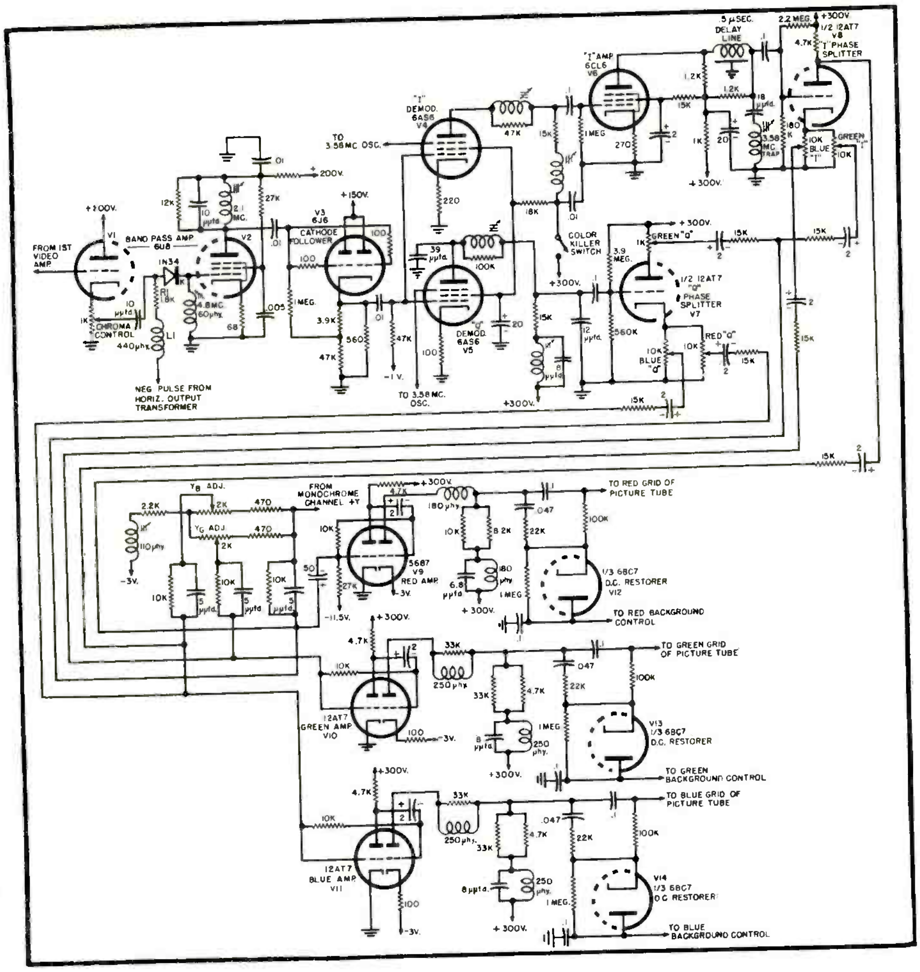


Fig. 6. Chrominance circuit containing a manual color killer switch and a 1N34 crystal circuit for eliminating the color burst signal from the chrominance channel.

There are many ways of handling the color signals and the chrominance circuits of one manufacturer would differ in some respect from those of his competitors. Figs. 2 and 5 illustrate two possible approaches. Still another is shown in Fig. 6 and it contains several interesting features. The color signal is received from the first video amplifier by a bandpass amplifier. The chroma control is contained in the cathode of this stage and as much signal as desired is tapped off here and transferred to a second bandpass amplifier *via* a 1N34 crystal. The purpose of the germanium crystal is closely linked to the negative triggering pulses which are fed into the circuit *via* R_1 and L_1. The negative pulses appear during the horizontal retrace interval when the color burst is passing through the circuit. The arrival of the pulse prevents the 1N34 from conducting since the pulse amplitude is greater than that of the color burst coming from V_1 and, consequently, the color burst is effectively prevented from continuing farther into the chrominance section. At all other times, the signal polarity is such that the 1N34 conducts and so whatever voltage is present across the chroma control reaches the grid of V_2. This, then, is the way this circuit removes the color burst from the chrominance channel.

The bandpass of V_1 and V_2 extends from 2.1 mc. to 4.8 mc. and the signals within this range are amplified and then transferred to a 6J6 cathode follower (V_3).

The next recipients of the color signal are the *I* and *Q* demodulators. The signal is fed in equal measure to grid No. 1 of both 6AS6's. At the same time, grid No. 3 of each tube receives a 3.58-mc. subcarrier voltage. The peak-to-peak value of this signal is on the order of 18 volts and the only difference between the 3.58-mc. voltages is a 90° phase difference.

In the *I* section, the demodulator is followed by an amplifier and then a phase splitter. The latter tube makes positive and negative *I* voltages available to the matrix. Bandpass of the *I* section is 1.3 mc.

In the companion *Q* section, the demodulator is followed by a single phase splitter which provides positive and negative *Q* signal voltages for the matrix. The bandpass of this section extends to .5 mc. in accordance with the nature of the received signal. It is interesting to note that should the bandpass of this channel be broadened above .5 mc., color infidelity would occur because of the presence of some higher frequency *I* signals in the *Q* channel. When the bandpass is limited to .5 mc., these "spurious" *I* signals are attenuated below the point of visibility and do no damage. But if the cut-off were extended, they would reach the picture tube and cause color "distortion."

There are several features worthy of special mention in the *I* and *Q* stages of Fig. 6. The "B+" voltage for the screen grids of V_4 and V_5 may be cut off by a manual switch called the "color killer" switch. When a black-and-white broadcast is being received, this switch is turned to the off position, disabling both demodulators and preventing any spurious signals from passing through the color section. For a color broadcast, the switch is turned back on again. This is a simple (and economical) form of color killer circuit. However, it does possess the disadvantage of requiring the set user to know when a color transmission is being received, otherwise all he will get will be black-and-white pictures. In the two previous systems, the color killer network functioned automatically; when a color signal was received, the killer voltage was automatically removed and a color picture appeared on the screen.

Another feature of Fig. 6 worth noting is the use of an actual delay line in the *I* section. In the other systems, the delay was distributed throughout the *I* system.

The voltages which the *I* and *Q* phase splitters apply to the matrix are nearly all individually adjustable. In this respect it is of interest to note the names applied to these controls. In the *I* phase splitter, there is a "Green *I*" and a "Blue *I*" adjustment. The "Green *I*" control is so named because the voltage from this point goes to the green amplifier stage and variation of this voltage would affect the hue of the green seen on the screen. The same type of reasoning applies to the "Blue *I*" adjustment since the voltage from this control goes to the blue amplifier stage. Three similar controls are employed in the *Q* phase splitter.

Finally, there are two adjustments near the point where the brightness signal enters the matrix. These are labeled as Y_B and Y_G adjustments and they control the amount of *Y* signal fed into the blue and green amplifier stages *via* the matrix. Definite relationships exist among the *I*, *Q*, and *Y* voltages and these relationships must be carefully observed if the proper hue, brightness, and saturation are to be obtained on the screen. By making a number of controls available, the service technician can make whatever compensating adjustments may be required to achieve the proper color rendition.

Part 6. How a color television scene is transformed into signal voltages; analysis of the detected video signal.

THUS FAR we have discussed at length the general formation of a color signal and what happens to this signal at various stages in the receiver. We have not, however, gone into any examination of what the color video signal looks like when it is viewed at the video second detector. Since this is something with which the service technician should be familiar, discussion of the remaining sections of a color receiver will be held in abeyance while we analyze color video signals.

Perhaps the best place to start is at the transmitter where a color-bar test pattern is being picked up by a color camera. The test pattern chosen, Fig. 1, consists of four vertical bars in the order of blue, red, green, and white. These represent the three color primaries and white. The light from this color pattern is received by the color camera and the rays from each different primary color are directed to a specific camera tube. That is, the red rays of light go to the red camera tube, the blue light goes to the blue tube, and the green light is sent to the green camera tube. Within each tube, the photosensitive mosaic is activated only by the light received. Thus, on the mosaic of the blue camera tube, for example, the incoming light is focused on the left edge in the same position as the blue bar on the test pattern. Also, a bar appears at the right edge of the mosaic because white contains blue and this blue component affects the blue camera tube. In between these two bars the mosaic surface would be unaffected because there is no blue in the two center bars of the pattern.

By a similar type of analysis we can see that each camera tube would have parts of its mosaic activated and other mosaic parts quiescent or unaffected.

Now, as the scanning beams (in the camera tubes) scan across one horizontal line of this color pattern, here is what we obtain. At the start, each beam is passing over the portion of the pattern occupied by the blue bar. During this time, an output voltage will be obtained from the blue camera tube only. See Fig. 1A. The red and green tubes are developing zero output because none of this blue light is reaching them.

The next bar to be scanned is the red bar and now the red camera tube becomes active, producing an output voltage while the blue and green tubes render zero output voltage. The third bar is green and the output voltage is now derived from it. The final bar is white and when this is being scanned, the same voltage output is obtained from the blue, red, and green camera tubes. This is because white contains all three primary colors in more or less equal amounts and all three color tubes are similarly affected.

Figs. 1B, 1C, and 1D show graphically the manner in which the voltage output from each color camera tube varies as the beam moves across the screen from left to right. This, then, is the color voltage information obtained from the scene to be transmitted. The next step is to convert this information into appropriate *I*, *Q*, and *Y* signals which will then be transmitted to the receiver. To achieve this transformation, the three voltages are fed into a matrix network. (This is similar to the matrix network in the receiver where the reverse action occurs, *i.e.*, *I*, *Q*, and *Y* are reconverted to equivalent red, blue, and green voltages.)

Within the matrix at the transmitter, the *I*, *Q*, and *Y* voltages are formed according to the following defining equations:

$$Y = .59G + .30R + .11B \quad . \quad . \quad . \quad (1)$$

$$I = -.28G + .60R - .32B \quad . \quad . \quad . \quad (2)$$

$$Q = -.52G + .21R + .31B \quad . \quad . \quad . \quad (3)$$

(The reader undoubtedly appreciates by now the fact that both *I* and *Q* signals can be expressed in terms of color-minus-difference voltages or directly in terms of *R*, *B*, and *G*. All are equivalent.)

Thus, coming out of the matrix at the *Y* terminal would be the waveform shown in Fig. 1E. The blue voltage is only 11 per-cent of what it was when it entered the matrix, the red is only 30 per-cent, and the green is only 59 per-cent. For the *I* signal, we take 28 per-cent of the voltage produced by the green tube, 60 per-cent of the voltage from the red tube, and 32 per-cent of the blue tube output. Negative values, required for the green and blue components of the *I* signal, are achieved by passing these components through phase inverters. The *Q* signal formation follows in similar order.

Note that the white bar produces a full output in the *Y* channel, but zero output in the *I* and *Q* channels. In the *Y* channel, the white amplitude is made up of 59 per-cent green, 30 per-cent red, and 11 per-cent blue. When you add .59 plus .30 plus .11, you obtain 1. On the other hand, consider what happens to this white voltage in the *I* and *Q* channels. The scanning of the white bar produces equal voltage output from the red, green, and blue camera tubes with the result that the matrix receives voltages from each of these tubes at the same time. If we assume that each camera tube is providing 1 volt of signal, and this is what the matrix receives, then equation (2) tells us that what finally appears at the *I* terminal at the output of the matrix when the white bar is being scanned is —.28 volt from the green channel, —.32 volt from the blue channel, and + .60 volt from the red channel. The combination of —.28 and —.32 with +.60 produces a net result of zero, which means that all three voltages cancel each other out completely.

This particular situation was purposely selected in order to reduce all color signal output to zero when black, white, or grey are being scanned.

In the *Q* channel we have a similar situation for its voltages, too, cancel out when white is being scanned.

Once the *I*, *Q*, and *Y* signals have been formed, they are sent through appropriate amplifiers until they have been strengthened sufficiently to perform the next step in the formation of a total color video signal. Let us concentrate first on the *I* and *Q* color signals. These are employed to amplitude modulate separate 3.58 mc. color subcarriers, their only difference being a 90° phase difference between them. After this operation has been performed, the modulated *I* and *Q* signals appear as shown in Figs. 1H and 1K. (Negative modulating voltages, such as the —.32 for *I* blue, appear only as a reversal of subcarrier phase. That is, a positive modulating voltage will cause the resulting modulated signal to have one phase, a negative modulating voltage will cause it to have the opposite phase. In outward appearance, however, both modulated waves will possess the same shape or envelope.) These are actually the color sidebands produced by the modulation, the 3.58-mc. carrier having been suppressed in the balanced modulators. The various colors (red, green, and blue) produce different amplitudes on the modulated waves in accordance with their amplitudes in the *I* and *Q* signals.

The next step is to combine these signals into one. Since the 3.58-mc. color subcarriers that were employed in the modulators differed in phase by 90°, their sidebands differ in the same way. Hence, their resultant is not obtained by adding their amplitude arithmetically (as $3+4=7$) but rather by taking the square root of the sum of their squares (as $\sqrt{3^2+4^2}=\sqrt{9+16}=\sqrt{25}$ or 5). If we follow this procedure for the *I* and *Q* modulated signals of Figs. 1H and 1K, we obtain the result shown in Fig. 1M.

As a sample calculation, consider the blue voltage portion of the *I* and *Q* voltages of Figs. 1H and 1K. The peak amplitude of the *I* blue is −.32 and this figure squared is equal to .1024. By the same token, the *Q* blue is .31 and this squared is equal to .0961. The addition of .0961 and .1024 gives us .1985 and the square root of this number is .44. The remaining calculations are worked in a similar manner, with the results indicated.

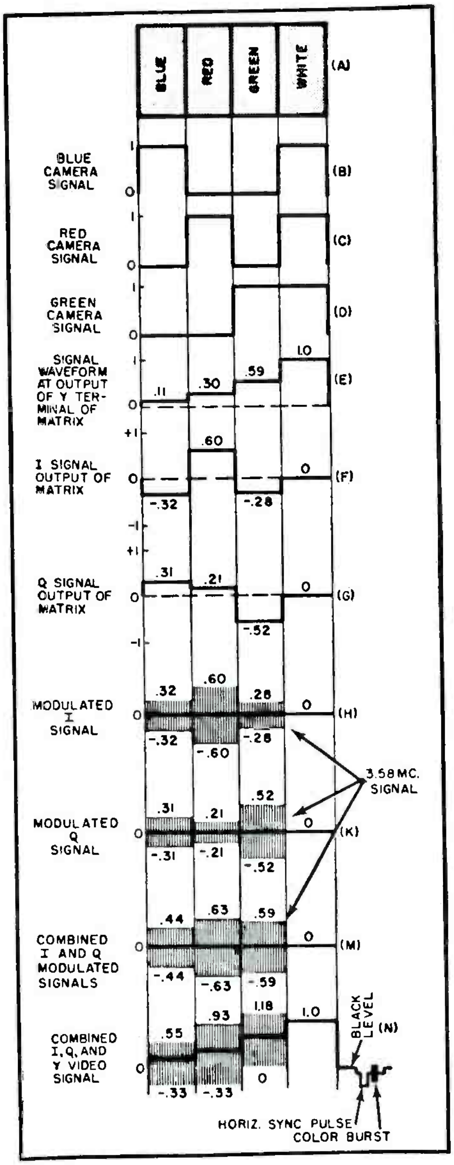
The color signals have now been combined and the next step is to add this resultant to the monochrome or brightness signal. Here the addition is straightforward, with the color sidebands extending for equal distance above and below the brightness level. The *Y* component represents the brightness of that color and brightness in a video signal is determined by how far the average level of a video signal is from the black level. (The black level is the reference against which brightness is measured.)

The blue portion of the signal (representing the blue bar on the scanning pattern) has a brightness level of .11. Therefore, the average level of the blue *I* and *Q* (*i.e.*, color) signal is placed 11 per-cent of the distance between the black level and the maximum brightness level. Red has a brightness value of .30 and so it is moved farther away from the black level. Finally, the brightness level of green is .59 and it is positioned 59 per-cent of the distance *away from* the black level. White has a brightness value of 1 and it is positioned at the farthest point from the black level of the video signal.

The total signal, with *I*, *Q*, and *Y* combined and with sync pulses and a color burst appears as shown in Fig. 1N. In this illustration, several items are of interest. First is the color burst and in the examination of any color video signal this burst must be present in order to insure the proper reproduction of colors in the picture. It is this burst which establishes the frequency of the color subcarrier generator in the receiver and any deviation from its correct phase will result in color distortion (*i.e.*, a shift in color away from its original hue).

Second, the negative tips of the 3.58-mc. modulated blue signal and of the red signal extend beyond the black level well into the blacker-than-black or sync-pulse region. At the other end, the positive tips of the 3.58-mc. modulated green signal extend beyond the point where the brightest level is indicated. These extensions beyond the normal excursions of the video signal are permitted by the FCC standards, but in practice they seldom occur. Actually, they appear only for highly saturated colors and such saturations are almost never encountered. Theoretically, though, they are permissible.

Fig. 1. The various stages in the formation of a color TV video signal using a color-bar pattern as a subject.



At the video second detector, a good oscilloscope would produce the signal pattern shown in Fig. 1N. Beyond the detector, the color components of the total video signal are shunted off to the chrominance section of the receiver while the monochrome portion is passed through a separate amplifier stage or two. The demodulated *I* and *Q* signals then meet the *Y* signal again in the receiver matrix network and through the interaction of these three signals, the original blue, red, green, and white bar pattern is re-created on the picture tube screen.

It might be instructive to follow this reconstruction in detail to see how the original colors are re-obtained. It was shown in the discussions of the receiver matrix in Part 5 that:

$$R = Y + .62Q + .96I$$
$$B = Y + 1.7Q - 1.1I$$
$$G = Y - .64Q - .28I$$

Let us consider the blue color first since it appears first on the bar test pattern. From the *Y* signal we obtain a voltage of .11 volt since this is the average brightness level of the blue bar. From the *Q* channel we get 1.7*Q* volts or 1.7 times whatever blue voltage the *Q* channel possesses. If we refer back to Fig. 1G, we see that the *Q* voltage when blue was being scanned was .31. (This means 31% of whatever voltage was being delivered by the blue camera tube to the transmitter matrix. If we assume 1 volt of signal was being provided by this tube, then .31 volt of blue voltage was obtained at the *Q* terminal of the matrix.) Thus, this .31 is now multiplied 1.7 times to provide .527 volt from the *Q* channel toward the formation of the final blue bar to be presented on the screen. Thus far, then, we have .11 volt of blue voltage from the *Y* channel and .527 volt from the *Q* channel. Still to come is the voltage from the *I* channel. This is −1.1 times whatever blue voltage the *I* channel possesses. Again, if we refer back to Fig. 1F, we see that the *I* voltage when blue was being scanned was −.32. This value, multiplied by −1.1 gives us a total of .352 positive, since the multiplication of two negatives yields a positive. Electronically the multiplication of two negative numbers means that the reversal in polarity that occurred in the transmitter matrix is now being counteracted. Adding all three contributions from the *I*, *Q*, and *Y* channels, we obtain: .11 + .527 + .352 which equals .989 or essentially 1 volt of blue signal. Is this the same as the original voltage obtained from the blue camera tube? The answer, of course, is Yes!

The red and green signal values can be obtained in the same manner and the computations and solutions are shown in Fig. 2. For white there would be no contributions from the *I* and *Q* channels since it was demonstrated previously that the scanning of white produced no *I* or *Q* voltage.

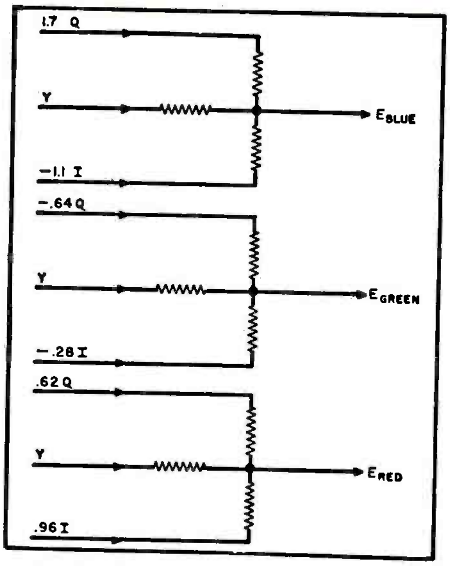


Fig. 2. Matrix circuit for adding I, Q, and Y signals in a color TV receiver to recreate red, green, and blue signal voltages for the picture tube.

White, then, would be obtained solely from the Y signal, which is as it should be.

In the foregoing discussion, a relatively simple color bar pattern was employed. With that knowledge behind us, we are now in a position to examine the video signal produced when the color-bar test pattern of Fig. 3A is scanned. Here we not only have the three primary colors, but mixtures of these colors such as yellow, cyan, and magenta.

The waveforms shown in Figs. 3B, 3C, and 3D indicate how the output voltage from each color camera tube varies as the scanning beam travels across the pattern from left to right. Consider the output from the blue camera tube first. When red, yellow, or green is scanned, the voltage developed by the blue tube is zero because these colors possess no blue. When cyan is reached, the voltage output of the blue tube jumps up to our assumed value of one. Cyan is formed by combining green and blue and it is the blue component which activates the blue camera tube. The output of the blue tube remains steady at 1 volt as the beam moves over the blue bar and the succeeding magenta. The latter color represents a combination of blue and red. When the scanning beam passes over the red bar, the output of the blue camera tube drops back to zero. It shoots back up again to 1.0 volt when white is reached.

For the red camera tube, an output signal is obtained for red, yellow, magenta, and white. And finally, for the green camera tube, output is present as the beam moves over yellow, green, cyan, and white.

Explanation of the waveform that appears in the Y channel rests, as it did before, on the equation:

$$Y = .59G + .30R + .11B$$

Where a single color appears by itself, the value employed is that which is placed in front of that color in the foregoing equation. The figure of .89 which is indicated for the yellow is derived from the addition of .59 for the green component of the yellow plus .30 for the red component. Cyan, a mixture of green and blue, has a brightness value of .59 plus .11. The brightness value for magenta is similarly formed by addition of .30 from the red and .11 from the blue.

A similar procedure is followed in the formation of the I and Q waveforms. In the I signal, for example, red is .6 as indicated by equation (2). Yellow is a combination color and it is formed by adding .6 for its red component with −.28 for its green component. The result of this addition (.6−.28) is .32. Similarly, for the Q signal, the value for yellow is obtained by adding .21 for its red component and −.52 for its green component as indicated by equation (3). The result of this addition (.21−.52) is −.31. The remaining color values for both I and Q signals are obtained in the same manner.

The final video signal, formed by the combination of Y, I, and Q is shown in Fig. 3H. Again, the modulation envelope is formed by adding the square root of the sum of the squares of the I and Q values of each color to its Y value. For red, for example, we would add $\sqrt{.36+.044}$ or .63 to .3 to obtain a positive excursion of .93. For the negative excursion, subtract .63 from .3. Similarly for the other colors. It is this signal which would be seen at the output of the video second detector in the television receiver.

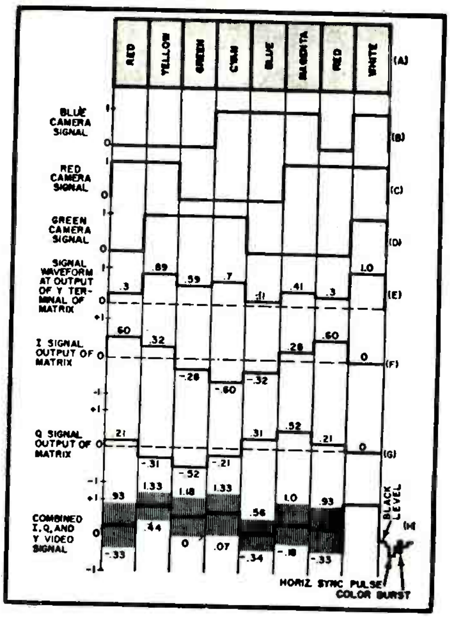


Fig. 3. Formation of a color video signal from a more complicated color-bar test pattern than was used in Fig. 1.

The presence of combination colors means that when these colors are being presented on the receiver picture tube screen, more than one electron gun is in operation. For example, to present a yellow bar, both the green and red must be activated by the signal. For cyan, the green and blue guns are required and for magenta, red and blue dots must be struck. There are, of course, many, many other combinations of colors and for a large number all three electron guns are operating to some extent. Appreciation of these facts concerning video signals and how they are formed will materially aid the technician in his work on color television receivers.

Part 7. The color sync section—its job is to make certain that the correct colors are reproduced.

THE SERVICE technician is by now fully acquainted with the function of the sync circuits in a black-and-white receiver. Briefly stated, they serve to maintain the picture in synchronism with the scene being transmitted by the station. In a color receiver similar circuits are employed for the same purpose. In addition, color receivers must be told what colors to produce at each point in the picture and for this purpose a special color sync signal is sent. This sync signal takes the form of a burst which is placed on the back porch of each horizontal sync pulse and consists of at least 8 cycles of the missing 3.58 mc. color subcarrier.

In the receiver this special color sync burst is separated from the rest of the signal and routed to a color sync section. (Here, again, the similarity to the sync pulses is apparent.) The purpose of the color sync section in a color television receiver is to insure that the color subcarrier which is recombined with the received color signal possesses the correct frequency and the proper phase. Both are important if we are to re-obtain the desired color voltages at the output of the I and Q demodulators.

It may be well to recall at this point that each color is represented by a different angular position of the resultant I and Q vectors. See Fig. 1. For example, green is 61° behind the reference burst (in a counterclockwise direction); red is 77° ahead of the burst, etc. To produce a given color requires that the I and Q vectors combine with each other to produce a resultant whose position occupies the angular position of that color. There is nothing fundamentally rigid about these different color positions. Actually, all they represent is a system in which various colors are represented by certain angular positions with respect to a given reference. In the present instance, the phase of the color burst is the reference and the correct reproduction of the color scene at the receiver hinges on the fact that the phase of the color burst is fixed by the FCC and that the color subcarrier which is re-inserted in the color signal has its phase established by the color burst.

Should something occur at the transmitter which causes the color burst phase to vary, without a corresponding change in the angular positions of the various colors, then the set viewer will be treated to the spectacle of seeing the various colors in the picture change. By the same token, any instability in the color sync circuits of a receiver will also lead to the development of the wrong colors. In fact, it has been found that a change of only ± 5 degrees in the phase of the color subcarrier will produce a noticeable change in the color picture. From this it is evident that the tolerances in the color sync section are among the most stringent in the entire color receiver. It is safe to predict that many of the service technician's headaches will originate right here.

There are several approaches to the development of 3.58-mc. signals possessing the proper phase and frequency. One method, illustrated in Figs. 2 and 4, employs an automatic phase control (a.p.c.) system in conjunction with a crystal oscillator. The input to the color sync section is at the burst amplifier. This stage is normally cut off (by a high positive voltage on the cathode) except when the color burst is passing through the receiver. At these instants, a negative pulse of about 37 volts is obtained from a winding on the horizontal output transformer and applied to the cathode of the color burst amplifier. The pulse counteracts the positive cathode voltage and permits the tube to conduct, amplifying and then transferring the color burst to the following phase detector.

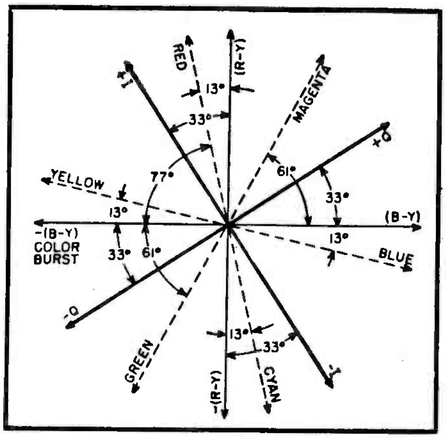
The transformer in the plate circuit of the burst amplifier has a high-impedance primary and a bifilar secondary tightly coupled to the primary. The burst signal voltage is on the order of 60 volts peak-to-peak on either side of the secondary center tap.

In the phase detector, two triodes are employed to compare the frequency and phase of the received color burst with the frequency and phase of a locally-generated c.w. signal. The latter voltage is brought into the phase circuit *via* a color phasing amplifier and possesses an amplitude of 25 to 35 volts peak-to-peak. If any phase difference exists between the two signals, a correction voltage is developed at point "A" and fed to the grid of a reactance tube. Here it alters the effect of the reactance circuit on the 3.58-mc. crystal oscillator and thereby causes the frequency of the oscillator to change.

For a clearer analysis, the phase detector circuit is shown by itself in Fig. 3. The incoming burst appears across the full secondary of the phase discriminator transformer and since the center-tap of this winding is effectively at ground potential (*via* C_1 which has negligible impedance at 3.58-mc.), the signal polarity at one end is 180° out-of-phase with the signal polarity at the other end. We can represent this relationship as shown in Fig. 5A. E_{K1}, the burst voltage applied to the cathode of one phase detector section is 180° out-of-phase with E_{G2}, the voltage which the grid of the other phase detector section receives.

At the same time, the cathode of V_2 and the grid of V_1 receive a portion of the generated 3.58-mc. voltage from the color phasing amplifier. This voltage, labeled E_0, can be represented as shown in Fig. 5B. The resultants of E_0 and E_{K1} and E_0 with E_{G2} are also indicated in Fig. 5B and it can be seen that they are equal. That is, E_A is equal to E_B. This represents the condition when the generated 3.58-mc. oscillations possess the proper frequency and phase with respect to the incoming color burst. There is no output voltage across C_1 and none to the reactance tube.

Fig. 1. Color phase diagram showing the positions of the various key colors and the I and Q vectors. The position of the color burst is shown.



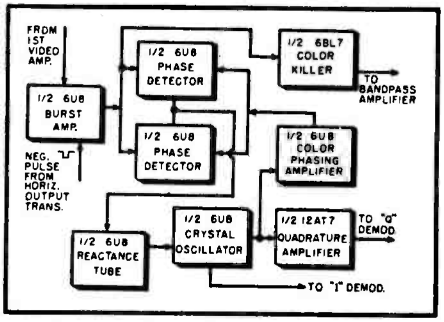


Fig. 2. Block diagram of a color sync section of a color television set.

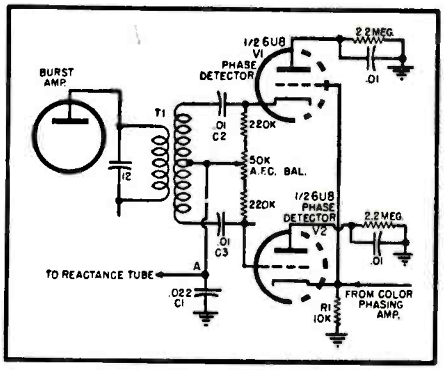


Fig. 3. Phase detector circuit of the color sync section of the set of Fig. 4.

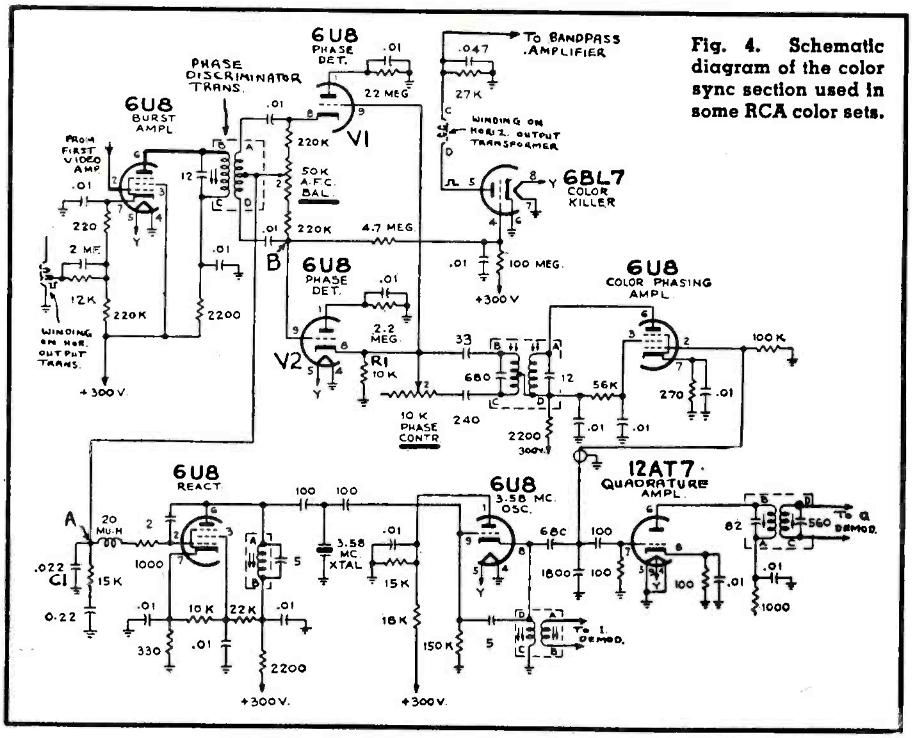


Fig. 4. Schematic diagram of the color sync section used in some RCA color sets.

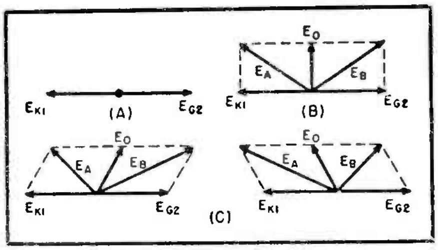


Fig. 5. Various voltage vector relationships in the phase detector circuit. (A) The incoming burst voltage applied to V_1 and V_2. (B) The combination of the burst voltage and color phasing voltage. (C) When the phasing voltage, E_o, lags (left) its normal phase, or when it leads it (right), the voltages across the phase detector tubes in Fig. 3 are unequal.

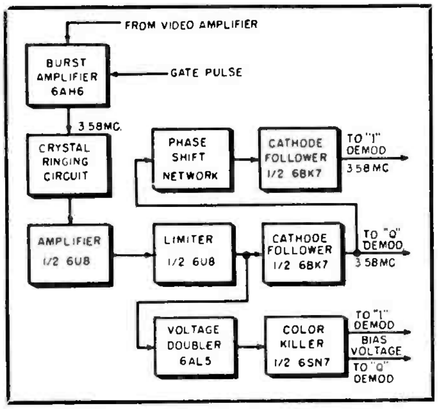


Fig. 6. Block diagram of a color sync section using a crystal ringing circuit.

On the other hand, when the frequency of the generated 3.58-mc. voltage speeds up or slows down, one section of the phase detector conducts more heavily than the other and the reactance tube receives a correcting negative or positive voltage from the phase detector. Fig. 5C shows the positions of E_o for these two latter conditions. Notice in each instance that E_A and E_B are no longer equal in length; in one case E_A is greater than E_B and in the other case it is shorter than E_B.

The correcting voltage for the reactance tube appears across condenser C_1 and is applied to grid 1 of the reactance tube (point "A"), as explained previously.

The plates of V_1 and V_2 do not enter into the operation of the phase detector circuit. They merely serve as tube shields. In some later phase detector circuits 6AL5 double diodes are used, the plates of the diodes functioning as the grids do in the circuit of Fig. 4. Another possibility is to use triode tubes connected as diodes, with the plate tied directly to the grid.

A color phase control in the output circuit of the color phasing amplifier permits manual adjustment of the phase of the local oscillator voltage applied to the phase detector. The range here is 150 degrees. This control is generally made available at the front panel (exposed or hidden behind a plate) to enable the set viewer to compensate for any color changes (*i.e.*, shifts) in the color sync circuits. It is also possible for the phase of the color burst signal to be altered by passage through the receiver and manual adjustment is necessary for proper color rendition. In viewing a picture, the color phase control is adjusted to achieve the most pleasing flesh tones or color of some familiar object.

One other control in the phase detector circuit is the a.f.c. balance potentiometer. This enables the technician to bring both sections of the phase detector into balance should this adjustment be required.

The crystal oscillator also produces the 3.58-mc. color subcarrier signal voltage needed by the *I* and *Q* demodulators. The *I* demodulator receives its voltage directly from the cathode of the oscillator tube. The 3.58-mc. signal for the *Q* demodulator is fed first to a quadrature amplifier where the 90° phase shift is introduced. Then it is transferred to grid No. 3 of the *Q* demodulator. Both 3.58-mc. signals are on the order of 25 to 30 volts peak-to-peak amplitude at the demodulators.

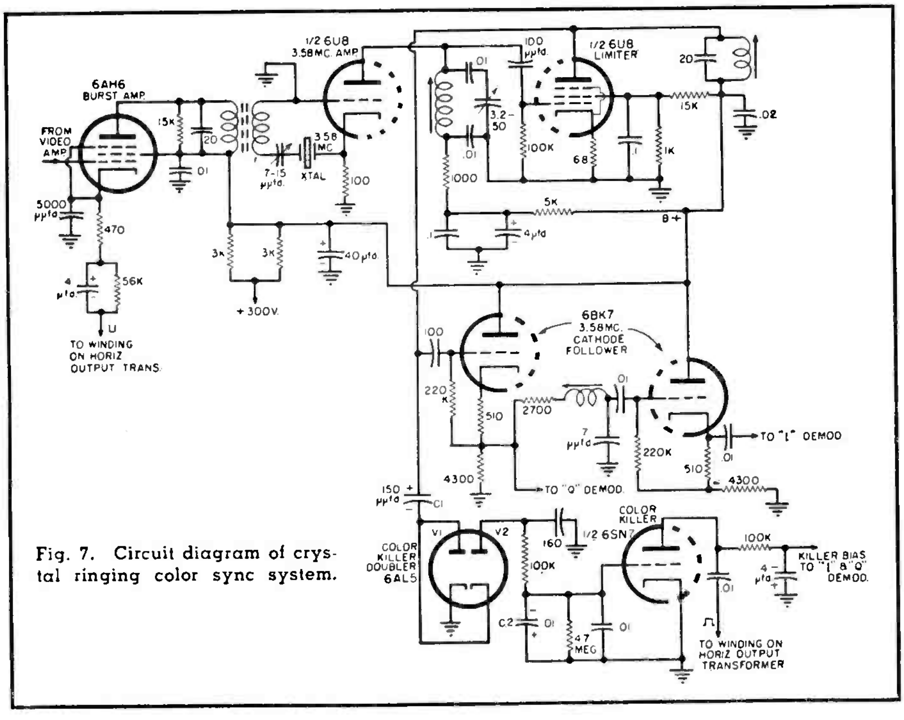


Fig. 7. Circuit diagram of crystal ringing color sync system.

The final item in the color sync section is the color killer stage. The grid of this tube ties into the phase detector at a point ("B" in Fig. 4) where a negative voltage is developed when a color burst (and, hence, a color signal) is being received. The negative voltage is strong enough to bias the color killer tube to cut-off, even when its plate receives a positive pulse from the horizontal output transformer. With no current through the tube, no voltage is developed across the plate load resistor of this tube and no bias voltage is produced for the grid of the bandpass amplifier. This enables the bandpass amplifier to conduct, which is the desired condition when color signals are being received.

Consider, now, what happens when no color signal and hence no color burst is present. The voltage at point "B" becomes slightly positive and the killer tube conducts each time its plate is pulsed positively. The flow of current through the killer tube establishes enough negative voltage across its plate load resistor to bias the bandpass amplifier to cut-off. This prevents extraneous information from reaching the color circuits and producing a random colored background.

A second type of color sync section is shown in Figs. 6 and 7. This is seen, both from its block diagram and actual circuitry, to differ in several important respects from the a.p.c. system. The most important difference lies in the use of a crystal ringing circuit as the generator of the 3.58-mc. color subcarrier signal. This circuit takes the place of the previous crystal oscillator and the phase detector network and is seen to represent a saving in parts and tubes. Its method of operation is as follows.

A quartz crystal is used which, when excited by the color burst at the start of each horizontal line, will continue to "ring" or oscillate at its natural frequency (here 3.58 mc.) for the duration of the line. A color burst from the burst amplifier activates the quartz crystal and because of its extremely high "*Q*" (hence, low loss) it continues to oscillate with very little decrease in amplitude until the next burst arrives. The trimmer condenser in series with the crystal can change its resonant frequency by several hundred cycles and thus take care of normal crystal tolerances.

The stage following the crystal is an amplifier and the stage beyond that is generally a limiter to smooth out variations in the output of the ringing circuit. Output from the limiter may be used as one of the 3.58-mc. driving voltages for the *I* or *Q* demodulators while the same output, passed through a 90° phase shifting network will provide the driving voltage for the other demodulator.

The crystal ringing method is fairly simple and when properly designed will operate satisfactorily. It does not contain any particularly critical components and so will remain stable once it has been adjusted.

A color killer network may be readily tied in with the ringing system. One approach to this is shown in Fig. 7. A portion of the oscillations developed by the crystal ringing circuit is fed to a double-diode rectifier. The circuit is a voltage-doubler and operates as follows. During the positive half of the applied wave, tube V_1 conducts and effectively charges condenser C_1 to the peak value of the wave with a polarity as indicated in Fig. 7. On the negative half cycle, the applied voltage combines with the voltage present across C_1 to yield approximately twice the peak value of the 3.58-mc. wave itself. Since the voltage is now negative, V_2 conducts and charges C_2 to approximately the same value. The voltage across C_2 is negative with respect to ground and is high enough to bias the color killer tube to cut-off. This prevents the flow of current through this tube when the plate is triggered by positive pulses obtained from the horizontal output transformer. As a result, no voltage is developed in the output circuit of the killer tube and so none can be forwarded to the grids of the *I* and *Q* demodulators. This permits the demodulators to accept color signals which is the desired action under these conditions.

Consider now what happens when no color signal is present. At these times there are no color bursts to excite the ringing crystal and so no 3.58-mc. oscillations are generated. That means that the color killer tube receives no negative voltage from the preceding bias rectifier and therefore the killer tube is able to conduct freely whenever its plate is triggered positively. This conduction leads to the development of a fairly large negative voltage in the plate circuit of the killer tube and this voltage is forwarded to the grids of the *I* and *Q* demodulators, keeping these latter stages in a cut-off condition.

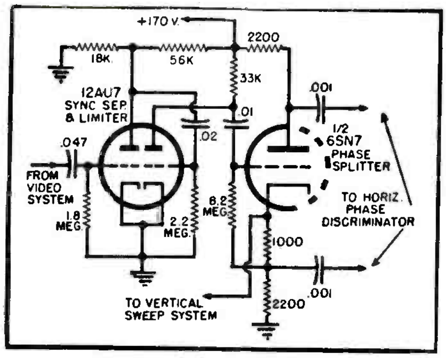


Fig. 8. Sync separator section of a color TV set. Note similarity to the circuits used for this function in monochrome sets.

Sync Separators and A.G.C.

The sync separator and a.g.c. sections of a color television receiver do not differ either in form or purpose from the same stages of a black-and-white receiver. As proof of this, the sync separator stages of a color television receiver are shown in Fig. 8. The input signal is obtained from the video detector or some point immediately thereafter and fed to the sync separator stages where as much of the video signal as possible is removed. In Fig. 8, the separated pulses then go to a phase splitter or inverter where positive pulses are made available to a vertical blocking oscillator. At the same time, both positive and negative pulses are made available to the phase detector in the horizontal sweep system. Appropriate filters are inserted between the pulse take-off points and their respective sweep systems to remove the undesired pulses and permit only the desired pulses to get through.

The a.g.c. stage used in nearly all color television receivers is of the keyed or triggered variety, that is, positive pulses reach the plate of the tube at the same instant that positive horizontal sync pulses in the video signal arrive at the control grid of the a.g.c. tube. The tube current that flows when these two pulses are active establishes the negative bias voltage that is fed back to the control grids of several video i.f. stages and the grid of the r.f. amplifier.

Many of the a.g.c. systems now employed in monochrome sets may be used in color sets with similar results. The introduction of the color signal has not basically altered the need for or purpose of automatic gain control.

The deflection systems of most present-day color TV receivers, like the a.g.c. systems, strongly resemble their monochrome counterparts. These, together with the high-voltage and convergence circuits, will be discussed next month.

Part 8. The deflection and high-voltage systems of typical color TV sets using the tri-gun tube.

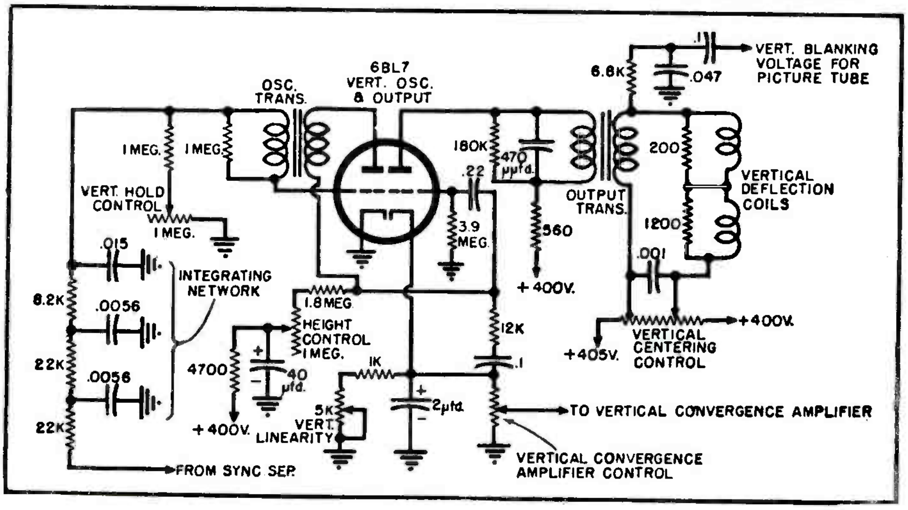
THE deflection system of a tri-gun color television receiver possesses a marked similarity to the deflection system of a monochrome receiver. This is best illustrated by an examination of the deflection system of a color television receiver.

In the vertical section, Fig. 1, there is an integrating network, a blocking oscillator, and an output amplifier. Application of the deflection voltage is made in the normal manner (*i.e., via* transformer) to the two windings of the deflection yoke. The only significant change from monochrome practice is the addition of a vertical convergence amplifier control which evidently supplies some voltage to a special amplifier. More on this presently.

In the horizontal system, Fig. 2, there is a 6SN7 synchroguide horizontal oscillator and control tube, followed by a 6CD6 power output amplifier. The power requirements of the horizontal output stage in a color receiver are greater than for a comparable monochrome receiver because, first, three beams must be deflected instead of one, and second, a 20.000 volt accelerating voltage is required by the tri-gun color picture tube. In addition, there is also a special focus rectifier in the high-voltage system and it, too, must be supplied with power.

The horizontal output transformer contains one main winding and several

Fig. 1. The vertical sweep system of an RCA color set for a 15-inch tube. Aside from the voltage made available for a vertical convergence amplifier, the circuit is identical to the vertical stages found in many black-and-white television receivers.



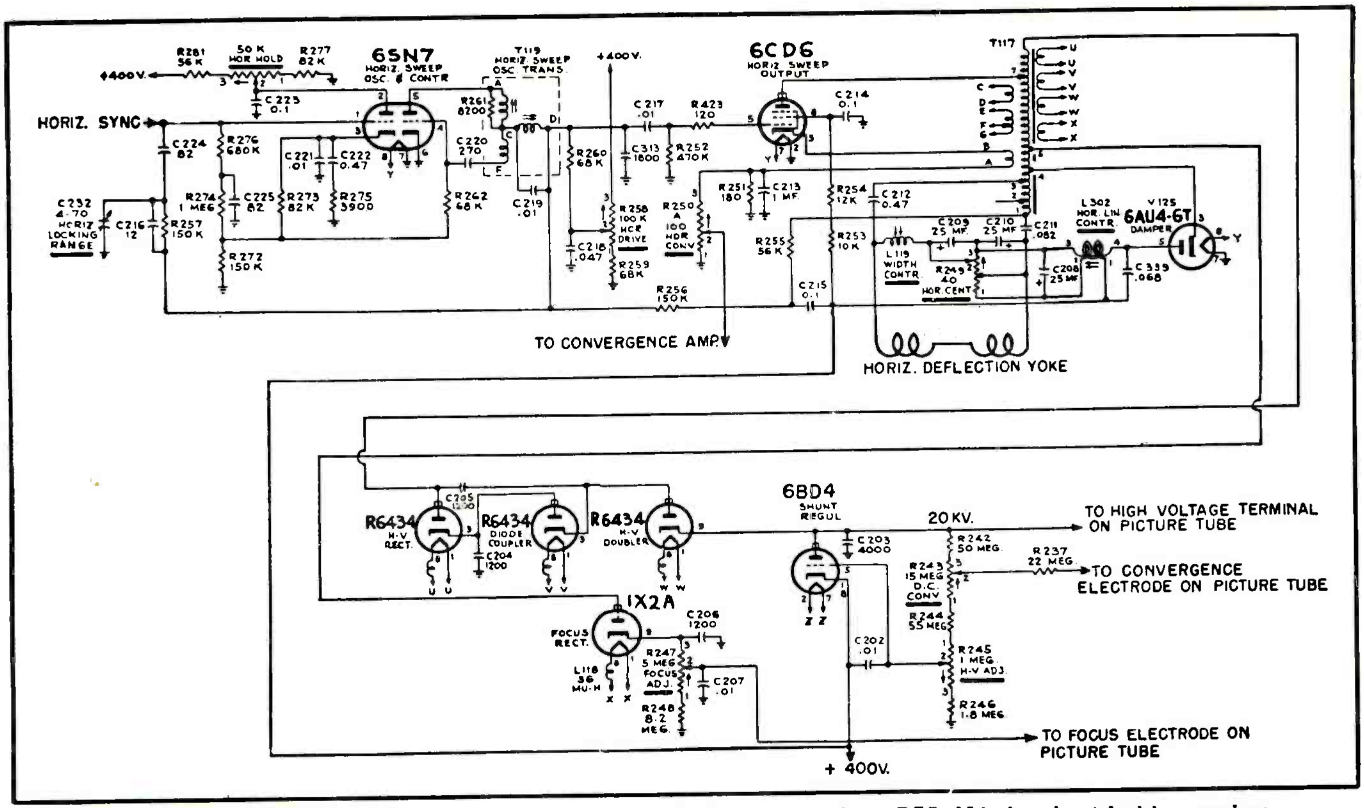


Fig. 2. Schematic diagram of the complete horizontal deflection system of an RCA 15-inch color television receiver.

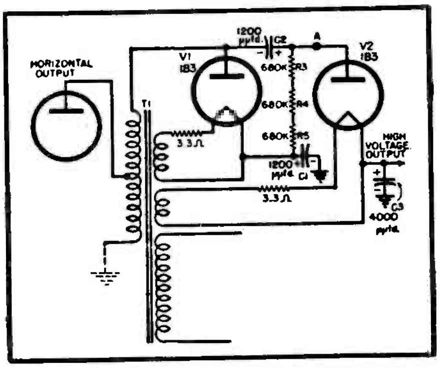


Fig. 3. A voltage-doubler circuit of the type used in monochrome sets for high voltage. The bottom of the primary of T_1 appears grounded to the 15,750-cycle horizontal retrace pulses.

auxiliary windings. The principal winding provides connections for the plate of the 6CD6, the high-voltage rectifiers, the deflection yoke, and the 6AU4 damper tube. The auxiliary windings provide positive and negative triggering pulses for the various a.g.c. and chrominance circuits, and heater power for the high-voltage rectifiers.

In the circuit of Fig. 2, three high-voltage rectifiers are employed to develop the 20,000 volt accelerating potential required by the tri-gun picture tube. The circuit is apparently unlike any we have ever seen in monochrome receivers although the labeling on each tube does provide some clue as to its function. The first tube is labeled as the high-voltage rectifier, the second tube is called a diode coupler, and the final tube is the high-voltage doubler.

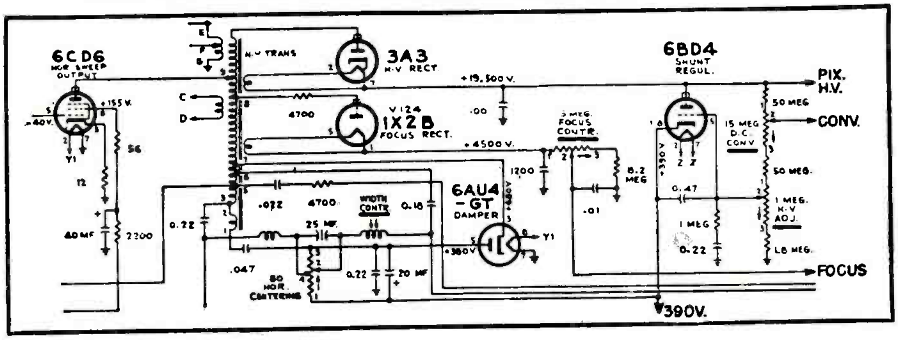
To understand how this section operates, let us examine a high-voltage doubler that was used for a time in monochrome sets. The circuit is shown in Fig. 3. In brief, it operates as follows: During the retrace interval, the voltage developed across the full primary-secondary winding of the output transformer rises sharply to, say 11,000 volts. This causes V_1 to conduct, and C_1 charges to 11,000 volts (after the first few cycles) with the polarity as indicated. In the longer interval between retraces, C_1 and C_2 are seen to be essentially in parallel with each other through the primary-secondary winding of T_1 and R_3, R_4, and R_5. Hence, C_2 also charges up to the full 11,000 volts.

At the next retrace interval, 11,000 volts once again appears across the transformer. If we pause at this moment and add up the voltages existing between point "A" and ground, we see that the transformer voltage and the voltage across C_2 are equal to 22,000 volts. This potential is applied to V_2, causing this tube to conduct, and C_3 charges to 22,000 volts with the polarity indicated. Losses in the circuit plus the current drain on the power supply by the picture tube usually reduce the output voltage to some value less than twice the peak applied pulse, say 20,000 volts.

It can be seen from the preceding discussion that the purpose of the resistive network of R_3, R_4, and R_5 is to help transfer the charge from C_1 to C_2 and thereby assist in the voltage doubling action. The same job can be accomplished more efficiently (*i.e.*, with less high-voltage power loss) by substituting a diode for the resistive network. When this is done, the circuit of Fig. 3 becomes equivalent to that of Fig. 2.

Within the same high-voltage supply of Fig. 2 is a special triode (6BD4) labeled a shunt regulator. The purpose of this tube is to maintain a constant load on the high voltage power supply so that changes in picture contrast will not cause the high voltage to change.

Fig. 4. Color TV high-voltage supply using a type 3A3 rectifier, especially developed for the high-voltage circuits of color receivers. Contrast this RCA circuit with the more complex arrangement shown in the circuit of Fig. 2.



with corresponding variations in brightness, focus, and deflection (*i.e.*, picture size). What the regulator tube does, in essence, is vary its internal resistance in a manner opposite to the current drawn by the picture tube. For example, when a bright element is being traced out on the screen, picture-tube current is high and the drain on the high-voltage power supply is increased. During this interval the drain of the regulator tube is reduced by a proportionate amount.

Conversely, when a darker portion of the picture is being traced out, the current requirements of the picture tube are reduced. This reduction would tend to cause the high voltage to rise were it not for the fact that now the regulator tube increases its current drain, thereby maintaining a constant over-all load on the power supply. And this, in turn, keeps the high voltage constant.

The shunt regulator accomplishes its purpose in a relatively simple manner. The tube is shunted across practically all of the high voltage bleeder. The plate of the tube goes to the top of the bleeder network while the cathode is returned to a positive potential point, in this instance about 400 volts. The grid is then tapped into the bleeder network at a point which will provide it with the necessary bias voltage with respect to the cathode.

The circuit is now ready to function. If the high voltage rises, due perhaps to less current drain by the picture tube, then this increase, in part, will be transmitted to the grid of the regulator triode because of the grid tap on the high-voltage bleeder string. A more positive grid means increased tube current flow and if the circuit has been properly designed, this increased current will just take up the slack shed by the picture tube and bring the high voltage down to its correct level. On the other hand, when the picture tube draws more current, the high voltage has a tendency to drop. This lowers the voltage across the bleeder, providing less positive voltage for the shunt regulator and thereby driving its grid more negative. This reduces the current drawn by the regulator and tends to counteract the increased picture tube current. Again, the high-voltage system sees a fairly constant load and its voltage value remains stable.

The focus rectifier, a 1X2A, is connected to a lower point on the output transformer winding than the high-voltage rectifier and, in consequence, develops a lower output voltage. The voltage ordinarily required by the focus electrode in the tri-gun picture tube is in the neighborhood of 2500 to 5000 volts. The need for a separate rectifier stems from the appreciable amount of current that the focus electrode draws.

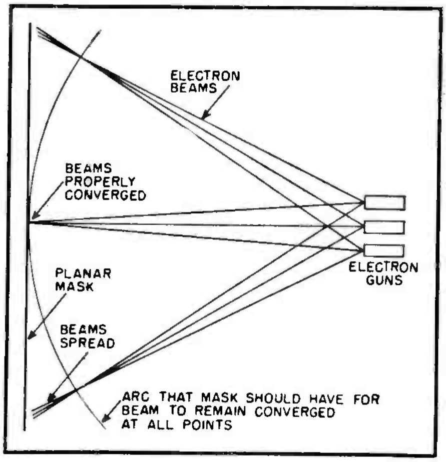


Fig. 5. Electron beams are not converged at edges of flat screen because it does not conform to the arc of focus points.

The convergence electrode of the picture tube must also have a high voltage, between 8500 and 10,500 volts, but since the current drawn by this element is practically nil, the voltage can be obtained directly from the 20,000 volt line by simply inserting a resistive divider network between the 20,000 volt line and chassis ground. This is the procedure followed in the circuit of Fig. 2.

The damper tube in the output circuit absorbs whatever excess energy is developed during the horizontal retrace interval and converts this into an equivalent amount of voltage which is then combined with the receiver "B+" to provide a boosted "B+" voltage. In the circuit of Fig. 2, this boosted "B+" is employed only by the plate of the 6CD6 horizontal output amplifier.

Electrical centering is usually employed with the tri-gun color picture tube. For this purpose there are vertical and horizontal centering potentiometers, each with enough d.c. potential difference across it to achieve the picture centering variation.

While many of the initial receivers employed three high-voltage rectifiers, subsequent models functioned satisfactorily with a single high-voltage tube. The circuit shown in Fig. 4 uses a newly-designed 3A3 high-voltage rectifier. 19,500 volts are developed directly and this value is maintained by a 6BD4 shunt regulator. Aside from this change, the rest of the circuit is similar to that of Fig. 2.

Also used to some extent instead of the 6BD4 is a 6353 gaseous regulator. The unit is shaped in the form of a long, narrow cylinder which is filled with hydrogen gas. Operation of this rectifier is similar to VR tubes where the current drain is dependent on the applied voltage. As the voltage attempts to rise, the current drain increases and this keeps the voltage from rising. The 6353 may be considered as a passive regulator in that the applied voltage must exceed a certain level before the unit will begin to function. Electronic regulators, such as the 6BD4, are capable of providing more effective control. Their cost, however, is higher now.

Convergence Amplifiers

The one remaining section of a color television receiver still to be examined is the convergence amplifiers. It was probably noted in some of the previous diagrams that there were voltage take-off points in the output stages with the notation, "to convergence amplifier." A typical circuit to which these voltages are fed is shown in Fig. 6, but before we undertake an examination of how these stages operate, it may not be amiss to review briefly what they do and why they are needed.

The scanning surface of the fluorescent screen in the picture tube is either flat or slightly curved. The same is true of the shadow mask which is positioned slightly in front of the phosphor dot screen. Now, in order to obtain an image which possesses the correct colors and is properly focused, two independent actions must occur. First, to have each of the three electron beams strike only one color, it is necessary that the beams pass through the same hole on the shadow mask at the same time and strike individual phosphor dots.

When the beams are in the center of the screen, we can cause them to converge properly by adjustment of the d.c. voltage which is applied to

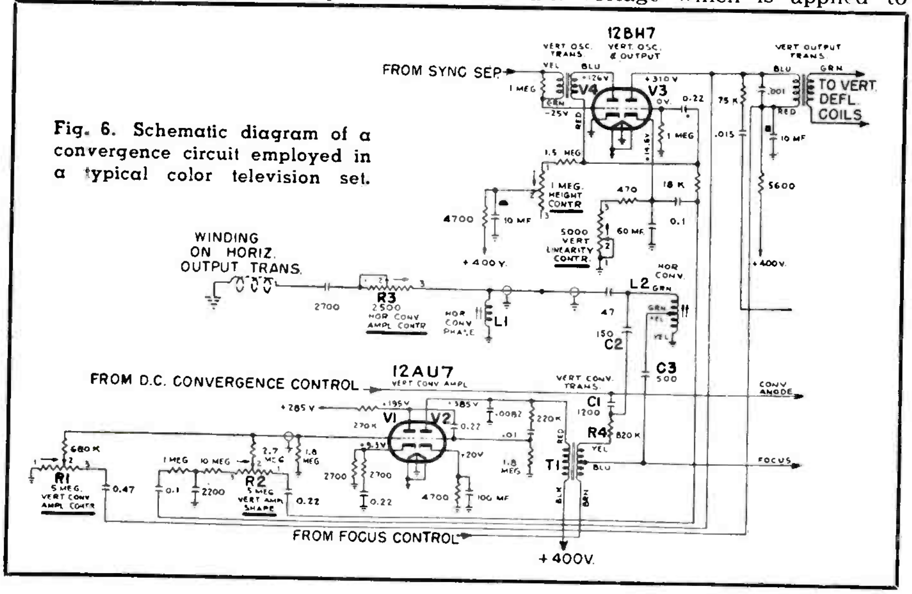


Fig. 6. Schematic diagram of a convergence circuit employed in a typical color television set.

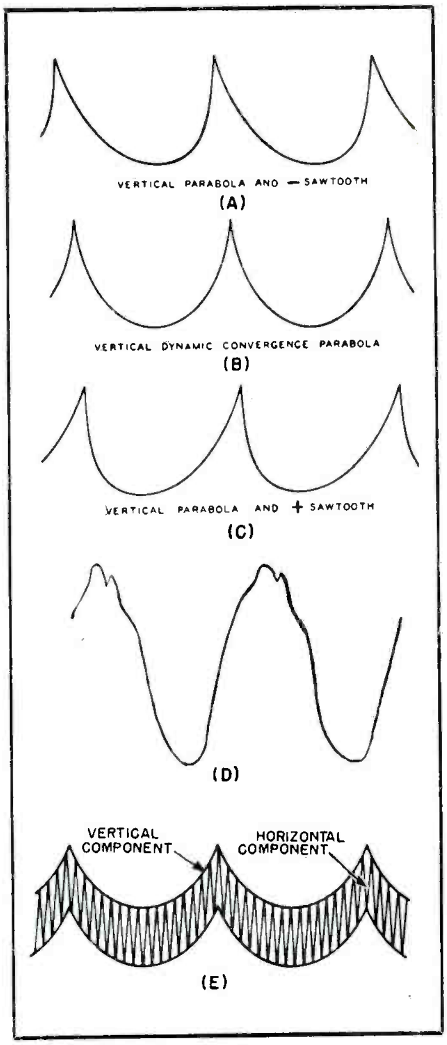


Fig. 7. (A), (B), and (C) show the vertical dynamic convergence waveforms employed in the circuit of Fig. 6. (D) is the convergence waveform in the horizontal circuit, and (E), the resultant parabolic waveform which is combined with the d.c. focus and convergence voltages.

the convergence electrode in the picture tube. This adjustment, however, is effective only in the center of the screen. As the beams move away from the center, they tend to converge at points in front of the mask because the distance from the flare of the tube to the center of the screen (or mask) is less than the distance from the flare to the ends of the screen or mask surfaces. See Fig. 5.

A similar situation exists for beam focus (at the phosphor dot screen). That is, a beam properly focused at the center of the screen will move progressively out of focus the farther it swings from the center.

To correct both of the foregoing conditions, we need a special parabolic voltage (shown in Fig. 7B) which, when added in series with the d.c. focus and convergence voltages, causes them to change (*i.e.*, increase) as the beam moves away from the center of the tube. It is the purpose of the convergence amplifiers to provide such a correcting voltage.

A 12AU7 dual-triode amplifier in Fig. 6 functions as the vertical convergence amplifier. The input to the first triode, V_1, is obtained from the vertical output amplifier. One line, from the vertical amplifier V_3 plate, develops a parabolic wave across R_1. This is the "Vertical Convergence Amplitude Control" and it controls the amplitude of the parabolic wave reaching V_1. The variation extends from 0 to 200 volts peak-to-peak.

A second control in the input circuit of V_1 is the shape control, R_2. This varies the tilt of the parabolic wave by introducing either a positive or a negative saw-tooth voltage. The latter is obtained from either the plate or cathode of the vertical output amplifier, depending upon the position of the center arm of the shaping control. (R_2 has one end connected to the plate of V_3 and the other end to the grid. The signal shift between these two circuits is 180° and by altering the position of the movable arm of R_2, we can add positive or negative saw-tooth voltage to the parabola appearing across R_1. At some intermediate point on R_2, zero saw-tooth voltage is applied to V_1.)

The voltage reaching the grid of V_1 is amplified, first by V_1 and then by V_2. After that it is transferred to T_1 where it combines with the horizontal convergence voltage. The latter signal is developed by tapping off a negative pulse from a winding on the horizontal output transformer and feeding this pulse to two series-tuned resonant circuits, L_1 and L_2. The waveform present across L_2 is shown in Fig. 7D. It is essentially a sine wave but with enough parabolic curvature to adequately perform its function. R_3 controls the amplitude of the horizontal convergence waveform. The movable slug in L_1 controls the phase of the waveform at minimum setting of R_3 while the slug in L_2 controls the waveform phase at maximum setting of R_3.

The horizontal and vertical convergence circuits combine their output voltages *via* C_2, C_3, and R_1, producing the resultant waveform shown in Fig. 7E. This voltage is then appropriately combined with the d.c. focus and convergence voltages and applied to the corresponding electrodes in the tri-gun picture tube.

In monochrome receivers, the picture tube has a single brightness control which is used to vary the background or over-all screen illumination. All other d.c. potentials on the tube are fixed at certain specified values. In the tri-gun color picture tube, we are dealing with three separate electron guns and three separate phosphors. Not all the phosphors possess the same efficiency; red, for example, has the lowest efficiency and hence requires the highest beam current. Failure to provide for this will give the screen a bluish-green tinge. In consequence, the screen and control grid voltages for each of the three electron guns are individually adjustable. See Fig. 8.

The controls in the cathode leg of the picture tube determine control-grid bias. The higher the arms move up on the controls, the more negative the control grids become. The green and blue guns possess the same bias as the red gun only when their potentiometer arms are at the bottom of the controls (maximum counterclockwise position). For all other settings of these two controls, the blue and green guns have a more negative grid, hence less gun current.

A sample procedure indicating how these six controls are adjusted is as follows. (The control-grid potentiometers are frequently called the background controls.)

1. Set the three screen-grid controls to maximum.
2. Set the background controls to produce a grey picture at low brightness.

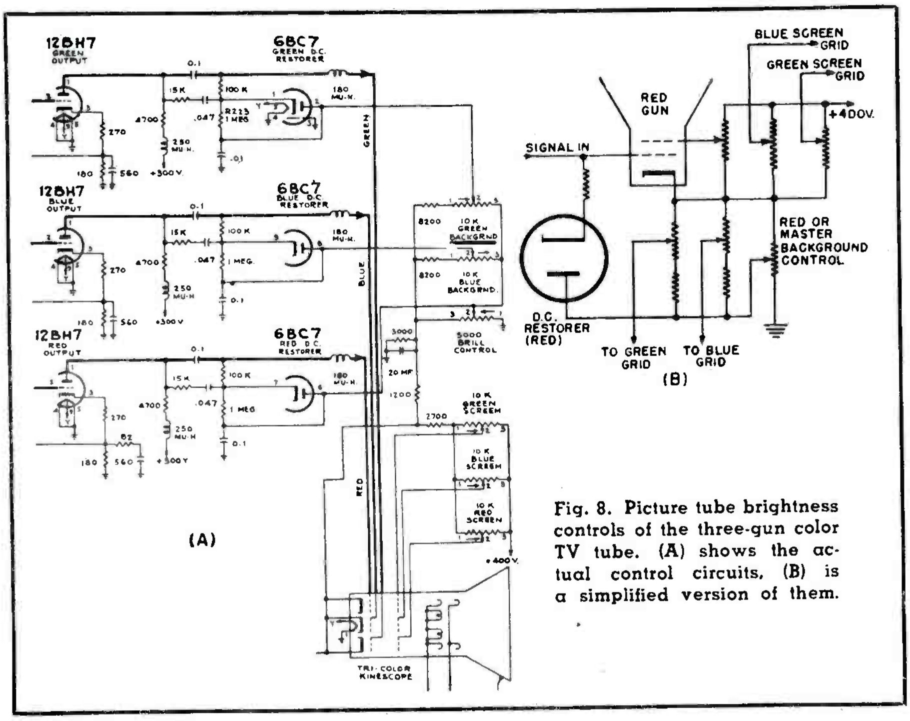


Fig. 8. Picture tube brightness controls of the three-gun color TV tube. (A) shows the actual control circuits, (B) is a simplified version of them.

3. Turn up the brightness control. (Note that this is the red background control. It is the only one of the group that extends to the front panel.)

4. As the brightness is increased, note which color becomes dominant and the screen-grid voltage on the gun associated with this color.

5. Reduce the brightness and reset the background controls.

6. Repeat steps 3, 4, and 5 until no color tinting can be observed over the normal range of brightness levels.

The proper setting of the background and screen-grid controls to produce a black-and-white picture is also the proper setting for color reception.

Part 9. Concluding article analyzes a color TV receiver which uses R-Y, B-Y demodulation rather than I and Q.

THE color television receivers which have been produced to date can be divided into two categories: those which utilize the full color signal to develop a picture on the screen and those which use only part of the color information. We have, in previous articles, discussed receivers in the first category. In the present article we will turn our attention to receivers in the second category.

By way of review, we have seen that a complete color signal consists of the following:

1. A monochrome signal with components that extend from 0 to 4 mc. This is the *Y* signal.
2. A color subcarrier whose frequency is set at 3.58 mc. (actually it is 3.579545 mc.).
3. This color subcarrier is modulated by two color signals called the *I* and *Q* signals.
4. The *Q* signal has color frequencies that extend from 0 to 500 kc. or .5 mc. This means that the upper *Q* sideband extends from 3.58 mc. up to 3.58 + .5 or 4.08 mc. The lower *Q* sideband goes from 3.58 mc. down to 3.58 −0.5 or 3.08 mc.
5. The *I* signal has color frequencies that extend from 0 to 1.5 mc. When this modulates the color subcarrier, upper and lower sidebands are formed. The lower sideband extends from 3.58 mc. down to 3.58 −1.5 or 2.08 mc. If the full upper sideband were permitted to exist, it would extend all the way up to 3.58 + 1.5 or 5.08 mc. Obviously this would prevent the use of a 6 mc. over-all band for the television signal (video and sound). To avoid this spilling over beyond the limits of the already established channels, the upper sideband of the *I* signal is limited to about .6 of a megacycle. This brings the upper sideband of the *I* signal to 4.2 mc.

The need for two color signals of unequal bandwidth stems from the color characteristics of the human eye. Three primaries are required only for relatively large colored areas or objects. On a television screen, these are the objects produced by video frequencies from 0 to .5 mc. For medium-sized objects (those produced by video signals from .5 to 1.5 mc.), the eye is sensitive only to bluish-green or reddish-orange. The NTSC signal, *via* its *I* component, is fashioned to take advantage of this characteristic.

We know that when we present all the color of which the NTSC signal is capable, a very pleasing picture is obtained. Just how much less color the eye can take in a picture and still be satisfied is as yet unknown. However, some color receiver manufacturers have designed (and produced) color sets in which the bandpass of the color signal is limited to about .5 or .6 mc.

Here is the basis for this action. A color picture signal can be represented by the following equation:

$$E_T = E_Y + E_Q \sin (\omega t + 33°) + E_I \cos (\omega t + 33°) \quad . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

The E_Y term, of course, represents the monochrome portion of the signal. The E_Q and E_I represent the color voltages. Since E_Q is multiplied by $\sin (\omega t + 33°)$ and E_I is multiplied by $\cos (\omega t + 33°)$, the E_Q and E_I signals are 90° out-of-phase with each other. (Sine and cosine functions are 90° out-of-phase with each other.) This, of course, is well-known by now.

If we now limit the color video frequencies to a maximum of .5 mc., it can be shown that equation (1) becomes:

$$E_T = E_Y + .492 (E_B\text{-}E_Y) \sin \omega t + .877 (E_R\text{-}E_Y) \cos \omega t \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

E_Y remains unaltered since nothing has been done to affect it. However, in place of E_Q we now have E_B-E_Y and in place of E_I we have E_R-E_Y. Also, we note that E_B-E_Y is multiplied by $\sin \omega t$ instead of $\sin (\omega t + 33°)$. Therefore, E_B-E_Y is shifted 33° from the E_Q position on the color phase chart. See Fig. 2. The same situation is true of E_I and its replacement E_R-E_Y. Thus, if you take an incoming color signal containing E_I and E_Q voltages and shift the phase of the re-inserted carrier by 33°, you obtain (at the output of the demodulators) E_R-E_Y and E_B-E_Y signals.

This, then, is the basis of color receivers which have their color bandpass restricted to .5 mc. All large detail in a picture produced by such a receiver would be colored in the same way and to the same extent as in an *I* and *Q* demodulator system. However, above .5 mc., all detail in the picture is in black and white (or monochrome) and so we can say that the over-all picture is less colored in an E_R E , E_B-E_Y system than it is in an *I* and *Q* set.

At this point, the reader might very well ask, "Why use the modified system if it provides less color in the picture?" The answer, supposedly, lies in certain economies which can be effected in the E_R-E_Y, E_B-E_Y method. Whether or not this is so—and there is considerable difference of opinion on this point—our primary interest is circuit design and this will now be examined.

The block diagram of an *R-Y, B-Y* color receiver is shown in Fig. 1. The r.f. and video i.f. sections are similar to those of other color receivers discussed in previous articles. The gain of the r.f. tuner and the i.f. stages is controlled by an a.g.c. voltage derived from a conventional a.g.c. keyer tube.

The video i.f. system feeds its signals to two separate detector circuits. One detector is designated as the *Y* detector and its output consists of the usual monochrome video and sync information. The *Y* detector output is applied to a cathode follower, which transfers the video signal to two *Y* amplifiers and beyond this to the color circuits for combination with the *R-Y* and *B-Y* voltages. A 1 microsecond time delay network between the first and second *Y* amplifiers slows down the monochrome signal so that it is in step when it recombines with the color components in the matrix. (The latter, as we shall see, is considerably less complex in these receivers than in *I* and *Q* sets.)

The *Y* detector also provides the signal for the receiver's sync system. The second of the two detectors is the chrominance (chroma) detector and it delivers two output signals. One signal is the conventional 4.5 mc. intercarrier sound i.f. signal which is then passed, in turn, to a 4.5 mc. amplifier, a limiter, a ratio detector, and two audio amplifiers in the usual manner. The other signal is the color signal and it is applied to a chroma amplifier. See Fig. 3. At the output of this amplifier, the signal is applied to two separate sections of the color system. Part of the signal goes to a burst gate amplifier. The other portion is transferred to a chroma cathode follower and from here to grid 3 of the 6BE6 *R-Y* and *B-Y* detectors. A chroma control in the cathode leg of the cathode follower stage is mechanically ganged to the contrast po-

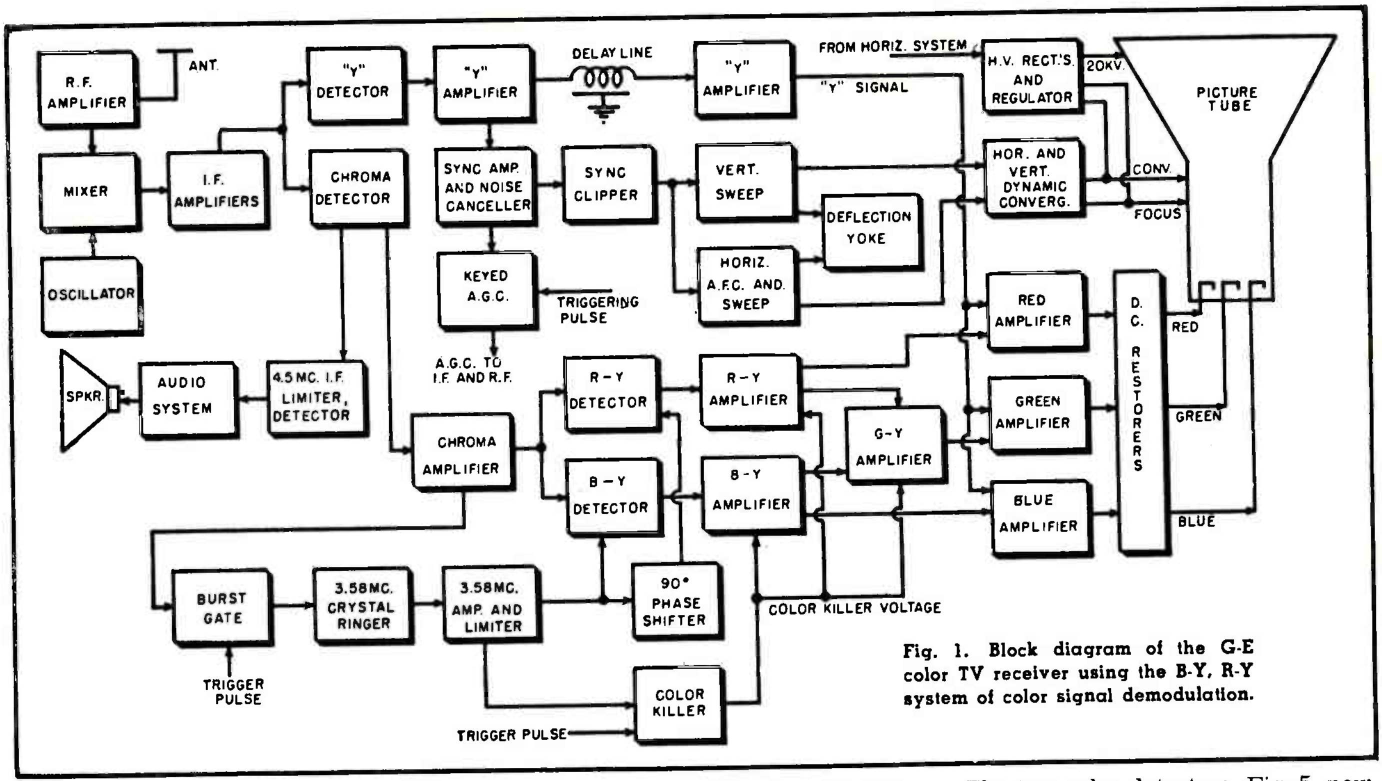


Fig. 1. Block diagram of the G-E color TV receiver using the B-Y, R-Y system of color signal demodulation.

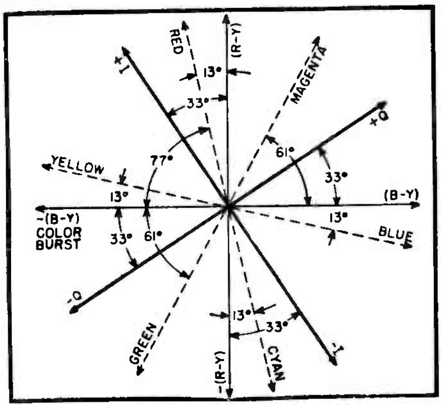


Fig. 2. Color phase diagram showing the position of the B-Y and R-Y vectors relative to the I and Q vectors.

tentiometer in the Y cathode follower circuit so that both the Y and color signals will be similarly affected when the controls are rotated.

The burst gate tube is normally biased to cut-off. However, during the horizontal retrace interval, it is driven into conduction by a pulse obtained from a winding on the horizontal output transformer. The tube conduction period lasts just long enough to pass the color burst. After this, the pulse disappears and the burst gate amplifier lapses back into cut-off.

The color burst which the burst gate amplifier passes is used to shock-excite a crystal ringing circuit. The oscillations are amplified, then limited, and finally transferred to the $R-Y$, $B-Y$ detectors. A 90° phase-shifting network in the plate circuit of the limiter provides the two demodulators with 3.58-mc. signals that are 90° apart. A prior hue control, in the output circuit of the amplifier, permits the set owner to make a limited correcting adjustment in the phase of the generated 3.58-mc. oscillations. The control is set to natural flesh tones.

The two color detectors, Fig. 5, now have all of the ingredients needed to recreate the demodulated color video signals. The output circuits of both 6BE6's are almost identical because both color systems now have the same bandpass, 0 to .5 mc. (In practice, the bandpass frequently extends a little more than this, perhaps to .6 or .7 mc.) This arrangement obviates the need for any special delay lines in the color circuits; the only delay line in the receiver is that found in the Y section.

The $R-Y$ and $B-Y$ detectors are each followed, in turn, by an amplifier and then the signals are divided between two separate signal paths. First, portions of the output voltages from both amplifiers are fed to a simple resistive adder (R_1, R_2, and R_3) to form a negative $G-Y$ signal. This is possible because, as shown in Part 2 of this series,

$$-(G-Y) = .51\ (R-Y) + .19\ (B-Y)$$

The specific proportions are developed by the adder network and fed to a $G-Y$ amplifier. Here the signal is inverted, giving us the needed $G-Y$. Now we have all three color-minus-brightness signals ($R-Y$, $B-Y$, and $G-Y$) and by simply adding $+Y$ to each, we obtain the original red, blue, and green video signals. The addition of

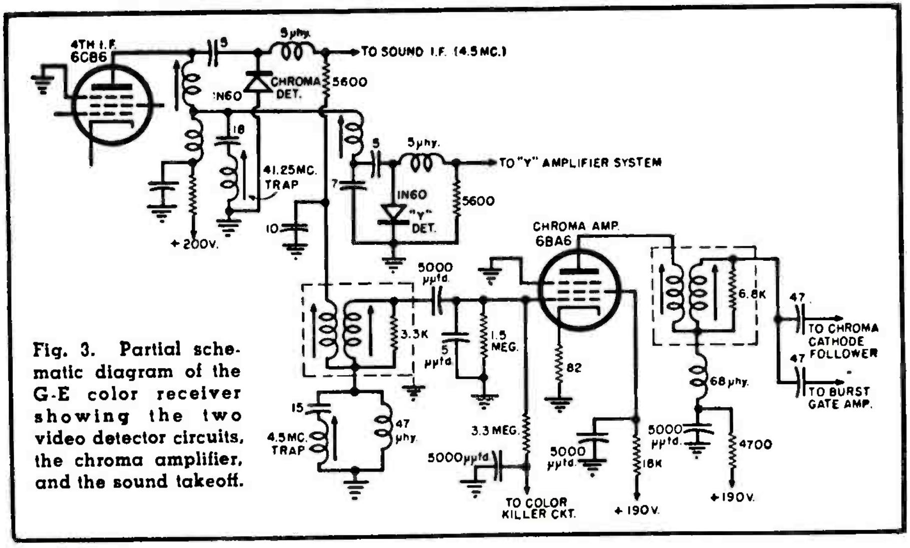
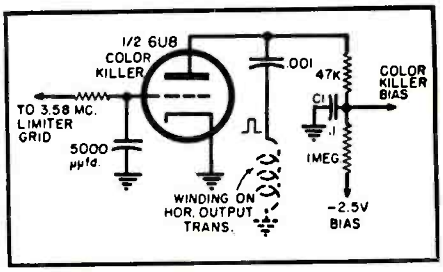


Fig. 3. Partial schematic diagram of the G-E color receiver showing the two video detector circuits, the chroma amplifier, and the sound takeoff.

Fig. 4. Color killer circuit of the G-E set.



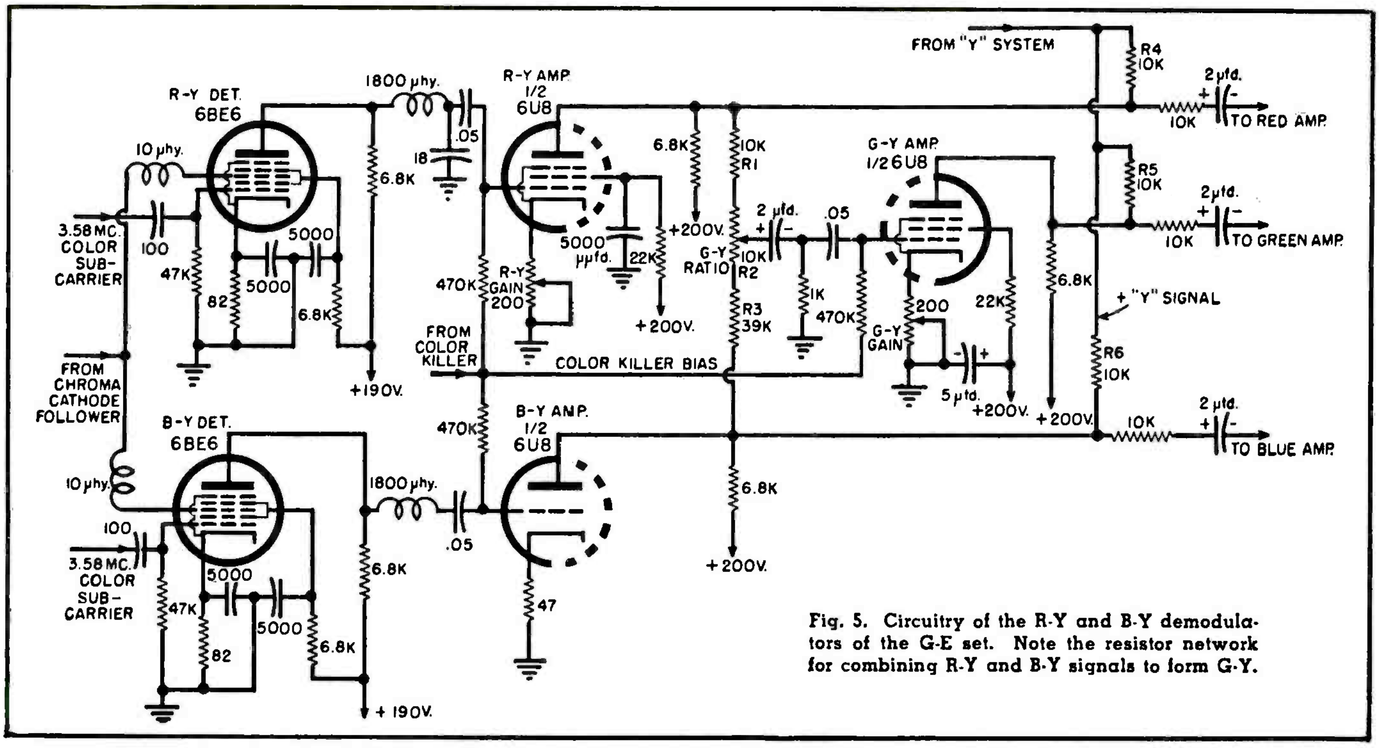


Fig. 5. Circuitry of the R-Y and B-Y demodulators of the G-E set. Note the resistor network for combining R-Y and B-Y signals to form G-Y.

+*Y* takes place *via* R_4, R_5, and R_6 (Fig. 5).

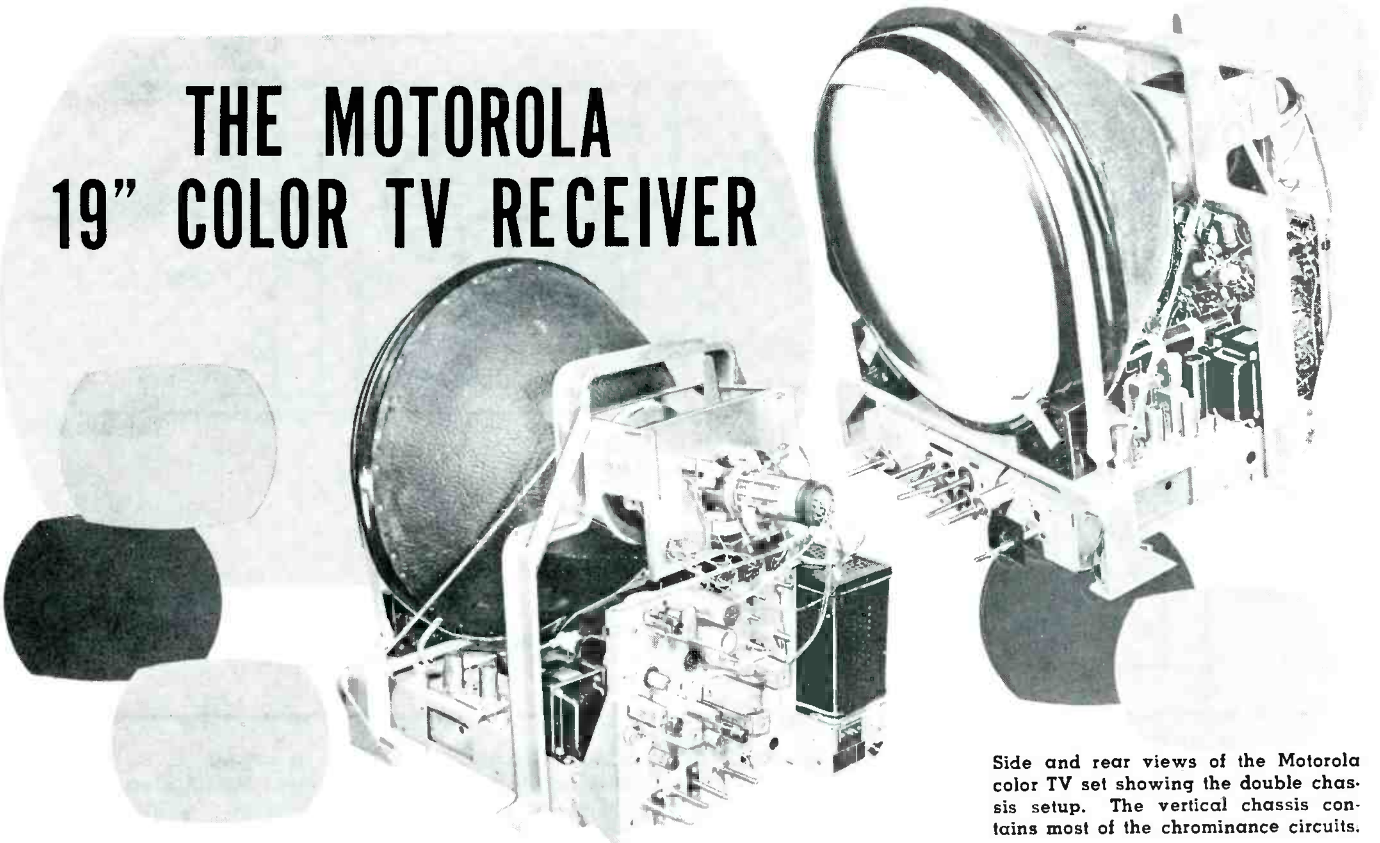
The output section of the chrominance portion of the receiver consists of separate channels for the red, green, and blue color signals. Each branch has two amplifiers and a d.c. restorer. The amplifiers use degenerative feedback to reduce their input impedance and to enable the proper mixing action to occur between the color-minus-brightness signals and the *Y* signal.

A color killer circuit is also employed in this system to prevent the appearance of any spurious color signals when a black-and-white program is being viewed. The grid of the killer triode, Fig. 4, is connected to the grid of the 3.58-mc. limiter tube. When no color signal is being received, the 3.58-mc. crystal is quiescent and the grid-leak bias on the limiter tube is zero Under these conditions the color killer tube conducts whenever its plate receives a positive pulse from the horizontal output transformer. The resulting current flow develops a negative charge across C_1 and this, added to the —2.5 volts normally present across the condenser, is sufficient to bias all *R-Y, B-Y*, and *G-Y* amplifiers to cut-off.

When a color signal is received, the 3.58-mc. generated oscillations develop enough negative grid-leak bias on the limiter grid to cut off the color killer tube. This prevents the tube from conducting, even when pulsed, and the only negative voltage appearing across C_1 is the —2.5 volts from the receiver power supply. This voltage is not sufficient to prevent the color-minus-brightness amplifiers from operating.

The remaining circuits of an *R-Y, B-Y* receiver are similar to those in *I, Q* receivers. -30-

THE MOTOROLA 19" COLOR TV RECEIVER



Side and rear views of the Motorola color TV set showing the double chassis setup. The vertical chassis contains most of the chrominance circuits.

By **M. S. KAY**

Part 1. First complete analysis for service technicians of the first 19-inch color TV receiver widely available.

ONE of the first color television receivers to appear on the market using the 19" *CBS* color tube was the *Motorola* TS902A-03. This chassis used 29 circuit tubes, a 19VP22 19-inch tricolor picture tube, three germanium diodes, and three selenium rectifiers. Power consumption of the total receiver was a very moderate 375 watts.

The tremendous progress which commercial color television had made in less than one year after its official adoption is best revealed by the fact that relatively so few tubes are required to present a full color picture. When it is recalled that the first color receiver, the *RCA* CT-100, had 36 tubes, 3 germanium diodes, and 2 selenium rectifiers (plus a 15GP22 color tube) only 9 months before, we realize that a 20 per-cent reduction in so short a time is a remarkable feat.

A block diagram of the *Motorola* receiver is shown in Fig. 1. Of the r.f. and video i.f. stages, little need be added to what has already been said in prior articles appearing in this book. Actually, this *Motorola* set uses the same circuits here that they ordinarily use in their black-and-white receivers with some minor modifications to encompass the wider composite color signal. Also, sound take-off is accomplished at the plate of the 3rd video i.f. rather than beyond the second detector. This enables the circuit designers to impose additional attenuation on the sound carrier prior to the video detector in order to minimize the appearance of the 920 kc. signal obtained when the sound and color subcarrier signals beat with each other.

Of particular interest here are the circuits which are found beyond the video detector. The schematic diagram of Fig. 2 reveals two video amplifiers which resemble monochrome video amplifiers except for the lack of special peaking coils in the output of the first video stage. However, it will be noted that the principal load resistor for V_{6A} is only 820 ohms (R_{92}), a value low enough to maintain the amplifier response up to 4 mc. In the output of the 2nd video amplifier there is compensation and hence higher value load resistors are permissible.

Both the color and monochrome components of the composite signal remain together through both video amplifiers. Separation then takes place at the plate of the 2nd video amplifier. The brightness component is led off to a separate brightness output amplifier (V_{29}, a 12BY7) *via* R_{98} and L_{16}, a .6-microsecond delay line. (The reduction in delay time from the usual 1 microsecond to .6 microsecond will be discussed presently). At the same time, the chrominance portion of the signal appears across R_{97A} and R_{98}, and is applied to a 12BY7 bandpass amplifier, V_8. Just how much chrominance signal reaches V_8 is governed by the setting of R_{97A}. This potentiometer, the contrast control, acts in conjunction with R_{97B} in the cathode leg of the brightness output amplifier. Both are mechanically ganged, permitting the simultaneous adjustment of the chrominance and monochrome signal levels. A separate control is available at a subsequent point in the color system to permit independent adjustment of the color intensity of the picture.

Brightness Signal. The brightness or monochrome signal is amplified by V_{29} and then passed through a 3.58-mc. filter before being applied to all three cathodes of the picture tube. The 3.58-mc. trap serves to attenuate any color sidebands that may be present at this point. The trap also tends to limit the bandpass of this circuit to a value somewhere between 3 and 3.2 mc. Hence, in spite of the fact that monochrome signals up to 4.2 mc. are initially sent from the station, only those frequencies up to 3.2 mc. are actually effective in developing the picture.

The monochrome signal at the picture tube cathode has negative polarity, a condition that is required for the proper combination of the brightness and chrominance components of the color signal. Actually, the matrixing of the two portions of the color signal occurs within the picture tube itself rather than in a separate resistive network.

Bandpass Amplifier. The color signal, once it leaves the 2nd video amplifier, travels to V_8. A potentiometer in the cathode leg of this tube varies the gain of this stage and since only the color portion of the signal is thus affected, the control is labeled on the diagram as the chroma control. For the consumer, this knob is labeled "color intensity," this being considered more descriptive of its action. Maximum gain occurs when the knob is fully clockwise so that the 10,000-ohm resistor is completely out of the circuit.

The color burst signal also passes through the bandpass amplifier. To insure that sufficient burst voltage is available at all settings of the chroma control, a special positive pulse is fed into the grid circuit of V_8, the bandpass amplifier. This pulse is obtained from the horizontal output transformer and is so timed that it arrives at the same instant as the color burst. The pulse decreases the bias on the tube, causing it to furnish more plate current during this interval. In this way, a color burst signal is obtained which, at every setting of the chroma control, is strong enough to adequately drive the color a.f.c. network.

A 1N60 germanium diode is connected between the chroma control and the grid circuit to maintain the amplitude of the burst signal at its most efficient level. Here is how it does this. The cathode end of the 1N60 is connected to the top end of the chroma control and hence is subject to whatever positive potential exists at this point. Let us say this is + 5 volts. The other end of the 1N60 connects to R_{102}, a 10,000-ohm resistor in the grid circuit of V_8. This same resistor develops the positive boosting pulse. If the pulse raises the voltage across R_{102} above + 5 volts, the 1N60 conducts and serves to maintain the voltage across R_{102} at the same level as the voltage across the chroma control. When the chroma control is completely in the circuit, V_8 grid bias is greater and more positive boost voltage is received for the arriving color burst. On the other hand, when the chroma control is completely out of the circuit, V_8 is operating at full gain. At this point no intensifying pulse is needed and none actually reaches it because the 1N60 tends to maintain the voltage across R_{102} at zero volts.

Burst Amplifier. The output of the bandpass amplifier is applied to two points: a bandpass cathode follower and a burst amplifier. Considering the latter first, the signal is brought to the amplifier by way of L_{201}. L_{201} and C_{206} form a 3.58-mc. tuned step-up network in which the applied burst voltage is actually fed to the grid of V_{23A} in greater amplitude than it is applied. Adjustment of C_{206} will vary the phase of the burst which the burst amplifier receives. When the circuit is precisely tuned to 3.58 mc., the signal developed by the circuit will have the same phase as that of the incoming burst signal. If C_{206} is detuned, the signal developed by the resonant circuit will either lag or lead the incoming burst signal. Since the color a.f.c. stage receives the burst from this amplifier, it will shift the phase of the generated 3.58-mc. subcarrier to follow suit. This, in turn, will alter the colors produced on the screen. Because of this action, the shaft of C_{206} is extended to the front panel and labeled "color shading control." Its proper setting is determined by the set user according to the color of some familiar object.

The burst amplifier stage shown in Fig. 2 appears to have no "B+" screen voltage. Instead, the grid is connected to a special winding on the horizontal output transformer and from this point it receives periodic positive pulses. These pulses are timed to arrive with the color bursts and possess sufficient amplitude to drive the tube into conduction. R_{201}, R_{202}, and C_{201} serve as a phase shifting and shaping network to insure that only the color burst passes through the stage. The action of the network is illustrated in Fig. 3.

Color Sync Section

The entire color sync section, consisting of V_{24A}, V_{24B}, V_{28A}, V_{28B} and V_{22B} is sufficiently similar to the color sync sections discussed in previous articles reproduced in this book not to warrant any additional explanation here. Of interest, however, is the phase shifting network, T_{204}, which provides two 3.58-mc. signals to the color demodulators which are 90° out-of-phase with each other.

The network is shown by itself in Fig. 4A. The plate of the buffer connects to the top of L_{210} and it is from this point that the *R-Y* demodulator obtains its 3.58-mc. signal. On a vector diagram of this network, then, we can use the *R-Y* vector as our starting point. See Fig. 4B. Let us call the voltage across L_{210}, E_1. This same voltage also appears across the series combination of C_{212} and C_{213} and divides across them in inverse ratio to their capacitance. Of interest is the voltage across C_{213} and this is shown as E_2 in Fig. 4B. E_2 is also the voltage which is applied across the series combination of C_{211} and L_{209}. Since this combination is resonant to 3.58-mc., whatever current flows through C_{211} and L_{209} will be in phase with E_2. This current is labeled I_2 in Fig. 4B. The voltage drop produced across L_{209} by I_2 leads the current by 90°. This is E_3 and is the 3.58-mc. voltage which the *B-Y* demodulator receives.

Of interest to the service technician is the manner in which this circuit would be adjusted. A v.t.v.m. is connected to the cathode of V_{25A}, the *R-Y* demodulator by means of a chassis test point through a 100,000-ohm isolating resistor. The ground terminal of the meter goes to the receiver chassis. With the receiver in operation, a d.c. voltage will appear at the cathode of V_{25A} because the diode is detecting the applied 3.58-mc. oscillations. This voltage will be somewhere in the neighborhood of 25 volts. The slug in L_{210} is now adjusted until the v.t.v.m. reading is maximum.

The next step is to adjust L_{209} and a moment's reflection will reveal that since C_{211} and L_{209} form a series resonant circuit, they will impose maxi-

Fig. 1. Block diagram of the Motorola 19-inch color TV receiver. The pulse fed to the bandpass and burst amplifiers is obtained from the flyback transformer.

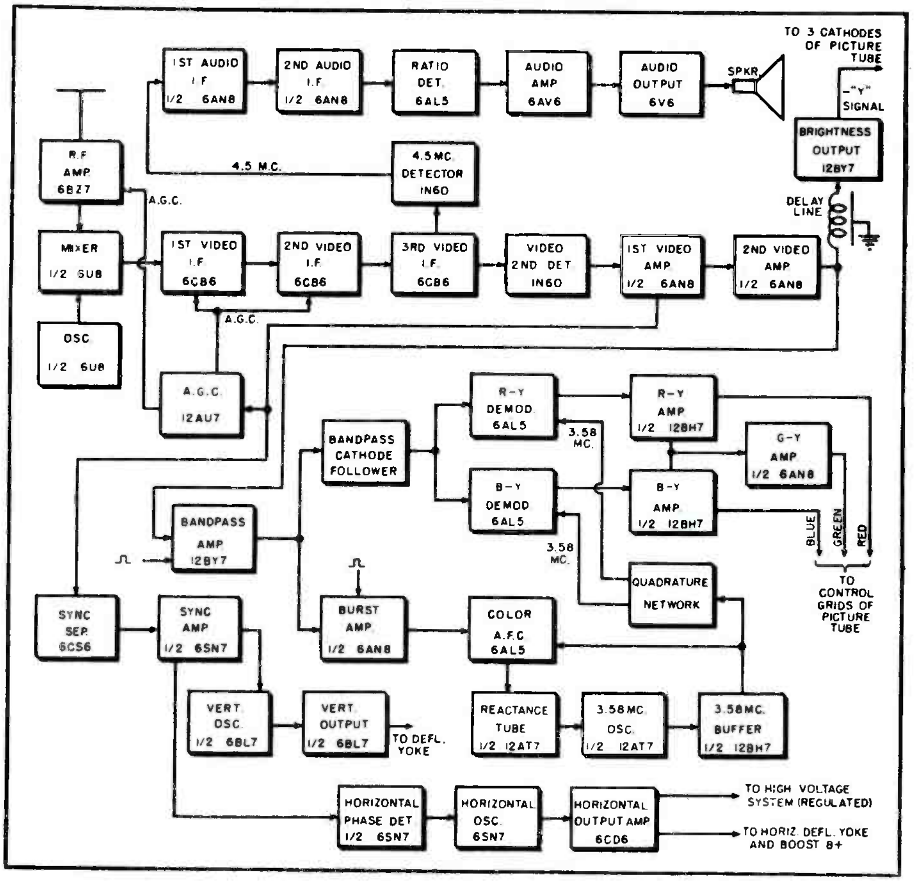
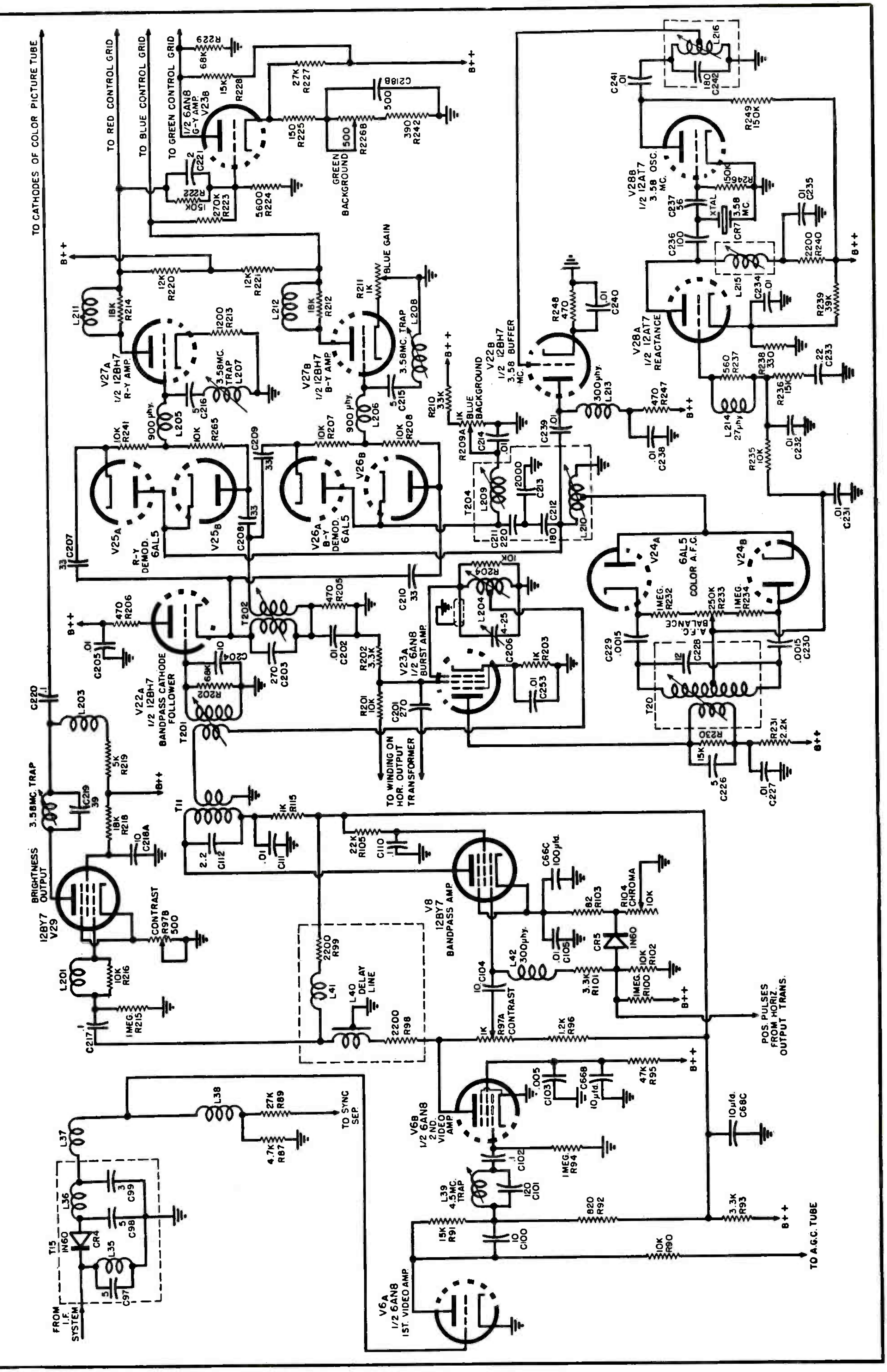


Fig. 2. Schematic diagram of the chrominance circuits of the Motorola receiver.



mum load across the rest of the quadrature network when they are tuned to 3.58-mc. Hence, the slug in L_{209} is rotated until the meter at the cathode of V_{25A} dips. To insure that the alignment is precise, the over-all procedure is repeated several times until no further adjustments are required.

Important, also, to the service technician is the manner in which the entire color oscillator a.f.c. system would be aligned. In black-and-white receivers the only a.f.c. system used is that found in the horizontal deflection section; in color sets we not only have the latter, but the a.f.c. network in the color sync section as well.

First, connect a v.t.v.m. to the cathode of V_{24A} (Fig. 2) using a 100,000-ohm isolation resistor. The meter should read approximately 12 volts of 3.58 mc. oscillator injection. (Short the control grid of V_{23A} to ground to eliminate spurious incoming signals.)

Next, remove the short circuit from the V_{23A} grid and tune in a color signal. Set the color shading control to midrange. Fully retract the slugs of the burst amplifier grid coil, L_{204}, and T_{20}, the coupling transformer to the a.f.c. circuit. Adjust both slugs for maximum v.t.v.m. readings. This insures that both diodes of the a.f.c. network are obtaining the maximum color burst amplitude.

Now, remove the burst signal by grounding L_{204}. Move the v.t.v.m. to the center arm of R_{238} and adjust this potentiometer to give a zero reading on the v.t.v.m.

Remove the short from L_{204} and adjust L_{215} in the plate circuit of the reactance tube to bring the 3.58 mc. oscillator in phase with the incoming burst. This condition is reached when the v.t.v.m. reads 0 volts, indicating that no connection voltage is being developed by the a.f.c. circuit.

Note how the diodes are used to demodulate the 3.58 mc. signal for the meter.

Color Demodulators

This receiver uses balanced diode demodulators which respond to phase differences in the incoming color signal in much the same manner as the diodes in the color sync section. As a matter of fact, both circuits are similar, as the following analysis will reveal. (The discussion will cover only the *R-Y* demodulator, since the *B-Y* demodulator is exactly similar to it).

The incoming color sidebands appear across transformer T_{202} and both *R-Y* diodes receive equal and oppositely-phased portions of this voltage. See Fig. 2. The connection of the two transformer windings is placed at a.c. ground potential by the presence of a .01-μfd. capacitor (C_{202}).

At the other end of this circuit, a 3.58-mc. subcarrier voltage is applied from the buffer stage, linked to the 3.58-mc. crystal oscillator. If we were to draw a vector diagram depicting the phase relationship in this circuit, it would appear as shown in Fig. 5A. BC, the voltage across the first winding of T_{202}, represents the color signal applied to V_{25A}, and BD, the voltage across the second winding of T_{202}, is the color signal for V_{25B}. At the same time, the 3.58-mc. subcarrier is present across L_{210} and it assumes the vector position BA.

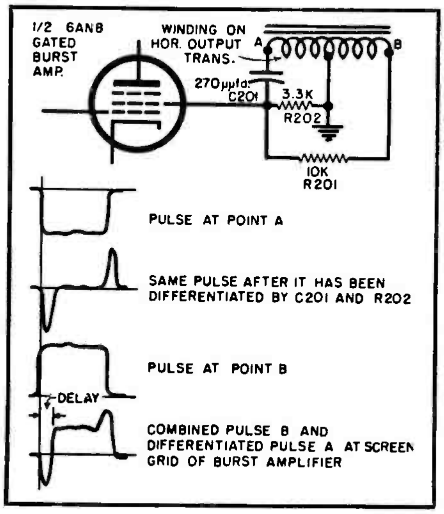
Tube V_{25A}, then, is subjected to voltages BC and BA, producing a combined voltage which, in Fig. 5A, is labeled "Resultant No. 1." V_{25B} and its circuit produces "Resultant No. 2." In the case shown in Fig. 5A, both resultant voltages are equal and since they develop equal and opposite voltages across their respective load resistors, R_{241} and R_{265}, the net output voltage from the circuit will be zero.

(If the current path through R_{241} and R_{265} appears somewhat obscure, remember that each 33-$\mu\mu$fd. capacitor (C_{207} and C_{208}) charges up whenever V_{25A} and V_{25B} conduct and then the capacitors discharge through the load resistors during each half cycle when the diodes do not conduct.)

Zero output is obtained when the incoming color sideband voltages are 90° out-of-phase (i.e., in quadrature) with the injected 3.58-mc. subcarrier voltage. In the *R-Y* demodulator this, of course, will happen when the *B-Y* color sidebands are applied to it. However, for *R-Y* signals, the phase relationship is other than 90° (or 270°) and output voltages are obtained. See the resultants in Figs. 5B and 5C. These represent the demodulated *R-Y* color voltages and their sum is transferred to the following *R-Y* amplifier through a 3.58-mc. trap.

The polarity of the signal voltages which are obtained from these demodulators depends upon two things: the phase of the applied subcarrier signal and the manner in which the incoming signal voltage is fed to the demodulator diodes. Concerning the subcarrier signal, this can be applied to its respective demodulator either possessing the proper phase or 180° from this position. When the latter condition holds, we obtain $-(R\text{-}Y)$ from the demodulator instead of *R-Y*. The same action is true of the *B-Y* demodulator.

Fig. 3. In order to key the burst gate amplifier on correctly to coincide with the arrival of the color burst, the keying pulse from the flyback transformer must be delayed. Shown below is the phase shift network used and how it performs.



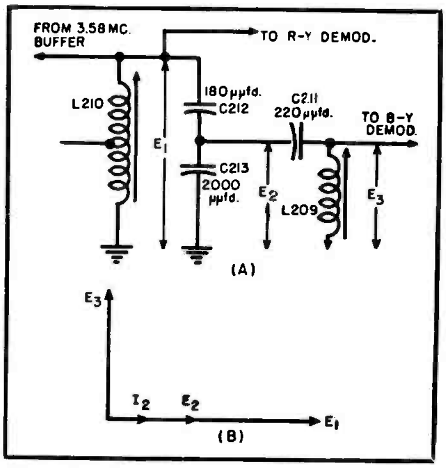


Fig. 4. (A) Simplified version of the quadrature network (T_{204} in Fig. 2) and (B), the phase relationships of the voltages in this network for demodulators.

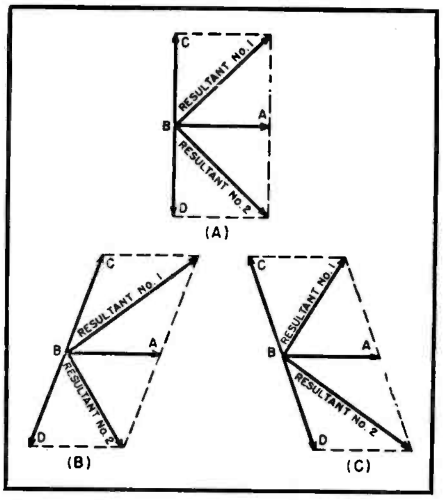


Fig. 5. Vector diagrams illustrating the operation of the diode color demodulators.

A reversal in signal output polarity will also be obtained if the connections to the diodes are reversed. Thus, if you examine the two demodulators in Fig. 2 you will note that the incoming signal connections to the *B-Y* demodulator are the reverse of the connections to the *R-Y* diodes.

In the present receiver, both sets of detectors produce negative output voltages, that is, $-(R\text{-}Y)$ and $-(B\text{-}Y)$. Reversal to the positive phase is achieved by separate *R-Y* and *B-Y* amplifiers after which these two signals are transferred to the control grids of the color picture tube.

For the proper rendition of colors on the screen, it is important that the two diodes comprising each demodulator be balanced as closely as possible. While the circuit is not critical and small circuit unbalances due to parts tolerances will not noticeably affect the color reproduction, still any appreciable unbalance will have a very marked effect.

Part 2. Sweep and convergence circuits of this first commercial large screen color TV set; also CRT circuits.

IN THE PREVIOUS article we covered the signal circuits of the *Motorola* color television receiver, from the antenna to the cathode and three control grids of the picture tube. In this article we will concentrate principally on the deflection and convergence circuits and on the color picture tube itself.

Deflection Systems

The deflection systems of a tri-gun color television receiver possess a marked similarity to the deflection systems of monochrome receivers. The same type of deflection waveforms are required at the deflection yoke and these are produced in more or less the same manner. Circuit variations that do exist stem primarily from the altered requirements of the high-voltage supply or because of the added precautions needed to maintain the three beams in close convergence over the entire area of the screen. Just what these differences are will become evident as we analyze, step-by-step, the deflection system of the *Motorola* color television receiver.

In the vertical section there is an integrating network, a blocking oscillator, and an output amplifier. The incoming sync pulses, both horizontal and vertical, are applied to the integrator network but, because of the time constant involved, only the vertical sync pulses develop a sizable voltage at the grid of the blocking oscillator. The latter, in turn, uses these periodic pulses to synchronize its frequency to that of the received broadcast. A vertical hold control helps bring the oscillator frequency to a point where effective lock-in can be achieved.

The amplitude of the deflection wave developed by the oscillator is governed by the vertical size (*i.e.*, height) control. The saw-tooth shape of this wave is established by a time-constant network in the output circuit of the vertical oscillator. This signal is then applied to the grid of the vertical output amplifier and, beyond this, to the vertical deflection coils of the yoke.

The only significant departure from monochrome practice is the fact that the bottom end of the vertical output transformer connects to a vertical convergence circuit. More on this presently.

In the horizontal sweep system there is an a.f.c. network, a stabilized horizontal multivibrator, and a power output amplifier. These are then followed by the horizontal output transformer, the high-voltage system, and the boost "B+" circuit, wherein additional "B+" voltage is developed by utilizing the excess deflection energy. (The latter portion of the circuit is shown in Fig. 1.)

The final stage in the horizontal deflection system is a 6CD6 power output amplifier. The power requirements of the final stage in a color receiver are greater than for a comparable monochrome receiver because, first, three beams must be deflected instead of one and, second, a 25 kv. accelerating voltage is required by the tri-gun picture tube.

The horizontal output transformer contains two principal windings and a number of auxiliary windings. The two principal windings provide connections for the plate of the 6CD6, the high-voltage rectifiers, the deflection yoke, and the 6AU4 damper tube. The auxiliary windings provide positive and negative triggering pulses for the various a.g.c. and chrominance circuits, and filament power for the high-voltage rectifiers. In the circuit of Fig. 1, three high-voltage rectifiers are employed to develop the 25 kv. accelerating potential required by the tri-gun picture tube.

The accelerating potential required by the focus electrode is much less than the 25,000 volts of the *Aquadag* coating. Hence, it is possible to obtain the focus voltage from a prior point in the high-voltage rectifier system. A variable resistor is inserted between the first 3A2 and the diode coupler that follows it, and from this resistor the needed focus voltage is obtained.

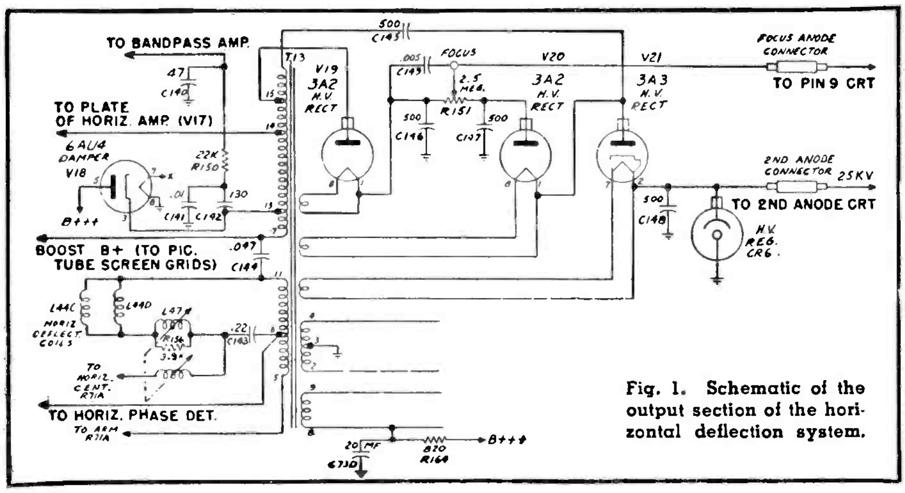


Fig. 1. Schematic of the output section of the horizontal deflection system.

Within the same high-voltage supply is a special gaseous regulator. The unit, labeled CR6, is a long, narrow cylinder which is filled with hydrogen gas. The purpose of this device is to maintain a constant load on the high voltage power supply so that changes in picture contrast will not cause the high voltage to change, with corresponding variations in brightness, focus, and deflection (*i.e.*, picture size). What the regulator tube does, in essence, is vary its internal resistance in a manner opposite to the current drawn by the picture tube. For example, when a bright element is being traced out on the screen, picture tube current is high and the drain on the high-voltage power supply is increased. During this interval the drain of the regulator tube is reduced by a proportionate amount.

Conversely, when a darker portion of the picture is being traced out, the current requirements of the picture tube are reduced. This reduction would tend to cause the high voltage to rise were it not for the fact that now the regulator tube increases its current drain, thereby maintaining a constant overall load on the power supply.

The damper tube in the output circuit absorbs whatever excess energy is developed during the horizontal retrace interval and converts this into an equivalent amount of voltage which is then combined with the receiver "B+" to provide a boosted "B+" voltage. In the circuit of Fig. 1 this boosted "B+" is employed only by the plate of the 6CD6 horizontal output amplifier and by the screen grids of the picture tube.

Electrical centering is usually employed with the tri-gun color picture tube. For this purpose there are vertical and horizontal centering potentiometers, each with enough d.c. potential difference across it to achieve the picture centering variation.

Convergence Circuits

The one remaining section of a color television receiver still to be examined is the convergence circuit. Convergence, it will be recalled, is the action which causes the three electron beams to pass through the same hole in the aperture or shadow mask at the same time. When the beams do this, they emerge from the mask at the correct angle to strike the dots of the proper color.

At the center of the screen, beam convergence is accomplished by physically tilting the electron guns inward as well as by external, individually adjustable, beam-bending magnets. The

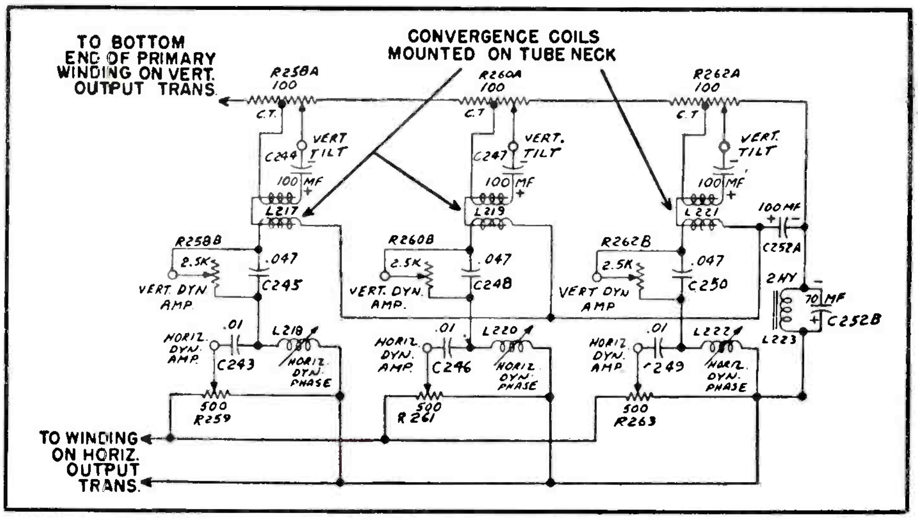


Fig. 2. Schematic diagram of the dynamic convergence circuit used by Motorola.

adjustment of beam convergence at the center of the screen is known as static convergence.

There is, in addition, dynamic convergence and this is concerned with maintaining the beams in proper convergence at points away from the center. The need for this arises from the fact that the shadow-mask surface is not completely spherical and therefore does not follow the curve necessary to keep the beams converged at all points. To correct this condition, we must introduce an additional voltage which will change the convergence point of the beams as they sweep over the face of the screen, both from side to side and up and down. At the center of the screen no additional convergence voltage is needed. The shape or form of the voltage best suited to achieve this variation is a parabolic wave.

The dynamic convergence system consists of three separate coils mounted on the neck of the picture tube. Each coil is positioned over a pair of pole pieces which is part of the structure of each electron gun. The internal pole pieces shape and confine the fields so as to affect only the particular electron beam to which the individual pole pieces correspond. Each beam will be moved at right angles to the magnetic field produced by the coils. Furthermore, since the guns are spaced at intervals of 120 degrees from each other, the red and green beams will be shifted at an angle while the blue beam will move straight up and down.

Each of the foregoing coils is supplied with vertical and horizontal parabolic currents and it is the amplitude and phase of these currents which govern the convergence of the three beams at every point on the screen. In the paragraphs to follow the dynamic convergence circuit of the *Motorola* will be examined. See Fig. 2.

Driving voltages for this circuit are obtained from two points—the plate circuit of the vertical output amplifier and from a separate winding on the horizontal output transformer. Let us start with the horizontal section of this circuit first.

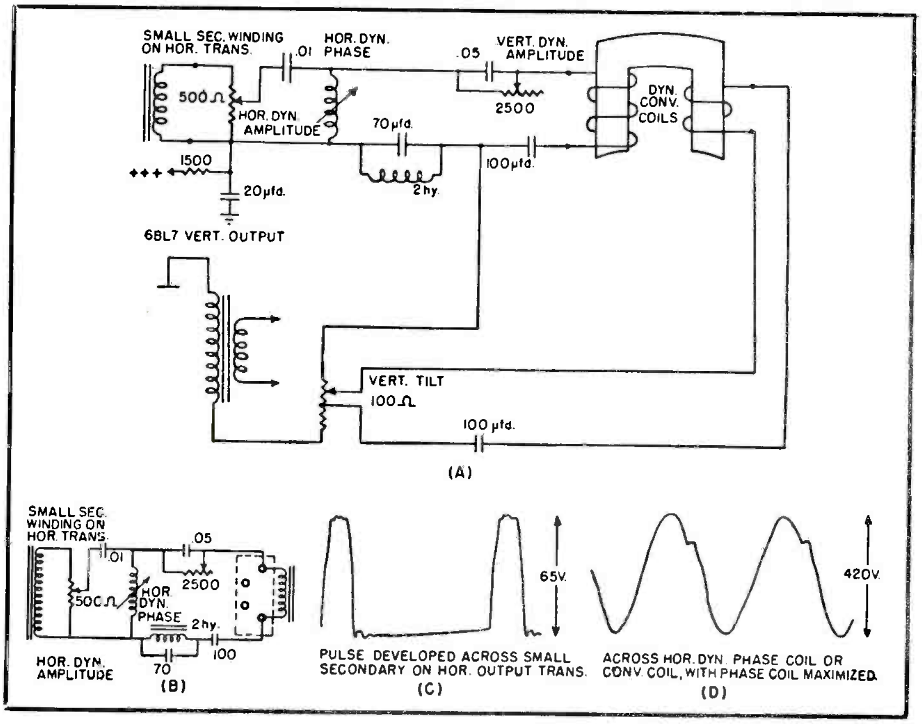
A simplified diagram of the convergence network is shown in Fig. 3A and if we consider the operation solely in terms of the horizontal line frequency, then the diagram can be further simplified to the form shown in Fig. 3B. A pulse having an over-all amplitude of 65 volts is made available at the horizontal output transformer winding. The portion of the pulse which the rest of the network receives is governed by the arm setting of the horizontal dynamic amplitude control. Whatever value of pulse the control picks off is then used to shock-excite a series resonant circuit formed by the .01 μfd. capacitor and the horizontal dynamic phase coil. The circuit is tuned to 15,750 cycles per second and the strong circulating currents develop fairly large sine-wave voltages across each of the resonant components. See Fig 3D. This voltage, in turn, is forwarded to the dynamic convergence coils on the picture tube neck and through the resulting magnetic field, influences the electron beams which the guns develop. So far as the 15,750 cps voltages are concerned, the .05 μfd. capacitor, the 70 μfd. capacitor, and the 100 μfd. capacitor all present low impedances between the horizontal phase coil and the convergence coil.

The horizontal dynamic amplitude control determines how much voltage reaches the convergence coil and, in consequence, how powerful a magnetic field is developed. The phase of the 15,750 cps sine wave depends upon the adjustment of the phase coil. Changing the frequency of the circuit by adjusting the phase coil slug will vary the phase of the voltage applied to the convergence coil. This, in turn, will change the deflection angle of the electron beam and thereby alter its point of convergence with the other two beams as they move from left to right across the screen. Thus, it is possible to change the beam convergence at the sides of the screen permitting us to counteract the normal misconvergence of the beams. Each beam has a similar convergence circuit and responds in a similar way.

One further point concerning this circuit. The series resonant network develops a sine wave instead of a parabolic wave. However, only the bottom portion of the wave is used in the converging action and this is close enough to a parabola in shape to do an effective job.

Let us consider now the vertical portion of the dynamic convergence network. Referring back to Fig. 3A, we note that the bottom end of the vertical output transformer reaches "B+" through the vertical tilt potentiometer

Fig. 3. (A) The horizontal and vertical dynamic convergence circuit for a single convergence magnet. There are three of these mounted on the neck of the three-gun picture tube. (B) Simplification of the circuit. (C), (D) are circuit waveforms.



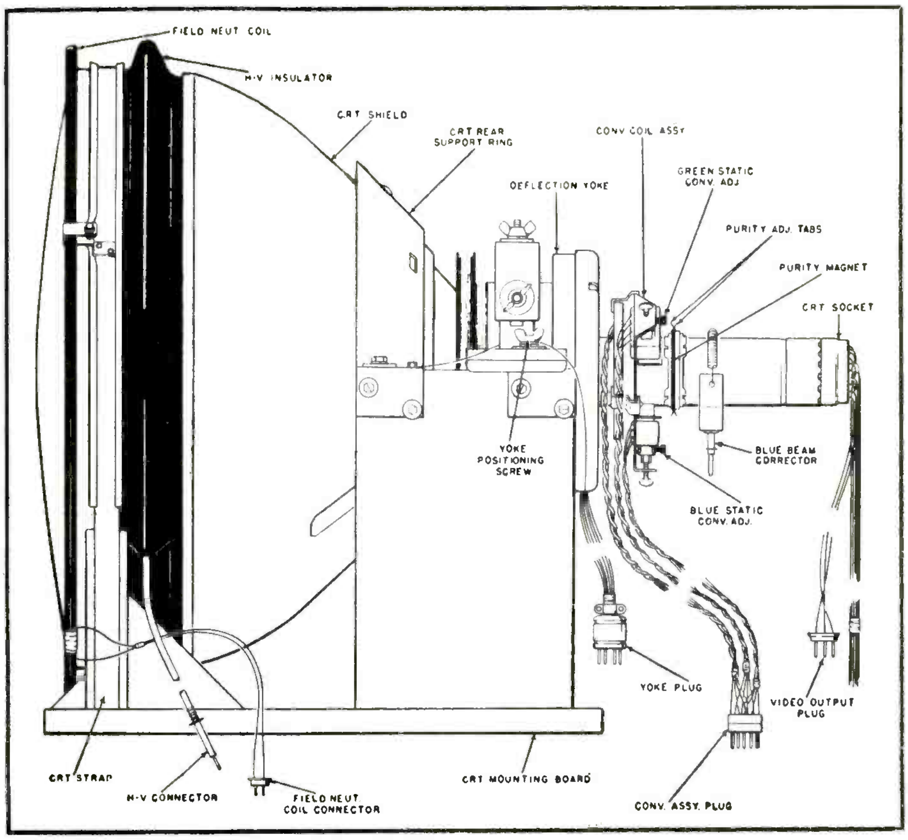


Fig. 4. Three-gun color TV picture tube with the various external components.

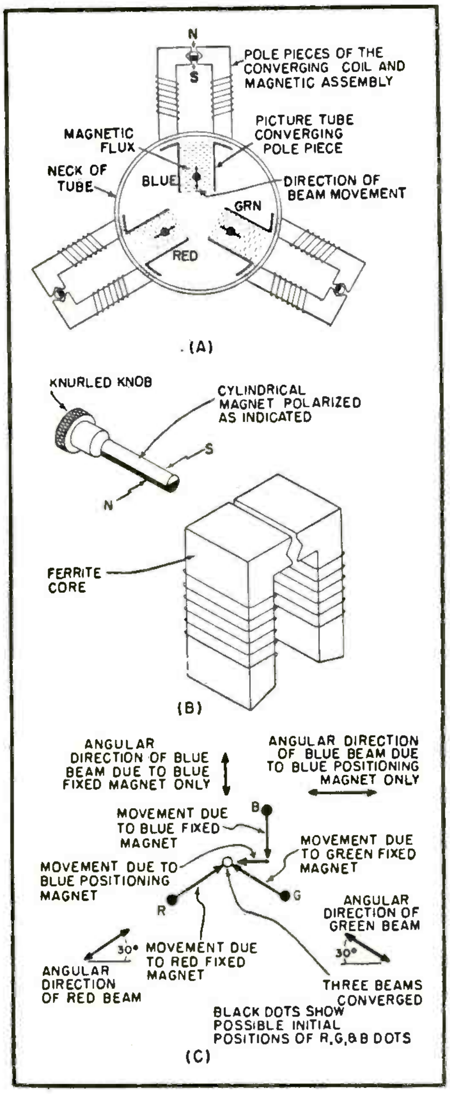


Fig. 5. (A) External and internal convergence components of the CRT. (B) Detailed drawing of the convergence coil and magnet assembly. (C) Effect of the three fixed magnets and the blue positioning magnet on the three CRT beams.

(100 ohms), a 2 henry choke (with a parallel 70 μfd. capacitor), and finally a 1500 ohm resistor. The flow of plate current (from the vertical amplifier) develops a voltage across the 2 henry choke and the subsequent flow of current between the choke and its parallel capacitor produces a parabolic voltage across the combination. What happens here is that the saw-tooth plate current is converted *via* the capacitor (principally) into a parabolic wave and this voltage is applied across the convergence coil. The path from the choke and the 70 μfd. capacitor to the convergence coil consists of a 100 μfd. capacitor, the horizontal dynamic phase coil, and the parallel combination of a .05 μfd. capacitor and a 2500-ohm potentiometer. At the vertical sweep frequency of 60 cycles, the horizontal dynamic phase coil and the 100 μfd. capacitor offer negligible opposition. The vertical current, however, finds that the opposition of the .05 μfd. capacitor is high and, so, the current is driven through the 2500-ohm potentiometer. The latter, then, rightfully becomes the vertical dynamic amplitude control.

Still required is some method of varying the phase of the vertical dynamic convergence voltage and this is achieved through the presence of another winding on each convergence coil. This is the so-called tilt coil, the word tilt referring to the effect which its voltage has on the vertical parabolic wave.

The method of developing the required tilt (or phase) voltage is quite simple. The saw-tooth plate current of the vertical output amplifier flows through a 100-ohm potentiometer. The control contains a center tap and the movable arm may be moved above or below this tap. When the arm position is above the tap, the saw-tooth voltage fed to the tilt coil possesses one polarity; when the arm is below the tap, the polarity is reversed. Finally, no saw-tooth voltage is fed to the tilt coil when the arm and center tap coincide. In other words, a saw-tooth of variable amplitude and with positive or negative polarity may be added to the electron beam. The net effect of this is to add the saw-tooth to the vertical dynamic parabola voltages to shape them as required for best convergence in the vertical plane.

External Picture Tube Components

We come now to the components which are mounted on the neck of the 19-inch tri-color picture tube. See Fig. 4. The first item that we recognize is the deflection yoke. This is, to a considerable extent, similar to the deflection yokes used with black-and-white tubes. However, its design is more complex because three beams must be deflected instead of one and it is of the utmost importance that a symmetrical and uniform magnetic field be maintained throughout the deflection area. Also, the deflection power required is about twice that of present black-and-white TV sets (for the same size screen) and special insulation must be employed in the yoke structure to prevent arcing.

A second component found on the neck of the color picture tube is the purity coil or magnet. This device adjusts the axis of each electron beam so that it approaches each hole in the shadow mask at the right angle to strike the appropriate color phosphor dot. In other words, the purity magnet provides for the proper alignment of the three beams with respect to the phosphor-dot plate and the shadow mask. When this component is properly set, a uniform color field will be obtained for each gun. For example, with only the red gun in operation a uniform red raster should be observed. Any departure from pure red at any point on the screen indicates that the beam is striking phosphor dots other than red. Similarly, when only the green gun is in operation, a uniform green raster should be obtained, and when only the blue gun is active, a blue field should be visible.

The color tubes with which we are most concerned utilize magnetic convergence and toward that end employ three sets of convergence coils, each positioned directly over the pole pieces which are internally associated with each grid No. 4. The magnetic fields set up by the coils are coupled through the glass neck of the tube to the internal pole pieces which serve to shape and confine the fields so as to affect only the particular electron beams to which the individual pole pieces correspond. For example, the change in convergence angle of the red beam is a function only of the current through the external coil which couples to the internal set of pole pieces adjacent to the red beams. Likewise, the currents through the green and blue external magnets affect respectively only the green and blue beams.

Each external coil possesses two separate windings to provide for horizontal and vertical dynamic convergence correction. For the static convergence adjustment, each coil has associated with it a small permanent magnet whose position can be varied.

A diagram of the individual static convergence magnets is shown in Fig. 5A. The heavy dots represent the individual electron beams as they pass through the gun on their way to the screen. The arrows at these beams indicate their direction of movement. Note that the red and green beams are confined to paths which make an angle of 60 degrees on either side of a vertical axis. The blue beam, on the other hand, can only move vertically, up or down.

Now it could readily happen that while the color dots of the green and red beams fall within the same trio, that of the blue beam does not. This means that while we can always cause the red and green beams (or color dots) to converge, it may not be possible to have the blue beam meet the other two. Still required is another adjustment, that of being able to move the blue beam from side to side (or laterally). To effect this, a special blue beam positioning magnet is also found on the neck of the tube. See Fig. 4. Now perfect convergence of the three beams at the center of the screen is always possible.

Note that no ion traps are used in this tube, principally because the color screen is aluminized. The layer of aluminum presents a barrier to any oncoming ions and prevents them from reaching and damaging the screen. Electrons, having only 1/1800th of the mass of an ion, encounter little difficulty in passing through this aluminum layer.

We would like to thank the *Motorola* Service Department for its cooperation in the preparation of this series. Particular thanks are due Mr. T. M. Alexander and Mr. Frank Uhrus.

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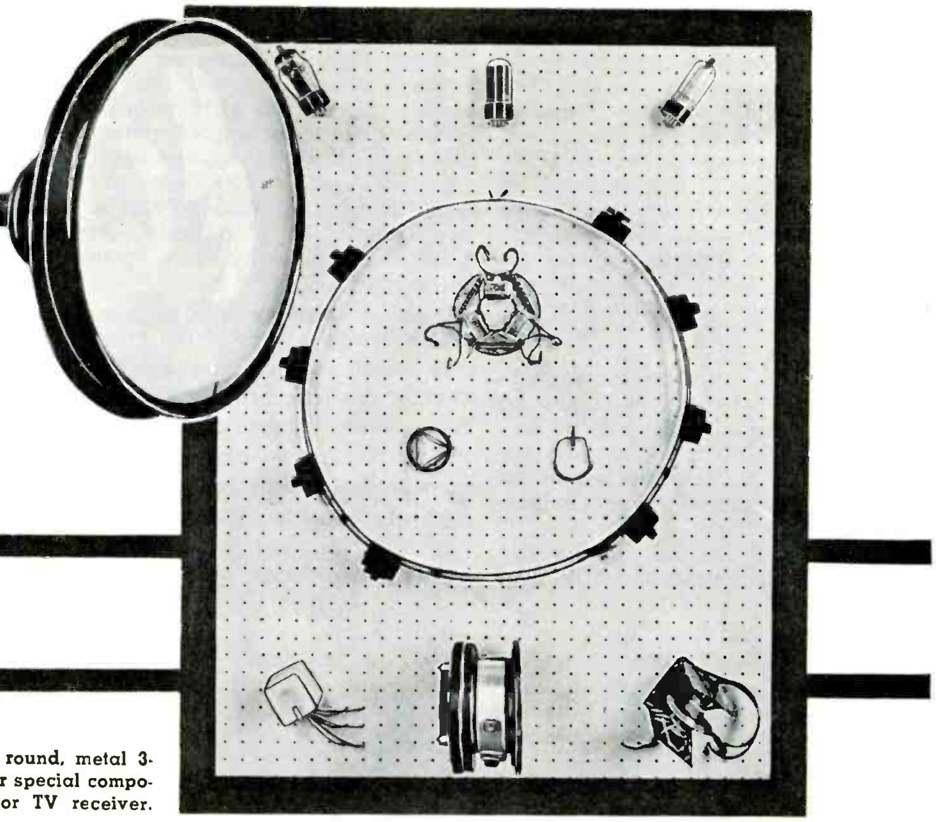
SIMPLIFIED RCA COLOR RECEIVER

By
WALTER H. BUCHSBAUM
Television Consultant
RADIO & TELEVISION NEWS



Shown here are the RCA 21" round, metal 3-gun color picture tube and other special components used in the 28-tube color TV receiver.

Here is a complete analysis of the new circuits in the RCA 28-tube color set, hailed by many as the "color 630."

WHEN the first *RCA* 630 receivers were shown, back in 1947, few people realized that this represented the cornerstone of a fast-growing pyramid of better, cheaper, and more plentiful TV receivers. Remembering those early days of television and studying the new *RCA* simplified color receiver, we are inclined to name it the color 630. Using only 28 tubes, two less than the original 630, this set incorporates a 21-inch round color picture tube, a far cry from the 10BP4 used in the first 630 sets. The performance of this color set is as good as any seen earlier, and it certainly presents a very acceptable picture.

When *RCA* unveiled this new color receiver, other large TV manufacturers were handed all the necessary data as part of their licensing arrangement. This allows them to produce color TV sets based on the same or similar circuits and offers their engineers a chance to further improve the *RCA* designs.

For the service technicians this means that the majority of the new color receivers due to come out now will use all or some of the novel features of the *RCA* 28-tube set. It is with this in mind that we describe the new and outstanding features of the simplified color receiver, leaving the circuits which have been explained in previous articles in this chapter as parts of the block diagram only. Emphasis will be placed on explaining those features which are completely new and are bound to find wide application in the new color receivers.

Over-all Design Features

Fig. 5 shows the entire *RCA* 28-tube color receiver with the rear, top, and side panels removed for easy access. The entire receiver chassis is a single piece, mounted upright alongside the picture tube. The 21-inch round color picture tube uses a metal envelope which is covered by a plastic insulating sleeve. Support for the tube is provided by a ring near the junction of the neck and funnel, which forces the entire tube against the plastic front panel and mask assembly. Shielding is provided for the deflection yoke. Just behind the deflection yoke is the convergence coil assembly, purity magnet, and blue beam positioning magnet, all of which are used with other large 3-gun color picture tubes.

As shown in Fig. 5, the receiver chassis itself is not much larger than many of the earlier monochrome sets, although the high voltage section needs more space and better insulation. The high voltage cable going to the picture tube socket provides the focusing potential for all three electron guns. Since the metal envelope serves as second anode, there is also a high voltage lead going in that direction. One of the new features of the 21-inch round tube used in this receiver is the permanent magnet ring assembly near the screen of the picture tube in place of the old field neutralizing coil.

Even more interesting than the physical appearance of this receiver is its electrical arrangement as shown in the block diagram of Fig. 1. The v.h.f.-u.h.f. tuner is special only in its closer tolerances on bandpass and oscillator drift characteristics, otherwise its operation is the same as for black-and-white.

The i.f. section employs a total of 4 stages. A special bifilar "T" trap is used to provide the necessary attenuation for the sound i.f. and by using separate detectors for the sound and video signal, further separation of the two signals is obtained. Actually, the detector used for the sound is peaked towards the i.f. range of the color subcarrier, which is only about 900 kc. from the sound i.f. At the chroma-sound detector output a sharply tuned 4.5 mc. trap doubles as sound rejection for the chroma channel and as sound take-off coil for the sound channel. This latter section is essentially the same as most black-and-white intercarrier sound sections. A ratio detector at 4.5 mc. is used, followed by a standard audio amplifier.

The brightness-signal detector section feeds a delay line and then the signal is amplified and passed on to all three cathodes in the color picture tube. The sync separator utilizes the high level brightness signal and, in conjunction with other sync circuits, provides horizontal and vertical synchronizing pulses.

Sync and sweep circuits are very much like those used in monochrome receivers with a blocking oscillator circuit used in the vertical, and a phase detector type a.f.c. in the horizontal section. More saw-tooth power is needed in both sections since the dynamic convergence circuits obtain their power directly from the two sweep sections. In addition, the flyback section must provide 27,000 volts at almost 1 milliampere, plus the focusing voltage, and sufficient sweep to deflect all three electron beams linearly. Except for the convergence section, other color TV sets use the same type of vertical and horizontal circuits.

The convergence section itself uses no tubes—the d.c. convergence is accomplished by special permanent magnets located in the convergence coil assembly. A detailed discussion of this section appears in a later paragraph.

Color synchronization is accomplished through a phase detector, reactance tube, and crystal-controlled oscillator. To separate the color reference burst from the composite signal, a simplified diode burst gate is used. One side of the phase detector circuit also supplies a signal which controls the color killer stage. This latter circuit shuts off the entire chroma channel when a black-and-white picture is received.

A new feature is the introduction of a sort of automatic gain control system to keep the level of the chroma signal constant. By detecting the amplitude of the reference burst as well as its phase, the phase detector provides a bias voltage which controls the gain of the first chroma amplifier and thereby keeps the level at the output of the second chroma stage constant.

The radically new and greatly simplified high level demodulator section used in this receiver deserves considerable scrutiny and explanation. Using some really novel techniques, *RCA* engineers have been able to utilize one double triode to perform all the demodulating and matrixing functions in a single stage. The input to this section includes the color subcarrier and its sidebands, and two 3.579 mc. reference signals, properly phased; the output of this stage directly drives the three control grids of the tricolor picture tube. The three grids receive the red, green, and blue color difference signals, while the three cathodes are driven by the brightness signal. Thus, the addition of the *Y* signal to each of the three colors is accomplished directly inside the color picture tube.

While the double-triode demodulator circuit is far more economical than any of its predecessors, its operation also requires less adjustment and eliminates many of the variables found in earlier systems. The result is a surprisingly stable demodulator, simple to produce, still easier to adjust, and certainly a great step towards faster color TV servicing.

The block diagram is completed by the power supply which uses a power transformer and selenium rectifiers, and provides 200 and 400 volts "B+" as well as a small negative potential. This latter is obtained by returning the secondary to ground through the vertical and horizontal centering controls.

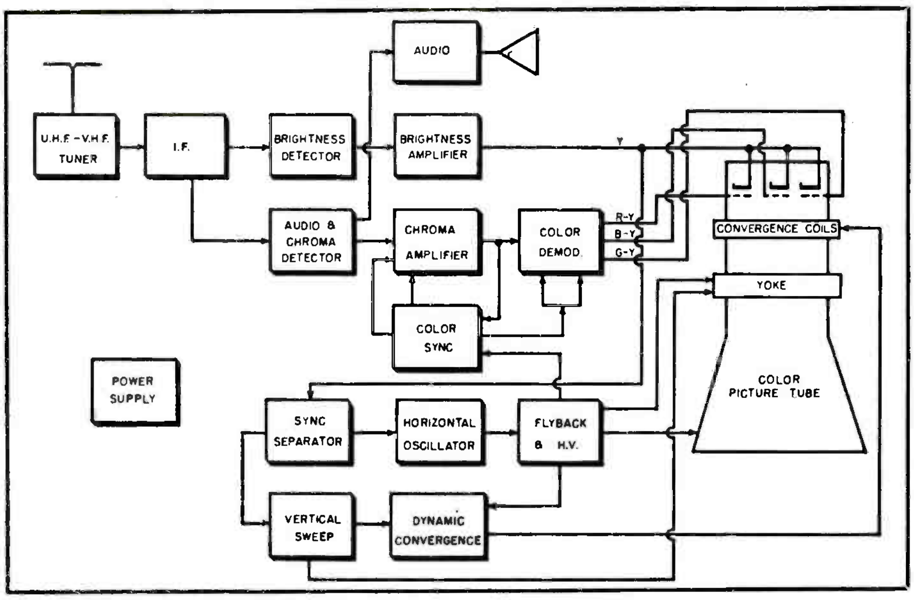


Fig. 1. Block diagram of the RCA set. Comparing this with the previous RCA color receivers using the 15" tube discloses the simplification and economies effected.

There are various minor innovations in practically every section of this receiver, but in this article emphasis will be placed only on the convergence section, the demodulator and chroma channel, and the operation of the bifilar "T" trap in the i.f.

The need for at least 60 db of attenuation of the sound i.f. carrier and the specification that this must be done in a very narrow frequency band led to the use of a bifilar "T" trap. This trap provides considerable attenuation without overshoot or ringing.

Fig. 2 shows the double-tuned bifilar trap used in the new *RCA* 28-tube receiver. Two separate traps are employed, one tuned to the sound i.f. and the other to the adjacent channel sound carrier, both connected in series. All three coils are slug tuned and their alignment presents no particular problem. The tapped tuning coil, L_1, is set in accordance with the i.f. bandpass specifications and each of the traps is aligned individually for maximum rejection at its respective frequency. Another sound i.f. trap is used in the brightness detector stage.

Triode Demodulator

Perhaps the most significant innovation presented in the new *RCA* 28-tube color receiver is the demodulator and matrix network. In this receiver a single 12BH7 provides the complete decoding action with sufficient signal output to drive the three kinescope grids directly. Before discussing the actual circuit, it is important to understand how a triode demodulator works. Consider the circuit of Fig. 3 which shows a triode used to detect the chroma signal. Theoretically either the *I*, *Q* or *R-Y*, *B-Y* signals could be detected here, depending on the phase relationship of the reference signal and the bandwidth of the output filter. Since the color difference system is used in the practical circuit, assume that the triode in Fig. 3 produces *R-Y*.

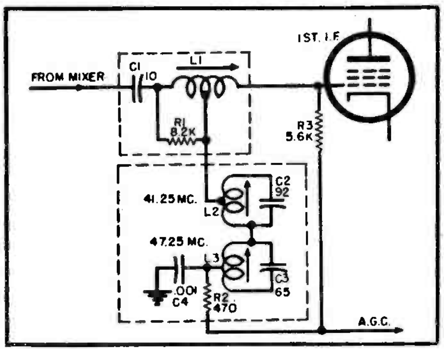


Fig. 2. Schematic diagram of the bifilar "T" trap which reduces very sharply the amplitude of the sound i.f. carrier.

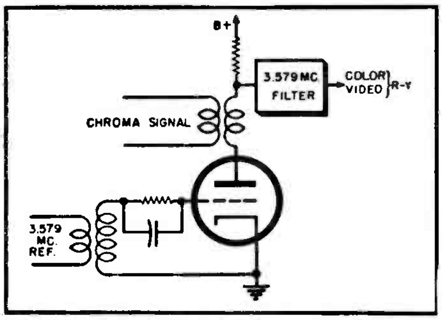
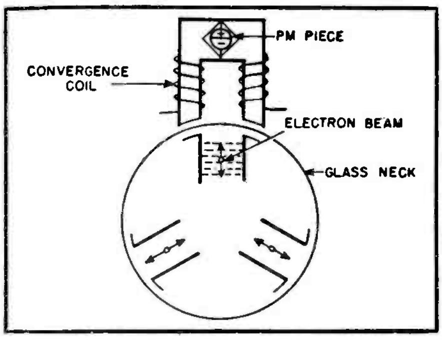


Fig. 3. Simplified diagram of the triode color demodulator circuit used by RCA.

Fig. 4. Convergence, d.c. and dynamic, elements used with the new large-screen three-gun color picture tubes used by RCA and others in their color TV sets.



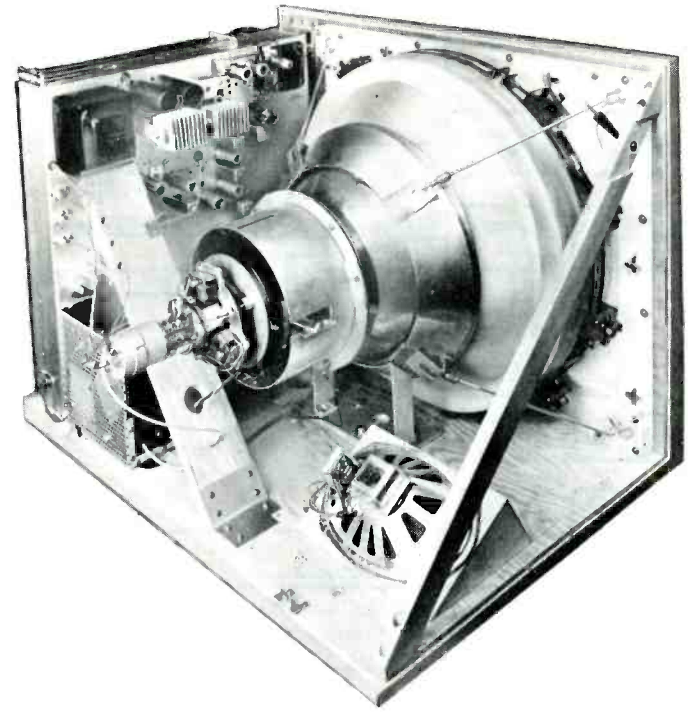


Fig. 5. View of an RCA color TV receiver of the type described in this article. Note the lack of a field neutralizing coil and CRT tube shielding.

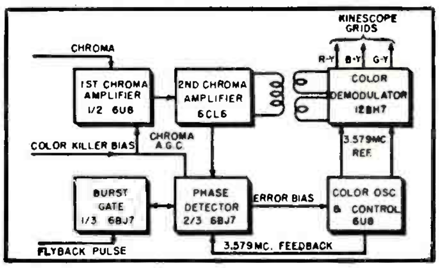
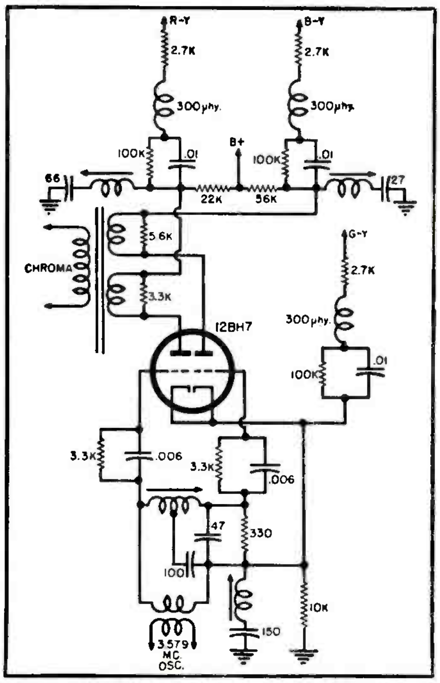


Fig. 6. Block diagram of the chrominance circuits. Note the chroma a.g.c. feedback.

If no signal appears at the grid, the plate current of the triode will depend on the plate voltage. In other words, the triode acts like a diode detector, for amplitude modulation. When a signal is applied at the grid, the plate current is dependent both on the instantaneous grid voltage and the plate voltage. This is the same action as obtained in a conventional demodulator such as the 6AS6, where the plate current is a function of the control and suppressor grid signals. In the triode it is necessary to choose operating points for plate and grid signal amplitudes so that the linear portion of the tube characteristic is used. Note that there is a special trap in the plate circuit which removes the 3.579 mc. reference signal and the color subcarrier.

Fig. 7. Complete schematic diagram of the double-triode color demodulator furnishing color difference voltages to CRT.



When using two triode demodulators, the chroma signal applied to each tube and the load resistors would have to be adjusted in relation to the respective color signals to obtain the proper amplitudes. Also necessary for such a demodulator are relatively large chroma signal and reference signal voltages.

Now consider the block diagram of Fig. 6 showing the entire chromaticity section of the new *RCA* set. Two stages of amplification are used with a bandpass of about 1 mc. centered at 3.579 mc. This provides sufficient driving power for the 12BH7 demodulator. Note that the color reference burst is obtained from the second chroma stage and that the color phase detector is utilized to provide an a.g.c. bias which controls the gain of the first chroma amplifier. This circuit helps maintain constant chroma signal for the demodulator and generally adds to the stability of the receiver.

The complete demodulator circuit is shown in Fig. 7. A single transformer drives the plates of both triodes, but in order to obtain the difference in amplitudes required, the ratio of the two secondaries is 1 to 1.41. The two plate load resistors are in the ratio of 2 to 5. When the correct phase and amplitude of reference signals are applied at the two grids, the red and blue color difference signals are demodulated. It is possible, by using these two signals in proper phase and amplitude, to obtain the green color difference signal. In the double-triode circuit of Fig. 7 the green matrixing action is performed directly in the cathode of the 12BH7. By joining the cathodes of the two triodes, the total cathode current is a function of the *R-Y* and *B-Y* signals. The plate load and cathode resistors are so chosen that the green color-difference signal appears directly at the common cathode. Thus, the double triode circuit of Fig. 7 performs not only the demodulating, but also the matrixing functions.

The coils and series resistors in each kinescope grid lead help in suppressing harmonic radiation of the 3.579 mc. reference signal.

One of the features of this circuit is the d.c. coupling to the picture tube. The three color difference signals are applied directly to the three grids while the brightness signal is d.c.-coupled to the three cathodes. Thus, the *Y* signal is added inside the color picture tube to the three difference signals and the full three-color presentation appears on the screen. Since d.c. coupling is used throughout, no d.c. restorer circuits are needed.

Magnetic Convergence

Many of our readers know of the convergence problems in the earlier shadow-mask color picture tubes. In those tubes, a special element, the convergence grid, carried a d.c. potential as well as a vertical and horizontal parabolic voltage, which helped the three electron beams to converge at the shadow mask. In addition, a set of small magnets was located around the neck of the tube to bring these three colors into registry.

In the large-screen color tubes available now, convergence is accomplished by three magnetic fields, each acting only on its respective electron beam. As shown in Fig. 4, small steel strips inside the neck of the tube form two magnetic poles when an external horseshoe magnet is placed over them. Each set of two poles has an electron beam in its field and since the field is confined between these poles, the action of one set of poles has little effect on any of the others. Each horseshoe magnet actually consists of two ferrite pieces with a small permanent magnet cylinder as shown in Fig. 4. This permanent magnet can be rotated, and thereby adjusts the d.c. convergence of its electron beam. In addition, a coil is wound over each ferrite leg and through this coil goes the vertical and horizontal convergence current. In addition to the convergence magnets and coil assembly there is also a blue positioning magnet, similar in appearance to an ion trap magnet, which will allow lateral motion of the blue beam.

We know from the earlier electrostatic systems that for the dynamic or a.c. convergence action a parabolic waveshape is necessary to compensate for the sweep of the electron beam over a surface which is not a perfect arc. Consequently, the magnetic a.c. field must be parabolic and therefore, the current through each coil must be parabolic.

The dynamic convergence circuit in the new *RCA* color set uses no tubes and is adaptable to other magnetically-converged color picture tubes. Fig. 8 shows the entire convergence circuit and it will be apparent that there are actually three separate, individually-adjustable networks. At the left is the cathode of the vertical output amplifier. By means of the capacitive network, C_1, C_2, and C_3, a parabolic current is obtained. This current is applied through three potentiometers, the vertical tilt controls, to each of the convergence coils. The series potentiometers determine the amplitude of this current. In order to keep the horizontal signal out of the vertical section a 400 millihenry choke is inserted in each lead. Since the convergence coils are relatively low in inductance for the 60 cycle vertical signal, they represent mostly a resistance and the parabolic voltage applied will produce a parabolic current and magnetic field.

The horizontal signal is obtained from a special winding on the flyback transformer and is originally a pulse voltage. This voltage results in a sawtooth current through coil L_4 and a parabolic voltage is developed across C_{10}. The amplitude of this voltage is determined by the potentiometer in each convergence coil assembly. By autotransformer action, the signal applied to the centertap is induced into the entire coil assembly which, together with the 400 millihenry choke, forms a series resonant circuit at the horizontal frequency. The result is a parabolic current at 15 kc. flowing through the convergence coils. The trimmer capacitor across each coil varies the resonant frequency slightly and thereby changes the phase of the parabola in each coil.

Although further modifications in the convergence system will undoubtedly be introduced in the future, the circuit shown in Fig. 8 is already a great improvement over previous *RCA* circuits in that it requires no tubes and permits adjustment of each individual electron beam as to d.c., vertical, and horizontal convergence. By making these adjustments independent of each other, the over-all set-up, installation, and alignment of color TV receivers has been greatly simplified. —30—

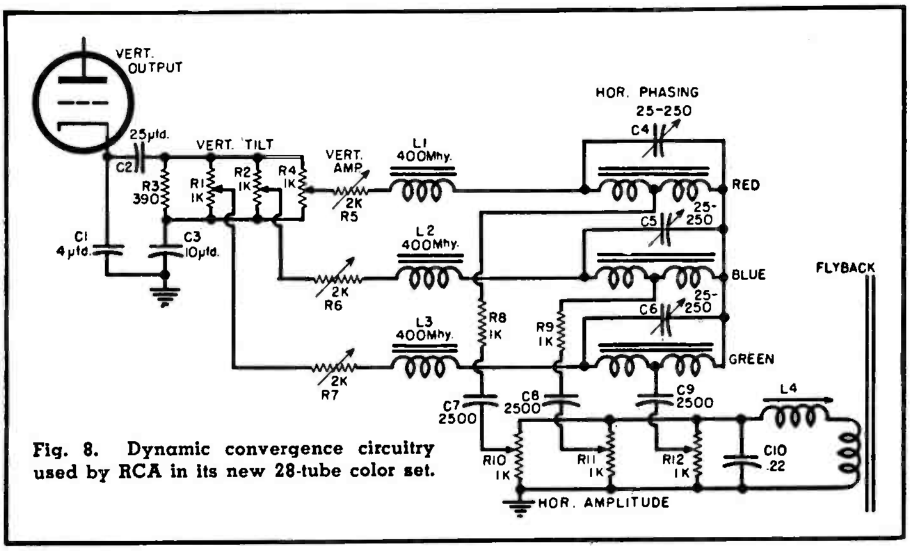
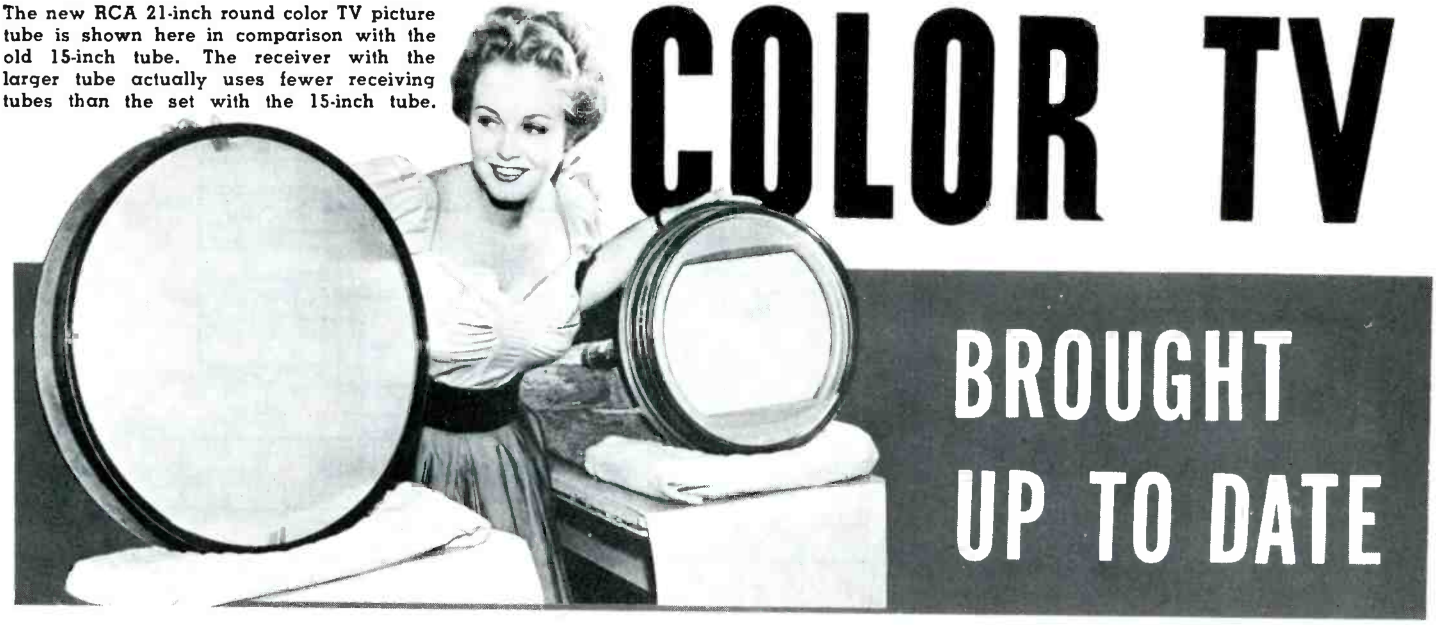


Fig. 8. Dynamic convergence circuitry used by RCA in its new 28-tube color set.

COLOR TV BROUGHT UP TO DATE



The new RCA 21-inch round color TV picture tube is shown here in comparison with the old 15-inch tube. The receiver with the larger tube actually uses fewer receiving tubes than the set with the 15-inch tube.

By **HARRY E. THOMAS**

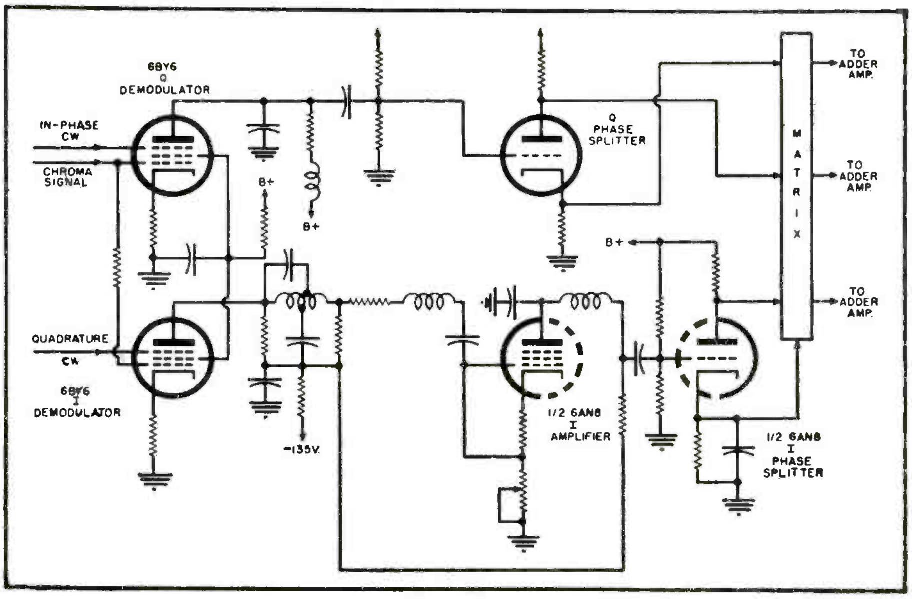
The cost of color sets is coming down, due in part to the great strides in tube reduction described here.

THE rapid progress in color TV receiver circuitry within the last year is particularly evident in the tube economies seen in the latest models. For example, the reduction in tube count in *RCA's* latest receiver, described in the preceding article in this collection, is accompanied by improved performance, although this set uses only 28 tube envelopes instead of the 39 tubes used in their original 15-inch set. Other manufacturers have likewise reduced their over-all tube count. Also, in attaining general improvement in color reproduction, all models now use stabilized color phase circuits and employ improved picture-tube circuits. Tuning and color controls have also reached high degrees of flexibility equalling the convenience standards existing in present monochrome receivers.

Color picture tubes themselves have likewise shown remarkable improvements, among which are large size color screens of up to 250 square inches using a light, round, metal tube blank; an adjustable magnetic field equalizer affecting the whole picture-tube screen irrespective of extraneous magnetic fields; a shorter, more efficient electron gun; and temperature-compensated components within the picture tube itself.

In summarizing, the most important contribution to receiver circuitry is the development of high level demodulation. Two triode demodulators (in one envelope) plus a suitable transformer and coupling networks handle large enough signals to directly drive the grids of the picture tube. This results in savings over old-style circuitry of one demodulator tube, three adder tubes, three amplifiers, three restorer diodes, a phase splitter, and a phase inverter. Even when using double section tubes in old circuits, this results in a saving of six tube envelopes. This type of demodulation provides improved linearity, better maintenance of stability, and assures color processing which is independent of tube characteristics.

Fig. 1. A pentode low level demodulator circuit of the type used in early color receivers. Note the matrix section and the adder tubes, not used in later sets.



Further comparison of low level and high level demodulation systems is particularly interesting in that two types of low level systems have been used—one involving pentodes and one using double diodes. Figs. 1 and 2 show two early pentode circuits where the chrominance signal in both cases is applied to the demodulator control grid while the in-phase and quadrature c.w. gating signals are applied to the respective suppressors. Note in Fig. 2 that the demodulator is a 6AS6 tube whose suppressor characteristic is specifically tailored for gating applications.

Fig. 3 shows double diodes employed as gating tubes in the demodulator circuits of a difference color TV receiver. These circuits also require additional amplification between the demodulators and the picture-tube grids. The circuits of Figs. 2 and 3 combine matrixing steps within the demodulator and amplifier circuits, thus eliminating adder, phase splitting, and inverter tubes which are necessary in the *I* and *Q* signal system of Fig. 1. Fig. 4 is a schematic of the high level triode demodulators used in more recent *RCA* receivers.

Another improvement and saving involves the convergence system. With suitable magnetic coupling directly from the horizontal and vertical output amplifier circuits, it is possible to eliminate one amplifier tube. This system is a low level one, quite different from the original circuitry used with the 15-inch color tube in the "CT100" receiver, where convergence voltages were applied to focus electrodes at the picture tube.

By using selenium rectifiers, as is becoming common practice in heavy duty power supplies, a net reduction of four tubes is attained over the total receiver tube count of the older models.

Other circuit improvements resulting in tube savings are: (1) the elimination of a quadrature amplifier by suitable phasing obtained in the coupling networks linking the subcarrier oscillator and the demodulator (see Fig. 4); (2) the inclusion of the chroma bandpass filter as an amplifier coupling network leading to the demodulator circuits; (3) the elimination of a focus rectifier tube and associated components due to improvements in the electron gun of the picture tube; (4) the reduction of two tubes in the sound amplifier system by economies in multiple section tube envelopes; (5) the use of a simple diode as a burst gate instead of employing a burst amplifier stage; and (6) the reduction of tubes in miscellaneous circuits throughout the receiver such as vertical deflection (½ tube), color sync and a.f.c. (½ tube), picture i.f. (1 tube), and luminance channel (1 tube).

Picture Tube Developments

It is interesting to note that the picture tube developments paralleling the circuit advances were covered in two steps—the first embodied in the development of 19-inch picture tubes, and the second in the additional advances incorporated in the 21-inch model.

Following the first 15-inch picture tube which had obvious drawbacks, both *RCA* and *CBS* started on a development program for a 19-inch tube. Three advances that resulted from this work were the process of photographically depositing color phosphors directly on the picture-tube face plates, the use of a curved shadow mask which serves also as a template in the photographic process, and the inclusion of internal pole pieces for exact convergence of the individual beams plus auxiliary pole pieces for additional correction of the position of the blue beam. Also, the 19-inch tube uses low level dynamic convergence with electromagnetic correction coils placed directly above the color guns and on the neck of the tube.

The 21-inch tube is the latest one developed by *RCA,* which has discontinued production of the 19-inch model. This tube uses a color equalizer consisting of a sectionalized magnetic field produced by adjustable permanent magnets positioned around the front rim of the tube. The individual magnet adjustments give selective control of fields over the face of the tube and compensate for unwanted fields when setting up for color purity.

An improved shorter electron gun is used in the 21-inch tube, requiring two-thirds the focussing voltage used in the longer 19-inch tube. The mask has an indexing system affording self-alignment and exactly correct mask-to-phosphor screen spacing. This refinement in design does not require undue precision in manufacture. The mask itself is thermally self-compensated and maintains indexing at all operating temperatures. Loss of register between apertures and phosphor dots is thus eliminated.

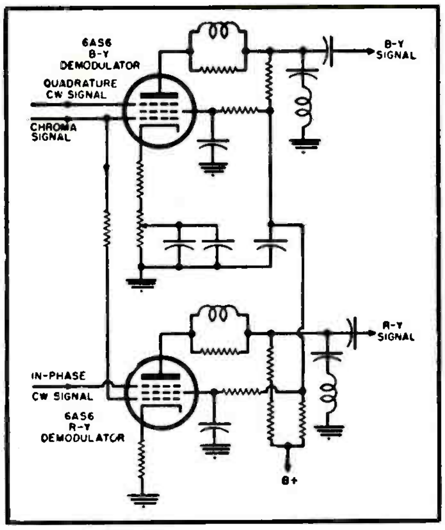


Fig. 2. The circuit shown here is a pentode low level demodulator whose output is a set of B-Y and R-Y difference signals.

The relatively high voltage and power requirements of color picture tubes led to the development of several special tubes which appear in the output systems of current color TV receivers Among these is the 6CB5 horizontal sweep output tube which delivers nearly 1 milliampere at 27,000 volts as required for the three color tube electron guns. This tube is in effect a heavy duty 6CD6G.

Increased picture-tube voltages and beam currents led to the development of two high-voltage rectifiers: the 3A3 in an octal base, and the 3A2 in a miniature base. Precise regulation of the picture tube's ultor (highest electrode) potential is obtained by the use of several new tube types: the 6BD4, 6BK4, and 6BU5 are grid-controlled, shunt-regulator tubes whose cap connection is capable of withstanding the full developed high voltage.

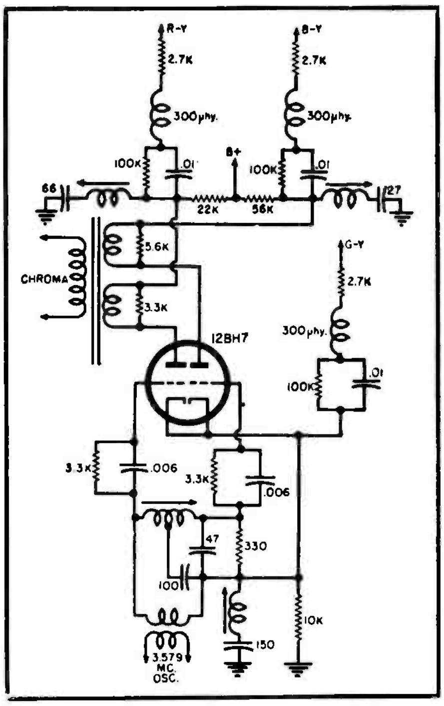


Fig. 4. High level triode demodulators used in recent RCA 21-inch tube sets.

Since heavier damping currents are naturally entailed with the increased power of color deflection systems, a new heavy duty damping diode, the 6LB4, was developed to supersede the heavy duty 6AU4.

All-in-all, color receiver circuitry has probably made proportionately more progress in its early development stages than was made on monochrome receivers. —30—

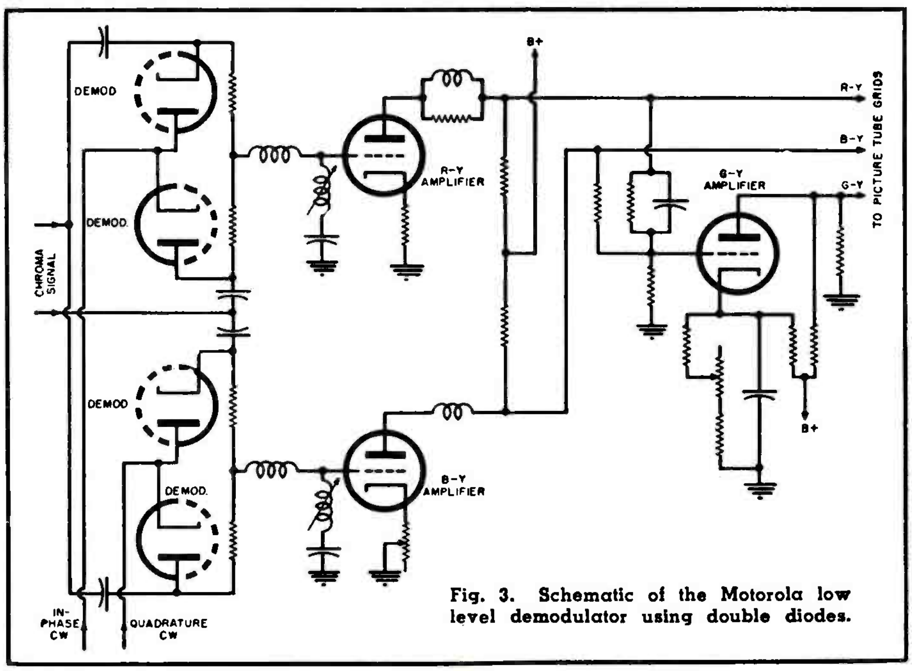


Fig. 3. Schematic of the Motorola low level demodulator using double diodes.

BOOK REVIEWS

All of these books were written for service technicians and others interested in installing and servicing color TV.

"COLOR TV SERVICING" by Walter H. Buchsbaum. Published by *Prentice-Hall, Inc.*, New York. 252 pages. Price $6.35.

This volume, written by Radio & Television News' Television Consultant, is for the practicing and experienced TV technician. Those without a thorough understanding of monochrome television principles will find this text rough sledding since the author has assumed that only those who really know their radio and black-and-white television circuitry will be able to "graduate" to servicing color receivers.

Because of this limitation in the scope of the volume, the reader is directed to the similarities and differences between monochrome and color receivers which precludes all discussion of basic television theory. This is a valid position inasmuch as the complex and relatively expensive color receivers will not be entrusted to the offices of the novice technician or apprentice.

Those whose background qualifies them for color service work will find this volume extremely helpful in preparing for the deluge that is sure to come or in the actual day-to-day servicing of existing receivers if the technician is operating in an active color market. The author covers the principles of colorimetry; color TV signals; the color TV system; picture tubes and their circuits; typical color receivers; antennas, tuners, and i.f. sections; the special circuitry unique to color; installation and troubleshooting procedures involving the actual receiver; and, finally, miscellaneous troubleshooting techniques.

The technician seeking an advantage over his less alert competitors will find this volume a real help in putting him ahead of the game for the new boom in color TV.

* * *

"INTRODUCTION TO COLOR TV" by M. Kaufman and H. Thomas. Published by *John F. Rider Publisher, Inc.*, New York. 154 pages. Price $2.70. Paper bound. Second edition.

So rapidly has the art of color TV progressed since the first edition of this book was published early in 1954 that it was deemed necessary to present a second, up-to-date volume on the subject.

Although much of the current color receiver service work is still being handled by factory organizations (for engineering and control purposes) the day is not far off when the job will have to be tackled by the independent service technician.

Rather than trying to jump into the middle of the color picture the technician should begin now to prepare himself for the job he may soon face. This book is one way for him to get a head start over his competition.

The new and simplified circuitry that characterizes present-day color receivers is covered in detail along with a complete schematic of the new *RCA* Model CTC4 color set.

The text is lavishly illustrated which helps to clarify still further the already lucid presentation by the authors.

* * *

"COLOR TELEVISION FOR THE SERVICE TECHNICIAN" by Albert C. W. Saunders. Published by *Howard W. Sams & Co., Inc.*, Indianapolis, 108 pages. Price $2.50. Paper bound.

Public acceptance of color television is inevitable and its march is inexorable so the on-the-ball service technician will prepare for its advent before he is handed his first color installation job.

A good start toward getting a practical working knowledge of color circuitry would be this new book by Mr. Saunders. The material is presented in a straightforward, clear, and easy-to-understand manner. The text progresses in an orderly fashion from a discussion of colorimetry, through the color signal, color carrier, and signal analysis. The tri-color picture tube receives thorough treatment along with the all-important details on how such tubes should be handled and installed for maximum safety.

The balance of the book is devoted to a discussion of the color receiver itself, how it should be installed, how it operates, and troubleshooting procedures for this circuitry. The various commercially-available color sets are discussed in some detail both as to their similarities and their differences.

The appendix contains a wealth of hard-to-locate information which will be of help to the color technician. Lavish use of diagrams, color charts, and other illustrative material adds immeasurably to the value of this book

* * *

"COLOR TELEVISION FUNDAMENTALS" by Milton S. Kiver. Published by *McGraw-Hill Book Company, Inc.*, New York. 309 pages. Price $6.00.

Now that color is becoming an accepted part of network programming schedules more and more color receivers are going to make their appearance. This slowly growing acceptance of colorcasting is of vital interest to technicians since they will be entrusted, for the most part, with the task of insuring good reception. Color sets will require more servicing, more troubleshooting, and more careful consumer instructions than black-and-white receivers of the same tube size. Technicians familiar with color circuitry and the fundamentals of color will be in an enviable position professionally—since they will be "specialists."

One excellent source for such "professional training" would be this work by Mr. Kiver. He has covered his subject matter progressively so that the student can tackle the more advanced concepts after acquiring the proper "background" for the circuitry under discussion.

The text material is lavishly illustrated with schematics, charts, graphs, and color plates. Two appendices covering additional facts on color TV and technical specifications of the NTSC color signal are supplemented by a glossary of color television terms. All-in-all this is a practical, complete, and worthwhile handbook for the practicing technician and the student.

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"COLOR TELEVISION RECEIVER PRACTICES" by Hazeltine Corp. Laboratories Staff. Published by *John F. Rider Publisher, Inc.*, New York. 194 pages. Price $4.50 (paper) and $6.00 (cloth).

This text has been derived from a series of intensive lectures on color television principles given by *Hazeltine* for the benefit of visiting engineers. It covers the fundamentals of a color TV system, details on the standard transmitted signal, and a complete discussion of the various receiver circuits. A good working knowledge of monochrome receiver circuitry is prerequisite to an understanding of this text which is designed for technicians and engineers. —30—

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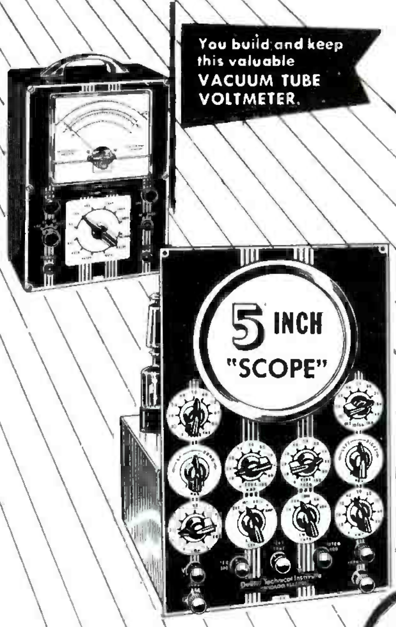

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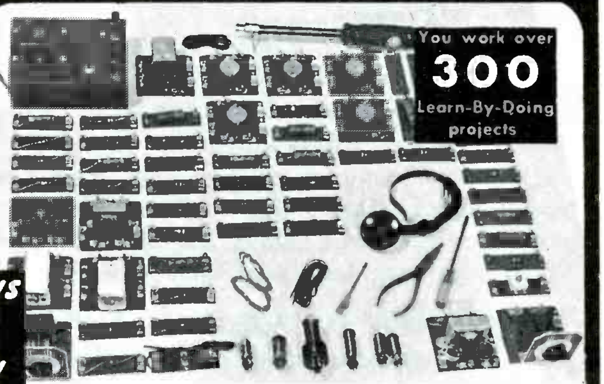

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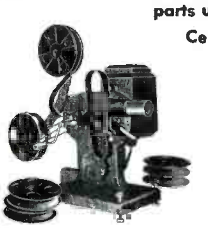

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RADIO & TELEVISION NEWS
JANUARY 1957

CHAPTER 3

COLOR PICTURE TUBES AND COMPONENTS

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the CBS Colortron

Fig. 1 Over-all view of CBS-Hytron's picture tube for color television. It is engineered so that it may be produced in quantity.

By

ROBERT B. TOMER and **WILLIAM R. SULLIVAN**

CBS-Hytron

A new color tube—although its operation is basically identical to the RCA tube, its mechanical construction is so different that production problems are eliminated and restrictions on potential tube sizes are removed.

IT has long been recognized that one of the principal obstacles to low-cost, mass-produced color television has been the means by which the colored picture was reproduced. In recent years, most of the effort in this field has been directed toward perfecting a cathode-ray tube, capable of creating colored pictures in much the same manner as those used in black and white television. The problems involved in the successful accomplishment of this objective are prodigious. However, there has been tremendous progress in the direction of solving many of them.

Until recently, the only successful color tubes which had been demonstrated were exceedingly difficult to manufacture and almost as difficult to adjust and maintain in operation. With the announcement by *CBS-Hytron* of its new *CBS*-Colortron, the last barrier to mass production color television appears to have been removed. This new tube makes use of principles already demonstrated as being sound in earlier color tube designs and goes beyond that point to achieve a simplicity of design closely approaching that of black and white tubes.

Before discussing the improved features of the *CBS*-Colortron, a review of the earlier type of color tube may be helpful. One of the most successful of these earlier color tubes makes use of the principle of parallax to achieve the necessary separation of the three primary colors within the same tube structure. Three electron guns, located in the neck of the tube, are modulated by three individual signals. The beams from these three guns are aimed so as to come together, or converge, upon a mask containing a multiplicity of small holes. As the three beams pass through the holes in the mask, they become divergent again and arrive at the screen as three individual beams. The screen is printed with three types of phosphor, capable of producing the three primary colors—red, green, and blue. The individual phosphors are printed as very small dots on the screen and are arranged in groups of three so as to form little triangles, or triads, each containing a red, a green, and a blue dot. As the three individual beams strike the screen, they are caused to fall exactly over the center of one of the three color dots. Thus, the beam from the red signal gun passes through the mask and travels on to strike the red dot on the screen. The beam from the green signal gun passes through the same hole to continue on and strike the green dot. The blue dot is excited in like manner. This principle of separation by parallax is shown in Fig. 3A.

As stated earlier, tubes utilizing this principle have been demonstrated before. Their chief drawback has been their inherent complexity of construction and their dependence upon highly skilled artisans during their assembly. It has been because of these factors that the first estimates of color television set costs have been so high. It was inevitable that lower cost and more reliable designs would be sought. The *CBS*-Colortron is the result of such an effort.

The color television picture tube differs from its counterpart in black and white in three essential respects. It is these basic differences which will ultimately determine the cost differential between a color television picture tube and a black and white tube. The first of these differences is in the gun structure. The color picture tube in its present practical form requires three electron guns as compared to only one in the black and white tube. While it may conceivably become possible to design color tubes in the future, having only one gun, at present the three gun design seems to be the only practical design for a compatible color system.

The second essential difference consists of the mask which permits the three beams to be separated at the screen for proper color registration. There is no way of eliminating this added element in the parallax type of color tube. However, its method of fabrication and assembly leaves much latitude for improvement and consequent cost reduction.

The last essential difference consists of the special tri-phosphor screen, used in color television tubes, as compared with the simple screen used in black and white television. There appears to be no possibility of eliminating this essentially complex part of the color tube. However, once again the method of producing the screen leaves considerable area for improvement.

It has been in the latter two areas that the greatest significant advances have been made in the *CBS*-Colortron. Earlier designs made use of a flat, prestretched mask, firmly bolted to a heavy spacer frame, which was in turn clamped to the glass plate containing the phosphor dots. This assembly was not only difficult to maintain in proper registration during its assembly, but created equally difficult problems in evacuating and outgassing the completed tube. Because of the large mass contained in this structure, the time required to raise and lower the temperature of the entire tube during the evacuation process was considerably longer than for black and white tubes. This, of course, added to the ultimate cost of such a tube. In addition, the losses due to non-linear expansion and contraction in this subassembly ran very high, adding even further to the cost.

Other factors contributing to the high cost in the earlier flat mask type of color tube were such items as an internal decorative mask and the use of an additional glass panel used to seal the open end of the tube and serving as a window through which to view the phosphor screen mounted inside the tube. Both of these items are eliminated in the *CBS*-Colortron.

In order to achieve a significant reduction in the cost of preparing the phosphor screen, a new method of printing the dots had to be developed. The method used in the earlier color tubes was a silk screen process. This is a sort of stenciling operation where a silk screen, containing a pattern of holes, is laid over a flat glass plate and the phosphors are forced through it onto the glass by a wiping or squeegeeing motion. The process is essentially a hand operation, requiring a high degree of skill and experience. Since it must be repeated three times on each screen, the possibility of error multiplies rapidly.

A method of depositing the phosphor dots through the use of photographic techniques has been perfected which results in a great improvement in accuracy and which is capable of being performed by automatic equipment, thus effecting a substantial reduction in cost. This photographic technique has certain other advantages that may exceed those of direct cost. Through the use of this technique, it has been possible to eliminate the use of a separate piece of flat glass for supporting the phosphors. They can now be deposited directly onto the faceplate as in the black and white tube. By eliminating the extra glass surfaces of the older flatplate color tube, contrast is improved in the picture because there is less light dispersion and fewer halations caused by room lights, windows, etc. Still another advantage accrues from the placing of the phosphors on the inside of the faceplate. This inside surface is, of necessity, a curved surface so as to be able to serve as an arch and support the weight of the atmosphere pressing in upon the faceplate which would otherwise cause it to collapse.

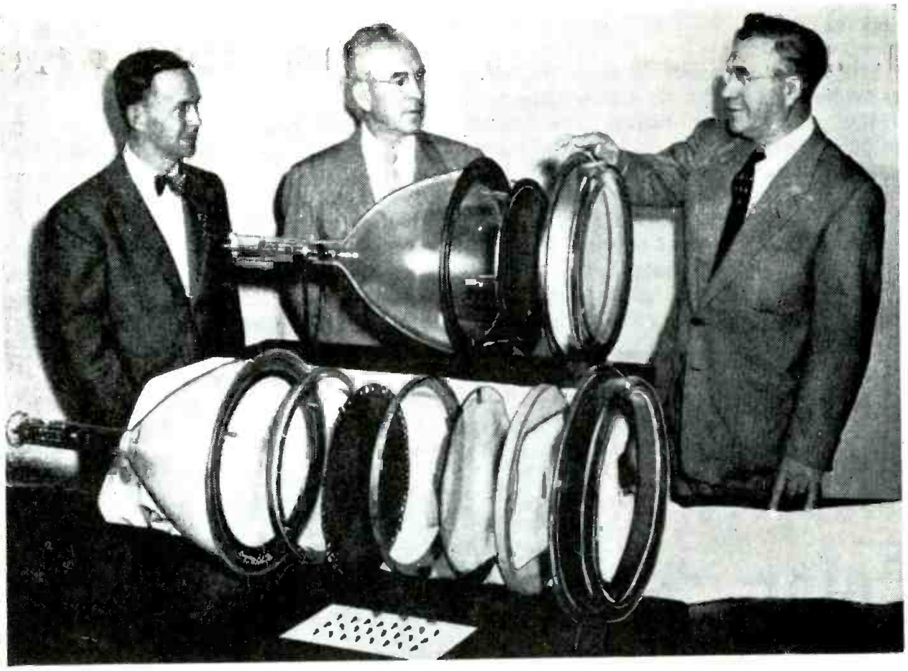


Fig. 2. The CBS-Colortron (top) in "exploded" form to show component parts as compared to the separate components which go to make up another type color tube.

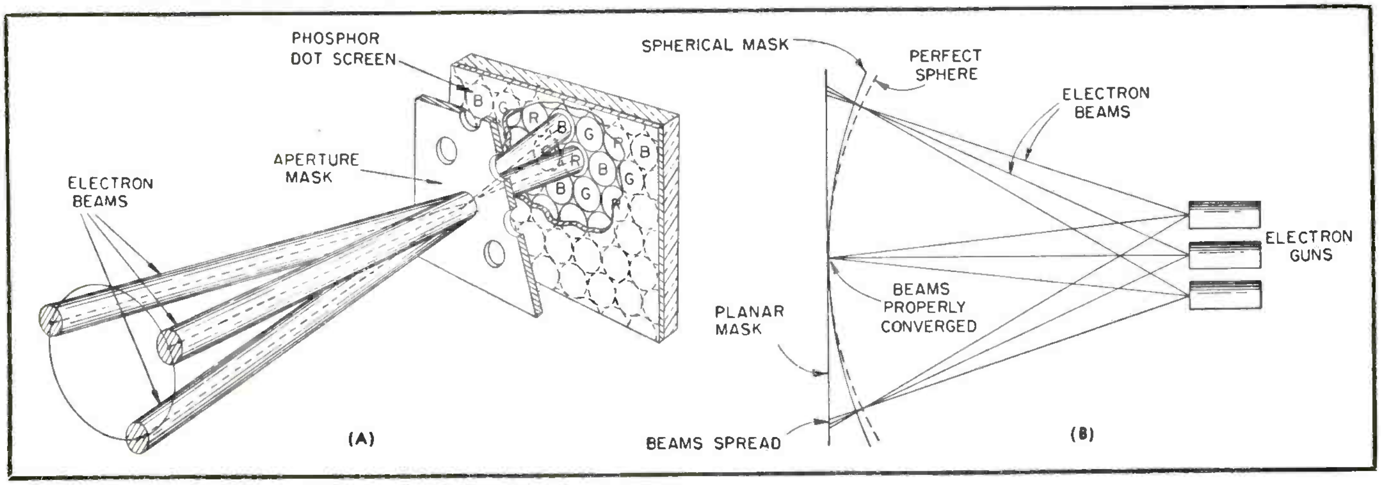
The use of a curved phosphor screen permits the use of a matching, curved mask. This combination of a curved mask and a curved faceplate distinguishes this type of tube from the earlier flat mask and flat phosphor plate tube.

One of the most difficult problems for the circuit designer using the flat mask type of color tube is that of obtaining proper convergence over the entire screen area. Fig. 3B shows diagrammatically why this problem exists.

It can be seen that in the case of a flat mask tube, if the beams are brought to convergence at the center of the screen, they will not be properly converged out near the edges of the picture. This is because the beams describe an arc as they swing back and forth across the mask, and the mask, being flat, fails to coincide with the plane of their point of convergence except at one point. Dynamic means of correcting this condition are required within the color receiver. A parabolic voltage waveform is required to modulate the convergence lens in order to shift the plane of the convergence point back onto the mask near its edges.

It is apparent from Fig. 3B that if the mask were a section of a sphere, the need for this dynamic convergence would be virtually eliminated. Actually, in a practical tube design, the mask and faceplate curvatures do not coincide exactly with the plane of the convergence point of the three beams. However, the correction obtained with even a moderate amount of curvature is considerable, and in the case of the *CBS*-Colortron, it is on the order of six to one over the flat mask type of tube. This means that the requirements placed upon the circuit designer are greatly lessened and the problems of the service technician in maintaining sets in proper working order, once

Fig. 3. (A) Convergence of the three beams at the mask. Note that each beam passes through the hole in the mask at the correct angle to strike its corresponding phosphor dot. (B) Illustrating the need for dynamic convergence to correct for the variation in length from deflection point to the aperture mask as the beams travel from the center to the edge of the mask. Note that the use of a spherical mask reduces the amount of correction required.



they have been in the field, are likewise reduced.

The aperture mask is stamped into an arched-shape and six spring clips are welded around the edges. The studs holding three of the spring clips have small v-shaped surfaces on their heads which are designed to fit over three mating domes, or hemispheres, on the inside of the faceplate beyond the picture area. These hemispheres, which are molded into the glass, precisely locate the mask in relation to the screen. The six springs are clipped over the inside lip of the metal flange which is used to attach the faceplate panel to the funnel. These clips provide a small amount of forward thrust to keep the mask pressing down on the mounting hemispheres. There is no other assembly operation to be performed except to bring the faceplate panel and the funnel together and weld their flanges around the edges. The simplicity of this method of assembly is apparent.

In summary, the *CBS*-Colortron appears to be the first such color tube ideally designed for mass production on largely existing manufacturing facilities. It eliminates several components found in earlier models and achieves an improvement in contrast, as well as a simplification of circuit requirements, adjustment time, and a reduction in the amount of really serious field service problems that would be the result of drifting of convergence circuits. —30—

New G-E Color Picture Tube

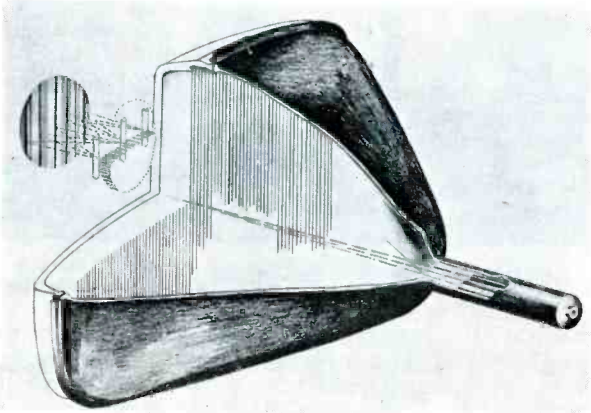


Fig. 1. Shown here is a drawing of the G-E post acceleration P.O.F. color TV tube, still in the development stage.

Using a grille instead of a shadow mask, and vertical phosphor stripes instead of dots, yields high brightness.

A COLOR TV picture tube that gives many times more brightness than the tubes in color sets now on the market was recently demonstrated by the *General Electric* Tube Department. Developmental models of this tube were demonstrated in various degrees of room lighting and produced a bright picture in light comparable to a brightly lighted store.

The new tube, which may not be ready for the production lines until 1957, has a 22-inch rectangular face and uses three guns. However, it is of the post acceleration type, meaning that the electron beams directed at the phosphor screen inside the face of the tube are accelerated after passing through a grille located in close proximity to the phosphor screen. The screen itself consists of *vertical* color phosphor stripes rather than color phosphor dots.

Fig. 2. Detail drawing showing how the electron beams enter the grille of the G-E tube and are deflected to the screen.

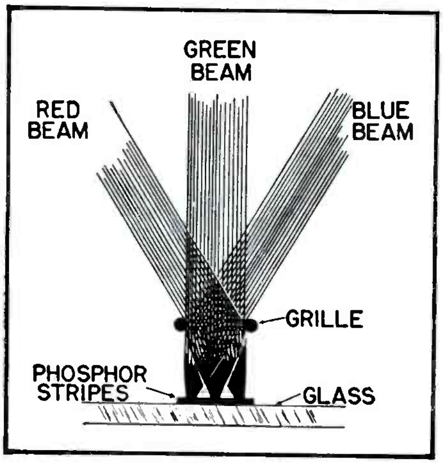


Fig. 1 is a drawing of the *G-E* tube, which is known as the P.O.F. tube (phosphor on the envelope face). Considering first the neck end, three electrostatic guns are shown lying in a plane instead of in a triangular array as in the shadow-mask tube. This type of gun structure allows each gun to be more or less independent of the other two insofar as convergence adjustments are concerned.

On the other end of the tube is the grille (or color selective electrode), which consists of a parallel array of wires fastened to the envelope itself. In front of this is the tube envelope surface on which the red, green, and blue vertical phosphor stripes are printed. In normal operation, the final gun electrode and cone potential are held at about 6½ kilovolts, and the grille is held at a potential of about 200 volts less. The phosphor screen is run at approximately 25 kilovolts.

Fig. 2 shows in simplified terms the operation of the front end of the tube. The electron beams are shown entering the grille with a relatively large angular separation. Actually the angular separation is less than 1 degree. As the electron beam from one of the guns enters the grille region two effects occur; first, the central ray of this beam no longer travels in a straight line, but instead assumes a parabolic path exactly as occurs when one throws a ball which is then acted upon by the earth's gravitational field. In this case the strong electrostatic field between the screen and the grille accelerates the electrons to the high screen potential.

A second action which occurs as the beam enters the grille region is focusing. With properly applied potentials, each pair of grille wires forms an electron optical cylindrical lens which reduces the size of the beam in the horizontal dimension from its initial diameter of about 35 mils to only 5 mils. This makes the beam width small in comparison with the phosphor stripe width, and allows a guard band to form on either side of the beam landing area. Thus, the beam can move about on a particular stripe without striking an adjacent stripe allowing for good color purity.

One strict requirement of this tube is that the ratio of screen-to-grille voltage must be regulated since the electron trajectories between grille and screen and also the properties of the cylindrical lenses are dependent on this ratio.

As claimed by engineers at *G-E,* the advantages of this tube over the shadow-mask type are that the P.O.F. tube yields higher brightness and uses less deflection power, simplified convergence circuitry, and simplified components on the neck of the tube. The higher brightness results from the fact that, because of the grille-type structure of the color selective electrode, 90 per-cent or more of the electrons ejected from the guns strike the phosphor screen in contrast to about 14 per-cent for the shadow-mask type tube. Less power is used because the beam is operated at a voltage of 6½ kilovolts versus the 27 kilovolts used in the shadow-mask type tube.

Because of the increased brightness of the P.O.F. tube, color selective safety glass can be used resulting in more saturated colors and better contrast in an illuminated room. —30—

A New Single-Gun Color Tube

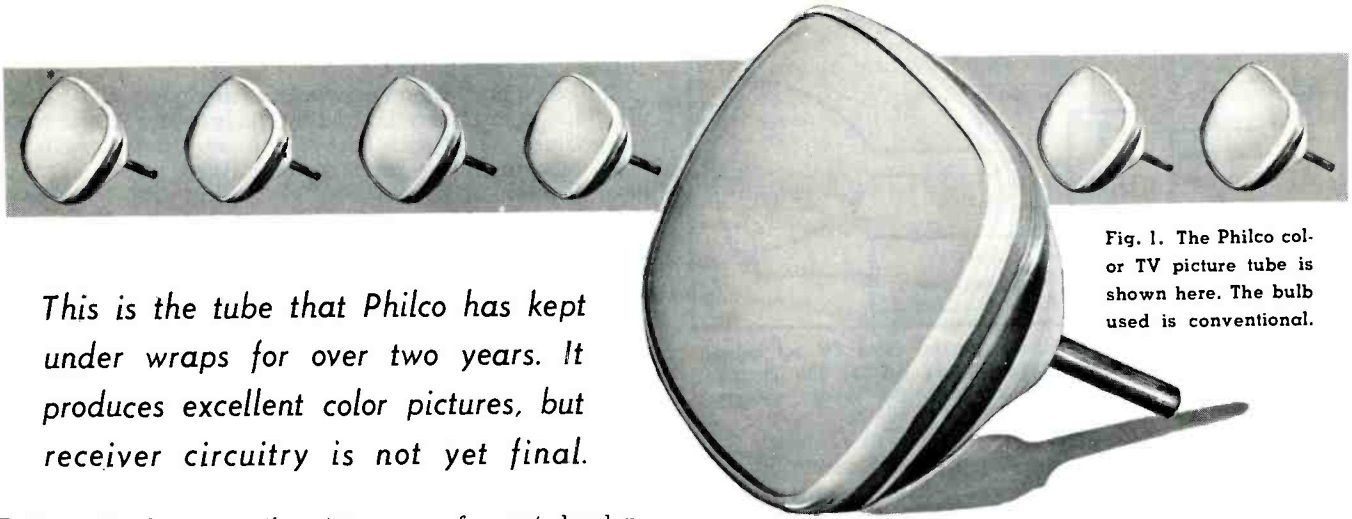


Fig. 1. The Philco color TV picture tube is shown here. The bulb used is conventional.

This is the tube that Philco has kept under wraps for over two years. It produces excellent color pictures, but receiver circuitry is not yet final.

FINALLY, after more than two years of secret development, the *Philco Corporation* has divulged the principles of operation and the extent of development already accomplished on its "Apple" color TV system. At the same time, the company released information on the single-gun color tube it developed to go with this color TV system. The word "Apple" has been used by *Philco* as a code name for this system, which has been one of the best kept secrets in the electronics industry.

Basically, the tube uses a single electron gun to excite the vertical color phosphor stripes on the face plate. Instead of directing the beam to a particular color stripe in a regular switching and deflecting sequence, as the *Lawrence* single-gun tube does, the "Apple" tube allows the beam to sweep across the face of the tube as in monochrome practice but the modulating information to the beam is switched according to the position of the beam. In other words, as the beam passes over a red stripe the red signal is passed to the gun. The same holds true for blue and green. Such a principle requires an indexing system to provide information concerning the whereabouts of the writing beam and a modulating system to provide the required beam modulation.

The "Apple" color picture tube, shown in Fig. 1, may be generally described as an all-glass 21" rectangular picture tube providing 260 square inches of useful screen area, having a diagonal deflection angle of 74°, and using magnetic focusing and deflection. The color television display system described here requires a picture tube that must satisfy certain specific and unusual requirements. These are:

1. Small spot size
2. Two electron beams that "track" each other and have a minimum of "crosstalk"
3. A screen consisting of a repeating pattern of vertical red, blue, and green luminescing phosphors arranged in lines in a precisely described fashion on the face of the tube
4. A secondary emission index-producing structure as an integral part of the screen

The two fundamental parts of the "Apple" system are "sequential writing" and "electrical index." The expression "sequential writing" means that the beam passes successively over triplets of fine vertical red, green, and blue stripes, as shown in Fig. 2. A particular color is produced by modulating the beam during the time it is passing over each triplet according to the proportions of primaries in the desired color.

The expression "electrical index" refers to a signal derived from the anode of the "Apple" tube itself that continuously gives information on the location of the beam. The beam current responds to two types of instructions: the color video signal from the transmitter and the index signal.

The index signal is obtained from the tube by means of the structure shown in the insert in Fig. 2. A line, called the index stripe, of a material having high secondary emission compared to the aluminized background of the tube face, is placed behind every red line. A second beam, the "pilot" beam, parallel to the writing beam, is produced

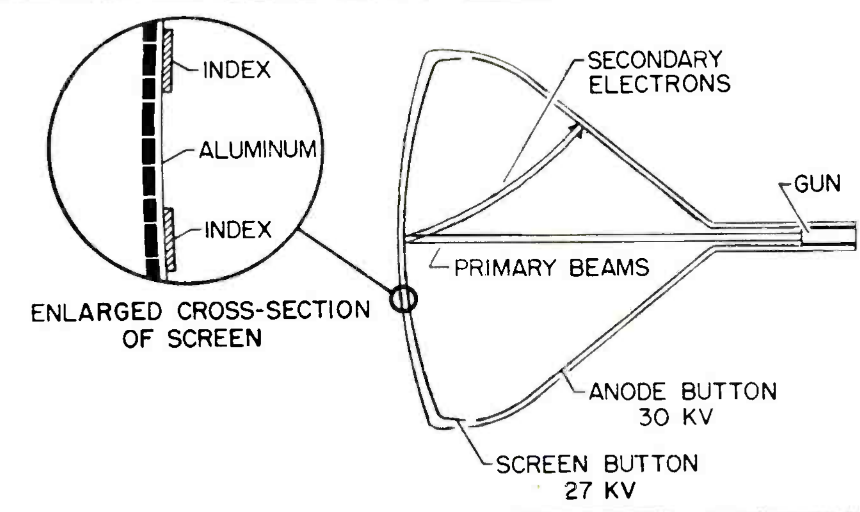
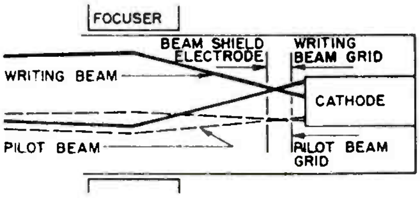


Fig. 2. Top cross-sectional view of the "Apple" color TV tube showing the path of the electron beam from the gun, and the path of the secondary electrons which are knocked off the screen and collected.

Fig. 3. Method of producing two electron beams in a single electron gun. Note the co-planar grids, one for each beam. Both beams, one for writing the picture on the screen and the other for indexing, must track perfectly if the system is to work.



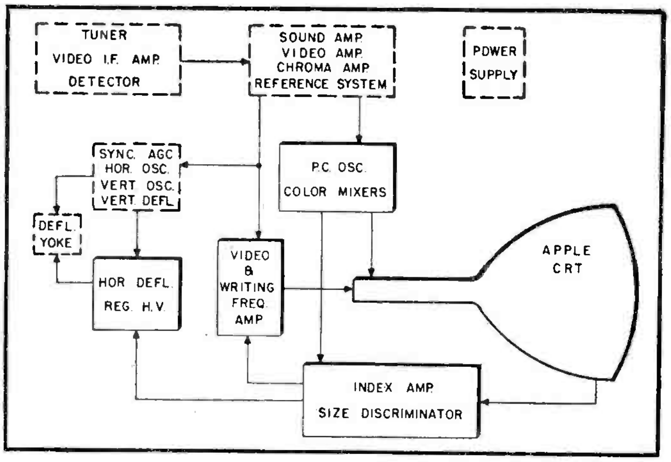


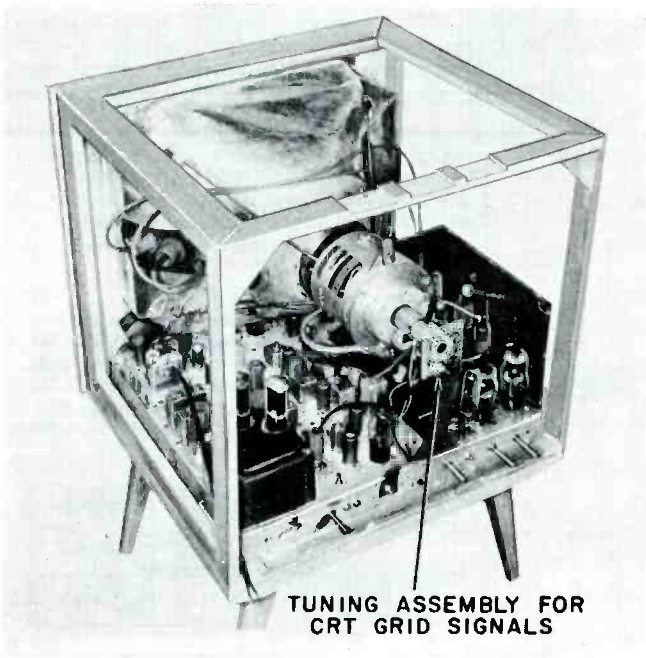
Fig. 4. Block diagram of developmental color TV set using single-gun color tube described in this article. The circuits enclosed in the solid boxes are peculiar to the "Apple" system.

at the gun and sweeps the index stripes in company with the writing beam. The secondary emission current produced as the "pilot" beam crosses these index stripes is collected and amplified, resulting finally in a signal at the same frequency as that at which the writing beam must be varied to produce colors.

The "pilot" beam is so aligned that it always strikes the same color line as the picture writing beam. However, the beams must be kept separate to avoid intermodulation between the "pilot" carrier and writing frequency signal.

The luminescent screen or anode of the "Apple" tube consists of a repeating array of red, blue, and green vertical stripes as mentioned previously. The stripes are not contiguous but have a 50% duty cycle; that is, the spaces between the lines are as wide as the phosphor lines themselves. The spaces between the lines are filled in with guard bands made of a dark-colored, non-luminescent material which improves color saturation and enhances contrast under normal ambient light by reducing the reflectivity of the screen. Correct white balance is built into the screen of the "Apple" tube by adjusting the relative efficiencies of the blue and green phosphors through the addition of varying amounts of non-activated material so that scanning of the screen with a constant, unmodulated beam produces white.

Fig. 5. Inside view of Philco developmental color TV receiver based upon beam-indexing principle and using "Apple" tube.



Among the important advantages of the "Apple" tube is its similarity to a black-and-white tube. In fact, in the absence of a chrominance signal, it cannot help making a good black-and-white picture. None of the writing beam in the "Apple" tube is intercepted nor deflected in such a way as to waste any high voltage power, and there is no problem of matching the characteristics of three guns to obtain good colorimetry.

The color saturation obtainable at any particular brightness level is obviously limited by the spot size at the beam current associated with that brightness. If the spot is too large to land on one primary color stripe at a time, then de-saturation of primary colors occurs. This consideration, plus that of reasonable structural resolution, made the development of an electron gun producing a spot substantially smaller than usual in a monochrome tube, a prime necessity for this beam-indexing tube.

A combination of a small, countersunk aperture and close cathode-to-grid spacing is primarily responsible for obtaining a greatly reduced spot size.

A second requirement is that the two beams "track" each other. Since one beam is used to tell where the other beam is, the relative position of the beams must be known at all times. The two beams are formed close together by using a single cathode, and two separate, co-planer, control grids, each with its aperture close to the end of the grid, these ends being separated by .002 inch. The center-to-center separation of the two beams at the grid plane is only .029 inch. See Fig. 3. This setup assures good "tracking," since both beams are so close together that they will be acted upon in exactly the same amount by deflecting fields, etc.

The third special requirement of this beam-indexing tube arises from the need for preventing the control voltage of one beam from affecting the intensity or position of the other beam. This is satisfied by using a simple shield between the two beams in the region just above the grid apertures. This shield, shown in Fig. 3, effectively eliminates beam "crosstalk" as a limitation on the functioning of the system.

The final unique feature of the *Philco* beam-indexing color tube is the index structure which provides the required continuous monitoring signal. This signal is generated by the difference in secondary emission between an array of magnesium oxide stripes applied to the gun side of the aluminized screen and the bare aluminum between these stripes. There are two contact buttons on one side of the tube envelope (see Fig. 5), and one of these is connected to the screen aluminum coating, making it possible to maintain the screen potential at approximately 27 kilovolts. The second contact button connects to the bulb coating which is maintained at 30 kilovolts. The three kilovolt differential between screen and bulb coating results in the collection of the secondary electrons from the screen by the bulb coating.

To obtain the indexing signal, an external band of a conductive coating encircles the screen viewing area to form a coupling to the screen aluminum film. A metal mounting band is strapped over this coating and is used to support the tube and yoke-focuser cup in a manner similar to monochrome receiver practice. The mounting feet, which support the assembly in the cabinet, are insulated from the metal mounting band but are grounded to the foil shield. The circuit elements formed by the band, the aluminized screen to which it is coupled, and ground, are tuned to resonance at the index sideband frequency. Index signal take-off is accomplished by a coaxial lead connected to the mounting band. To shield the index circuit from external interference, an aluminum foil shield is folded to cover the rim of the CRT. The tube and circuitry do not appear sufficiently sensitive to magnetic fields to require any magnetic shielding or compensation for earth field effects.

Fig. 4 is a block diagram of the circuitry of the receiver shown in Fig. 5. This is one version of a complete "Apple" receiver. The circuits shown in the light dashed lines follow conventional color receiver practice and the "Apple" receiver imposes no special requirements here. The remainder of the receiver outlined in heavy solid lines is shown in four separate sections: the index amplifier, the "pilot" carrier oscillator and color mixers, the writing frequency amplifier, and the horizontal sweep and high voltage.

The horizontal sweep-high-voltage section is similar to monochrome practice. Some details include the use of a pair of 6CD6 tubes for horizontal drive, and a special high-perveance diode, the L-1379, as the damper. The 30 kilovolt supply is obtained by a voltage doubler using 1B3's.

To aid in maintaining horizontal sweep linearity with changes in line voltage, and to maintain a nearly constant picture height, it appears advantageous to derive the plate supply voltage for the horizontal and vertical oscillators from the regulated energy in the horizontal system.

Vertical dynamic focus only is used in this receiver; for this, a vertical frequency parabola is applied to a focus control tube. The high-voltage supply must have two regulated outputs in order to maintain optimum focus, horizontal sweep operation, and index. This has been accomplished by use of two all-glass gas regulators.

The mixer unit consists of two tubes whose triode sections accomplish nearly all the color signal processing required by the receiver. The functions of this section are to generate an unmodulated "pilot" frequency carrier, and to transfer the chrominance modulation to a second "pilot" frequency carrier. The latter signal is mixed with the amplified index information derived from the CRT to form a chrominance-modulated writing signal which includes the positional information of the index signal.

The chassis shown in Fig. 5 contains the complete receiver including the power supply. This receiver, as a developmental type, does not use an excess of dual-section tubes, yet its complement is only eight tubes more than a shadow-mask receiver containing the same non-display circuitry. In the foreseeable future this differential may be not more than five tubes. Against this disadvantage are the potential advantages of an electron optical system requiring only two alignment adjustments and a cathode-ray tube completely free from static and dynamic white balance, and magnetic field problems. -30-

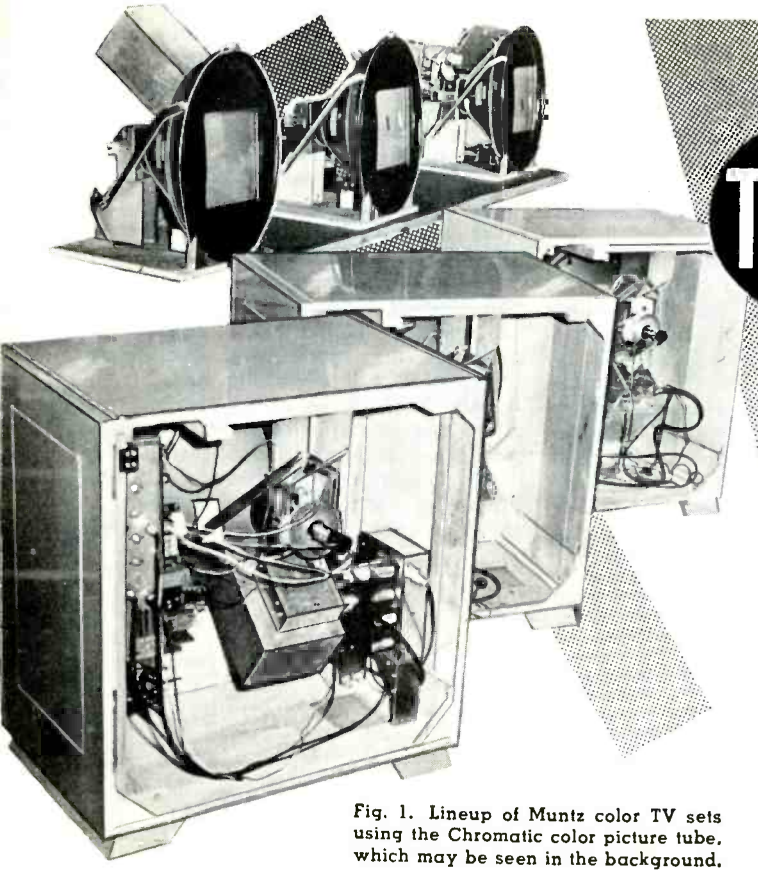


Fig. 1. Lineup of Muntz color TV sets using the Chromatic color picture tube, which may be seen in the background.

THE CHROMATIC

By **WALTER H. BUCHSBAUM**

Television Consultant

RADIO & TELEVISION NEWS

Report on the construction, operation, and progress of the "Chromatron," a single-gun picture tube for color TV

WITH the inauguration of color TV receiver manufacturing, the problem of color picture tubes is again receiving much attention. Other articles in this collection describe in detail the tri-color tube both as developed by *RCA* and as simplified by *CBS-Hytron*. Now it is possible to give some of the details concerning another type of color picture tube. This latter type, based on the ideas of Dr. E. O. Lawrence of the University of California, was publicized as being a "simple" and inexpensive rival of the *RCA* tri-color tube. The actual development work on the tube and associated circuits was taken over by *Chromatic Television Laboratories, Inc.*, a subsidiary of *Paramount Inc.* The tube described here is not necessarily the final design. Further improvements and changes are currently under development.

The current model of this color picture tube has been named the "Chromatron" and a complete 22-inch unit is shown in Fig. 1. The neck and flared portion of the tube are essentially the same as for other metal envelope picture tubes, but the cone is made in two parts to permit separate assembly of the color screen. Although the "Chromatron" is a round picture tube, the color structure is rectangular and occupies less than the full screen space. Picture width of the tube shown is 16 inches; the remaining screen space is taken up by the frame and mounting flanges required for the color structure. Fig. 2 shows the color structure in its frame before being assembled into the complete "Chromatron." In the manner of assembly this is very similar to the *RCA* tri-color tube which also contains a separate color structure, frame, and flanges. While the *RCA* system employs three electron guns, the "Chromatron" uses only a single gun, but it would be possible to use three guns.

The deflection components used for the "Chromatron" are essentially the same as used for black-and-white picture tubes. This is a considerable advantage over the *RCA* design which requires complex deflection yokes, a purity coil, and convergence and centering adjustments. The simplification at the neck of the tube is possible in the "Chromatron" because the complete color switching section is part of the color screen structure.

EDITOR'S NOTE: *Although, to date, most manufacturers of color TV receivers have designed their color TV sets for use with the 3-gun color tube, as produced by RCA, CBS-Hytron, and others, a large segment of the industry is investigating the possibility of using a single-gun tube such as described in this article. This tube is based upon the invention of Dr. E. O. Lawrence, and the development work of the Chromatic Television Laboratories. Engineers, manufacturers, and all others concerned in the color television industry are divided on which type of tube will predominate in the future. Each has its advantages and disadvantages.*

Which tube will be more popular? This depends upon which tube will result in a more simplified circuit, lower over-all set production cost, lower picture tube cost, and which tube will give the better picture. Although there is no reason why both the 3-gun tube and the single-gun tube cannot live side-by-side, in the final analysis, the public will decide as to which will be more popular.

The *RCA* tri-color tube has a screen consisting of small dots of colored phosphors each of which lights up either in red, green, or blue. These color dots are arranged in the correct sequence and the colored picture is the composite of the amount of light coming from a large number of dots.

The "Chromatron" uses lines of colored phosphor instead of dots and a special wire screen behind the phosphor strips makes the electron beam dance back and forth between the color strips to produce, effectively, a series of color dots. Fig. 4 shows the principle of the "Chromatron" color structure. A number of vertical strips are laid out, each containing a colored phosphor. The color sequence is arranged so that a green strip falls between each red and blue one. Behind the phosphor is a fine wire grid, so spaced that an electron beam passing between two wires will hit the green phosphor if there is no voltage between the wires.

The phosphor screen is aluminum backed, just as in some types of black-and-white picture tubes, and the aluminum backing is connected to a terminal outside the tube. If a voltage is applied between the two wire grids and the aluminum backing, a series of electron lenses will be set up between the wires and the screen. These lenses help to focus the electron beam so that a sharp spot is obtained on the screen. Although the focusing produced by these lenses is not as effective as the focusing coil or electrostatic focus element back in the electron gun, this "post deflection focus" (PDF) system has a considerable effect on the size of the spot. Because the acceleration of the electrons in the beam is so high near the screen, the focusing potential required is much greater than at the electron gun.

COLOR PICTURE TUBE

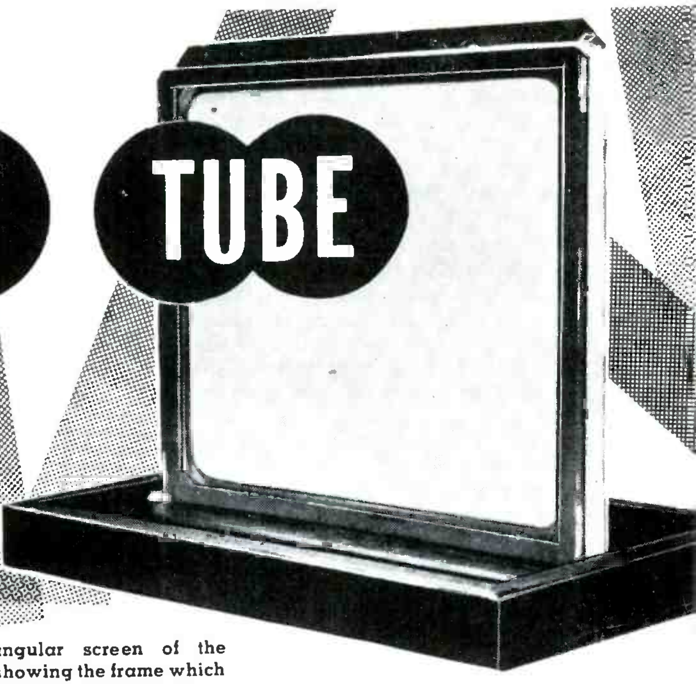


Fig. 2. Rectangular screen of the "Chromatron" showing the frame which holds the color grid wires in place.

In addition to the focusing potential, another voltage can be applied between the set of wires located behind the red and the blue phosphor strips. Depending on the polarity and magnitude of this voltage, the electron beam will be deflected from striking the green strips and hit the red or blue strips.

The color of the spot is therefore determined by the instantaneous voltage between the two sets of wire grids, while the size of the spot is determined by the d.c. voltage between the aluminum backing and the electrical center of the two wire grids. This is similar to the application of centering voltage in an electrostatic deflection cathode-ray tube. In the simplified sketch of Fig. 5, the condition is illustrated where the electron beam hits a green strip because no potential exists between the red and blue wire grids. If a positive voltage is applied to the red wire grid, for example, the electron beam would be deflected slightly more to the left and hit a red phosphor strip.

In addition to the deflecting action of the two wire grids, the electron beam is also moved by the vertical and horizontal deflection coils located around the neck of the tube. It should be understood that the action of the two wire grids is on the order of a minute jiggling motion, superimposed on the horizontal and vertical sweep movement of the electron beam. The colored phosphor strips, the wires, and the spacing between the wires are all so small that from the standard viewing distance individual colors are not discernible.

For operation under the NTSC standards for all electronic color TV, the color switching rate for the wire grids is 3.58 mc., the frequency of the color subcarrier. Rigid standards are needed to maintain the phase relationship between the three color components since it is this relationship which delivers the color or chromaticity information.

To switch at this rate raises some problems when we consider that the wire grids contain considerable capacity and require quite some power to move the electron beam sufficiently. The d.c. voltage on the wires for focusing is on the order of 5000 volts and the a.c. switching signal must, accordingly, be strong, usually about 500 volts. In one practical demonstration the driving power was about 25 watts. To increase the efficiency of the system somewhat an external inductance was used to resonate the approximately 1200 $\mu\mu$fd. capacity due to the wire grids.

The problem of driving the wire grids, however, is being solved by new driving methods and a modification in the design of the "Chromatron." One approach is to move the grid wires further away from the screen and, thus, reduce the capacity. This would help to reduce the required driving power considerably. In addition to the switching circuits it is also necessary to key the cathode or control grid of the electron gun so that only the red picture information or brightness level exists during the instant that the electron beam hits the red phosphor, and so on for the other colors. To accomplish this, the output of the three video amplifiers are switched, each delivering its signal, in turn, to the picture tube.

A block diagram of the circuitry needed to utilize the "Chromatron" with the NTSC color TV system is

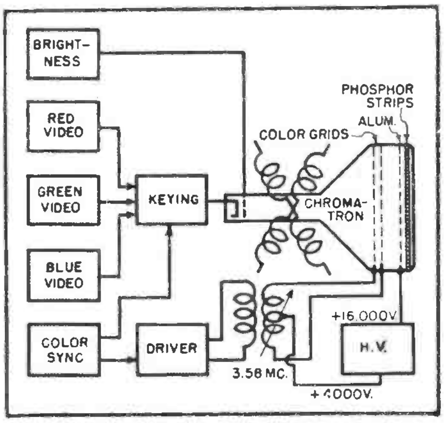


Fig. 3. Simplified block diagram of the circuits required with the "Chromatron."

Fig. 4. Representation of the "Chromatron" phosphor screen showing the grid arrangement behind the color strips.

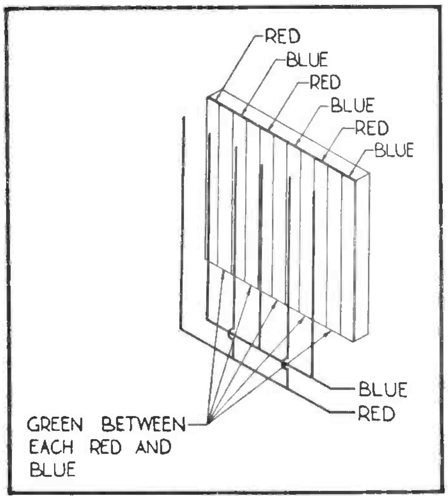
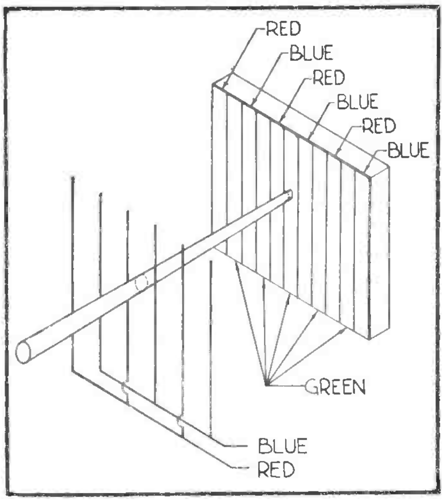


Fig. 5. Electron beam excites green phosphor strip when no deflecting voltage is fed to the blue and red grid wires.



shown in Fig. 3. The four video sections, containing the brightness and the three color signals, are required for the NTSC color system since the fine picture detail is transmitted on the brightness signal, and for color information each requires a separate amplifier. For the color signals, the amplifiers are relatively narrow-band stages, but for the brightness signal a 3.5 to 4 mc. bandwidth is desirable. Not shown in Fig. 3 is the synchronous detector which supplies the brightness and color signals. Also omitted are the vertical and horizontal deflection circuits.

The keying section is required to switch the output of each of the three color stages onto the single electron gun. In the *RCA* tri-color picture tube this is not necessary since each color channel is connected to one of the three electron guns. The tri-color tube is essentially a simultaneous device, while the "Chromatron" breaks the simultaneous NTSC system into a dot-sequential picture.

The operation of the color grids and their associated circuits is shown in some detail in Fig. 3. In order to maintain the d.c. focus potential between the two color grids and the aluminized phosphor backing, a center-tapped coil is required to make this potential equal at both grids. In Fig. 3, it is assumed that the secondary of the output transformer is resonated with the color grid capacity and properly matched to the primary for maximum transfer.

The driver stage can be a power amplifier driven by a voltage amplifier which, in turn, is driven by the color synchronizing oscillator. This 3.58 mc. oscillator is controlled by means of a keyed a.f.c. system from the color synchronizing burst transmitted after each horizontal synchronizing pulse in the composite color signal. In order to obtain true color rendition it is absolutely essential that the frequency remain constant and no phase shift or distortion be introduced.

The high voltage section of the "Chromatron" is somewhat different than for the *RCA* tri-color picture tube. Good regulation of the anode voltage is not required for the "Chromatron" whereas it is for the tri-color tube.

At the time of writing, several demonstrations of the "Chromatron" have been given. When demonstrated with the NTSC color TV system the "Chromatron" itself appears fairly good. The pictures on one of the tubes appeared to have considerable red streaking which apparently was due to the red phosphor's long persistence. This feature can be remedied by using a different red phosphor. At a viewing distance of about 10 feet, the individual lines are not visible and the viewer sees only the complete color picture.

One interesting aspect of the line structure is the fact that the lines and the grid wires behind them can be oriented either vertically or horizontally and both types of tubes have been tested. It was found that when the colored phosphor lines are in the same direction as the horizontal scanning lines the color moire pattern is much less visible at closer viewing distances. The actual width of the color phosphor lines has not been definitely set, but tubes with strips as narrow as 0.010 inch (10 mils) have been built. When these strips are applied horizontally, the resulting line structure is fine enough to enable the viewer at ordinary distances to see the complete color picture exclusively.

Chromatic Television Laboratories and some other tube manufacturers are developing improved tubes. Some of the planned improvements include much narrower phosphor strips, permitting a greater number of strips and therefore better resolution. Color grids will be made of finer wire and a better set of colored phosphors is under consideration. The problem of the persistence of the phosphors can be solved when a color combination is found which produces the correct primary colors and has equal brightness and persistence under the same accelerating potential. In the sample tubes demonstrated so far, the correct phosphor combination was lacking, but some fairly good pictures were observed with a compromise arrangement of phosphors.

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RECEIVING TUBES FOR COLOR TV

By
WALTER H. BUCHSBAUM
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RADIO & TELEVISION NEWS

Fig. 1. Some of the new tubes used in color TV sets. These tubes either perform new jobs or handle greater voltages and currents than heretofore found in TV sets. The unlabeled tube on the left is a 6BJ7.

Color TV circuits require new types of receiving tubes; the ones described here will be found in many color sets.

JUST as the advent of monochrome TV brought a host of new, special TV receiving tubes, the approaching production of color TV receivers is heralded by a rash of new and specialized receiving-type tubes. As might be expected, these new tubes either perform functions not previously found in television receivers, or else they are designed to provide simplified and more economical circuitry.

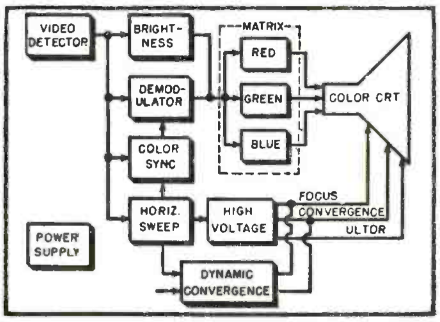
Before describing each of the new tubes, a short discussion on their various functions is in order. The color TV receiver differs from its monochrome counterpart mainly in the video, synchronizing, and sweep sections. Higher voltages and greater power are also needed. Fig. 2 shows in block diagram form the various sections peculiar to a color receiver. Functionally, the color demodulator, matrix, color sync, and dynamic convergence sections are completely different from monochrome circuitry. The demodulator section removes the color information from the color subcarrier and usually employs synchronous detectors or some other phase-sensitive circuit. In the color sync section, the 3.58-mc. color subcarrier burst is converted into a continuous sine wave of the same frequency. This calls for gating, a.f.c., and phase detector circuitry. Dynamic convergence presents less of a problem since this section merely shapes and amplifies portions of the horizontal and vertical sweep. While the matrix circuits are not found in monochrome receivers, their function is simply to add the luminance and color information signals so as to obtain the blue, green, and red signals for the CRT. Included in the matrix section are the three color video amplifiers which are of standard design but, generally, use multiple-element tubes such as pentode-triode combinations or triple diodes (for d.c. restorers).

The horizontal sweep section is included here mostly for its relation to other sections, but basically the same type of circuitry is found here as in monochrome receivers. Improved linearity and greater high voltage require new tubes and components in the flyback and high-voltage section. As we shall see, a number of new tubes were developed for this last section. Some tubes used in monochrome receivers have been improved for greater power capacity or simpler construction and have received new numbers.

Starting with the power supply, *G-E* has announced the 5AU4 which is a considerably fortified cousin of the old familiar 5U4 rectifier. The new tube is also an octal type, and its major feature is greatly improved current carrying capacity, resulting in fewer paralleled "B+" rectifier tubes.

For the demodulator section, the first color TV receivers used a 6AS6, which is a pentode in which the suppressor grid has almost as much control as the control grid. Since this is a somewhat special and expensive tube, several new and different gating tubes have been announced. *G-E* is promoting the 6AR8, a sheet-beam type tube which is used as a synchronous detector to remove the *I* and *Q* signals from the 3.58-mc. color subcarrier. The 6AR8 functions on the same principle as the 6BN6, used as an FM detector in some black-and-white TV receivers. *RCA* has come out with a pentagrid amplifier which can be used as a synchronous detector, the 6BY6. A less expensive version of the older 6AS6 is the newly announced 6DB6 which *CBS-Hytron* expects to put on the market. All three tubes are of the miniature 7-pin type. The color sync section of some late model receivers may be using one or the other of these three new tubes but, in general, the tubes found in this section will be double diodes and double triodes. Some recent new TV tubes like the 6X8 and the earlier 6U8, both containing a triode and a pentode in a single envelope, will appear frequently in the color sync section.

Fig. 2. Partial block diagram of a color TV receiver showing the sections that require new receiving tube types.



A real innovation resulted from the need for three identical d.c. restorers in the color set. The tube required is a 9-pin miniature containing three separate diodes. *G-E* and *CBS-Hytron* are both promoting their type 6BJ7 triple diode (see Fig. 1) which consists of three identical balanced diodes, each with the same characteristics as a single 6AL5 section. *RCA* is featuring another tube, the 6BC7, which is quite similar except that the degree of balance between diode sections is less stringent. In actual receivers both tubes will be found in essentially the same circuits and are practically interchangeable.

Another tube that will find considerable application in the color video section is the *RCA* type 6AN8 which is a 9-pin miniature containing a medium-mu triode and sharp cut-off pentode in a single envelope. This tube is similar to the previously mentioned 6X8 and may also be found in other receiver sections.

The most radical tube innovations are to be found in the high-voltage section. Since all shadow-mask tubes require at least 20 kv., regulated and with considerable current, new tubes were needed for rectification, regulation, and damping. The new 19-inch color picture tubes use 27 kv. and require at least 1 ma. of current from the high-voltage section. There are presently three new high-voltage rectifiers, all of which will be used in the latest color TV sets. *RCA* has announced that it will make the 3A2 and the 3A3, both similar electrically. The 3A2 is a miniature, 9-pin type with a top cap for the anode, while the 3A3 is an octal type with top cap. Both are shown in Fig. 1. *CBS-Hytron* also will produce the 3A3, while *G-E* has announced the type 2V2 which is similar in appearance to the 3A3 but uses only 2 volts instead of 3 volts for the heater. It might be mentioned here that in the most frequently used high-voltage doubler circuits for color TV receivers a third high-voltage diode is used in lieu of a resistance bleeder. This greatly improves regulation and increases over-all efficiency. The tube used for this purpose is usually the same type as the two doubler rectifiers.

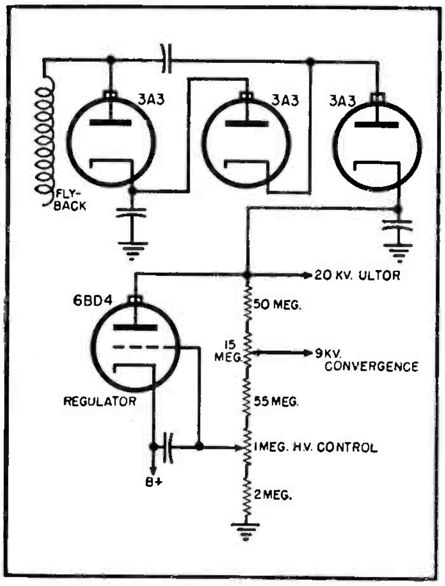


Fig. 3. Partial circuit diagram of a typical regulated high voltage supply for color TV sets. Note the use of a triode (in some cases a pentode) for picture-tube high voltage regulation.

Since the 20 or 27 kv. supply must have excellent regulation, a special tube was designed which performs essentially the same function in the high-voltage section as the shunt voltage-regulator tubes used in electronically regulated d.c. power supplies. Fig. 1 shows the new 6BD4, a special sharp cut-off beam triode which is being offered by *RCA* and *CBS-Hytron*. *G-E* is currently introducing a special pentode, the 6BU5 which is designed for the same application, but uses a pentode circuit for sharp cut-off characteristic.

To provide some idea of the operation of the new high-voltage regulator tube refer to the simplified diagram of Fig. 3, showing a portion of the high-voltage section of a typical color TV receiver. It is interesting to note that the plate of the regulator tube is connected directly to the 20 kv. source while the cathode goes to the "B+" voltage. The regulating action is provided by the change in grid bias due to voltage changes across the bleeder to which the grid is connected. In a typical circuit the plate current will vary from 1 to 0.1 milliampere as the grid voltage varies over about 8 volts. This will change the high voltage by only 300 volts while the load current varies from 0.1 to 1 milliampere. In other words, the regulator tube absorbs the difference to keep the high-voltage supply steady. Ordinarily such a large change in load current would occur when a bright white area on the screen, which requires all three color electron beams, suddenly changes to a completely black area.

By adjusting the setting of the grid voltage on the regulator tube, the tube's operating point, and therefore the actual high voltage at the plate of the regulator, is determined. This adjustment is important in setting up the color picture tube for correct operation. The circuit for the 6BU5 pentode regulator is essentially the same as in Fig. 3, except that the screen grid connection is added.

Since this is still the infancy of color TV we can expect many more new receiving-type tubes to be announced in the near future.

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Magnetic Convergence in Large-Screen Color TV

By **J. JOSEPH HILL**

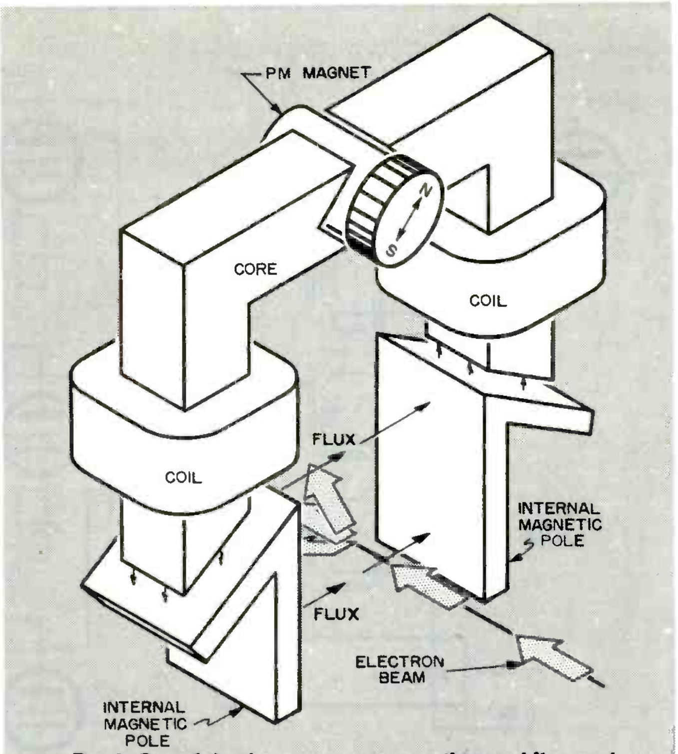


Fig. 1. One of the three convergence coil assemblies used with the large screen, 3-gun color picture tubes. This diagram shows the relation of the external assembly to the magnetic pole pieces in the interior of the tube neck, and its effect on the deflection of the electron beam.

Convergence circuits in large-screen color TV sets are becoming simpler; here is an analysis of three types.

THE basic principles of magnetic convergence have already been adequately covered in previous articles in this color TV collection, this article will be devoted to an analysis and comparison of the leading convergence circuits in use today.

Fig. 1 shows a typical convergence coil assembly such as is used with each gun of a three-gun color TV picture tube. Each assembly consists of small coils wound on a horseshoe shaped core, with a small permanent magnet mounted in "V" cuts on both core halves. Rotating this small magnet varies the polarity and strength of the flux flowing through the core and thereby accomplishes d.c. convergence. This flux passes through the glass neck to the pole pieces within the color kinescope. These pole pieces are positioned at each electron gun so that each beam passes between a pair of poles and is deflected by the magnetic flux of the poles.

In addition to the flux introduced by the permanent magnet, horizontal and vertical signals are introduced into the coils wound on the core and result in a varying flux which deflects the beam in synchronism with the scanning of the raster.

The convergence yoke, shown in Fig. 5, consists of three coil assemblies, spaced to coincide with the pole pieces, and held tightly against the neck of the kinescope by means of coil springs.

In the "*CBS-205*" color TV receiver circuit, shown in Fig. 2, is found a direct approach to convergence. For best dynamic convergence a parabolic waveform is required, as illustrated in Fig. 6. In addition a tilt function is added, which shifts the peak of the parabola for further correction as shown in Fig. 3.

Horizontal pulses from a winding on the flyback transformer, see Fig. 2, are fed to the convergence circuits. A positive pulse is fed to a two-stage saw-tooth generator, which makes available a saw-tooth voltage. This saw-tooth voltage is amplified in the convergence amplifiers causing a *parabolic* current flow through the inductance of the convergence coil L_1, as shown in Fig. 4. In addition, a horizontal tilt pulse is applied to the grid of each convergence amplifier, which causes a *saw-tooth* of current through L_1. 47,000-ohm resistors are used to isolate these various waveforms from each other. By varying the parabola and tilt currents for each gun, horizontal dynamic convergence can be effected over the entire face of the picture tube.

The vertical convergence network of the "*CBS-205*" circuit consists of three separate 100-ohm center-tapped controls connected to the vertical output transformer, and a 560-ohm—25-μfd. network. Because the current through the vertical output transformer flows through the 100-ohm controls, a saw-tooth voltage at the vertical rate appears across them, and is applied to the L_2 coil of each convergence assembly through a 100-μfd. d.c. blocking capacitor and a horizontal frequency choke. Adjustment of the center-tapped controls varies the amplitude and polarity of the vertical saw-tooth current. Because L_2 is designed to be resistive at the vertical frequency, the saw-tooth voltage causes a *saw-tooth* current through L_2.

The 560-ohm—25-μfd. network generates a parabolic waveform because of the vertical signals passing through it. This waveform passes through a 150-μfd. d.c. blocking capacitor, and then a 2500-ohm potentiometer and horizontal frequency choke for each color channel, and is applied to coils L_1. The vertical parabola and tilt controls are adjusted for uniform convergence of the three electron beams throughout the vertical sweep.

Fig. 7 shows the *Motorola* convergence circuit, which is designed to eliminate the need for vacuum tubes and utilizes ringing coils as waveform generators. In the ringing coil convergence circuits, sine-wave voltages are substituted for the parabolic waveforms with little sacrifice of convergence, since the maximum error involved occurs during retrace blanking time, as shown in Fig. 9A, and therefore is not seen in the picture.

The vertical waveforms are derived

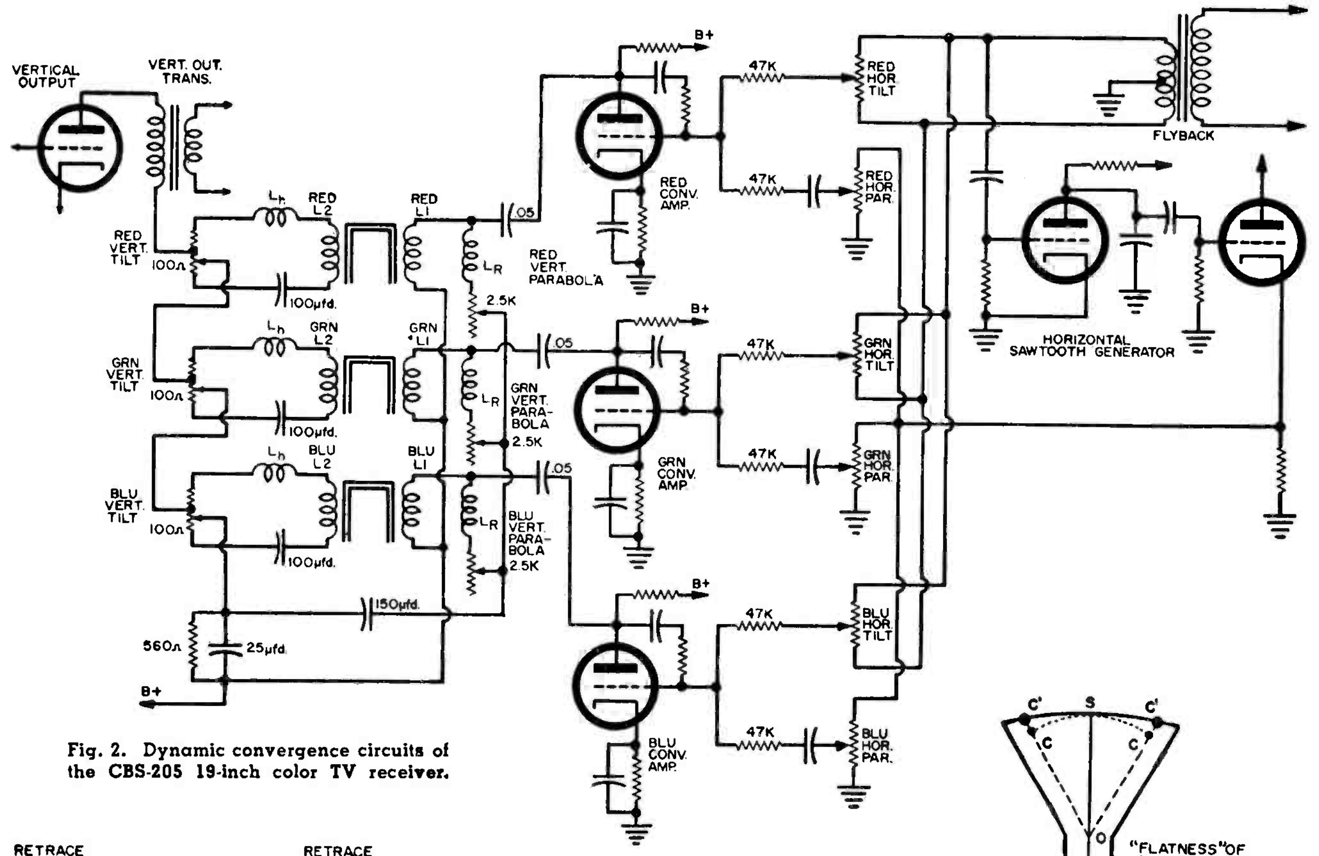


Fig. 2. Dynamic convergence circuits of the CBS-205 19-inch color TV receiver.

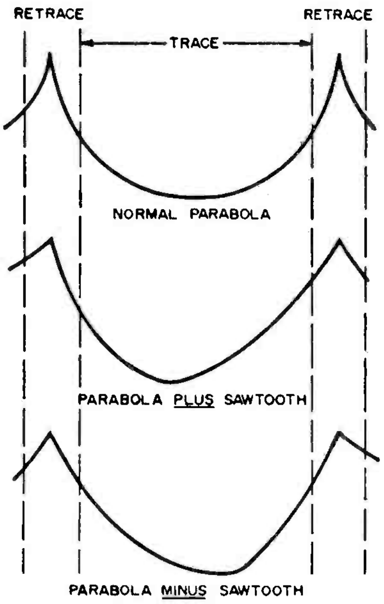


Fig. 3. Adjustment of dynamic convergence is effected by varying the "tilt" of the convergence parabolic waveform by adding or subtracting a sawtooth.

Fig. 4. Current waveforms through an ideal inductance corresponding to two voltage waveforms across it. The current waveform resulting from a sawtooth of voltage is a parabolic type.

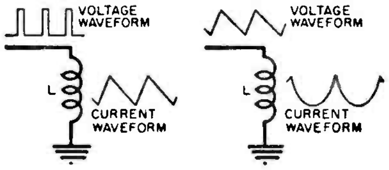
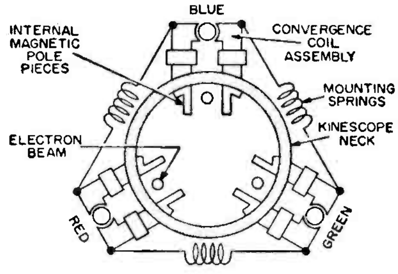


Fig. 5. Typical convergence yoke assembly. The convergence magnets are spaced 120 degrees around the neck of the tube to coincide with internal pole pieces in the neck of the tube.



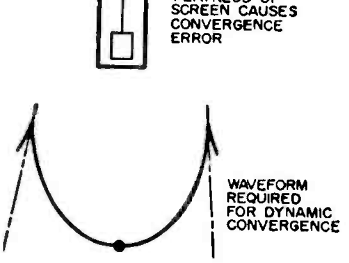
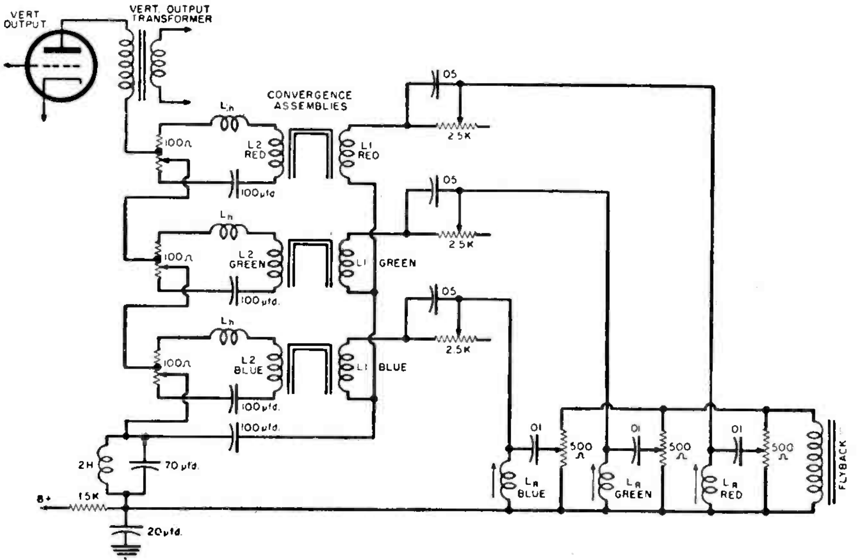


Fig. 6. Dynamic convergence, using a waveform such as illustrated here, varies the convergence of the three electron beams so that they coincide at the center of the tube screen (point S) as well as at the sides (points C').

Fig. 7. Dynamic convergence circuits for the Motorola 19-inch color TV receiver.



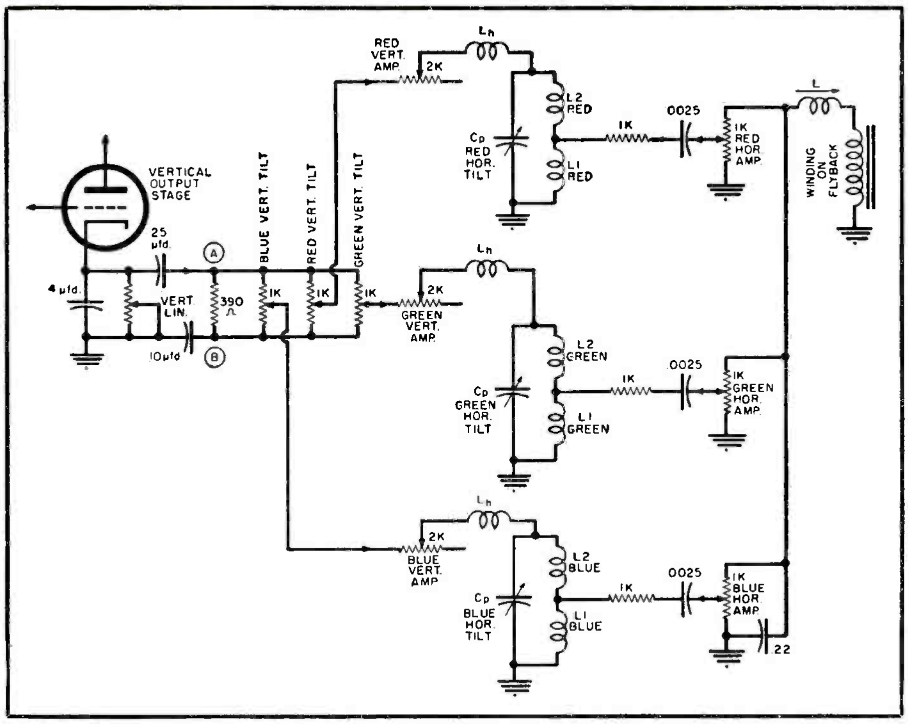


Fig. 8. The new RCA 21-inch color TV set uses the simplified dynamic convergence circuits shown here. Note the saving in vacuum tubes over the circuit of Fig. 2.

much as they were in the *"CBS-205,"* except for the vertical parabola generator, which consists of a 2-henry coil and 70-µfd. capacitor.

The vertical parabola is applied to L_1 (see Fig. 7) through a 100-µfd. capacitor, a 2500-ohm control, and the coil L_R. The vertical parabola amplitude is varied by the 2500-ohm control. The .05-µfd. capacitor bypasses the 2500-ohm control for horizontal waveforms, but is not large enough to bypass vertical signals.

The horizontal section utilizes ringing coils. For each gun, a horizontal pulse from the flyback transformer is applied through a pot to the coil L_R and the corresponding .01-µfd. capacitor. When the pulses strike this circuit a sine-wave oscillation occurs at the resonant frequency of the coil and capacitor, which is close to the horizontal rate. This waveform is shown in Fig. 9A. The amplitude of this sine wave can be varied by changing the amplitude of the pulse striking the coil. This is effected by adjustment of the 500-ohm control.

The horizontal tilt function is accomplished by adjusting the resonant frequency of the coil-capacitor combination. This is done by adjusting the coil L_R and results in the phase shift illustrated in Fig. 9B. By lowering the resonant frequency the lower crest of the sine wave is caused to occur to the right of center, whereas raising the frequency above the horizontal rate causes the crest to occur to the left of center.

The horizontal convergence sine wave is applied to L_1 through the .05-µfd. capacitor bypassing the 2500-ohm potentiometer. Proper horizontal convergence is accomplished through adjustment of the horizontal amplitude control (the 500-ohm potentiometer) and the horizontal phase coil (L_R) for each gun.

The latest refinement in tubeless convergence is illustrated in the *RCA* 21-inch circuitry shown in Fig. 8. Starting with the vertical convergence section, it is seen that the signal is derived at the cathode of the vertical output stage. The parabolic waveform here is coupled by the 25-µfd. capacitor to a phase shift network consisting of a 10-µfd. capacitor and a 390-ohm resistor paralleled by three 1000-ohm controls. By varying the 1000-ohm controls the tilt of the vertical parabola is shifted between the limits shown in Fig. 10. The waveform picked off each 1000-ohm control is applied through a 2000-ohm potentiometer and 400-millihenry horizontal frequency choke L_h to the convergence yoke coils which are connected in series, and then to ground. Varying the 2000-ohm potentiometer controls the amplitude of the vertical waveform current.

From a winding on the flyback transformer, horizontal pulses are applied to the coil *L*, three amplitude controls, and a .22-µfd. capacitor. The voltage pulse causes a saw-tooth current through the coil, as in Fig. 4, which is modified by the .22-µfd. capacitor into a parabolic waveform across the controls. This is accomplished by the choice of coil and capacitor used. This parabolic waveform is applied to L_1 through the .0025-µfd. capacitors and 1000-ohm resistors. By autotransformer action between L_1 and L_2, this voltage is stepped up, resulting in a greater convergence range.

The convergence coils L_1 and L_2 are tuned by a variable capacitor C_p at the horizontal frequency. At resonance, the coils are predominantly resistive, so that a parabolic current results in the coil. By tuning the coils above or below resonance, the parabola is altered, resulting in a tilt similar to Fig. 3. By adjustment of the horizontal amplitude controls and the tilt capacitors, uniform convergence of horizontal lines can be achieved.

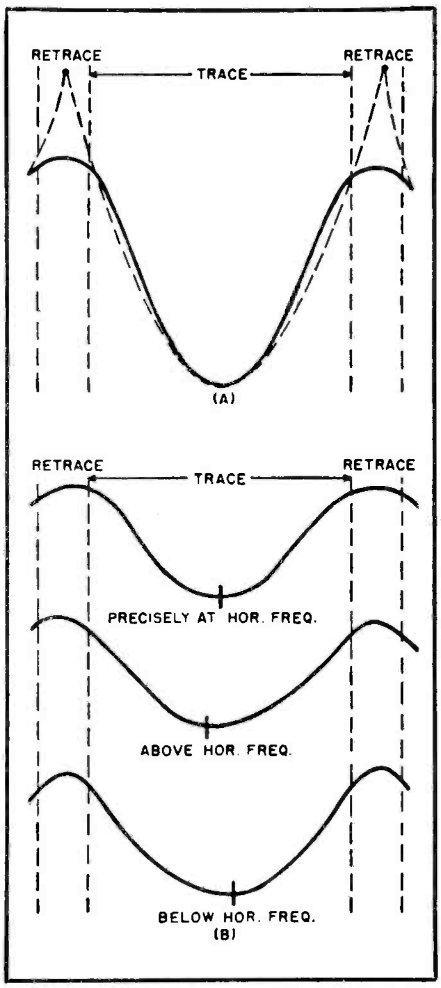
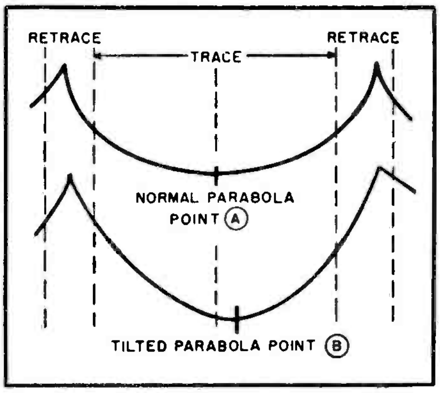


Fig. 9. (A) Comparison of sine wave and parabolic wave as applied to dynamic convergence. Note the similarity in their waveshapes during the trace period. (B) The effect of varying the phase of a convergence sine wave is to displace the point at which minima occur.

From this analysis it can be seen that convergence circuits are tending to be simplified, but the number of controls remains essentially the same. -30-

Fig. 10. The range of the vertical tilt adjustment possible for the parabolic dynamic convergence waveform produced by the circuit of Fig. 8 is shown here.



CHAPTER 4

INSTALLING AND SERVICING COLOR TV

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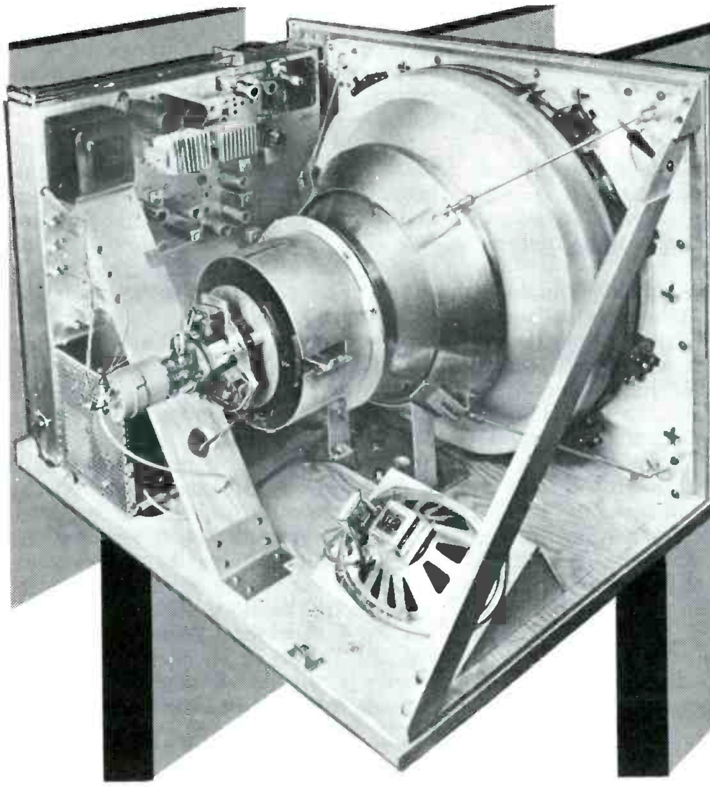

View of the new RCA 28-tube, 21-inch color TV receiver. Note the absence of a field neutralizing coil around the outer edge of the color tube.

SERVICING COLOR TV

By
MILTON S. KIVER*

Part 1. Large screen color TV is here now! Here are servicing techniques based upon experience with the commercial color TV receivers on the market today.

IN A PREVIOUS series of articles, we investigated the basic operating principles of color television receivers, using typical circuits taken from receivers which have been exhibited to the public. All this has been, in a sense, a forerunner for the job that the service technician will have when color sets are placed in the hands of the public in quantity—the job of servicing these receivers and of nursing them back to good operating condition.

The color television receiver, we have seen, contains many more circuits than a black-and-white receiver. This does not necessarily infer that color sets will be proportionately more difficult to service. Undoubtedly they will present more problems, but experience has shown that much of this difficulty can be reduced if the technician appreciates the differences between monochrome and color sets and develops a logical approach based on these differences.

Block diagrams of color television and monochrome receivers are shown in Fig. 1. To emphasize the differences between the two systems, every box in the color television diagram which has no counterpart in the black-and-white receiver has been shaded. This immediately reveals that the color sync section, the chrominance circuits, and the convergence amplifier(s) are nonexistent in a monochrome receiver. The picture tube has been shown as partially shaded to draw attention to the fact that while it differs considerably from its black-and-white counterpart, still the two have many points in common. Both use electron guns to develop scanning beams, and phosphor screens to convert this electrical energy into light. On the other hand, the color screen must present three colors in place of one and its structure was altered accordingly.

In the remaining receiver circuits, such as the r.f. section, the video i.f. amplifiers, the sound system, the sync separators, the a.g.c., and the sweep sections, both receivers use substantially the same circuits. Differences here are more a matter of degree rather than of basic form. In the video i.f. system, for example, the response is wider, but it still possesses the same general shape with the same trap frequencies. In the deflection system, principally the horizontal section, more drive is required and more high voltage must be developed but, again, anyone familiar with these circuits in monochrome sets would have little trouble in analyzing the corresponding circuits in color sets. Every bit of knowledge acquired by the technician from his work on black-and-white sets will be of value in servicing color receivers. This is an important fact to remember.

The First Step

The initial step in the servicing of a color receiver starts with the observation of the picture and listening to the sound. If one is affected, but not the other, then we would confine ourselves to that portion of the receiver which dealt with that particular signal alone. For example, suppose we found the picture normal, but the sound either distorted or missing. Then we would start at the sound-video separation point and proceed along the path followed by the sound only until it reached the loudspeaker. In every color receiver which has been shown to date, sound and video signal separation occurred either in the last video i.f. stage or in the video second detector. All sets operate on the intercarrier principle and consequently, the sound i.f. frequency is 4.5 mc.

The other alternative is for the sound to be normal, but for the picture to be affected. Speaking generally, the video signal travels by itself through the video amplifiers, through portions of the chrominance circuits, through several d.c. restorers and finally, to the picture tube.

Another consideration when the picture is affected is whether it is the picture which is at fault or the raster. If it is the raster which is causing the difficulty, then other circuits would come under consideration, for example, the vertical sweep system, the horizontal sweep system, or the high-voltage section.

Thus, as the initial step in analyzing a defective color television receiver, we see that three major items should be checked. The sound, the video portion of the picture, and the raster. Trouble in any one of these, without a corresponding distortion in either of the two

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*Author of "Television Simplified," "Television and FM Receiver Servicing," and other books.

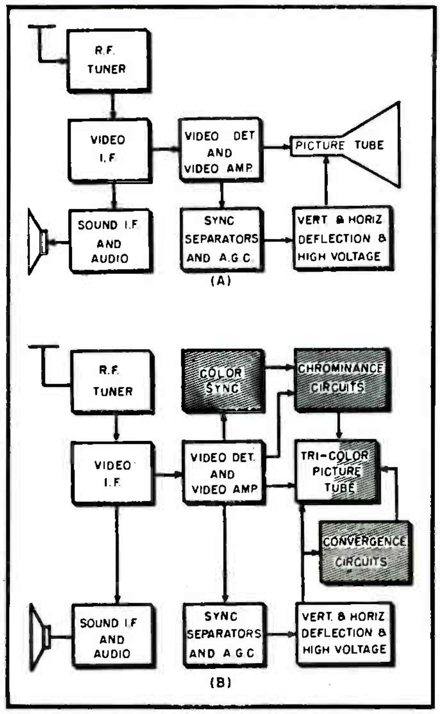


Fig. 1. Comparison of the block diagrams of a color and a black-and-white TV set. (A) is the monochrome set; (B) is the color receiver with the shaded boxes representing those sections not found in (A). ⟵

others, would more or less indicate that the trouble was confined to a specific well-defined section of the receiver and all subsequent tests should be directed toward this section.

Mention has already been made of the procedure to follow if the sound only is affected. This is exactly the same approach that would be taken in a monochrome receiver. Concerning trouble in the picture, the first thing to do is find out whether it is the raster which is at fault or the video signal. To perform this test, switch the set to a channel which is not being used. With the contrast control turned completely counterclockwise and the brightness control set at mid-position, a raster should be obtained which is more or less gray in appearance and which completely covers the screen. If this condition is observed, then we know the following facts concerning the receiver:

1. The picture tube has been properly adjusted insofar as purity and convergence are concerned. (We are referring here to the tri-gun color tube using a shadow mask.)
2. The deflection systems, vertical and horizontal, are functioning normally, producing the required beam sweep and the correct amount of high voltage.
3. The convergence circuit, with its amplifier and wave shaping networks, can also be presumed to be operating satisfactorily.

Now suppose that you have inspected the raster and found it to be OK. However, when you switch to a channel transmitting black-and-white pictures, you obtain an image which is color tinted, say yellow. Since the signal is a monochrome one, you know that the color sync section and the chrominance circuits are inoperative. Therefore, the trouble could not exist in these stages.

To find the source of the trouble, let us examine the video section of a typical color receiver. This is shown in Fig. 2. The *Y* or monochrome signal travels from its detector through a cathode follower and then a video am-

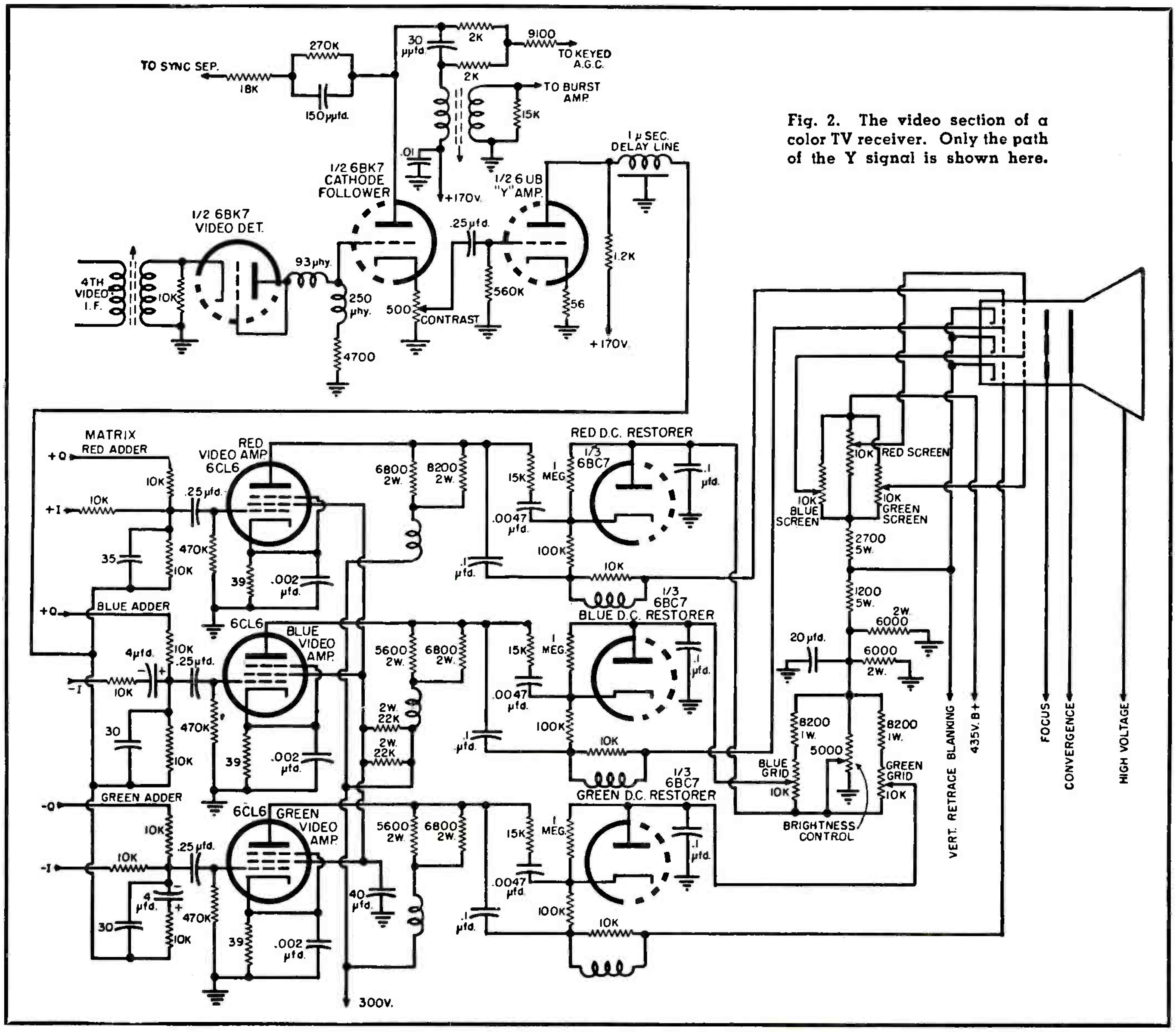


Fig. 2. The video section of a color TV receiver. Only the path of the Y signal is shown here.

plifier. Beyond this is the matrix, and if we continue to follow the *Y* signal, we see that it enters the matrix and is distributed equally to each of the color adder stages. This means that the red, green, and blue amplifiers will each receive equal amounts of the *Y* signal and if nothing happens in any of these sections, then each of the grids in the color picture tube should receive the proper amount of voltage to produce a black-and-white picture. (Note that we do not say each should receive the same amount of *Y* signal voltage. Actually, in most tubes, the red grid will receive more voltage because of the lower efficiency of the red phosphor. Whether this condition will always be true depends upon the progress made in developing more efficient phosphors.)

Up to the matrix or distribution point of the *Y* signal, all segments of the signal are kept together. Furthermore, nothing in the video detector or *Y* video amplifier can affect one color on the screen and not the others. It is only after the *Y* signal is divided among the red, green, and blue amplifiers that trouble in picture coloring could arise. This would occur if something prevented one of these sections from functioning normally. In the present instance we indicated that the picture had a yellowish overcast. The job, now, is to determine which section contains the defect.

There are several possible approaches to this problem. One would be to remove all of the 6CL6 color video amplifiers. This would remove the picture completely from the screen. Then reinsert one of the tubes, say the red video tube. The picture on the screen should be completely red. If it is, then this tube can be removed and the blue video amplifier tube inserted in its socket. The same picture should appear on the screen, only this time colored completely in blue. For the final test, remove the blue amplifier tube and insert the green video amplifier tube. The image now should be green. Failure of any one of these colors to appear at all or in sufficient strength would indicate that the trouble existed in its section. In the present instance, it was the blue section which was at fault. The green and the red voltages, reaching the picture tube, combined to produce a yellowish image.

The same solution can be achieved much more quickly if the service technician is familiar with the principles of additive color mixing. For example, red and green will produce mixtures ranging from orange to yellow. Green and blue will produce cyan; red and blue will give us magenta. The same facts are indicated on the chromaticity diagram (Fig. 3) and, to a more limited extent, on the color phase diagram (Fig. 4).

Here is how we would employ the chromaticity chart to help us locate the defective section in the case history just discussed. Since the predominant color on the screen was yellow, we would locate the general area occupied by yellow on the chromaticity diagram. See Fig. 3. Now, with your finger at this point, trace out a straight line to white and beyond this, to blue. Blue is the complementary color of yellow since blue added to yellow will produce white. Thus, blue is obviously missing from our picture and investigation of the blue channel is indicated.

The complementary color of cyan or bluish-green can be found in a similar manner. Place your finger on the area marked "bluish-green" and move it on a line through white. The color you meet on the opposite side of white is among the reds, hence red is the complementary color of cyan. For magenta, or reddish purple, the complementary color is green.

The same information is contained in the color phase diagram of Fig. 4. Yellow is located between red and green. Also, blue is at the opposite end of the yellow line, this being the position of the complementary color. The same procedure applies for other colors.

Thus, being familiar with color mixing is especially helpful to the color receiver technician. In fact, it is a good idea to have a chromaticity chart and a color phase diagram pinned up over your workbench for quick reference.

The statement was made that the receiver should be checked on a black-and-white picture before any check is made on color. This can be done even when receiving a color broadcast by disabling the color section of the set by removing the bandpass amplifier tube. This will prevent the color signal or the color burst from reaching the color sync or chrominance sections and actuating them. The result will be a black-and-white picture.

When a receiver gives normal indications on the raster test and with a black and white signal, then we know that in addition to the sections previously listed as being normal, we can now add the entire "*Y*" channel, plus the matrix, plus the color video amplifiers that follow the matrix. As the reader can well appreciate, this represents a fair-sized section of the set. (It is possible for the delay line to be defective and escape disclosure with the tests prescribed. More on this in a succeeding article.)

A precise method of determining whether each of the color video amplifiers is operating as it should is to measure the gain of each section. The check can be made by using a low-frequency signal generator and an oscilloscope. A frequency around 50 kc. is satisfactory. Connect the generator to the control grid of the red video amplifier (Fig. 2) and connect the vertical input terminals of the oscilloscope between the red grid of the picture tube and ground. Turn all the equipment on and adjust the signal generator until the 50 kc. sine wave appears on the face of the scope screen. Measure the peak-to-peak value of this wave after it has been adjusted to a suitable height on the screen. The measurement may be made with the scope only if such a facility is available or an external voltage calibrator may be employed.

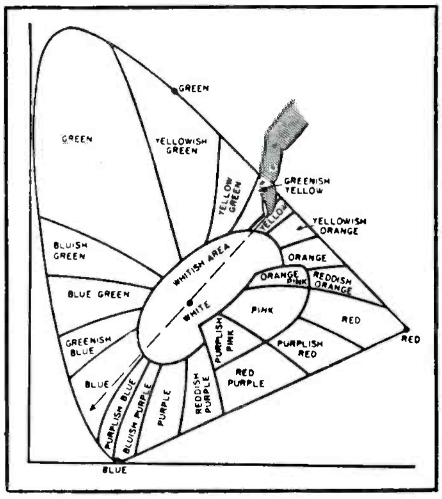


Fig. 3. Chromaticity chart being used to find the complementary color of yellow.

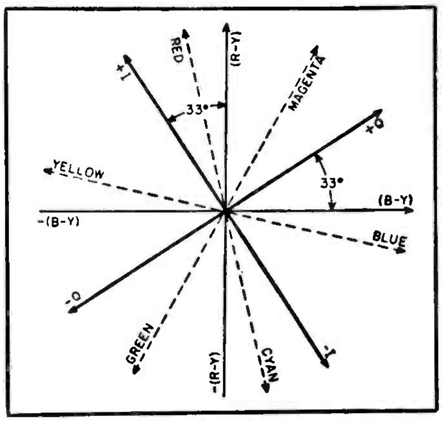


Fig. 4. A color phase diagram, such as shown here, may be used to find complementary colors for servicing applications.

Now transfer the scope to the control grid of the 6CL6 video amplifier and measure the peak-to-peak value of the applied signal. This figure, divided into the previous figure, will give the overall gain of the entire video system. If the manufacturer furnishes this information then a precise check can be made of the operating conditions of these amplifiers.

Raster Colored

Thus far we have assumed that the raster is a normal gray when observed by itself, without the presence of a picture. It is possible that this will not occur and that the raster, when viewed, will be colored or tinted. Let us see under what conditions this can occur and what can be done to correct it.

The components which affect or govern the shading or coloring of a raster (and subsequently, the coloring of a picture) are the purity coil, the electron guns, the voltages on each electron gun, and the d.c. and dynamic convergence controls. Let us consider each, in turn.

The purity coil is mounted near the base end of the picture tube and its purpose is to guide the electron beam from each gun to the correct color dots. That is, the green beam (*i.e.*, the beam from the green gun) should strike only green light-emitting phosphor dots, the red beam should strike only those phosphor dots emitting red light, etc. Any deviation from this desired action will lead to color contamination which means the appearance of colors other than the desired ones.

When the color purity coil is not positioned properly or the color purity control is not correctly set, then it will be impossible to obtain a pure white (or gray) over the entire screen. If white is achieved in one sector, the raster will be colored elsewhere. Color changes will occur gradually, rather than sharply or abruptly.

To determine whether the color purity is acceptable, the following procedure is recommended.

1. Turn the contrast control to minimum and the brightness control nearly to maximum.

2. Turn the blue and green screen controls completely counterclockwise. Turn the red screen control to the extreme right. This will cut off the currents in the blue and green guns and operate the red gun at maximum.

Now examine the screen, which should contain a red raster. If the red color is uniform over the screen, then purity of this color is indicated. It may be found that some departure from pure red is present near the edges of the screen, but if the color variation is not too great, the condition may be normal for that tube. If in doubt, then it might be advisable to go through the color purity adjustments as prescribed by the manufacturer.

Once a uniform red field is obtained, chances are that uniform green and uniform blue fields will also be obtained. The latter checks are carried out by advancing the associated screen grid control while the other screen grid controls are turned to the left.

Failure to obtain uniform red, green, and blue fields, even after the manufacturer's instructions are carried out, usually signifies that the tube or the purity coil is defective. Defects in picture tubes stem from electron guns that are out of alignment or shadow masks that are warped.

The voltages which are applied to the various electrodes of an electron gun will seldom be the cause of poor color purity. However, they can lead to a raster (or a picture) which is deficient in one of the primary colors. The visual result is as though we had placed a sheet of transparent filter paper over the screen, giving everything appearing on the screen a tinted appearance. The gun responsible for the color deficiency can be isolated by applying the principles of color mixing indicated earlier.

Another reason for a colored raster is improper d.c. and/or dynamic convergence of the electron beams. Color purity, which we have just discussed, serves to force each beam to strike only one type of phosphor dot whenever these beams strike the screen. Still required, however, is some means of bringing together all three beams so that each passes through the same hole in the shadow mask at the same time in order that adjacent dots will be activated. This action is needed to insure that the observer will see a single, resultant color from the action of the three beams and not two or three separate colors. In the absence of this converging action, it would be possible for the beams to strike phosphor dots at sufficiently separated points so that an observer would see three individual points of colored light. Under these conditions, mixing the colors would not be possible.

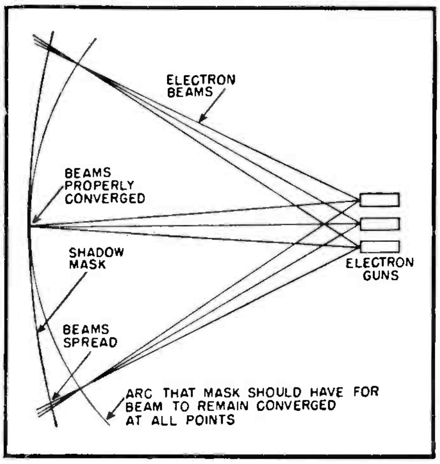


Fig. 5. The three electron beams from the three guns of the color tube do not converge at the edges of the curved tube screen because the latter does not conform to the arc made by the focus points.

When the d.c. convergence control is properly set, the red, green, and blue pin points of light in each trio of dots will blend together and produce white light on a raster. On the other hand, when the d.c. convergence control is misadjusted, the individual red, green, and blue pin points of light will everywhere be visible. This effect is perhaps best observed with a picture on the screen. The nonregistration of the colors leads to a blurred rainbow effect, such as we occasionally find in rotogravure pictures when the various colors are improperly aligned with each other.

Color impurity and improper d.c. convergence can thus be distinguished as follows: when the color purity is poor, it is not possible to develop uniform red, green, or blue fields on the screen. On the other hand, with poor convergence, individual primary color fields which are pure can be developed, but combination colors cannot.

In addition to d.c. convergence, there is also dynamic convergence. The need for this additional voltage stems from the fact that neither the shadow mask nor the phosphor dot screen are properly curved surfaces. That is, as the beam sweeps back and forth across the face of the tube, it follows an arc such as shown in Fig. 5. The curvature of the screen and the shadow mask deviate sufficiently from this arc so that a beam which is properly converged over the central area of the screen will not be correctly converged at the edges of the screen.

To correct this condition, special parabolic-shaped voltages are added in series with the d.c. convergence voltage and when the system is operating properly, the raster (or picture) is as correctly converged at the edges as it is in the center. It may be that with some tubes a slight amount of nonconvergence is normal at the sides of the screen and here you will see some of the red, green, and blue colors. When the dynamic convergence controls are not properly adjusted or the associated circuits are not functioning properly, then the nonconvergence will be marked.

The distinguishing characteristic of dynamic nonconvergence is the appearance of colors at the edges of an otherwise white (or gray) raster. This effect is best seen on a raster although it may be detected in a picture.

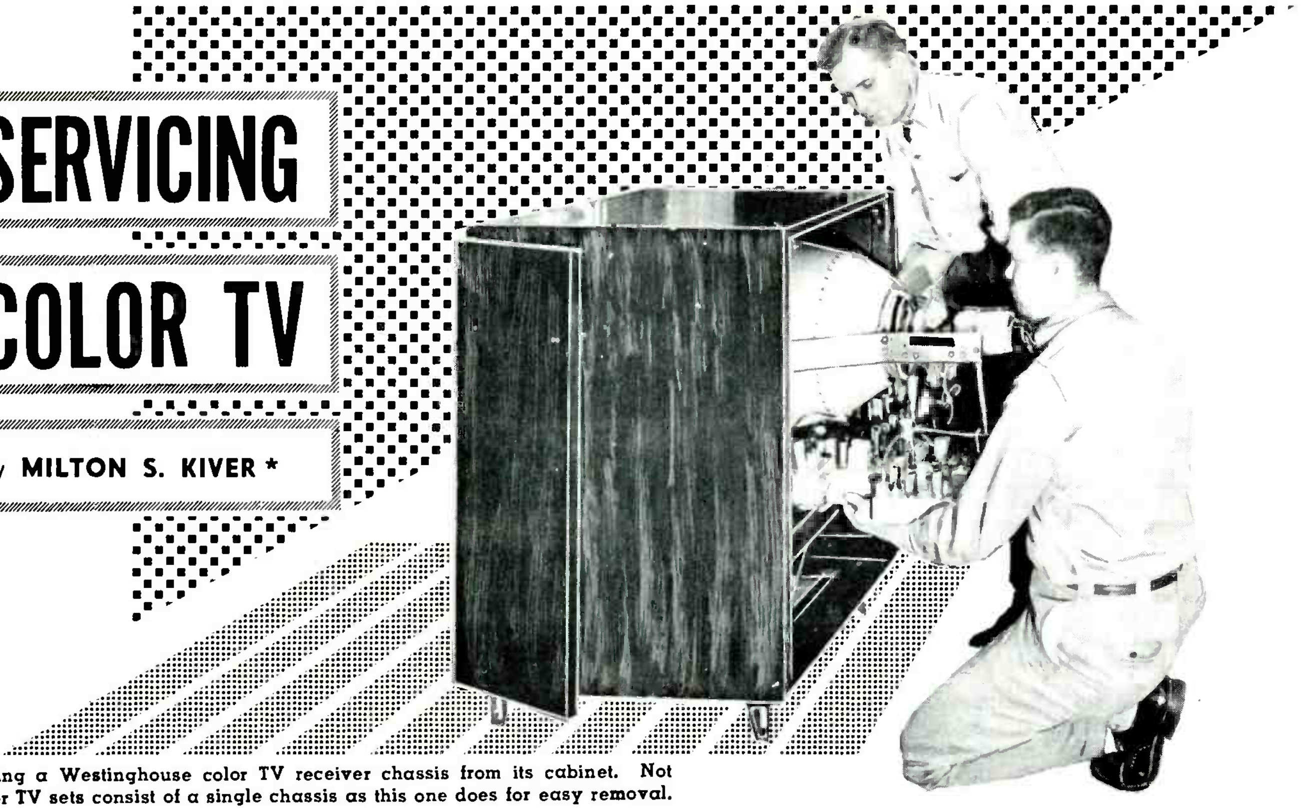
There is one further difficulty that may lead to the appearance of color in what should be a black-and-white picture. This time the effect is that of a picture having a mottled look. The picture contains a background of small colored dots such as you might obtain with colored snow in a picture in place of black-and-white snow in monochrome receivers. The colored dots have no discernible pattern, leading to the conclusion that they are random in nature.

The source of this trouble lies in the chrominance section of the receiver. Ordinarily, with the reception of black-and-white signals, one or more chrominance amplifiers are held beyond cutoff by a negative bias generated in a color killer stage. However, should something prevent this stage from functioning properly, and a killer bias is not developed, then signals will be able to pass through the chrominance section and reach the matrix and beyond this, the three color grids of the picture tube. The random appearance of the color is due to the fact that the 3.58-mc. color subcarrier oscillator is not being synchronized (since no color burst voltages are present in monochrome signals) and consequently there is no definite pattern to the phase of the signal it generates. Color is a product of the combined interaction of signal voltages reaching the color demodulators and the phase of the 3.58-mc. subcarrier.

Colored snow can also be obtained in the absence of any received video signals by the noise picked up by the antenna or generated in the receiver. This behavior is normal and need cause no concern.

SERVICING COLOR TV

By **MILTON S. KIVER** *



Removing a Westinghouse color TV receiver chassis from its cabinet. Not all color TV sets consist of a single chassis as this one does for easy removal.

Part 2. A practical time-saving approach to servicing color TV sets which show no color or unstable color.

THE previous article considered two major aspects of color TV servicing: checking the raster and viewing the black-and-white picture to see whether any extraneous color appears. These two checks would always be made in the sequence given, in order to isolate a disturbance to a specific section of the receiver. We have reference here to defects whose origins are not immediately recognizable from an initial inspection of the screen. However, if no picture at all can be obtained on the screen, then obviously raster inspection would hardly be necessary. In this instance, the best approach would be to trace the signal with an oscilloscope, starting perhaps at the video second detector. On the other hand, if we do obtain a picture on the screen and it is distorted, either in shape or in color, then the testing procedure outlined in Part 1 would be entirely in order.

We come now to those color troubles which have their origins in the color sections of the receiver. Analysis reveals that these color defects will generally fall into one of three categories.

1. No color at all, when we know that there should be color
2. Incorrect color rendition
3. Color instability

Once a specific trouble is categorized, the technician is then able to proceed in a logical manner to narrow down further the location of the defect. The rewards of a systematic procedure include not only shorter servicing time and the assurance of doing the job correctly the first time, but also the self satisfaction and pride that every successful technician feels from the knowledge of a job well done.

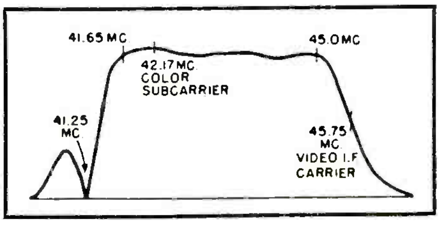
Complete Lack of Color

There are a number of reasons why a color set will not develop a color picture when it is definitely known that a color signal is being received.

One possibility which immediately suggests itself is misadjustment of the fine-tuning control. To appreciate the reason for this, let us consider the action of this control in its relation to the manner in which the set treats the signal.

In the incoming signal the picture carrier is always below the sound carrier. On channel 3 (60-66 mc.), for example, the picture r.f. carrier is positioned at 61.25 mc. and the sound r.f. carrier is at 65.75 mc. These signals mix with the output of an r.f. oscillator to produce the desired i.f. frequencies. In almost all designs the oscillator frequency is above any of the frequencies of the incoming signal. For the example chosen, channel 3, the r.f. oscillator frequency would be 107 mc.

Fig. 1. Over-all i.f. response curve of a color TV receiver indicating the need for a really broadband response.



The result of mixing the oscillator and r.f. carriers, is to produce a video i.f. carrier signal at 45.75 mc. (107-61.25 mc.) and a sound i.f. carrier at 41.25 mc. (107-65.75 mc.). On the response curve of the video i.f. system, these carriers would appear in the positions shown in Fig. 1.

The color subcarrier of the signal is positioned 3.58 mc. above the picture r.f. frequency. Its i.f., then, would be 42.17 mc. and it would occupy the position shown in Fig. 1. The left-hand edge of the response curve should extend to at least 41.65 mc., this being the end frequency of the video signal with its color sideband components. (41.65 mc. is 4.1 mc. from the video i.f. carrier of 45.75 mc.)

All of the foregoing signals will fall at the points designated in Fig. 1 *if* (and here is the crux of this discussion) the oscillator frequency is set at exactly 107 mc. This, in turn, depends upon the setting of the fine-tuning control.

Now let us see what happens if the control is rotated too far to one side or the other of this correct position. The viewer who thinks he is tuning his set for best picture by striving for high contrast, is in error because he will adjust the fine tuning control until the video carrier is on the flat portion of the response curve and not at the 50 per-cent point. With this situation, the high end of the signal spectrum, where the color information exists, will be pushed down the oppo-

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* Author of "Television Simplified," "Television and FM Receiver Servicing," and other books.

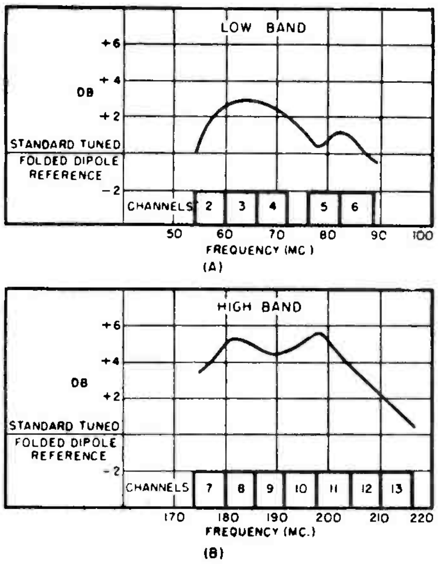


Fig. 2. Gain curves for a popular TV antenna. (A) is the low band; (B) is the high band. The flatter these curves are the better for color reception.

site side of the response curve. This will usually attenuate the color burst to such an extent that not enough will get through to activate the various color circuits. The result is that there is no color on the screen.

Rotation of the fine-tuning control in the opposite direction will lead to the loss (or attenuation) of the video carrier and its companion low video frequencies and will produce either a negative picture (as in black-and-white sets) or no picture at all. Present, too, will be sound bars because of the increased amplification accorded the sound signal.

Thus, adjustment of the fine-tuning control in present color television receivers is a more critical operation than in monochrome receivers and this fact must be carefully impressed upon the viewer. An excellent adjustment sequence for obtaining a good color picture is as follows:

1. Adjust the receiver in the usual manner for a black-and-white picture.
2. Advance the color control approximately two-thirds from its maximum counterclockwise position.
3. Carefully advance the fine tuning control clockwise until the picture just begins to disappear, then turn counterclockwise slowly to the position where the sound bars just disappear and color is in the picture.
4. Adjust the color control for the desired saturation or strength of color.
5. Adjust the hue control to achieve the most pleasing flesh tones or color of some familiar object.

Another method of adjusting correctly the fine-tuning control which the service technician can use is to rotate this control to the point where the visible 920 kc. beat pattern (between the 4.5 mc. sound carrier and the 3.58 mc. color subcarrier) on the CRT screen is minimized. This is a more precise method, particularly when the low end of the i.f. response curve has a steep roll-off.

The importance of having the color end of the video signal receive sufficient amplification—as indicated by the foregoing discussion—will also point out to the service technician other causes for poor or no color rendition in the picture. For example, a video i.f. response curve which falls off too rapidly at its low end, or an r.f. bandpass which is too narrow will produce the same results as misadjustment of the fine-tuning control.

In black-and-white receivers, the extent of the circuit's bandpass, while important, is nowhere near as critical as it is in a color receiver. In a monochrome set we might possibly lose some detail, a fact which very few observers could detect. In a color set, the picture will still be seen, but all semblance of color would be absent.

The critical dependence of color on bandwidth can conceivably force circuit realignment of the r.f. and video i.f. systems every time a tube is changed. Different interelectrode capacitances in tubes, even of the same type, will have marked effects on the bandpass of the fairly high frequency circuits now common in r.f. and i.f. systems. It may be that methods will be found to overcome this very evident weak point, but until that happens there is likely to be some difficulty even if it is encountered only part of the time.

In this same vein, it has been found that poor color in a picture or no color at all may also stem from inadequate bandwidth of the antenna system. This would encompass the antenna and any r.f. boosters and/or distribution amplifiers that may be employed. Particularly important is the response to those frequencies clustered around the color subcarrier. Ideally, gain or loss should not vary more than 1 db from 1.5 mc. below to .6 mc. above the color subcarrier. Now let us apply these suggested limits to a popular antenna operating over the 12 v.h.f. channels. The gain curves are shown in Fig. 2. Over the low band, the response falls within the limits specified. On channel 2, the gain variation from the low to the high end is greater than 2 db. However, in its favor is the fact that the high end receives more gain than the low end, thereby tending to accentuate the color signals. Furthermore, the gain variation around the color subcarrier frequency (near the upper end of the channel) is less than 1 db.

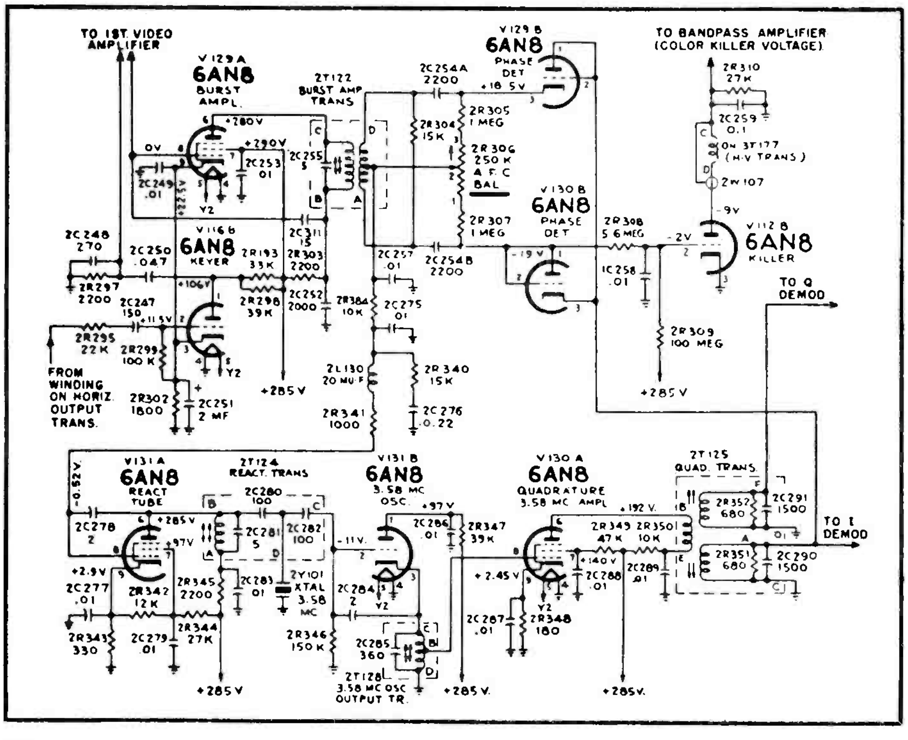
On the high band, the response is excellent for channels 7, 8, 9, and 10. On channel 11, gain variation near the upper end is quite marked and could lead to trouble. This is particularly true since the gain is decreasing here. Channels 12 and 13 are subject to an even greater drop-off in gain and the performance of a color receiver on these channels could be expected to be poorer.

High gain, narrow-band antennas such as the multi-element yagi may be especially troublesome in this respect.

Another item that is frequently found in the antenna system is an r.f. booster. If this is of the untuned wide-band variety, then it probably would not attenuate the color subcarrier any more than it might affect the video carrier. However, in an adjustable booster, where each channel is tuned in separately, narrow bandwidth is a distinct possibility. Also, it is well to remember that while one item, by itself, may not cause too much damage, the combined attenuation of several components can prove decisive.

What has been said with regard to

Fig. 3. Schematic diagram of the color sync section of an RCA CT-100 color receiver. Here, the 3.58 mc. oscillator is always in operation, even without color.



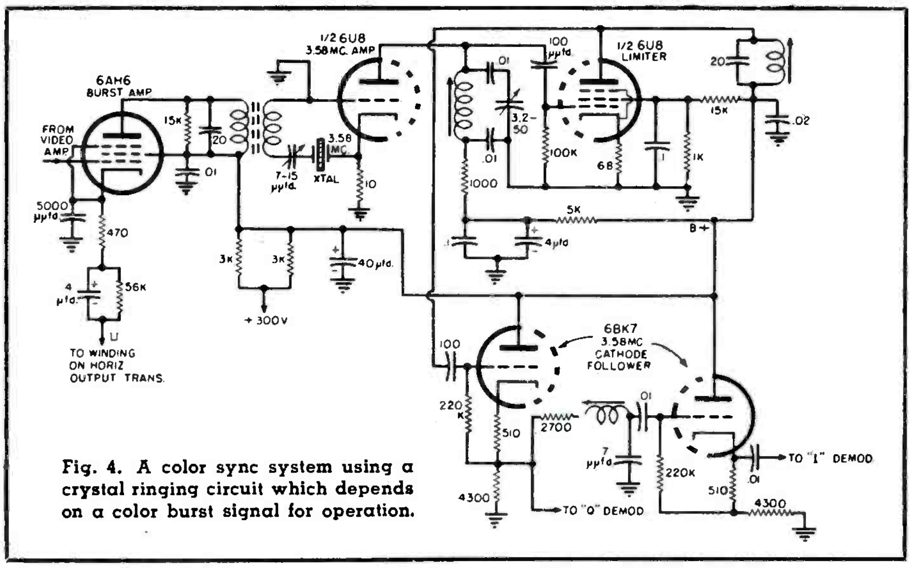


Fig. 4. A color sync system using a crystal ringing circuit which depends on a color burst signal for operation.

boosters applies with equal force to antenna distribution systems where the incoming signal is first amplified before it is dispatched to the various sets.

The necessity for knowing whether each component of an installation is doing its full share will be more pressing than ever and undoubtedly require additional testing equipment for the service technician. The technician will require more comprehensive methods for checking receivers in the home. If a set does not produce suitable color pictures, is the receiver at fault or does it stem from an inadequately applied signal? Some instrument, such as a color bar generator, which will definitely establish the condition of the receiver will almost be a necessity. The only other alternative would be to take the set back to the shop, a time consuming and certainly uneconomical procedure. The reliance of the service technician on accurate and reliable test equipment will be greater than ever.

There are, of course, additional reasons why a color television receiver is unable to produce color pictures. Consider, for example, the color subcarrier oscillator in the color sync section. The color signals which the *I* and *Q* (or *R-Y*, *B-Y*) demodulators receive from the bandpass amplifier are amplitude and phase modulated. To re-obtain the original information imparted to this signal, we need the presence of the missing subcarrier. This is supplied, with the proper phase, by the color sync section. Now, the heart of this section is the 3.58-mc. subcarrier oscillator and should something prevent this oscillator from generating the necessary voltage, no color demodulation will occur and with this, no color signals.

In the absence of color, then, a good place to check is at the 3.58-mc. oscillator. The tube might be tested first. If this is found to be good, an oscilloscope might be employed to check for the presence of a 3.58-mc. signal in the oscillator circuit. Measuring the control grid voltage of the oscillator is another good way to determine whether or not this stage is operating.

There are two methods in use for generating 3.58-mc. oscillations and a different service approach is required in each instance. For example, in the color sync system shown in Fig. 3, the 3.58-mc. oscillator is always in operation, color signal or no color signal. This means that if a color signal is reaching the color demodulators, the 3.58-mc. oscillator voltage should likewise be present unless the oscillator itself is inoperative. It makes little difference here whether the color burst reaches the color sync section or not. The oscillator, whether it is on frequency or not, will be developing a 3.58-mc. signal and some color should appear on the screen, even if this color has the wrong hue or is unstable.

On the other hand, consider the situation in a ringing-type color sync system, Fig. 4. Here, the 3.58-mc. generator is not in operation unless it is being pulsed by the incoming color bursts. Failure of the bursts to reach the ringing oscillator, perhaps because of a defective color burst amplifier, would result in a colorless picture. Hence, the logical place to check in this system is the color burst amplifier to see if the tube is good and if so, the rest of the color burst stage, including the voltages.

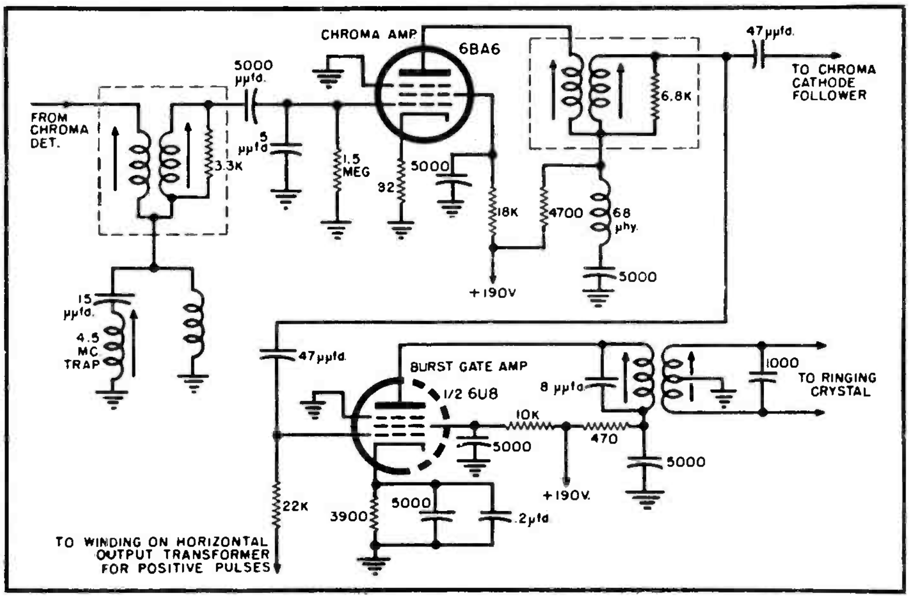
Note that in the color sync system of Fig. 3, trouble in the color burst stage, in the reactance tube, or in the phase detector would not keep the 3.58-mc. oscillator from operating. Color would appear on the screen even though, in all probability, the shading of the various objects would be wrong.

In the ringing system, for the generated 3.58-mc. voltage to reach the color demodulators, it is necessary that the stages between the oscillator and the demodulator be operating normally. This includes an amplifier, a limiter, and perhaps a cathode follower. See Fig. 4. Tests should be made, with an oscilloscope, at each of these points.

Another item which may be responsible for the absence of color is a defective bandpass amplifier. This stage stands at the head of the entire chrominance section of the receiver and any break in the signal path here would prevent the color sidebands from reaching the color demodulators.

Whether a defective bandpass amplifier will cause the complete absence of color on a screen, or simply lead to a condition where we have a black-and-white picture with a mottled (confetti-like) background depends upon the particular circuit in question. In the partial circuit of Fig. 5, the burst gate amplifier receives its pulses from the plate circuit of the bandpass (here called chroma) amplifier. Failure in the bandpass stage will not only prevent any of the color sidebands from reaching the color demodulators, but would likewise shut off the flow of color burst signals to the burst gate stage and the ringing oscillator that follows it. Hence, no 3.58-mc. oscilla-

Fig. 5. A defect in the chroma amplifier would completely inactivate the entire color section of the receiver using the chrominance circuits diagrammed here.



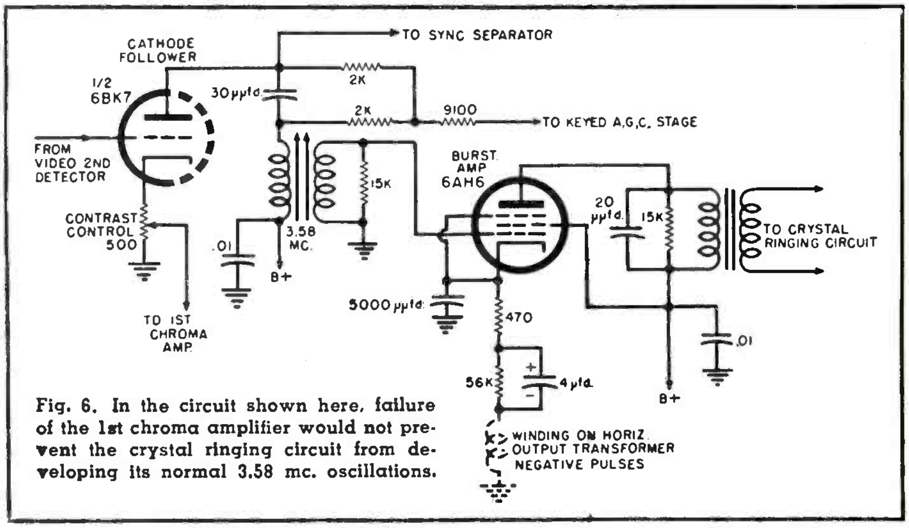
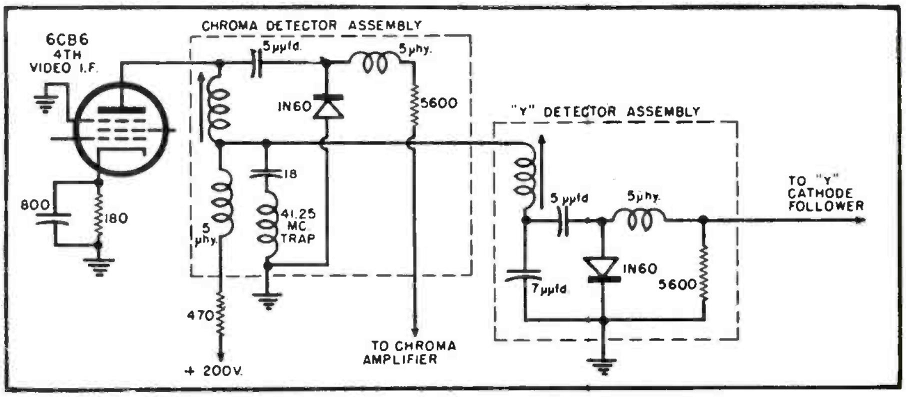


Fig. 6. In the circuit shown here, failure of the 1st chroma amplifier would not prevent the crystal ringing circuit from developing its normal 3.58 mc. oscillations.

Fig. 7. Any failure of the chroma germanium crystal in this circuit would remove color from the picture, but would not affect the monochrome presentation.



tions would be generated, either. The complete color section would be totally isolated from the incoming signals.

Consider now the circuit shown in Fig. 6. The first chroma amplifier, which is the bandpass stage, receives its signals from the video cathode follower and serves only to forward the color sidebands to the *I* and *Q* demodulators. The burst amplifier obtains its signals separately from the video cathode follower. Thus, the burst amplifier would not ordinarily be affected by any failure in the bandpass stage. This means that the 3.58-mc. ringing circuit would be suitably triggered and 3.58-mc. oscillations would be developed and forwarded to the *I* and *Q* demodulators. Also, since the color killer circuit is associated with the 3.58-mc. limiter, it, too, would be activated, leading to the removal of its cut-off bias from the two color demodulator stages. All we need, then, to produce colored confetti on the screen are noise or other extraneous voltages either in the second chroma amplifier circuit or in the grid circuit of the demodulators. It is quite possible that under these conditions this will happen.

Thus, whether a defective bandpass amplifier leads to a colorless picture or one which has random color, depends upon the relationship between the color sync section and the chrominance section.

A defective color killer can also be the cause of no color in a picture. If the killer cut-off bias is on at all times, irrespective of whether or not color burst signals are being received, then no signals will pass through the chrominance section and none will reach the picture tube. It is also true that if the receiver employs a separate detector for the color portion of the signal, as the circuit of Fig. 7 does, any failure here would likewise result in no color. This same set also has a germanium detector for the Y signal and consequently, this signal would appear on the screen.

Thus far, we have covered the troubles that may cause a poor black-and-white picture to appear on a color TV receiver screen and the troubles that would cause no picture or an incorrect raster. This article covered also, some of the causes of an incorrect color picture. Despite the trouble, however, it is interesting to note that our servicing procedure is much like what we use for monochrome set servicing, i.e., we are using the picture tube as our primary trouble indicator.

SERVICING COLOR TV

By **MILTON S. KIVER***

Part 3. Concluding article covers the sources and cures for incorrect color rendition and instability.

Fig. 1. A color-bar generator is probably the handiest color test instrument. A typical one is the RCA generator shown here.

A COMMON ailment of color television reception is incorrect color rendition, *i.e.,* color is present in the picture, but the hue is not what it should be.

One of the first things to check when the foregoing complaint is heard, is the hue control. (Sometimes this is called the color fidelity control.) This is either mounted on the front panel of the set or accessible from the front by lifting a small metal plate. Rotation of this control will have a marked effect on the colors observed on the screen. Red may change to yellow, green to blue, and blue to magenta or red. Circuitwise, the control may be located directly in the oscillator circuit, where it deals with the phase of the oscillator voltage, or it may affect the 3.58-mc. color burst which is used by the phase detector to establish the frequency and phase of the generated 3.58-mc. subcarrier voltage. Both methods have been employed to date.

If the various color circuits in the receiver are functioning normally, then some point should be found over the range of the hue control where the observed colors possess the proper hue. Probably the best reference to use is the color of a person's skin. In the absence of this reference, any familiar object, such as a yellow banana or a red apple, etc., may be employed. Of course, errors can be made here in assuming the shade of a color which, in actuality, may not be true.

The best solution, and one which will undoubtedly be used the most, is to substitute the signal from a color-bar generator for the transmitter signal. The colors then produced on the screen will be definitely known and any necessary adjustment can be made accordingly.

The color-bar generator is almost a necessity for any amount of color servicing. This is an instrument which develops a number of bars, each of which has a specific color. Some units, such as the *RCA* generator shown in Fig. 1, cause all of the different color bars to appear on the screen at the same time. See Fig. 2. From left to right, the bars are as follows: dull yellow orange, orange $(+I)$, bright red $+(R\text{-}Y)$, bluish red, magenta $(+Q)$, blue $+(B\text{-}Y)$, greenish blue, cyan $(-I)$, bright bluish green $-(R\text{-}Y)$, and dark green. Other color-bar generators present only one or two different colors at a time, additional colors being brought onto the screen by rotating appropriate instrument controls. Each color is identified on the color dial so that the technician knows what they should be and hence knows what to look for on the screen.

With a color-bar generator, it takes but a minute to determine whether or not the set is producing the correct colors. The hue control on the receiver is rotated until the colors on the screen assume their proper hue. If this condition is obtainable, then we know that the set control was misadjusted. However, if no position of the control knob will produce the proper colors, then further trouble is indicated. Let us investigate the most probable sources for trouble that would result in incorrect color rendition on the screen.

The color in the picture developed on the screen of a color television receiver is the responsibility of the color sync section, the chrominance section, and the color burst reference of the incoming signal. All the other sections beyond the video second detector can be checked by observing the monochrome portion of the color signal on the screen. This was indicated in Parts 1 and 2 of this series and is also the reason why the picture is observed first in black-and-white. With this in mind, let us see what the effect would be of various difficulties in the color sync and chrominance sections.

In the color sync section we have the burst amplifier plus whatever method is used to generate the 3.58-mc. subcarrier and to synchronize its phase with that of the incoming color burst. In the system shown in Fig. 4, the oscillator is continuously in operation and a phase detector and a reactance tube are employed to keep the oscillator frequency in step with that of the color burst. A hue or color phase control permits variation of the oscillator phasing and the check on this control has already been mentioned. A defective reactance tube would lead to the loss of color synchronization with the visual result that the colors would keep shifting. Under these conditions, too, rotating the color phase control would have no effect on the colors in the picture. This is because, in this circuit, any change brought on by the control could not reach the oscillator because of the intervening defective reactance tube circuit.

Another cause for the appearance of the wrong colors on the screen could be trouble (a defect or misalignment) in the quadrature amplifier output transformer shown in Fig. 4. This transformer is normally set up to provide the Q demodulator with 3.58-mc. subcarrier voltage which is 90° out-of-phase with the I demodulator. Any departure from this 90° (or quadrature) relationship will lead to incorrect color rendition.

There is another difficulty that can develop in the quadrature transformer, but to appreciate its significance we require the presence of a color phase diagram. See Fig. 3. Here we see the phase relationships between the various colors, together with the relative positions of the I, Q, $R\text{-}Y$, and $B\text{-}Y$ vectors and the color burst. Now, as we examine this diagram, we see that there is a positive I and a positive Q as well as the negative I and a negative Q. The positive I and Q vectors are 90° out-of-phase with each other; the same is true of the negative I and Q

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*Author of "Television Simplified," "Television and FM Receiver Servicing," and other books.

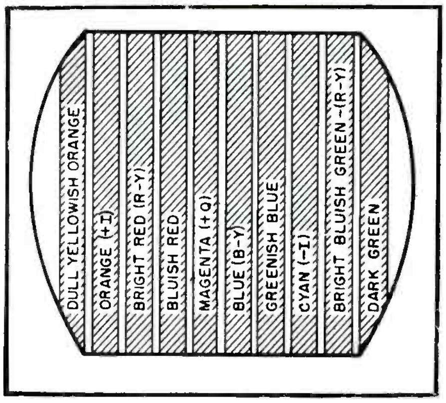


Fig. 2. Shown above are the relative positions of the various color bars developed by the generator in Fig. 1.

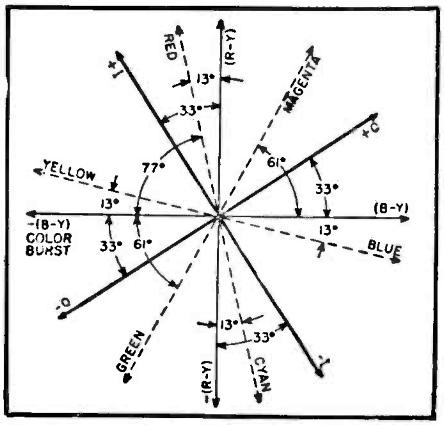


Fig. 3. Color phase diagram showing the positions of the I, Q, R-Y, B-Y vectors.

vectors. Since there are positive and negative values for each of these vectors, it will be evident that what we obtain from the quadrature transformer is not only important as to the 90° relationship between *I* and *Q* but also whether the set of signals are both positive or both negative.

As an experiment, an *RCA* color-bar generator was applied to a color television receiver. When the quadrature transformer was properly adjusted, the color sequence of dull yellow-orange on the left to dark green on the extreme right was obtained. However, it was also found that with further rotation of the slug in the quadrature transformer a pattern could be obtained in which the dark green stripe was at the left and the dull yellow-orange stripe at the right. In other words, the sequence of colors was exactly reversed indicating that although the *I* and *Q* subcarrier voltages obtained from the quadrature transformer were still 90° apart in phase, the *I* and *Q* voltages themselves had been completely reversed.

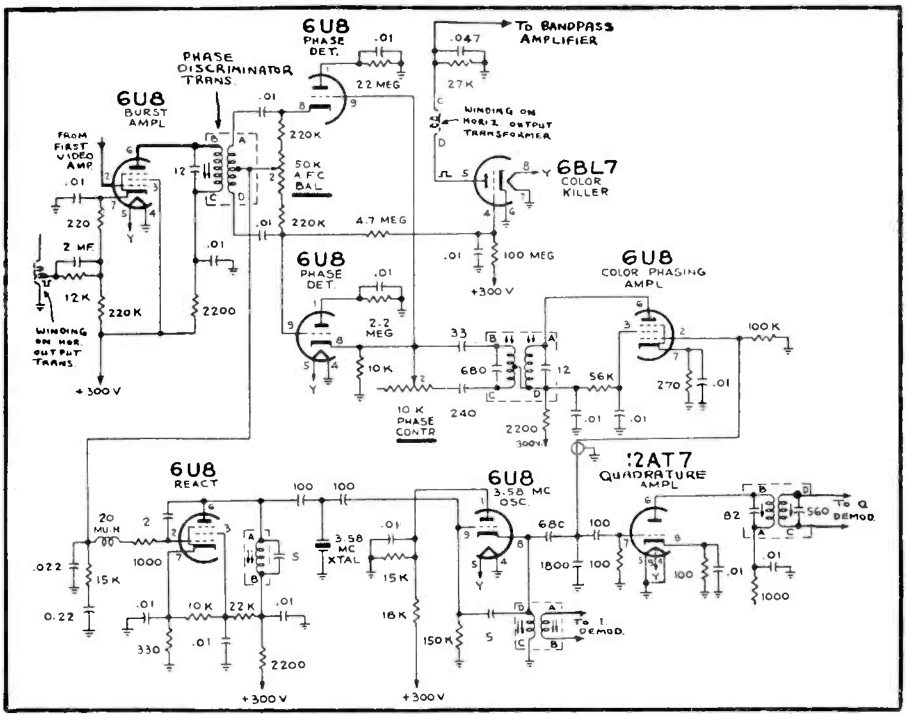
Looking at the color phase diagram, the normal sequence of color stripes would be from yellow-orange clockwise around to dark green. With the reversal, we started at dark green and then travelled counter-clockwise around the diagram to yellow-orange.

I and Q Stages

Trouble in the *I* and *Q* systems may also lead to the appearance of the wrong colors in the picture. A typical *I* and *Q* section of a color receiver is shown in Fig. 5. Note that each section, *I* and *Q*, provides positive and negative voltages to the matrix. This, we have seen, is required for the proper development of the various color signals. The question is, what would be the effect on the picture of a missing *I* or *Q* voltage or of a missing partial component, such as a —*I* or —*Q?*

The answer to these and similar questions may be found in the color phase diagram, Fig. 3. Positive +*I* extends into the orange sector of the diagram; —*I* is in the cyan region; +*Q* is near magenta while —*Q* is in the dark green region. If some defect should completely inactivate the entire *Q* section, then we would be removing all of the *Q* components from the picture. These include, from the foregoing analysis, magenta (+*Q*) and green (—*Q*). All that would be left in the picture would be the *I* components, which would consist chiefly of orange and cyan.

Fig. 4. Schematic diagram of the color sync section of an I and Q color TV set.



Many outdoor and indoor tests have shown that the removal of the *Q* components is not readily discernible by the viewer (layman or service technician) unless he has the original for comparison. Thus, it is often difficult to look at a color broadcast and determine from the picture just what colors are missing. On the other hand, a color-bar generator with its test pattern would immediately bring this fact to light. It is this facility that makes the instrument so useful. Passage of the color-bar signal through a defective *Q* section would yield black bars in place of the correct magenta and green. Furthermore, any other bar that depended upon +*Q* or —*Q* signals would likewise have its hue altered. A service technician who was familiar with the color phase diagram and receiver layout would immediately spot this deficiency and pin-point the trouble as existing in the *Q* channel of the receiver. The time saving in defect location is indeed remarkable.

Loss of the *I* signal components would have a more noticeable effect on any color picture because of the greater use made of the *I* components. Positive identification, however, could still be made only with a color-bar generator.

At the output of the *I* and *Q* sections, individual positive and negative *I* and *Q* voltages are made available for the matrix. It is possible that the negative *I* signal may be affected without disturbing the companion +*I* signal. Or, the same thing may happen in the *Q* section. What effect such individual loss will have on a picture can again be determined from the color phase diagram. Loss of —*I* would remove cyan from the picture; loss of +*I* would delete the oranges, light reds, and orange-yellows. Magenta would disappear with the loss of +*Q* while the elimination of —*Q* would affect the green. Again a color-bar generator would be a handy instrument to have around.

We have been using an *I* and *Q* receiver in the foregoing discussion, but the same method may be employed with an *R-Y, B-Y* system. The color phase diagram in Fig. 3 illustrates the relative positions of these two vectors and by studying the chart the reader can easily figure out for himself what the absence of either of these signals would mean to the color in the picture. (Detail, of course, is not affected to any extent since the monochrome portion of the signal will adequately provide this information).

In an *R-Y, B-Y* receiver, loss of one of these components would also affect the formation of the green color since green is formed by combining *R-Y* and *B-Y* according to the equation:

$$-(G-Y) = .51\ (R-Y) + .19\ (B-Y).$$

A missing *R-Y* or *B-Y* component would alter the final value of *G* and cause its appearance on the screen to be incorrect.

While the color sync and chrominance stages are the major sources of trouble when the color shading is incorrect, still other sections of the receiver may also be responsible. In the r.f. and i.f. stages, for example, poor alignment, particularly in the region occupied by the color signal, can lead to incorrect color on the screen. Of course, if the color burst itself is affected, then the color may disappear completely. This we have already noted.

Probably the best way of isolating such trouble is again by use of the color-bar generator. Apply the unmodulated signal at the video second detector, and observe the colors of the bars in the resulting pattern. Then modulate the signal and inject it at the antenna terminals. Again observe the pattern produced. If the colors are true on the first test, but altered in hue on the second test, trouble is indicated ahead of the detector. The best check to make then would be to observe the response pattern, both r.f. and i. f. Pay particular attention to the portion of the response which deals with the color signal sidebands.

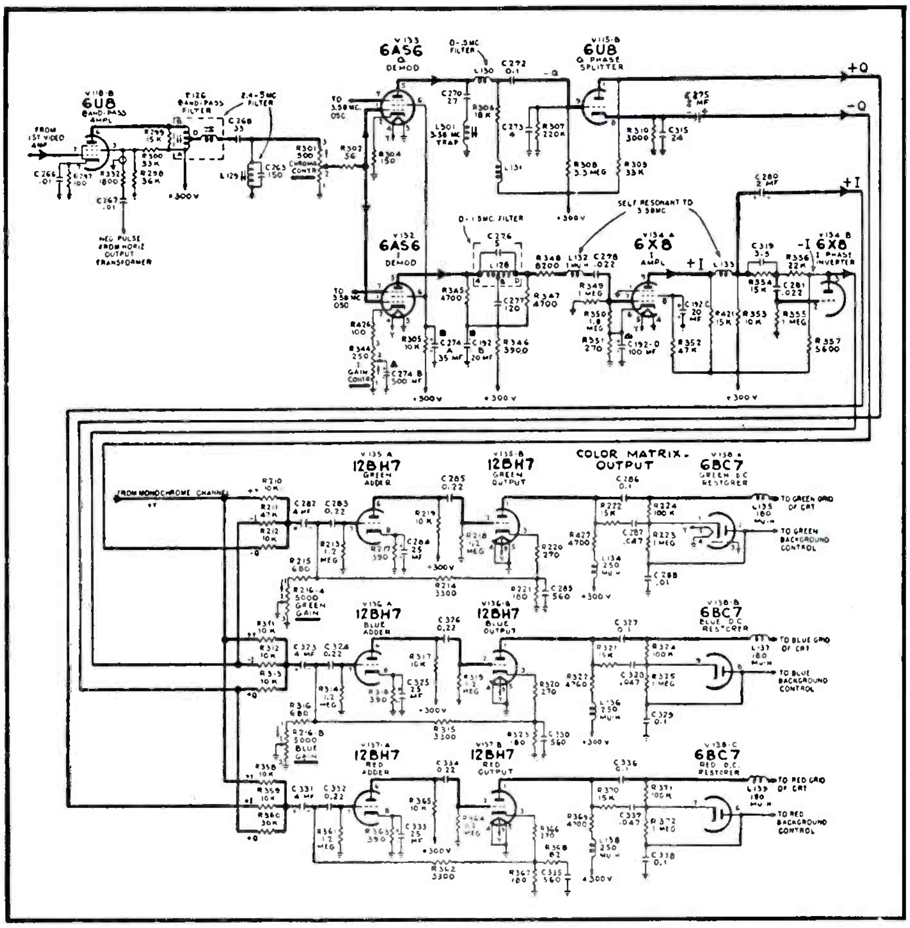


Fig. 5. Schematic diagram of the chrominance circuits of an RCA CT-100 color set.

The Delay Line

If the delay line in the *Y* channel does not introduce the proper amount of delay in the *Y* signal, the color rendition will be affected. To appreciate the visible consequence of this action, let us briefly review the part played by the *Y* signal in the over-all formation of the color picture.

The *Y* signal contains all of the video frequencies displayed in the picture. In the absence of color, perhaps due to a defective color section in a receiver or because the program is in black-and-white, a full black-and-white picture is obtained.

Now, to obtain a color picture, three pieces of information are required. First, there is the color or hue itself, be it green, blue, red, yellow, etc. Second, there is the saturation or the intensity of the particular color; and third, is its brightness. The first two components are carried by the color sidebands; the remaining item, brightness, is the information that the *Y* signal possesses.

With this in mind, let us examine some common colors to see how much of their total make-up is formed by the brightness component. In Fig. 6 we have a series of six colors: red, yellow, green, cyan, blue, and magenta. To ascertain their brightness values, we require the formula for the brightness signal, namely,

$$Y = .59G + .30R + .11B.$$

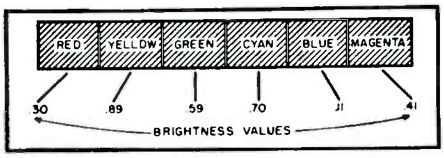
From this equation, we see that green has a brightness value of 59 per-cent, red a value of 30 per-cent and blue, 11 per-cent. Yellow and cyan are not given directly because they are combination colors. To arrive at their brightness values, we must add the brightness values of their components. Since yellow is formed from red and green, its brightness value is .59 plus .30 or .89. By the same reasoning, cyan has a brightness value of .70 and magenta a value of .41.

Of the six colors, yellow has the highest brightness value and blue the lowest value. On a screen, then, yellow will appear brightest and blue will be the darkest. However, if something should cause the *Y* component to disappear, perhaps by a defect in the *Y* channel, then the yellow would become quite dark. Cyan, which contained 70 per-cent brightness would become darker, although not as much as yellow. Green would lose even less brightness, red still less, and blue practically none at all since it possessed only 11 per-cent to start with. Thus, with the complete loss of brightness, the apparent intensity of the colors appearing on a screen would reverse, with the brightest colors (ordinarily) appearing darkest and the darkest colors appearing brightest. If you come across a situation like this, you can check for the brightness component by observing the picture in black-and-white. (This can be accomplished most easily by turning the chroma control to its extreme counterclockwise position). What you see on the screen should either be a very dim picture, just barely visible, or no picture at all.

Instead of the complete loss of the *Y* signal, we might encounter a situation in which the delay line in the *Y* channel did not introduce sufficient delay. This would occur if part or all of the line shorted out. Under these conditions, the *Y* signal would appear at the matrix before its corresponding color component. As a result, the *Y* component will combine with some other, prior color. If we had the color-bar pattern of Fig. 6 on the screen, part of the red bar would possess its proper brightness and part would be lighter in appearance because the higher brightness component of the yellow would now be mixing with the red. In the yellow bar, the first part would be normal, but the second half would be darker (although still yellow, of course) because it would be combining with the lower brightness component of the green bar. The same thing would occur all along the line.

On a completely black-and-white picture, a defect in the delay line would not have any noticeable effect

Fig. 6. Six saturated colors are represented here with their brightness values obtained from the Y equation.



because all components of the *Y* signal would be affected similarly. Hence, this trouble could not be detected by simply viewing a color picture in black-and-white. The best testing device would again be a color-bar generator.

It is possible, although not as likely, for the delay line to introduce too much delay. In that event the brightness signal would arrive later than usual at the matrix. In the color-bar pattern, the visual effect would be to alter the first part of each bar while the second half would possess the proper brightness value.

In receivers of the *I* and *Q* variety, a delay line is also employed in the *I* channel. Any variation in its characteristics would not affect the brightness of color, but rather the color itself. This is because the *I* signal combines with the *Q* signal in the matrix to form the color signals which are fed to the picture tube. Any variation in either *I* or *Q* would then directly concern the amount of signal which the red, green, and blue control grids of the picture tube received and this, in turn, is directly related to the colors produced on the screen.

Color Instability

The last general category of troubles that affect the color of a picture is the inability of the receiver to maintain the color rendition constant. Symptoms of this condition may either be an erratic variation in color or the appearance of color bands moving down across the image. Reasons for this behavior usually stem from a defect in the color sync section of the receiver. For example, in the sync system shown in Fig. 3, the reactance tube may be defective, the phase detector may not be functioning properly, or the oscillator may be off frequency. Another possibility in this particular arrangement is a burst amplifier which is not amplifying or passing the color bursts properly.

In the ringing type of color sync system, there is less possibility of loss of color lock-in. This is because the crystal must be triggered (or shock excited) by the incoming bursts and this tends to automatically establish the phase of the generated 3.58-mc. oscillations. On the other hand, if the crystal is not triggered, no 3.58-mc. oscillations appear and, of course, no color. Once the 3.58-mc. signal is developed there are actually no components beyond the ringing circuit which can cause the color to fluctuate. The color, of course, may be shifted from its true value, but this shift is fixed and rotation of the hue control will ordinarily bring it back to normal. This is not a defect since the circuits are operating within their designed limits.

—30—

COLOR PROGRAMS

Top TV programs and many local shows now available in color all over country.

THIS is truly the year for color television. Now for the first time, families with color receivers will be able to view at least one major color program every evening in the week. NBC, which has been in the forefront on color, is broadcasting weekly a well-balanced lineup of programs including its most popular shows. CBS is also telecasting about 5½ hours of color programs per week. Among the NBC shows to be regularly colorcast each week are "The Chevy Show," "The Goodyear Playhouse," "Robert Montgomery Presents," and "The Perry Como Show." In addition, the "spectaculars" will also be in color. Such CBS star programs as "The Arthur Godfrey Show" and "The Red Skelton Show" will be regularly shown in color. Special CBS color shows are "The Ford Star Jubilee" and "Shower of Stars."

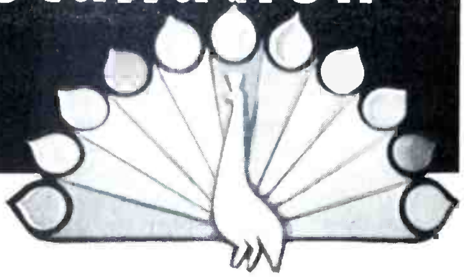
This means that all viewers within the reception area of any NBC or CBS network station which has the facilities to telecast network shows in color, can receive these programs on a color set, such as the RCA "Aldrich" model 21CS-781 ($495.00) shown in the picture above. Over 50 per-cent of the 200 NBC network stations now broadcast network color. The number of CBS color network stations is also high.

In addition to the network shows, many stations are originating local color shows. WABD, the New York City Du Mont station, plans to telecast cartoon shows in color during the day and evening. All shows originating at WNBQ in Chicago are broadcast in color. It broadcasts approximately 25 hours of local color a week. Many other stations now have color cameras and/or color film equipment and many stations are now expanding for color.

This all means that buyers of color TV sets this winter can look forward to many pleasant hours of entertainment in full-color.

—30—

Key to Color TV Installation and Servicing



By **W. W. COOK**
Technical Training Section, RCA Service Co., Inc.

Clear and concise instructions on how to repair the most frequent troubles occurring in new color TV sets. Also—how to set up a receiver for the installation.

BASICALLY, the installation procedure for the latest line of color television receivers is much less involved than for the earlier models. In most cases, the only installation requirement is de-magnetization of the picture tube. This should be done irrespective of whether or not it is considered necessary.

To accomplish de-magnetizing, use a coil 12 inches in diameter and consisting of 400 turns of #20 enameled wire. To this coil attach an a.c. line cord 10 feet in length with a switch. Apply 117 volts a.c. to the coil, holding the coil with its plane parallel to the face of the picture tube. Move the coil slowly about the face of the CRT for a few moments, then back away from the tube about 6 feet and turn the coil 90° so that it is perpendicular to the face of the tube. Remove the a.c. from the coil and the de-magnetizing job is completed.

Shown in Fig. 2 is a color-contaminated black-and-white picture on a color picture tube. This condition may be caused by a magnetized picture tube and the simple de-magnetizing procedure given here could save many fruitless hours of attempting to correct this situation by other means.

In some cases the condition shown in Fig. 2 could be caused by the yoke or purity magnet becoming dislodged during receiver shipment. If de-magnetizing does not cure the condition, turn the blue and green screen controls completely counterclockwise. A red picture with color impurity at the edges (see Fig. 11) will result. Adjust the yoke and or the purity magnet until a pure red picture is obtained (Fig. 12). Then readjust the blue and green controls to obtain a good black-and-white picture. It is very important that center convergence be maintained during the purity adjustment. Otherwise, a good red field may be obtained but the blue and green fields may be slightly contaminated causing a poor black-and-white picture.

After completing the purity adjustments the convergence should be checked. To do this, a convergence generator causing a crosshatch pattern (Fig. 1B) or regularly-spaced white dots (Fig. 13) to appear on the screen of the color tube should be connected to the receiver. Many dot generators provide both dot and crosshatch patterns. One method of using these patterns is to work with the crosshatch for dynamic convergence and dots for final static adjustments. Generally, dynamic convergence adjustment is not required for the initial setup of the receiver. Fig. 5 illustrates a condition where red and green has shifted. This is typical of static convergence complaints. A slight adjustment of the red and green d.c. convergence controls will correct this condition.

Obtaining a good black-and-white picture is extremely important if good color reception is to be expected. Some of the newer black-and-white picture tubes tend to give a slightly bluish tint to white areas whereas the early 10-inch picture tubes were on the brownish side. The black-and-white picture on a color tube should be adjusted so as to be slightly brownish in color. Most technicians lean too heavily in the blue direction. In many cases the picture is much too blue, even bluer than the bluest black-and-white picture tube. As a guide, check the picture against the one on a black-and-white receiver if one is available. If not, lean slightly toward the brownish hue. Doing this will actually enhance color reception since, if the tube has a bluish background, flesh tones will wash out or become very pasty looking.

After checking out the color receiver for black-and-white reception, check it for color. If color program material is not available when the receiver is installed or being serviced, a color-bar or similar color pattern generator must be used. A normal bar pattern presentation with the receiver correctly adjusted is shown in Fig. 1C. Note that the bars range from red on the left through blue to green on the right. Each bar has some significance when adjusting the color receiver. For example, the third bar from the left is vectorially 90° from burst phase and represents *R-Y*. The sixth bar is 180° from burst and represents *B-Y*.

When the color-bar pattern is adjusted properly, the fourth bar should have a magenta color. In Fig. 6 the second bar is magenta. This indicates that the hue control is adjusted improperly. It should be rotated until the fourth bar is magenta as seen in Fig. 1C. If the fourth bar can be made magenta by rotation of the hue control, but if as a result, the colors of the other bars are incorrect, a complete matrix adjustment must be made.

Basically, there are two methods by which this adjustment can be accomplished using the color-bar generator. An oscilloscope can be connected to the grids of the picture tube and adjustments made to obtain the proper waveforms. This method is the most accurate; however, it may be inconvenient to carry an oscilloscope into the customer's home. An alternate method of matrix adjustment which is simple and accurate will be described here. It is necessary in this method to make two of the guns in the kinescope inoperative while the third is being used. To accomplish this conveniently, connect a 100,000-ohm resistor between the grid of each gun to be cut off and ground. Take two clip leads, cut them in half, and insert a 100,000-ohm resistor in series with the two parts of each lead. Thus, one end of the lead can be connected to the grid and the other end to ground.

If the blue and green guns of a color tube were cut off by means of these clip leads, and if a color-bar generator were connected to the receiver, the resulting pattern (Fig. 7) would be that due to the *R-Y* signal. The sixth bar from the left, indicated by the arrow, should be the same brightness as the adjacent red background. This bar represents *B-Y* and the fact that its brightness is the same as that of the background indicates that the magnitude of the *B-Y* signal on the red grid is zero, which is correct. If the sixth bar is not the same brightness as the background, then the phase of the *R-Y* 3.58 mc. c.w. signal needs to be re-adjusted. All recent color receivers have a control for this; on the *RCA* color sets using the CTC5 series chassis, for example, the top slug of transformer T_{705} is the applicable adjustment (see Fig. 15).

After making the necessary adjustments to obtain the pattern in Fig. 7, remove the clip lead from the blue grid and attach it to the red grid. Now the green and red guns are cut off leaving a blue bar pattern (Fig. 8). In this pattern, the third bar from the left (indicated by the arrow) is of the same brightness as the background, which is blue. This bar represents *R-Y* (see Fig. 1C) and indicates whether there is any *R-Y* signal on the blue grid. If there is some *R-Y* signal on the blue grid, bar three will not show up as pure blue and the phase of the *B-Y* signal has to be reset. This is effected by varying the *B-Y* 3.58 mc. c.w. phase control.

Next, remove the clip lead from the green grid and connect it to the blue grid. A green bar pattern should be obtained (Fig. 9). Here the seventh bar should be the same brightness as the background. If not, adjust the *G-Y* phase control.

With all of the conditions met as shown in Figs. 7, 8, and 9, the bar pattern shown in Fig. 1C should be obtained after removing the clip leads. Checking the receiver in this manner will assure the customer proper color operation.

The antenna system is the only other link to be checked out during installation. Most TV stations currently transmitting color provide a color test stripe during black-and-white transmissions. This vertical stripe is positioned at the right hand side of the screen and is normally not visible. However, by setting the fine tuning control so that sound bars are barely visible and adjusting the horizontal frequency so that the picture moves to the left, the stripe will become visible, provided the color control is turned maximum clockwise. With the hue control set properly, the color of the stripe should be a greenish yellow.

If the stripe cannot be obtained and it is known that it is being transmitted, re-orienting the antenna is usually all that is required. In addition to this, it is a good idea to check the transmission line for opens and poor termination. Also check the lightning arrester if one is present.

Customer Instruction

After completing the color receiver installation it is very important that the customer be properly instructed on the use of the customer controls. Probably the best starting point is to obtain a good black-and-white picture. First, set the fine tuning control to the point where sound bars appear in the picture, then turn back the control until the bars just disappear. This must be done with the color control fully counterclockwise or in the off position. Adjust the contrast, brightness, and color controls for proper color saturation. The hue control can then be adjusted for proper flesh tones.

If there is no color transmission at the time of customer instruction, make sure he or she can demonstrate proper black-and-white picture adjustments. However, explain the proper use of the hue and color controls. Service calls can be greatly minimized by a good receiver installation and proper customer instruction.

Service calls after initial installation include the normal troubles encountered in black-and-white sets plus additional problems related only to color. The troubles dealing with color only include: no color, improper color, no color synchronization, and low color saturation.

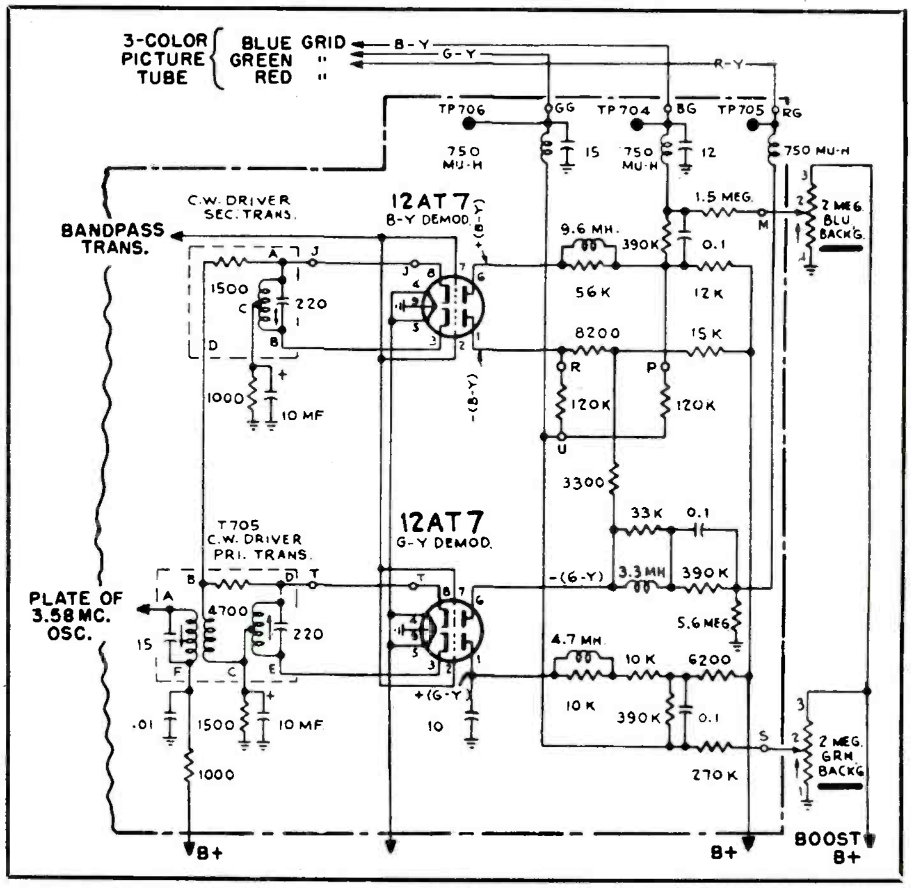
Before attempting to service the color circuits, it is important that the receiver must be capable of receiving a normal black-and-white picture. The same techniques apply for servicing the black-and-white circuits of color receivers as those presently employed in the service of standard monochrome receivers. The only exception to this is the picture tube circuitry.

It is possible that the customer may complain of a completely red screen during black-and-white reception, as shown in Fig. 12. This would indicate that the red gun of the tri-color picture tube is shorted. However, the bias voltages should be checked before replacing the picture tube. Also, the customer may complain of color fringing around objects in an otherwise black-and-white picture. This would indicate that either convergence is misadjusted or that there is trouble in the convergence circuits. Another possible customer complaint may be that there is color contamination in the black-and-white picture (Fig. 2). If the set was properly installed and adjusted initially, this trouble would indicate that the receiver has been moved. De-magnetizing will probably clear up this trouble. All of these malfunctions have no direct bearing on the color circuits yet show up as colored defects.

To service the color circuits, it is usually necessary to use a color-bar generator or other source of color signal for troubleshooting. This is necessary since there may be no color telecast at the time of the service call. Also, by using such equipment, the technician can check the color matrixing as a final step of the service call.

Troubles in the color section are usually confined to the bandpass amplifiers, color demodulators, and the color synchronization circuits. Inoperative bandpass amplifiers can cause no or weak color reception. If the demodulators should fail, one or more colors may be missing from the color picture. For example, using a color-

Fig. 15. Schematic diagram of color demodulator circuits of the RCA CTC5 chassis.



Crystal Controlled

WHITE DOT-BAR—COLOR DISPLAY—GENERATOR

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Model 660

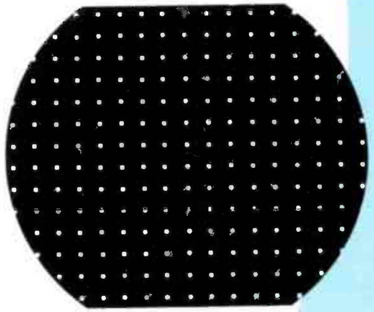
Weighs only 15 pounds

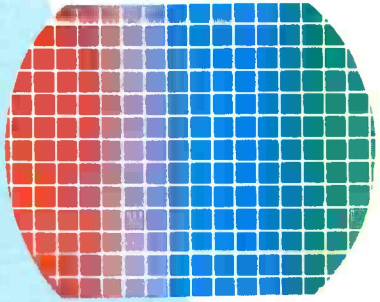
- This equipmenr features the necessary high degree of stability not found in Variable White-Dot generators. In the 660, all frequencies generated are crystal controlled and "locked" together for extreme stability.
- Frequency of chrominance (color) signal is exactingly crystal controlled to reduce possibility of alignment errors. This feature permits increased accuracy over ordinary color generators which use a free running oscillator.
- RF output frequency is in preset channels, 2 thru 6, to allow easy selection through a built-in switching arrangement.
- Small dot and crosshatch size down to two lines in both horizontal and vertical planes.
- Color display pattern with crystal accuracy is a blending in the following color sequence: Orange, Red, Magenta, Blue, Cyan and Green.
- Ratio of sync to video is variable from 10 to 90%.
- The small-size portobe design of this equipment permits easy on-location color TV checks to quickly determine ability of a receiver to produce color in the proper hue . . .even in the absence of a station signal.
- The circuit of the 660 is such that the instrument will be useable regardless of future color TV receiver design.
- The exceptionally stable timer circuit will hold synchronization over a very wide range of line voltages that may be encountered in on-location servicing.

For alignment of Color TV receivers.

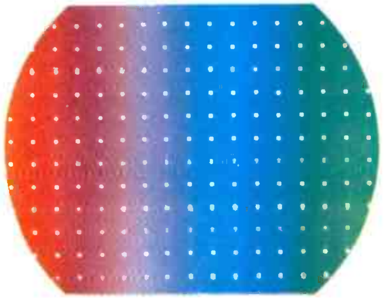
Easy to use . . .
Preset channels allow easy selection through a built-in switching arangement.

(Model 660 or Model 656 XC)
Small size white dot pattern. 300 white dots, less those in blanking.

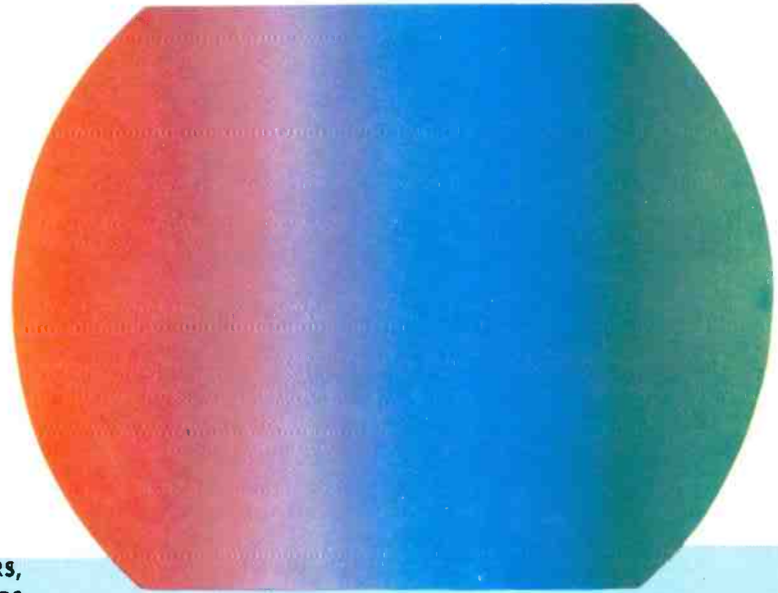




Color display pattern with Cross-hatch. (Vertical lines only or horizontal lines only may also be superimposed on color display pattern.)

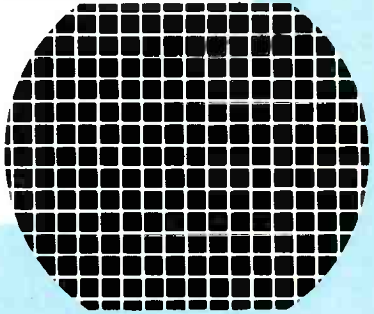


Color display pattern with white dots.



Color display pattern with crystal accuracy. Color sequence: A blended display of Orange, Red, Magenta, Blue, Cyan and Green.

(Model 660 or Model 656 XC)
White line cross-hatch pattern. 20 vertical and 15 horizontal, less those in blanking.



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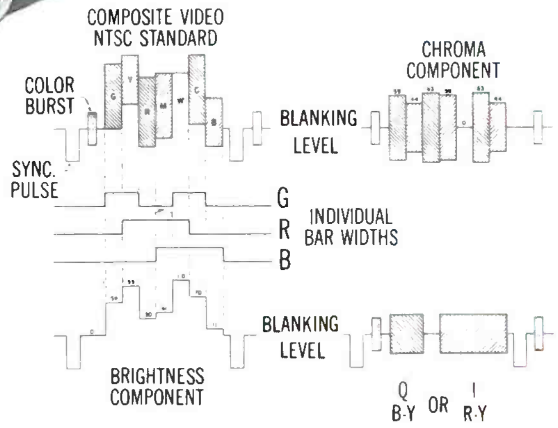
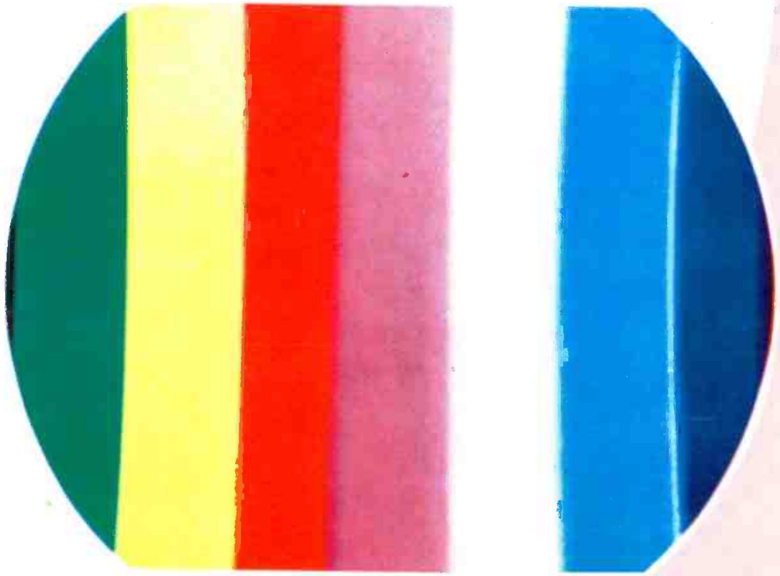
COLOR BAR — WHITE DOT-BAR Generator

- Designed for use with all TV color systems approved by F.C.C.
- Precisely crystal controlled: Sub carrier and horizontal framing. Produces clearly defined wave forms to provide ease of alignment and assure minimum possible error.
- NTSC standard phase and brightness: This NTSC standard signal was used in designing all color TV receivers and is now used by TV manufacturers.
- Self Checking: Assures operator that generator is producing accurate NTSC standard signal at all times.
- Generates 3 primaries, 3 complements plus black and white. (An essential feature of this equipment is that white is produced by adding the 3 primaries.)
- The Model 656XC is preferred for its accuracy, stability and long trouble-free operation. This instrument was designed and built in cooperation with leading color TV receiver manufacturers and is specified by them for their field service engineers.
- Output is either R.F. or Video. Video: 0-2 volts peak-to-peak open circuit. 0-1 volt peak-to-peak across 100 ohms with positive or negative output. RF: Modulated output modulated through color bar pattern—channels 2 thru 6. A sound carrier is also provided for accurate setting of local oscillator in TV receivers.
- Generator is self-contained . . . no complicated external synchronizing connections. Equivalent vestigal side band modulation. Avoids overloading of chroma channels.
- In addition to color bars, this instrument generates the necessary signals to align R-Y, B-Y or I and Q type demodulators. These signals appear at black level with equal amplitudes.
- Produces: White Dot-Crosshatch (20 vertical and 15 horizontal, less those in blanking); Vertical Lines only; Horizontal Lines only; and small size white dots which are "locked" to assure stability. This "locking" is achieved through the extremely stable (crystal controlled) timer circuit. White dots are of perfect size (approx. 2 lines thick) to permit accurate convergence adjustments. 300 dots are present in each raster, less those in the blanking region.



This NTSC standard waveform is to precise scale and is accurately produced in detail by the 656XC when viewed on a high-quality wide-band scope (at least 4.5 MC).



Generates color bars on the screen of any Color TV receiver in the following order from left to right: Green, Yellow, Red, Magenta, White, Cyan, Blue and Black. (All literature and alignment data published is based on this standard NTSC signal.)

Model 656XC

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*National Television Systems Committee as approved by Federal Communications Commission bar generator, the tube may display a normal bar pattern except that all blue may be missing (Fig. 10). This could be caused by a defective tube or component in the *B-Y* drive to the blue gun of the picture tube.

The color synchronizing circuits can cause two types of defects. If the 3.58 mc. reference oscillator should fail, the picture tube will not display color. If the transmitted burst pulse is not fed to the 3.58 mc. oscillator circuit, possibly due to a defective burst amplifier stage, the color picture information will roll. (This is similar to the effect produced by the absence of horizontal sync in a black-and-white picture.) This condition is illustrated in Fig. 4. It can be seen that red, green, and blue color stripes are running through the picture. By turning the color control off, a normal black-and-white picture may be seen. A wide-band (0-4.5 mc.) oscilloscope is very useful in tracking burst and chrominance signals through the color circuits.

In addition to troubles found only in the color circuits, defects in the i.f. and video stages can cause improper color rendition. For example, it can be seen in Fig. 3 that the edges of the bars are incorrect. This would show as "ringing" in a black-and-white picture. This effect will not vary with adjustment of the fine tuning control. The cause is an open ground in the video delay line which results in improper termination, thus the "ringing" or transient condition.

Fig. 1A is a photograph taken of the face of a color picture tube showing the peacock used at the end of an *NBC* color telecast. This picture illustrates the color display potential of a normal color television receiver.

As in black-and-white servicing, the picture tube presentation can be a valuable aid in analyzing circuit defects. Loss of color sync resulting in the picture of Fig. 4 would indicate immediately that the trouble was occurring in the color sync circuits. Once the trouble has been mentally analyzed the usual service techniques apply. First check tubes, then check for component failure by taking voltage and resistance readings.

After the technician becomes familiar with color receivers, service becomes almost as routine as black-and-white servicing. Probably the biggest challenge to the technician now entering this new field is the initial installation. However, after he has gained some experience, he will acquire confidence and proficiency.

—30—

For the RECORD

DON'T GO BROKE WITH COLOR TV

THERE will be a sizable risk to independent service technicians who, in future months, establish color TV service charges or contract rates that are based on previous monochrome requirements. The very nature of the color television receiver and its behavior is reason enough to anticipate an almost continuous demand for service on a monthly, if not on a weekly, basis for a long period of time.

The widespread public acceptance of color TV has recently been stimulated by a reduction of the list prices on such receivers. This price reduction has caused the public to visit dealers' showrooms in ever increasing numbers.

This cost reduction, unfortunately, is bound to be reflected in the quality of many color television sets reaching the dealers and customers. Because of this inevitable reduction of quality it will create a demand for service never anticipated by this industry—a demand that can be met by only a small minority of service operators who have been specially trained in the maintenance of a particular brand of color set. The leading set manufacturers have trained a substantial number of technicians to maintain the color sets sold by their own distributors. But many other manufacturers have apparently been content to sit back and wait.

Technicians are only kidding themselves if they feel qualified to service color sets using techniques which they themselves have established for black-and-white. New techniques and specially designed test equipment for color is absolutely essential, but even more important is the need for "color know-how."

It is no secret that thousands of color sets will be sold that use a minimum of tubes and circuits. Many will use triple- or quadruple-duty tubes in overworked circuits. Every known shortcut (and a lot of new ones) will be taken to produce sets of minimum standards in an effort to compete and to cut prices.

When these "competitive" color receivers reach the homes of the customers is when the unskilled and unprepared technician will run into real trouble. Most demands for maintenance will simply be "nuisance" calls as a result of aging of components, overloaded tube failures, and the effects of Junior's "skill" with the secondary controls. But there will be many major breakdowns and no longer will the picture tube serve to indicate likely trouble spots (compared to black-and-white).

Antenna requirements will be far more exacting and the orientation more carefully made. New, strange, and precise adjustments will be required on the receiver and a host of new and mysterious circuits will confront the technician.

Customers will be super-critical of their $500 baby and will be quick to heckle the dealer every time that red goes purple or when "Howdy Doody" suddenly turns green. He will soon learn from experience that the performance of the color set can be easily disturbed when the customer decides to play expert. These nuisance calls, and there will be lots of them, will eat up the technician's and dealer's profits at a rate far in excess of those encountered in the maintenance of the monochrome receiver.

Whatever complaints have become routine for monochrome will be multiplied many times in the case of the color set. It is in the interest of the welfare of color technicians of tomorrow that we point to the absolute necessity of anticipating the proportional time requirements for color TV service and to plan and make substantial adjustments when estimating contract requirements and other costs.

If you do not belong to an aggressive Service Association, then we'd like to suggest that you consider the possibility and the advantages of joining. One of the functions of these groups is (or should be) to study and recommend color service charges based on established requirements and the economy of the particular area served by the members. All of the existing service groups should now be giving serious study to the matter of establishing service charges for the maintenance of color TV. It's later than you think!

The most valuable asset of the TV service technician now and in the years to come is the ability to hold and to continually build a trusting clientele. It's taken several years for the average technician to establish a good fundamental relationship with his customers. But when color comes and he is not qualified to maintain a color TV set, he will quickly lose his precious customers to other technicians possessing the "know-how" of color troubleshooting and repair.

Even if color telecasting is not presently available in your area, the technician must prepare now for his future problems. Any service technician not willing to study and who assumes that he can "get by" without knowledge of color circuits is heading towards ultimate failure of his service business. . . . . O. R.

INSTALLING A COLOR PICTURE TUBE

By

WALTER H. BUCHSBAUM

Television Consultant

RADIO & TELEVISION NEWS

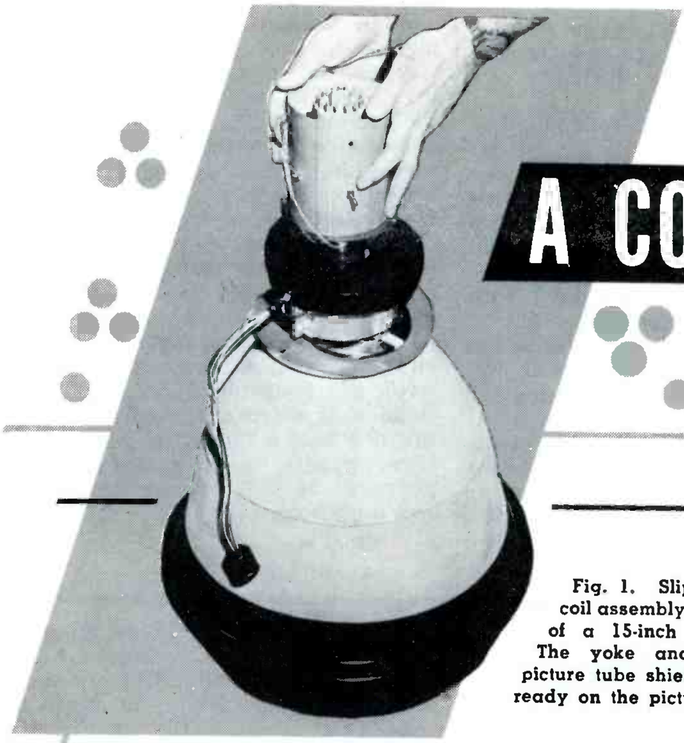


Fig. 1. Slipping a purity coil assembly over the neck of a 15-inch color tube. The yoke and Mumetal picture tube shield are already on the picture tube.

You may not install a color picture tube tomorrow, but you will need to know these facts when you do.

NOW that some manufacturers have started to ship the first color TV receivers to their dealers, information on installation problems is becoming available. The majority of these early TV receivers use the shadow-mask type color tube and this is usually shipped in a separate carton. Assuming that all circuits have been adjusted properly at the factory, the main job is to mount the color picture tube and adjust the various components and controls for proper pictures.

This article presents a detailed setup procedure for both the 15GP22 (*RCA*) and the 15HP22 (*CBS-Hytron*), as well as the new 19-inch tubes, based on manufacturers' instructions and the personal experience of the author. It might be mentioned here that a full day was spent for the first setup, but it took less than an hour the third time to produce acceptable color pictures. Installation procedures are presented here in hopes that they will save service technicians from many errors they might commit when they come in contact with color sets.

Before unpacking the picture tube, the color receiver should be air-tested for sound reception. Also check the "B+" and heater voltages. Next, check off the following items which go on the picture tube:

1. *Mumetal* shield.
2. Deflection yoke.
3. Purity-coil assembly.
4. Convergence-coil assembly and blue magnet for 19-inch tubes.
5. Field-neutralizing coil (omitted in some models).

The major test equipment required is a dot generator or a bar generator. If neither is available, a monochrome or color station signal can be used. For final testing, both monochrome and color signals should be used, although a lot can be accomplished with monochrome only. In addition to a conventional multimeter, a high-voltage probe or meter having a range up to 30 kv. should be available. A mirror will greatly help in some adjustments.

Since the high-voltage supply furnishes up to 27 kv. at 1 ma., the ordinary safety precautions should be increased. Wearing rubber soles and heels, plenty of space to move in, and some privacy, are a great help to the technician in his first encounter with the new color TV monster.

Preliminary Adjustment

Remove the color picture tube from the carton and place it face down on a padded spot. Figs. 1 and 2 show the location of the various items mounted on the 15-inch color picture tube. The *Mumetal* shield does not fit directly on the tube envelope, but contains foam rubber pads which cushion and center it. A plastic insulating ring, similar to the ones used on metal-envelope tubes, fits over the metal flange which connects internally to the 2nd anode or "ultor." Fig. 3 shows the components on the 19-inch color tube. The major differences between it and the 15-inch tubes are described in the section on convergence.

After mounting all parts, install the entire assembly on the receiver chassis. The blue gun should be on top, as shown in the socket end view in Fig. 2. Line the inner tube mask up with the cabinet escutcheon. Before connecting power to the receiver, be sure all plugs are in their respective sockets.

Turn the set on, allow for warm-up time, and tune in a monochrome or color telecast. Check fine tuning, contrast, brightness, and sync for best reception. In most color TV receivers, the high voltage is regulated, and this regulation as well as the actual voltage should be checked. The voltage at the kinescope "ultor" terminal—the metal flange near the face of the tube—should remain at 20 kv. (27 kv. for the 19-inch tube), with either a bright or dark raster. Check this by watching the meter and varying the master brightness control.

To improve regulation or increase the voltage to the correct value, adjust the high-voltage regulator control shown in the simplified diagram of Fig. 4. This control is usually located inside the high-voltage compartment.

Next, turn the color or chromaticity control counterclockwise for minimum color video and adjust the contrast or brightness control for a fairly clear picture. At this stage of adjustment, the coloring of the screen can be neglected and adjustments for a.g.c., horizontal and vertical sync, linearity, size, and centering should be made. Do not attempt to oversweep the edges of the internal screen mask, but rather leave the left and the top edge visible.

For these adjustments, especially for linearity checks, a station test pattern is very helpful. If none is available, the bar generator can be used. In color TV it is absolutely essential that both vertical and horizontal linearity be near perfect. Later adjustments will affect such other criteria as focus and convergence. Incorrect linearity will greatly complicate the dynamic focus and convergence adjustments, so be sure to get the proper aspect ratio, size, centering, and linearity before adjusting any of the color controls. Good synchronization, especially in the horizontal section, is also essential. Most receivers use a modified synchroguide circuit, requiring both locking and phasing adjustments for which standard black-and-white adjustment procedures apply.

The cylinder located near the picture-tube socket, as shown in Fig. 2, is the purity coil assembly. It consists of the purity coil, three small permanent magnet screws, and the magnetic shield cover. See Fig. 3 for the position of the purity coil on the 19-inch tube. Adjusting color purity involves orienting the three electron beams with respect to the center line of the picture tube. It is necessary to vary the location, direction, and magnitude of a transverse magnetic field for each of the three beams and, finally, optimize for best combined operation. One satisfactory method for doing this is outlined below.

1. Remove the video signal and turn down the green and blue screen controls. (See Fig. 5.) Adjust the red screen control for a screen color of almost pure red.
2. Slide the deflection yoke as close to the purity coil as possible, and screw the three permanent magnet screws out from the center for minimum effect. For the 19-inch tube, turn the d.c. convergence controls to minimum.
3. Rotate the purity coil and adjust the current through it until the center of the screen is a deep pure red. Consider only the center and disregard the edges. It is possible to obtain good purity with several combinations of coil current and position; select the one using the least purity-coil current.
4. Slide the deflection yoke forward until the entire screen is a uniform red. Now the neck shadows and color contamination along the edges should be eliminated by proper yoke placement. It may be necessary to touch up the purity-coil adjustment if it is not possible to get a clean red raster with the yoke placement.
5. Turn the red screen down and the blue screen up. If the screen color is not a uniform blue touch up the purity-coil current and rotation slightly.
6. Turn the blue screen down and the green screen up. It may again be necessary to touch up the purity adjustment.
7. Check purity again on red and blue. In some receivers a compromise must be made between best purity on all three colors.
8. It may be that all preceding adjustments cannot be made as smoothly and simply as described. Occasionally some stray magnetic field may interfere and this would be noticeable by sudden rather than gradual variations in purity or by stubborn color contamination at a particular spot on the screen. Such external magnetic fields may be due to a magnetized screwdriver, a permanent magnet speaker, or other magnetic device located near the receiver. Some color sets use a field neutralizing coil located near the screen as shown in Fig. 2, and this coil can be adjusted to overcome the effect of stray fields. In general, the field neutralizing coil is rotated and the current through it adjusted to aid the purity assembly in its operation. The adjustment procedure described appears quite complex and time consuming, but after some practice it is possible to perform the purity alignment in five minutes.

Convergence Adjustment

In order to get sharp and clear color pictures it is necessary for all three electron beams to strike the screen simultaneously at adjacent dots. For the 15-inch tubes, three separate forces make the beams converge and each of these must be carefully adjusted. The first consists of three small magnets located on the purity coil shield around the neck of the picture tube. Each magnet has its major effect on the electron gun lying underneath it, but also affects the beam from the other two guns. The purpose of the magnets is to position the three beams so that the three colored rasters coincide.

In addition to the magnets there is an internal, electrostatic-lens type element in the 15-inch tube which controls the beam convergence at the screen. It receives a high d.c. voltage, adjustment of which determines the convergence at the center of the screen. The convergence element also receives a horizontal and vertical dynamic convergence voltage which, when superimposed on the d.c. potential, determines the convergence at the edges of the screen. This dynamic convergence signal is required to compensate for the variation in electron beam path length as the beam moves from the center of the screen to the edges. Fig. 6 shows the wave shape of the dynamic convergence voltage.

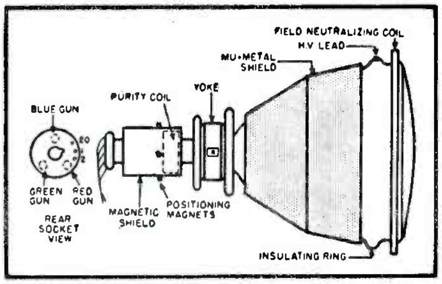


Fig. 2. Shown here are the various focusing and deflection components that mount onto a 15-inch color picture tube. The field neutralizing coil may be omitted in some receivers.

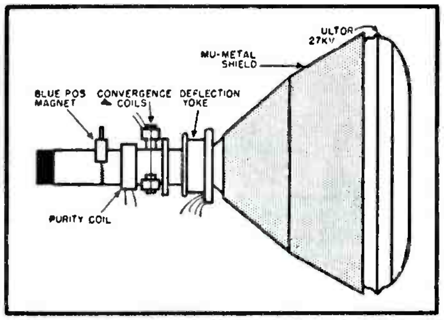
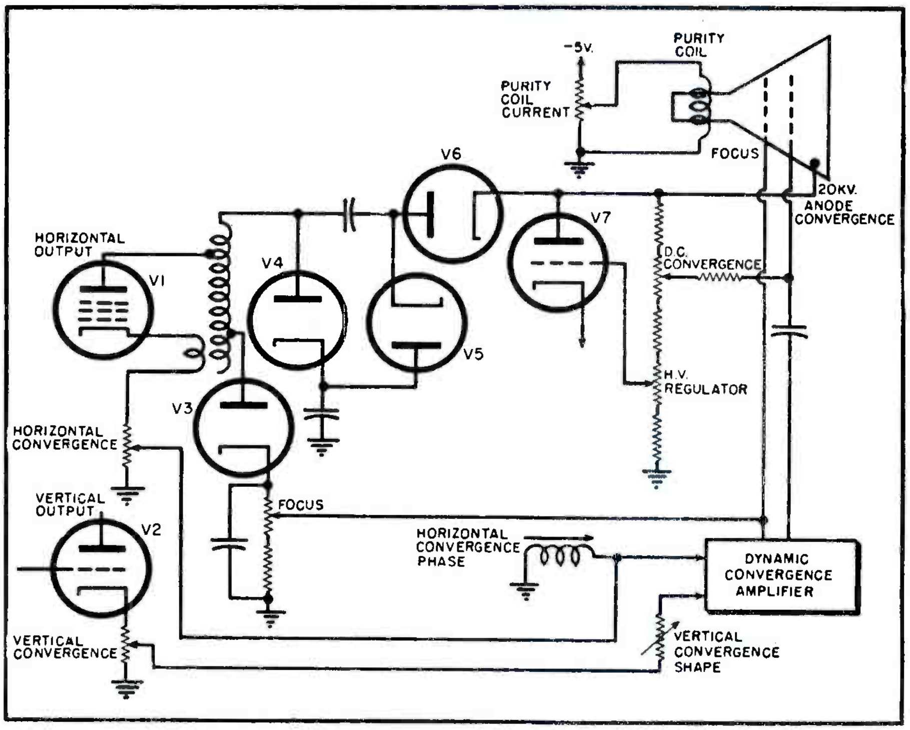


Fig. 3. A 19-inch shadow-mask type color TV tube shown with the various deflection and focus components. Note that here electromagnetic convergence is used rather than electrostatic.

It should also be pointed out that the beam focus must be varied as well. In the 15GP22 and 15HP22 there are three electrostatic focus elements connected together which receive a d.c. focus voltage, plus a portion of the dynamic horizontal and vertical convergence signal. The schematic presentation for this connection is shown in Fig. 4.

Before adjusting for convergence and focus, the screen should be tuned for a low-brightness white. This is done by turning the chromaticity control down and adjusting the red, blue, and green

Fig. 4. Focus, high voltage, purity, and convergence adjustments for color set.



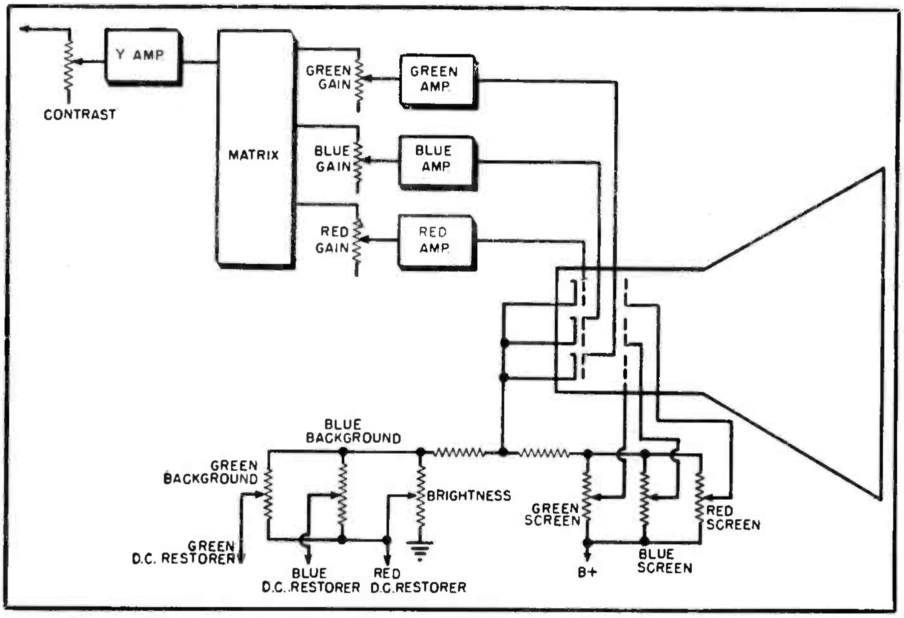


Fig. 5. Brightness, contrast, and color controls of a color TV receiver. Not all of these controls are adjusted by the service technician when he installs the tube.

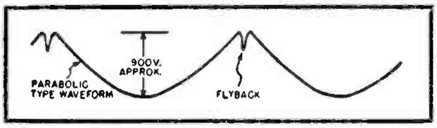


Fig. 6. Waveshape of the horizontal convergence voltage for a 15-inch tube.

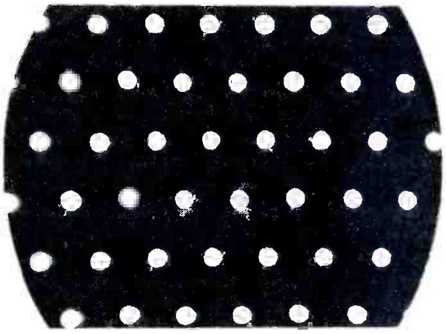
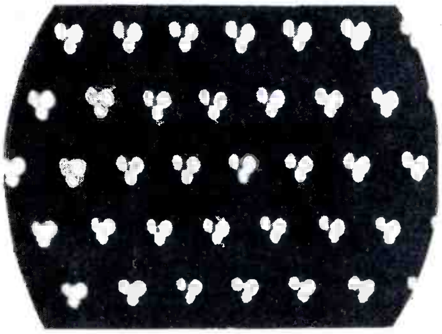


Fig. 7. Dot pattern generated by a dot generator and observed on the screen of a color picture tube when the three guns are in good convergence. Each dot actually consists of three different colored ones, so close they look like one.

screen controls until a neutral white or light gray is obtained. It should be pointed out that this will not be achieved when all three controls are set to exactly the same point. To get white some experimentation is required which usually provides a demonstration of the principles of colorimetry. When the blue screen is turned down and the red and green turned to about equal brightness, yellow will appear. Red and blue only will result in shades of purple. With some practice it is quite easy to get a neutral light gray quickly.

Fig. 8. The pattern appearing on the face of a color tube when a dot generator is used and the d.c. convergence voltage is lower than normally required.



To set the three positioning magnets roughly, adjust the centering controls until a corner of the raster appears. Usually this corner will show some of the colors even when the rest of the screen is white. It will appear that the three rasters do not overlap completely. Where all three overlap, white will appear. Where red and green overlap the screen will appear yellow. Red and blue give magenta, and blue and green produce cyan (a greenish blue color). At this stage it is best to "make haste slowly."

Turn each of the three permanent magnet screws inward one turn at a time, and observe the effect of each one on all three colors. It will become apparent that each of the magnets has major control over one color but also has considerable effect on the other two electron beams. In other words, the adjustment of each magnet must be followed by adjustment of the other two magnets until a good compromise setting is reached. The aim of this compromise is to get all three colors to coincide as well as possible. It should be pointed out here that perfect corner registry is not essential nor easily attainable.

The convergence adjustments must be made with some kind of video signal, otherwise lack of convergence is not apparent. The best type of signal consists of a number of very sharp pulses, producing a dot pattern on the screen. Other usable patterns consist of vertical and horizontal bars, preferably in a grid pattern, or a regular monochrome video signal. In the last instance it is preferable to use a station test pattern if available.

Poor convergence will give the appearance of three colored pictures out of register. When the monochrome video signal is used, the edges of objects will appear in three colors, rather than uniform gray. If the d.c. convergence is good, this poor registration effect will be most noticeable at the sides. This is somewhat tricky to check especially on moving scenes. For this reason the use of a grid or dot pattern is better. Adjusting convergence with a dot generator is fairly easy.

1. Connect the dot generator and adjust the brightness and contrast controls to avoid blooming and obtain sharp dots, locked in with the sweep circuits. Fig. 7 shows the screen of a color tube with a properly converged dot pattern.

2. Referring to Fig. 4, turn both vertical and horizontal dynamic convergence controls to minimum.

3. Turn the d.c. convergence voltage control to a low value until three separate dots are visible as in Fig. 8. The green dot is at the left, the red next to it, and the blue below.

4. Turn the d.c. convergence voltage control up until the three colored dots merge into a white dot at the center of the screen. If the convergence voltage is too high the pattern of Fig. 9 will appear where the blue dot is on top and the entire color sequence reversed from Fig 7.

5. It may not be possible to obtain perfect convergence at the center of the screen with the d.c. convergence control. In this event the positioning magnets must be reset. Every change in the positioning magnets will require some further change in the d.c. convergence setting. At the same time the focus control must be set each time for best focus. All these adjustments are interdependent to some degree and the best approach is to perform each step slowly, not advancing any control too far and carefully observing the dot pattern on the screen. In some picture tubes it may appear that the magnets should be positioned quite close to the guns, but this means that the optimum position has already been passed and the magnets should be withdrawn several turns.

6. After the center of the screen shows clear white dots without color fringing, the dynamic convergence controls are adjusted. The vertical dynamic convergence controls, see Fig. 4, are set first to make the top and bottom misregistration equal. Observe the dots going down the center line and when top and bottom dots appear equally misregistered, touch up the d.c. convergence control to converge the entire vertical center line of dots.

7. Now adjust the horizontal dynamic convergence control for equal misregistration of the left and right dots on the horizontal center line. As in step 6, touch up the d.c. convergence control to converge the entire center line.

8. If it appears impossible to converge both left and right edges, the horizontal dynamic phase control, as shown in Fig. 4, should be adjusted. Similarly, if vertical convergence cannot be achieved properly, the vertical

convergence voltage shape control can be adjusted.

9. The vertical dynamic convergence adjustments affect the horizontal and d.c. convergence settings and *vice versa*. Again it will be necessary to spend some time and care in making all adjustments and subsequent touch ups. The author had to start all over twice during his first convergence adjustment problem, but after some practice the convergence procedure now takes only about 10 minutes.

10. As a final check, vary the d.c. convergence control slightly and see if it improves convergence at the edges. If it does, some improvement in the dynamic convergence setting is needed. When d.c. adjustments show no such improvement, the dynamic convergence controls are properly set.

In the large screen, 19-inch shadow-mask picture tubes, the convergence adjustment is somewhat different since magnetic rather than electrostatic convergence is used. Between the purity coil and deflection yoke a set of three electromagnetic assemblies are located as shown in Fig. 3. In place of the three positioning magnets a single permanent magnet assembly is used which has major control over the blue electron gun. To adjust convergence in this system it is again helpful to use a dot pattern. Proceed as in the case of the 15-inch tubes up to the d.c. convergence adjustment, then follow the steps given below.

1. Set all dynamic convergence controls to minimum and adjust the red and green d.c. convergence potentiometers to give yellow dots in the center of the screen.

2. Adjust the blue d.c. convergence control and positioning magnet to obtain white dots in the center.

3. Adjust vertical and horizontal dynamic convergence controls for equal color triangles along the vertical and horizontal axes.

4. Readjust the three d.c. convergence controls for uniform white dots. Slight touch ups of the dynamic convergence controls may be required. Because the convergence forces are magnetic, the a.c. through the convergence coils will look like the voltage waveform in Fig. 6. The voltage across the coils will look somewhat like a sawtooth. Another feature of the 19-inch tube convergence adjustment is the reduced interdependence between the different controls. This makes for simpler and faster convergence adjustment.

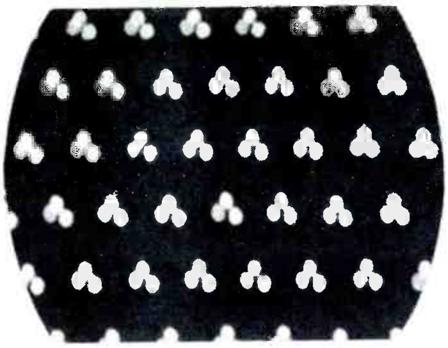


Fig. 9. Dot pattern when the d.c. convergence voltage is too high. Here, the blue dot is on top with the red to the left and the green to the right below.

Before looking at color pictures, the brightness and screen controls must be set properly. First, with no picture on the screen, turn the brightness control to maximum and adjust the red, green, and blue screen controls (see Fig. 5) to obtain a medium gray screen appearance. This should be approximately the brightness of an almost dark monochrome raster such as appears when no signal is received on a monochrome receiver. Balance out the three colors until a neutral gray shade is achieved. Now tune in a monochrome picture and set the contrast control for good white highlights. Adjust the blue and green background controls until the white is a true white and contains no dominant color. Next, turn the brightness control down until the white highlight is medium gray and touch up the green and blue background controls until this is again a neutral shade. The correct adjustment of these controls is achieved when the brightness control variation does not produce a change in hue, but only in brightness.

Color Adjustment

The great moment has arrived and we are ready for the first color pictures. In Fig. 5, separate red, green, and blue gain controls are indicated. Many manufacturers do not advise touch ups of these controls without special test signals or test equipment. Usually these controls are set carefully at the factory and do not need further adjustment.

Tune in a color telecast just like any other TV signal. Adjust the chromaticity control slowly until the colors appear vivid enough. Too little chromaticity will result in pastel shades or pale colors instead of rich saturated colors, while too much chromaticity will result in dark flesh tones. If it appears as if a red, green, and blue rainbow moves over the picture, the color sync section is out of synchronization. If flesh tones appear purple and red appears blue, the color sync phase is wrong. These adjustments are usually on the chassis or under a panel together with other secondary controls.

If it appears that the various colors are wrong, that red is too purple, yellow too orange, etc., this should never be compensated for with the screen, background, or brightness controls. Such a defect is best adjusted with a color test signal of known colors, such as can be obtained from a color bar generator or else from a station test pattern. Then the red, green, and blue gains can be set, the *I* and *Q* channels adjusted, and the entire matrixing unit can be serviced.

The customer should be carefully instructed in the use of the operating controls and warned against adjusting the secondary controls under the hinged front panel of the set and on the side or back of the chassis. —30—

COLOR TV NEEDS MORE EXPOSURE

IT IS with mixed emotions that I look back to the initial excitement of having a color television receiver in my home. This was just two years ago, in March, 1954. My decision to install the set was based on a personal curiosity to find out just how well (or not so well) a commercial television receiver would stand up in daily service under typical home conditions.

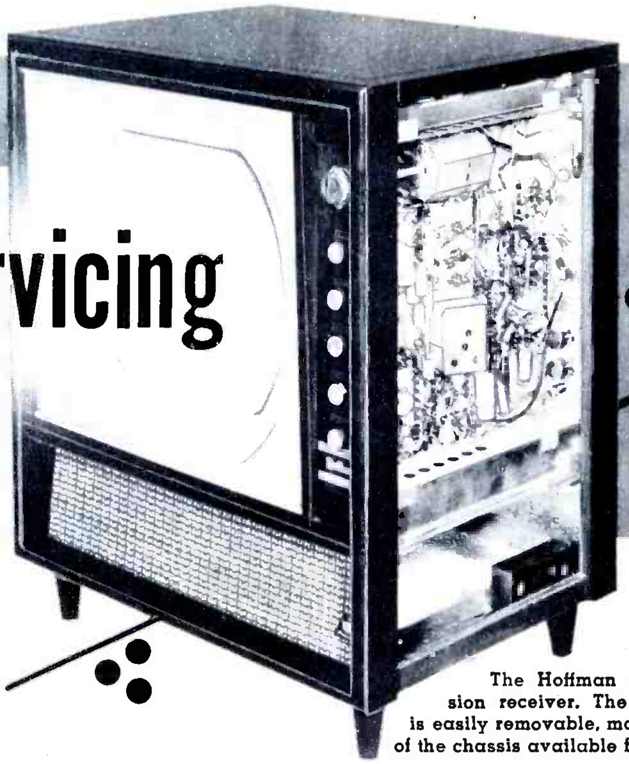
Picture quality, during 1954, left much to be desired. After living with color TV for many months, it became obvious that tremendous improvements were needed at the source, that is, in the TV studio itself. Through no fault of the receiver, skin tones would vary throughout the spectrum from red to yellow, and it was necessary to continuously compensate at the set.

During the past year, great improvements were made (especially in camera techniques, makeup, and lighting) which have overcome many of the faults noted during 1954. The color picture during 1955 ranged from good to excellent. The cost per hour to the color set owner dropped considerably as more color programs became available. Industry had finally made the decision to "put the horse before the cart." And we heartily agree with Leslie Hoffman, president of the Radio-Electronics-Television Manufacturers Association, who recently said that "the breakthrough of color TV, both in manufacturing and broadcasting, was the most significant merchandising development of 1955. Sales of the large-screen color sets during the fall and early winter indicate that exposure to color programs and such, rather than price, is the determining factor in public acceptance of this exciting new medium."

We have seen many fine color shows on our latest TV sets with its 19-inch screen. Our friends no longer imply that we should have our heads examined for having a color TV set in the house when there was practically no color to see. Reactions have now gone from the ridiculous to the sublime and, almost without exception, our friends and neighbors express sheer amazement and delight when they see quality color television for the first time. These reactions are due—first, because of tremendous improvements made in the transmission of color beginning at the camera and ending at the home screen—and second, because we now are using a set equipped with one of the recently-developed color picture tubes. The combination of tube, circuitry, and studio techniques and control all contribute to the upgrading of the television picture many times over.

Color TV Servicing in the Field

By
WALTER H. BUCHSBAUM
Television Consultant
RADIO & TELEVISION NEWS



The Hoffman color television receiver. The side panel is easily removable, making bottom of the chassis available for servicing.

Do you know what the most common color TV troubles are? Do you know how to deal with them? Read on.

THIS article is the result of a survey among service technicians and dealers who have already begun to install and service color TV sets in quantity. Only the most recent color TV receivers and the most frequently encountered difficulties are considered here.

Every service technician is familiar with the need for fully instructing the customer in the use of the various controls of his TV set. This need is even greater with color TV sets because of the increased complexity of the front panel adjustments. The problems of antenna selection and location are also more acute with color receivers because of the increased bandwidth requirements.

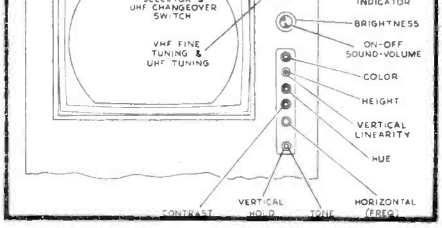
Customer Misadjustments

Just as in the early days of black-and-white TV, the customer's lack of understanding is the cause of a large number of service calls, especially during the first few weeks after a color set has been installed. Shown in Fig. 1 are the operating controls of the *RCA* 21-CT-660 to 664 series receivers, the latest 21-inch color sets. The station selector is not too complex, providing only v.h.f. and u.h.f. channel tuning with which many monochrome TV set owners are reasonably familiar. The brightness, "on-off," and volume control are likewise familiar and rarely prove troublesome. Under a small panel is a total of six controls, two of them duals, which are all capable of confounding the non-technical operator.

The color, hue, and contrast controls might, in theory, not need adjustment by the customer, but the general consensus among service technicians is that their temptation seems to be too great. All set owners desire to "improve" any or all of these vital parameters. After the set owner discovers that the contrast control operates the same for a black-and-white picture as it does on a monochrome set, he feels justified in setting this knob for color TV as well. The knob marked "Color" affects the amount of saturation or the color strength and few viewers can resist a little touchup. Similarly, the "Hue" control provides quite a humorous color spectacle if properly misadjusted. Needless to say, proper balance of contrast, brightness, saturation, and correct hues are lost until the service technician's next appearance.

The following routine is recommended for re-adjusting the front controls when customer misadjustment is suspected: First, for black-and-white reception, turn the color or chroma control fully counterclockwise and turn the receiver on. Then, tune in the weakest channel and adjust brightness and contrast to get a good picture. Check the operation of the vertical and horizontal hold controls by switching channels. The picture should lock in without further adjustments. In addition, check vertical linearity. Finally, tune in every available station, adjusting the fine tuning control for good pictures.

Fig. 1. Function and position of the various front-panel controls on the RCA 21-CT-660 series color television receivers.



To set up the receiver for color reception when no color telecast is available, use a color bar generator connected to the antenna terminals. Tune in the correct channel and set the fine tuning control to get the greatest amount of detail. Be sure that the control has sufficient range to pass through the maximum detail position. Advance the color or chroma gain control to about one quarter turn from its maximum counterclockwise position. Then advance the fine tuning control until the picture just begins to disappear; return the control to the point where the sound bars just disappear and color invades the picture. Re-adjust the color or chroma control for satisfactory saturation; white should be white and not some other color. Adjust the hue or color phase control for the correct setting; with the color bar generator this is rather simple since each bar is a pure color (red, green, or blue) and in a known position. When using a color telecast for setting up these controls, the flesh coloring is usually a good indication of correct hue setting. If possible, check color reception on all available channels.

If the color set is uncrated and tested at the shop before it is delivered, many troubles can be noticed and corrected before the customer starts complaining. When the set is uncrated in the home, some of the adjustments will probably require a touchup.

One manufacturer's service department reports that about 50% of all color sets installed require some purity adjustment. Others find that d.c. convergence adjustments are most frequently required. The purity adjustments are required for a receiver which is shipped with the picture tube in place, while the convergence alignment is usually required with a set whose picture tube assembly is shipped on a special pallet. Actually, both these adjustments are often needed after delivery of the set. Other adjustments such as color balance, color synchronization, decoding, matrixing, or i.f. alignment are only rarely needed, unless some component arrives damaged and must be replaced.

Whether all or only some convergence controls need readjustment, the simplest and most positive means of checking is to use the dot generator. To make certain that this generator is operating at the exact horizontal and vertical scanning frequency of the set, tune in a monochrome station picture and synchronize the dot generator to the TV receiver. It is usually sufficient to clip a lead from the generator to the "hot" side (usually red wire) of the horizontal deflection coils. After a stable dot pattern is obtained, check the dots in the center of the screen. Converge them by adjusting the permanent magnet slugs in the convergence coil assembly, shown in Fig. 2. If only the blue beam appears out, adjust the blue beam positioning magnet assembly (see Fig. 4). Concentrate these adjustments only on the dots at the center of the screen.

Now check the convergence at the top and bottom of the center line. If this requires touching up, the dynamic convergence controls must be adjusted. Fig. 3 shows that part of an *RCA* model 21-CT-662U chassis which provides the various dynamic convergence signals. If the convergence at the sides of the picture tube is unsatisfactory, adjust the horizontal dynamic convergence controls. In most TV receivers the convergence controls are all located together at a convenient point accessible from the rear of the chassis.

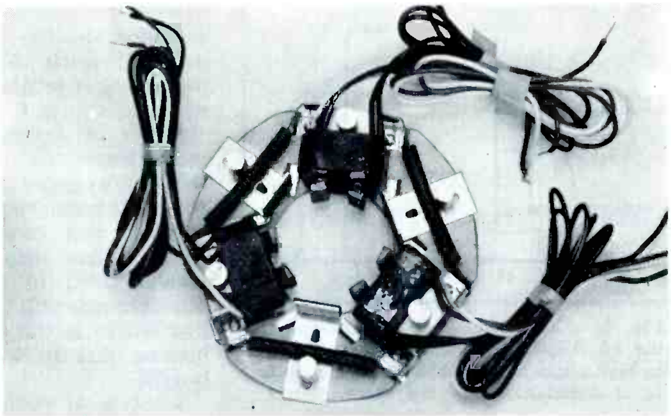


Fig. 2. Convergence magnet assembly. The knurled nuts are rotated for adjustment.

More detailed convergence instructions are included in the manufacturer's service notes for the receiver. Color purity is best observed without a picture of any kind and adjustments for purity should be made prior to the final convergence set-up, if this step is needed. In many receivers a slight color impurity is observed after installation although the convergence may be perfectly adjusted. Only a slight adjustment of the field equalizer magnets or the purity coil or magnet assemblies may be needed. These are shown in Fig. 4. Follow the manufacturer's data for purity adjustments.

Magnetic Effects

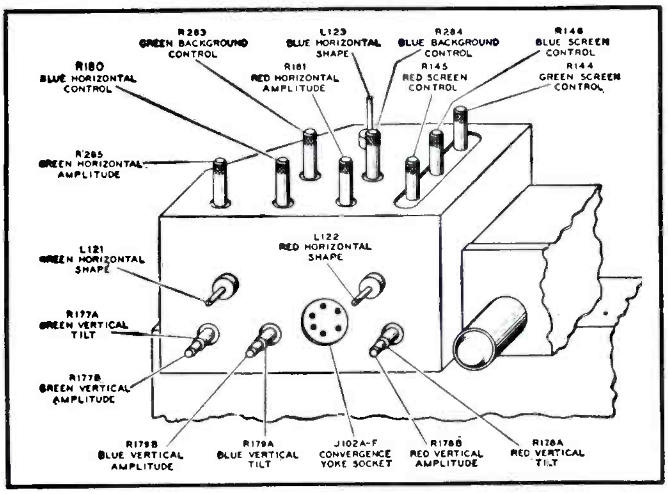
The current color picture tubes are furnished with a special magnetic shield over the electron beam area. Nevertheless, magnetic effects due to fields surrounding the tube can cause considerable color impurity. Such magnetic fields can be due to the chance magnetization of some of the iron brackets in the cabinet or chassis parts. During transportation or storage, receivers may be located under fairly strong a.c. or d.c. fields from power equipment, transformers, etc.

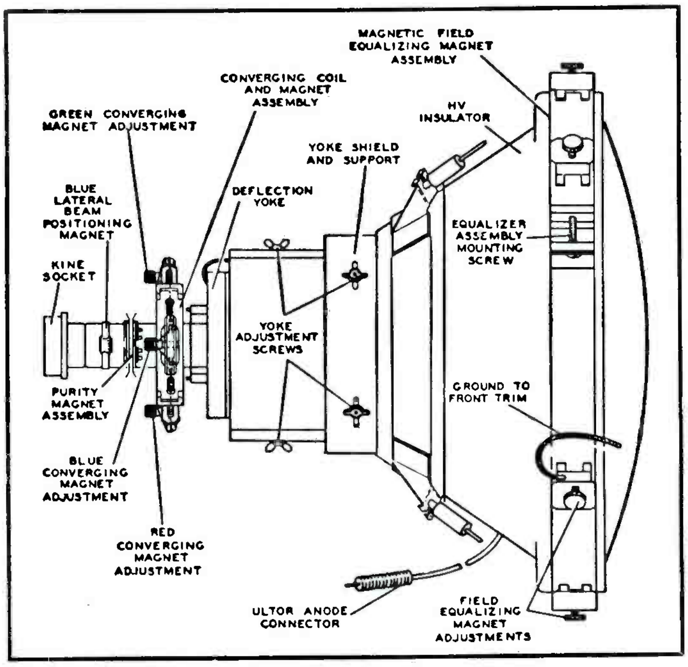
The magnetized parts can be neutralized by introducing a strong a.c. field and then gradually reducing the strength of the field. To accomplish this without using special magnetizing devices, the *RCA Service Company* recommends the construction of a coil which can be connected directly to the 117-volt a.c. line. A winding diameter of about 12 inches is used; an old 10- or 12-inch picture tube can be used as a mandrel with insulating tape serving to hold the wire in place. Approximately 425 turns of No. 20 enamelled wire are sufficient. The entire loop should be well taped and the two ends of the wire connected to a regular a.c. line cord. At least 8 feet of cord will be needed.

The actual demagnetizing is performed with the receiver in the cabinet, but with power off. At the start, the demagnetizing coil is kept at least 6 feet away from the color TV receiver and then is slowly moved over

Fig. 4. A standard color picture tube with the various external deflection and convergence components indicated, along with the magnetic field equalizer. See text. ➡

⬇ **Fig. 3. Shown here are the various controls for dynamic convergence adjustments on the RCA Model 21-CT-662U TV chassis. Operation of controls is discussed in the text.**





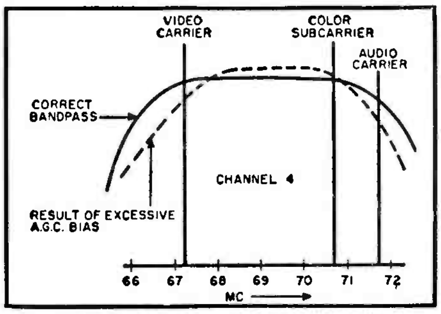


Fig. 5. The decrease in bandwidth of the r.f. amplifier of a color TV set due to high a.g.c. bias, as shown here, results in a deterioration of the color picture.

the sides, front, and rear of the cabinet. With the receiver back cover removed, place the coil inside the cabinet at the top and sides of the picture tube assembly.

It is important in demagnetizing to apply the coil with its magnetic field gradually. The demagnetizing should last about 2 minutes, then the coil is gradually withdrawn to at least 6 feet from the color TV set and the a.c. line plug disconnected.

The various convergence magnets and field neutralizing magnets should be withdrawn from their maximum effective position during the demagnetizing procedure. After a set has been demagnetized the entire purity and convergence set-up procedure will have to be repeated.

Local Color Troubles

As anticipated, local reception conditions have a very pronounced effect on the color picture. Minor reflections which could be tolerated on a monochrome picture cannot in color. One of the prime requisites of a good color installation is an antenna system that brings in ghost-free signals.

The strength of the signal is also important and installation troubles on color TV receivers have been noted both on weak and excessively strong pictures.

For black-and-white signal reception, adjustment of the contrast, a.g.c., and fine-tuning controls usually takes care of excessive signal strength. On really strong signals, the a.g.c. bias increases considerably and this increases the input impedance of the r.f. amplifier. This increased impedance has two serious effects: it changes the r.f. bandpass and it increases the mismatch with the antenna transmission line, setting up reflections on the line. These reflections appear as ghosts, insignificant on monochrome, but distracting in a color picture. Further, the change in r.f. bandpass reduces the gain of the color subcarrier sidebands, reducing the color information. Fine-tuning control adjustment in this instance either moves the video carrier down on the response curve slope or else the color components are moved towards the sound-trap frequency and color is completely lost. This detuning due to excessive signal strength is illustrated in Fig. 5.

The remedy for excessive signal strength is simply to insert a suitable attenuator pad between the transmission line and the receiver antenna terminals. Such 300-ohm attenuators, consisting of printed ceramic circuitry, are available in 6, 10, and 20 db values.

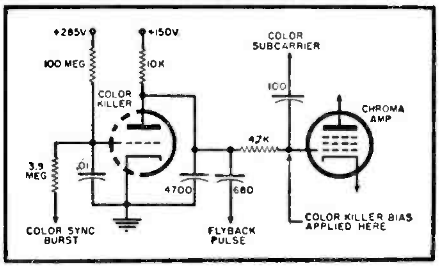
Weak or fading signals present a much more difficult problem. The effects of weak or fading signals on the color TV receiver are varied. The color content and contrast changes. Although this may be annoying, the viewer used to fringe reception on monochrome will understand this fault. Far worse is the effect on color-killer biasing due to weak or fading color bursts.

A typical color-killer circuit is shown in Fig. 6, and illustrates how the killer bias depends on the presence or absence of color sync bursts. If, in a certain location or on some retransmitted programs, the color sync burst is attenuated and appears at the color-killer circuit too weak to deactivate the killer bias, the receiver will not pass any color information at all. In other words, although color signals are received, the picture on the screen will be black-and-white because the burst is too weak. Defects in the color-killer circuit, misadjustment of the burst amplitude control, or misadjustment of the fine-tuning control could all cause excessive killer bias and loss of color reception.

Aside from misadjustment of controls and circuit defects, the problem of poor color-killer action has been encountered frequently in weak-signal areas. It is particularly troublesome if the technician does not realize the cause for loss of color. During a particular telecast the set owner may lose the color picture. When the technician arrives, he finds that on instruments and on fairly strong signals, good color reception is obtained. Either misadjustment by the customer or some intermittent defect might be suspected unless the action of the color-killer circuit is appreciated.

High-gain antennas are commonly used in weak signal areas and many of them have a rather narrow bandwidth, especially the earlier types. Stacked yagi antennas cut for one channel often have less than 5 mc. bandwidth and may not be suited for color reception. All antenna manufacturers have lately announced fringe area models which are better suited for color reception because of their broadband features.

Fig. 6. Color-killer circuit of a color TV set. Note how the bias from the killer tube feeds the control grid of the chroma or bandpass amplifier. Excessive negative bias will cut off set's color.



Service Tips

When the vertical or horizontal linearity seems to be off on color reception, check the centering control action before adjusting linearity controls. Unless the picture is centered quite accurately, nonlinearity may appear. To check vertical linearity quickly without a test pattern or dot-bar generator, adjust the vertical hold control so that the picture rolls slowly through the screen. Observe the width of the vertical blanking section as it moves from bottom to top. The width of that bar should be constant as it moves over the screen.

Most color TV receivers have special high-voltage plug and connector assemblies. Breaks or inadvertent disconnection of these high-voltage cables may cause loss of raster.

The latest *RCA* and similar color sets have special high-voltage interlocks which short the high voltage to chassis when the back cover is removed. When the service technician removes the back cover and plugs in an a.c. cheater cord in the customary manner without removing the high-voltage short, the high-voltage supply can be seriously damaged. The high-voltage safety interlock simply consists of two spring clips, one connected to the high voltage and the other to ground, held apart by an insulating rod mounted on the rear cover. When this rod is removed, the two clips make contact. In order to operate the set without the back cover it is necessary to separate the interlocking spring clips again by inserting a suitable plug. Such a plug can be made of lucite or similar tubing cut to size.

Color balance is usually preset at the factory and should not need touching up in ordinary installation procedure. Customer complaints of colors being too much of one shade are sometimes due to room lighting conditions. For example, the presence of a lamp with a red shade, dominantly green curtains, blue fluorescent light, yellow insect-repelling lamps, etc., will tend to give the impression of improper color balance. The service technician should point out these circumstances to the customer before adjusting color matrixing controls.

Customer misadjustments, purity and convergence changes due to shipping, or local magnetic fields, are the principal troubles the service technician can expect in installing the new color TV receiver models. Demagnetizing of the entire set might occasionally be required to assure good color purity and a special demagnetizing coil should be constructed for this purpose. Extremely strong or weak signal conditions are also frequent causes for service calls. Antenna requirements for color TV reception prove to be more stringent than for black-and-white TV, especially concerning bandwidth. Many of these problems were expected and their cures are becoming known with the increase in installations. —30—

BOOK REVIEWS

These books offer the background and servicing information required for color TV service technicians, engineers, etc.

"COLOR TV TRAINING MANUAL" by C. P. Oliphant & Verne M. Ray. Published by *Howard W. Sams & Co., Inc.*, Indianapolis. 258 pages. Price $6.95. Paper bound.

This volume represents a basic color course for the practicing television technician. The text material is divided into three sections covering the principles of the color television system, color receiver circuitry, and the servicing of the color set. Those with training and experience in the servicing of black-and-white sets should have no difficulty in handling the material as presented since the book has been designed to be used for home-study as well as for the more formal training courses offered by schools.

There are about 500 illustrations in this manual, 126 of them in color. An appendix carries actual color picture tube displays, information on the use of several commercial color bar and white dot generators, and a glossary of color TV terminology. Test questions at the end of each chapter permit self-checking. The answers have been included to make the manual self-contained.

We believe that alert service technicians will find this a valuable springboard to the new business and increased profits which are to be made in color television work.

* * *

"COLOR TELEVISION ENGINEERING" by John W. Wentworth. Published by *McGraw-Hill Book Company, Inc.*, New York. 459 pages. Price $8.00.

This book is an easily-understood explanation of color TV for engineers and technicians already familiar with monochrome TV. It deals with both the physical and psychological aspects of color, colorimetric techniques used in TV, underlying electronic principles, and studio equipment, test equipment, and other devices used in all phases of color telecasting and receiving.

* * *

"PRINCIPLES OF COLOR TELEVISION" by The Hazeltine Laboratories Staff. Published by *John Wiley & Sons, Inc.*, New York. 562 pages. Price $13.00.

This is an engineering text which covers the basic concepts of the production and transmission of the color signal. Based on the continuing series of technical reports that have emanated from the *Hazeltine Laboratories* over the past few years, this volume is a compilation and up-to-date picture of the entire subject.

The text material covers light and photometry, color perception, color space and color triangles, colorimetry, color in a TV system, required information content, characteristics of the eye, choice of color components and their interleaving in the composite signal, the production of the composite color signal, synchronization, nonlinear amplitude relations and gamma correction, FCC color standards, equipment for producing the transmitted signal, color receivers, decoders for three-gun displays, decoders for one-gun picture tubes, and test and measuring methods.

From the listing of contents, it is obvious that this book is directed toward a readership with advanced technical training. Practicing engineers, students in the graduate engineering faculties, and research engineers will derive the greatest benefit from this work. A fairly comprehensive mathematical background and a familiarity with engineering theory and the techniques of monochrome television are prerequisite and have been assumed by the authors.

* * *

"COLOR TELEVISION STANDARDS" by Donald G. Fink. Published by *McGraw-Hill Book Company, Inc.*, New York. 520 pages. Price $8.50.

An authoritative statement of underlying factors relating to the choice of color television standards, and the effect of the standards on broadcasting and receiving equipment. This material has been compiled from the Proceedings of the second National Television Systems Committee.

* * *

"HIGHLIGHTS OF COLOR TELEVISION" by John R. Locke, Jr. Published by *John F. Rider Publisher, Inc.*, New York. 43 pages. Price 99 cents. Paper bound.

This compact little book, written by an engineer from *General Electric Company's* radio and television department, is an introduction to the subject of color based on the standards recommended by the NTSC, and subsequently adopted by the FCC.

The discussion deals with only those features or circuits which are unique to color receivers. Circuits and techniques found in standard monochrome receivers are not covered. The discussion covers colorimetry, the NTSC color signal, the transmitter, the color receiver, the tri-color picture tube, and color receiver circuitry.

Those interested in the new medium will find this book enlightening and instructive, providing information that applies to all receivers designed to conform to the NTSC standard.

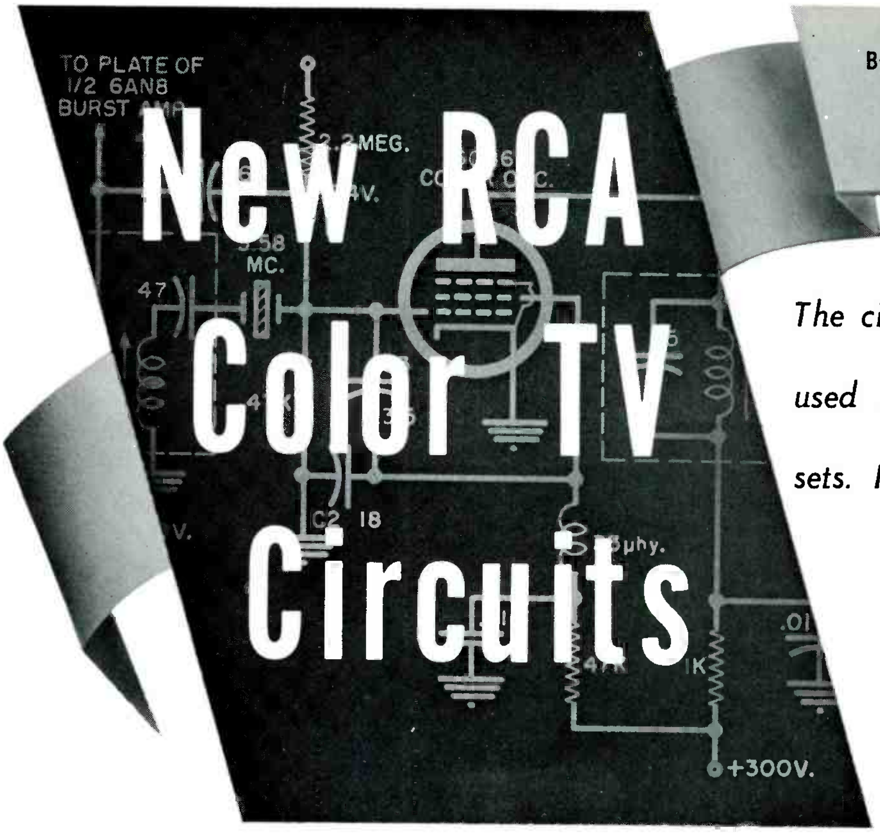
* * *

"COLOR TELEVISION" by The Electronic Education Unit, *Philco Corporation*, Donald G. Fink, consulting technical editor. Published by *Philco Corporation*, Philadelphia. 152 pages. Price $5.00. Paper bound.

This book has been prepared especially for practicing service technicians who are ready to take the plunge into color work, and is part of the company's "Factory Supervised Service" program.

The text material covers all phases of color, including theory, design, transmission, reception, installation, and servicing. A brief but comprehensive review of black-and-white theory and practice has been included to enable the user to start off on the right foot. The balance of the nine chapters covers colorimetry, transmission and reception, circuit description, color tube assembly and associated circuits, color tube and receiver adjustments, color receiver alignment, servicing procedures, and the installation of a color TV receiving system.

The presentation of the material is elaborate and colorful. Graphs, circuit diagrams, and scope patterns in full color contribute a great deal to the over-all picture of the subject. –30–



New RCA Color TV Circuits

By **WALTER H. BUCHSBAUM**
Television Consultant
RADIO & TELEVISION NEWS

The circuits described here are being used for the first time in color TV sets. Here, too, are installation hints.

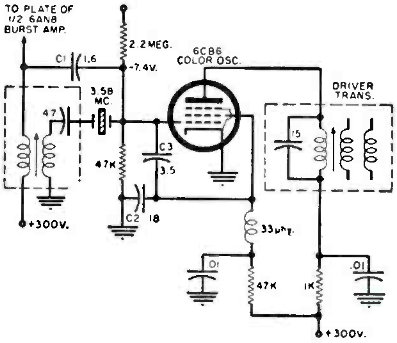


Fig. 1. Partial schematic diagram of the crystal-tube 3.58 mc. oscillator.

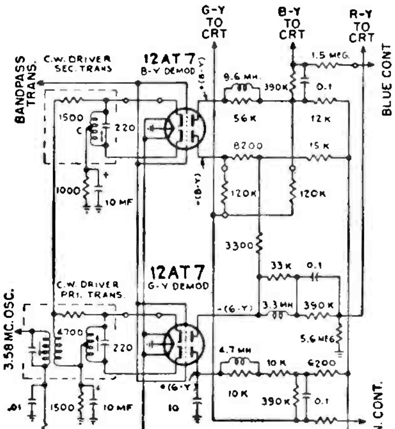


Fig. 2. Color demodulator circuits of "Super" and "Special" color receivers.

THE new line of *RCA* color receivers is divided into three series. The "Special" and "Super" series use practically the same chassis. The "Deluxe" sets use a chassis which is considerably different. A total of 26 tubes plus the picture tube, two crystal diodes, and a 3.58 mc. oscillator crystal are used in the "Special" chassis, CTC5 and CTC5A. The tuner is basically a v.h.f. type with u.h.f. attachment optional. Both video and intercarrier sound i.f. sections are conventional with one exception: separate second detectors are used for the sound and picture i.f.'s. This minimizes the possibility of 920 kc. interference. A single high-voltage rectifier is used to supply the 25 kilovolts for the ultor and a separate rectifier provides the focusing potential.

New Circuits

The color sync section and the 3.58 mc. oscillator used in all new *RCA* receivers is considerably different from previously used circuits. A simplified circuit diagram of the 3.58 mc. oscillator is shown in Fig. 1. The burst amplifier provides a strong synchronizing burst signal which is applied to the 3.58 mc. crystal and, through C_1, to the control grid of the oscillator tube. Feedback from the screen grid of that tube through the divider network C_2 and C_3 causes continuous oscillation of a 3.58 mc. signal which is then furnished to the demodulators from the driver transformer. This circuit is quite a departure from previously used crystal oscillators which were controlled by a reactance tube and phase detector.

The color demodulator used in the "Special" and "Super" series of receivers is also new. Here (see Fig. 2) two dual triodes are used to provide all three color difference signals and directly drive the three kinescope grids. The color subcarrier and its sidebands are applied to all four triode grids while the color sync signal is applied to each cathode, with proper phase correction. One of the plate circuits produces the green and one the blue color difference signals while the red difference signal is the result of matrixing circuits between the plate voltages.

Since the demodulation occurs between grid and cathode, the tube also acts as an amplifier between grid and plate. This amplification of the color video signals makes it possible to go directly from the low level of the 3.58 mc. color subcarrier to the higher video signals required to drive the color picture tube grids. The cathodes of the color picture tube are driven by three *Y* signals, properly proportioned by means of a voltage divider network in the plate circuit of the second video amplifier.

The color demodulator circuit of the "Deluxe" line is patterned after the older pentagrid converter, synchronous detector system, and uses three output amplifiers which matrix directly into red, green, and blue difference signals.

The "Deluxe" chassis uses the triode section of a 6AW8 tube as a video noise inverter. A simplified diagram of this circuit is shown in Fig. 3. Video signals of the same polarity but at different amplitudes are applied to the grid and cathode of the first video amplifier and to the cathode of the noise inverter triode. These noise pulses are amplified in the noise inverter so that they are equal in amplitude, but opposite in polarity, to the noise pulses passing through the first video amplifier. This results in cancellation of noise pulses at the input to the first sync amplifier stage and the a.g.c. tube. To avoid cancellation of the sync pulse, the grid of the noise inverter is connected to a threshold control which varies the bias and, therefore, the conductivity of this tube. The bias is adjusted so that noise at a higher level than the sync tips is cancelled.

The *RCA* "Special" and "Super" models permit the color burst to pass the chroma amplifier and demodulator sections. This would ordinarily cause a yellow-orange stripe to appear at the left side of the picture and although, with proper centering and width adjustment, this would not be visible, its presence could be mistaken for parts of the actual picture. For this reason the triode section of the 6AW8 first video amplifier is used as a special blanking amplifier. Its purpose is simply to drive the screen of the second video amplifier negative and thereby cause the cathodes of the kinescope to cut all three electron beams off during the horizontal retrace time. The blanking tube is gated by a pulse from the horizontal flyback section; the blanking amplifier also supplies horizontal pulses to the burst keyer.

Installation

The extent of the installation adjustments required may vary from simply unpacking the set and connecting it to the antenna and power line, to a full kinescope set-up procedure. Detailed instructions for complete color purity, convergence, and color background adjustments are included in the service manual for the receiver. Some useful installation pointers will be mentioned here.

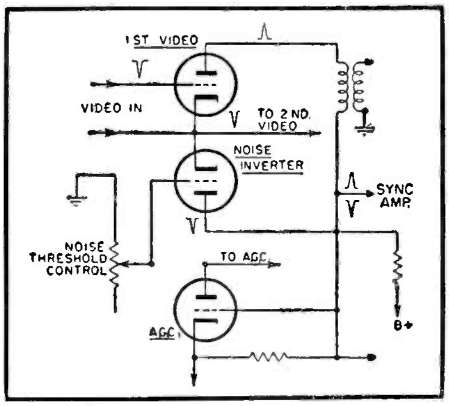


Fig. 3. Simplified schematic diagram of the video noise inverter circuit of the "Deluxe" chassis. Notice how the noise pulse from the first video amplifier is bucked by an inverted pulse at the input to the first sync amplifier tube.

The receivers are shipped with the color picture tube fastened to the front frame of the set and not to the chassis. The safety glass and mask can be removed quite easily but require that the rear cover of the set also be removed. Two spring hooks behind the small panel covering the controls on the front of the set must be pulled forward and down to release the facemask. After this frame is pulled forward, release, from the rear of the set, the four clips holding the safety glass. Be sure to prevent the glass from falling.

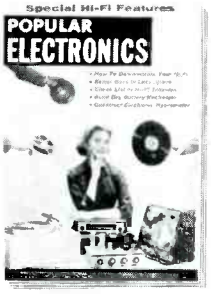
Most of the adjustments are available from the front panel, only the vertical and horizontal centering, focus, and width controls are located at the rear of the chassis. The customer-operated controls are under the hinged panel, but by removing the whole cover, the remaining front controls become accessible.

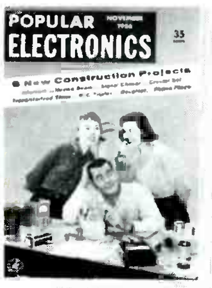
After unpacking the receiver, check its appearance for obvious breakage. Remove the rear cover and check internally for proper tube seating, loose components, or any sign of breakage. After replacing the rear cover, connect the receiver to the antenna and the 117-volt a.c. power line. Turn on the set and tune to a color program. If it appears impossible to get horizontal locking and the image appears quite dark, adjust the a.g.c. control.

Next, adjust for a proper black-and-white picture by turning the color control fully counterclockwise until the "on-off" switch clicks. Vary the conventional black-and-white controls until the picture looks correct, then, advance the color control clockwise until the desired color intensity is achieved.

The hue control determines the correct color phase and its misadjustment will produce weird flesh colors.

It has been assumed that there was no difficulty in obtaining a good black-and-white picture without color impurity and without the primary colors appearing at the edges of picture elements. If either purity or convergence adjustments are required, the full set-up procedure should be followed. —30—





By **FRANK HADRICK** and **HUGH S. WYETH**

Service Division, Admiral Corporation

Installation Notes on ADMIRAL COLOR SETS

Hints for installing the new Admiral low-priced color sets—also, unusual color TV circuits are explained.

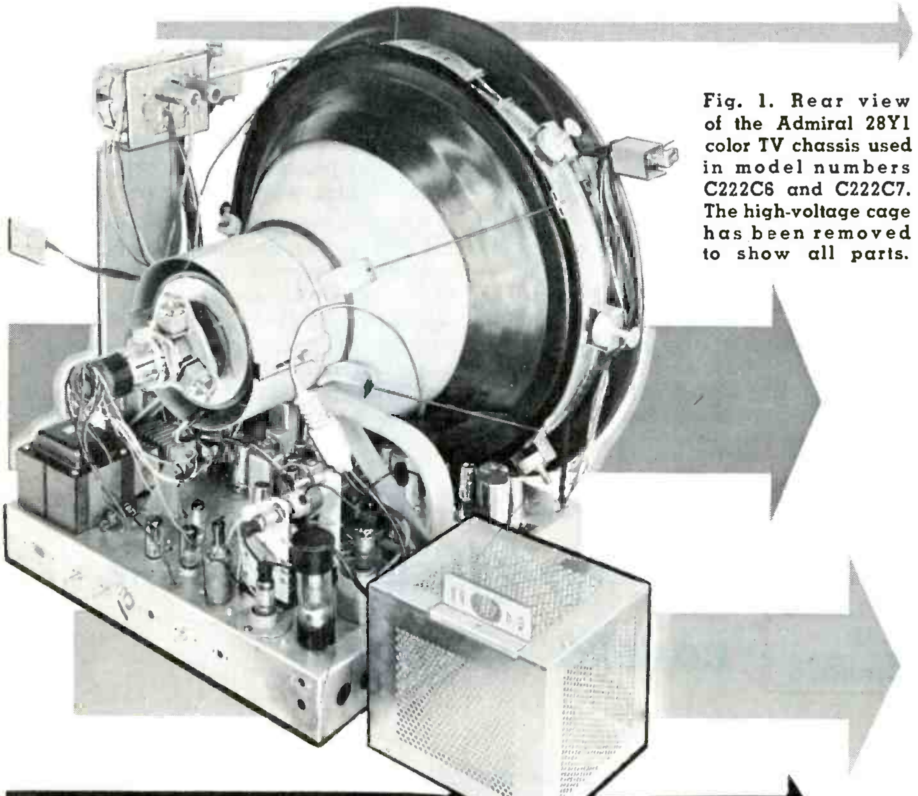


Fig. 1. Rear view of the Admiral 28Y1 color TV chassis used in model numbers C222C6 and C222C7. The high-voltage cage has been removed to show all parts.

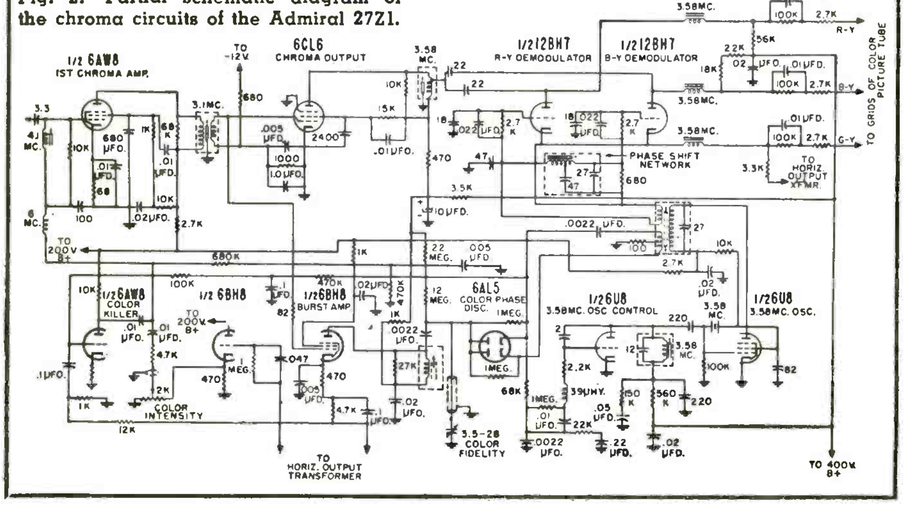


Fig. 2. Partial schematic diagram of the chroma circuits of the Admiral 27Z1.

GOOD service begins with a good installation. The basic installation and convergence procedures required by the *Admiral* color TV receivers using the 21AXP22A three-gun color picture tube (see Fig. 1) are described in detail in the service notes for these sets. These should be studied very carefully before an installation is attempted. A few basic installation rules which apply to the *Admiral* sets will be reviewed here for emphasis.

The service technician should be equipped to disable the various safety interlocks incorporated in these sets. A clip lead can be used to bypass the interlock switch behind the picture window. A common installation and service tool will undoubtedly be the plastic "plug" required to disable the high-voltage shorting interlock when the cabinet back is removed.

Although the metal parts of the picture tube are demagnetized by the factory before the receiver is shipped, they sometimes become remagnetized before the receiver is finally installed, making it impossible to obtain satisfactory purity and convergence. As a precautionary measure to avoid lost time, many technicians routinely demagnetize the picture tube with the receiver in its final operating position, in the customer's home, before making any adjustments. This means that another service tool for color will be a suitable degaussing or demagnetizing coil. These can be purchased, or the technician can wind his own. About 400 turns of No. 20 magnet wire wound on a 12- to 14-inch diameter form and equipped with a long a.c. power cord, works very well.

The color stripe signal transmitted by many TV stations consists of a burst of 3.58 mc. appearing just before and immediately following the horizontal blanking pulse in the composite black-and-white video signal. Since, therefore, the receiver color circuits are gated on by this stripe signal only during horizontal retrace time, it is necessary to shift the phase of the horizontal oscillator so the horizontal flyback pulse will coincide with at least part of the 3.58 mc. color stripe burst immediately following the blanking pedestal. Shorting the color stripe test point on the back apron of the *Admiral* chassis to the chassis produces the necessary phase shift of the horizontal sync pulses, thus shifting the phase of the horizontal oscillator and allowing the color stripe to be correctly reproduced with the receiver otherwise properly tuned and adjusted.

The last but most important part of every color receiver installation should be instructing the customer. The operating instructions packed with the receiver should be reviewed with all those who will operate and use the color receiver. A few minutes spent here will cut down the number of profit-killing "nuisance" calls.

Circuits

In the triode high-level demodulator circuit used in the *Admiral* 27Z1 chassis (Fig. 2), *B-Y* and *R-Y* signals are demodulated at the plates of the 12BH7 demodulator tube. *R-Y* and *B-Y* are added in a common cathode load resistor to form *G-Y*. The output of the luminance (*Y*) amplifier is direct coupled to the cathode of the picture tube. Use is then made of the picture tube to add the chroma information received from the demodulator and the luminance information to obtain the final red, green, and blue signals.

The actual demodulation or detection of the chroma signal is accomplished by applying a 3.58 mc. sine wave from the crystal-controlled 6U8 3.58 mc. oscillator between the grid and cathode of each demodulator triode. This sine wave is of sufficient amplitude to cause the demodulator triodes to operate as class C amplifiers, thus allowing current to flow for only a short period of time during the positive-going portion of each cycle. Each demodulator triode then acts as a switch, turning on just once during each cycle. A phase-shifting network delays the 3.58 mc. sine wave applied to the *B-Y* demodulator to produce the correct relationship between the *R-Y* and *B-Y* outputs.

One tube, the 1st chroma amplifier, amplifies the chroma signal and also the color sync burst. It is necessary that the gain be kept constant for the color sync burst and, at the same time, the gain must be allowed to vary during chroma time. Also, for black-and-white programs, this tube must be cut off during video or picture time, but have full gain during horizontal blanking time. All these requirements are met by gating.

During black-and-white programs, a positive pulse of sufficient amplitude to cause grid current flow is obtained from the color killer tube and applied to the control grid of the 1st chroma amplifier. This grid current charges the grid circuit capacity to a high enough voltage to bias the tube to cut-off; the *RC* time constant of the grid circuit is long enough to hold the tube at cut-off until the next positive pulse. Thus, the 1st chroma amplifier is cut off except during horizontal blanking time on black-and-white programs.

On color programs, the color killer tube is cut off by a negative voltage applied to its grid and obtained from the color phase discriminator. Although the color killer can no longer supply a positive pulse to the 1st chroma amplifier, a positive-going pulse appearing across the color intensity control is still applied to the chroma amplifier grid. This pulse develops just enough bias to cause the 1st chroma amplifier to cut off when the intensity control is fully counterclockwise. At any other setting of the intensity control, the pulse supplied to the 1st chroma amplifier grid is of lower amplitude and the tube will conduct during chroma time. By varying the intensity control setting and thus, the amplitude of the biasing pulse applied to the 1st chroma amplifier grid, the gain of the tube is controlled.

Also during color programs, a negative voltage is developed at the color phase discriminator which is dependent on the incoming color sync burst amplitude. This voltage is applied to the grid of the 1st chroma amplifier in the same manner as a.g.c. voltage is applied to the i.f. amplifiers. The use of this circuit provides automatic chroma control, which automatically increases the gain of the chroma amplifier should the strength of the color signal decrease.

Essentially, the operation of the color circuits in the 28Y1, 27Z1, and 29Z1 chassis is identical. The more obvious differences between the three chassis affect the power supply and the horizontal deflection-high voltage circuits. The 28Y1 is similar to the 27Z1 except that two 3A2 high-voltage rectifier tubes in the former have been replaced by one 3B2 in the 27Z1. The 29Z1 uses vacuum-tube rectifiers, rather than selenium rectifiers and electromagnetic static convergence.

—30—

Installing Hoffman COLOR Sets

By

WALTER H. BUCHSBAUM
Television Consultant
RADIO & TELEVISION NEWS

This set uses two unusual circuits which are explained here; also some installation hints.

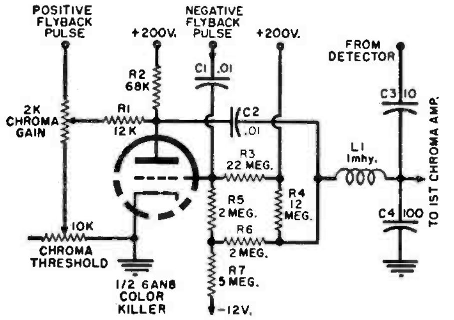


Fig. 2. Partial schematic of color-killer circuit of Hoffman 703 color TV chassis.

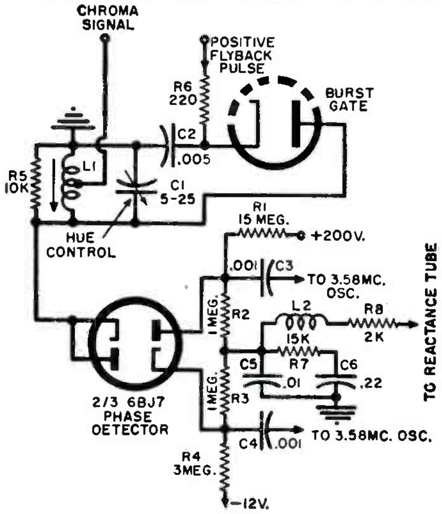
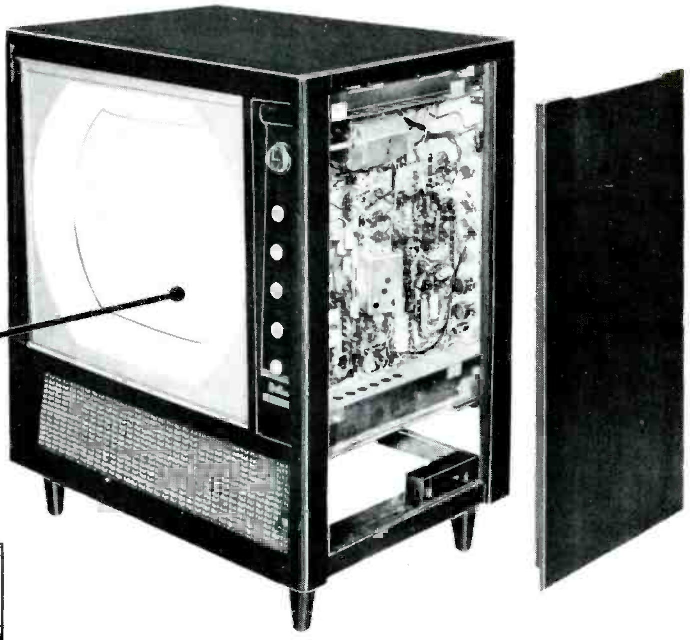


Fig. 3. Burst gate and phase detector.



HOFFMAN "Colorcaster" receivers are shipped with the picture tube in place. Since the entire side panel of the cabinet is removable (Fig. 1), all necessary adjustments can be reached without having to remove the chassis from the cabinet.

The picture-tube assembly may require some attention during installation or picture-tube replacement. Behind the deflection yoke is the convergence yoke. Each of the three convergence magnet coils contains a small permanent-magnet screw, accessible from the back, which is adjusted for d.c. convergence for each beam. The purity magnet located behind the convergence yoke is adjusted in conjunction with the field neutralizing coil to eliminate color contamination. If only the red electron beam is on, for example, proper purity exists if the entire screen is a uniform red without blotches of yellow or purple. The blue beam positioning magnet, which is just in front of the tube socket, operates in conjunction with the convergence yoke. For detailed adjustment of the purity and convergence system, the manufacturer's data should be consulted.

In many instances when the set performs well on monochrome broadcasts but not color, this is due to the misadjustment of the color-killer circuit. The color burst sent out with each horizontal synchronizing pulse is often slightly attenuated, especially for programs relayed over coaxial cable. As a result, the color-killer circuit does not operate properly.

Fig. 2 shows the vital portions of the color-killer circuit of the 703 chassis. Effectively, the bias on the grid of the first chroma amplifier depends on the amount of flyback pulse amplified by the color-killer stage. During a color telecast, the grid of the color-killer tube receives from the detector the color synchronizing burst which overcomes the effects of the negative pulse at the grid and allows more current to pass. As a result, the bias on the chroma amplifier is such that it conducts. Voltage divider R_4, R_6, and R_7 determines the d.c. potential at the grid of the chroma amplifier; another divider network determines the d.c. voltage on the color-killer tube. Part of the latter is the chroma gain potentiometer located on the front panel. The other potentiometer is called the chroma threshold control because it is adjusted to provide just the right bias so that during a color program, enough of the color burst can get through to reduce the killer bias. For this reason the threshold control should only be adjusted during a color telecast, and care must be taken to see that even if the color signal is weak, the color-killer circuit will allow it to pass.

Among the *Hoffman* color television receiver circuits is one which is quite unfamiliar. This is the combination burst gate and color phase detector, shown in simplified form in Fig. 3. Two diodes of a 6BJ7 are connected as a phase detector which compares the local 3.58 mc. signal to the received color sync burst. The phase error voltage, just as in many horizontal sync circuits, is derived from the center of the two balancing resistors R_2 and R_3 and applied to the grid of the reactance tube which controls the local 3.58 mc. oscillator. The color sync burst is taken from the output of the second chroma amplifier and has considerable amplitude.

The burst is only part of the horizontal blanking pulse so, to make the phase detector operate only during the period of the color sync burst, it is necessary to shut the circuit off and turn it on only during the proper period.

The third diode of the 6BJ7 is effectively shunted across the tapped resonant circuit L_1-C_1 and will normally prevent any signals from affecting the phase detector. During the horizontal retrace time, a pulse derived from the flyback section is applied to the cathode of the gating diode. This pulse is so shaped that its effective peak occurs exactly during the instant when the color sync burst appears. The amplitude of the gating pulse is about 145 volts, making the cathode more positive than the plate of the diode, and preventing any current flow. The shunting effect of the diode is therefore removed from the circuit during the color sync burst and the phase detector can function.

Since the error voltage, if any, is derived only during a very small portion of the horizontal scan time, it must have a filter with a long time constant to properly control the reactance tube.

Accurate horizontal synchronization is required since, if the gating pulse is out of step, the phase detector cannot function properly. Weak horizontal sweep will also result in a weak gating signal and color synchronization may therefore be lost entirely. In troubleshooting color defects, it is paramount to make sure that horizontal sync and flyback sections work perfectly since any defect there will affect not only the color burst gate, but also the color-killer circuit. —30—

COLOR TV DEFINITIONS

Tentative definitions prepared by NTSC Panel 19 under the chairmanship of R. M. Bowie and approved by NTSC.

BLACK-AND-WHITE Deprecated (see Monochrome).

BRIGHTNESS The attribute of visual perception in accordance with which an area appears to emit more or less light.

Note: *Luminance* is recommended for the photometric quantity which has been called *brightness*. *Luminance* is a purely photometric quantity. Use of this name permits *brightness* to be used entirely with reference to the sensory response. The photometric quantity has been often confused with the sensation merely because of the use of one name for two distinct ideas. *Brightness* will continue to be used properly in nonquantitative statements, especially with reference to sensations and perceptions of light. Thus, it is correct to refer to a *brightness* match, even in the field of a photometer, because the sensations are matched, and only by inference are the photometric quantities (*luminances*) equal. Likewise, a photometer in which such matches are made will still be called an "equality-of-*brightness*" photometer.

A photoelectric instrument calibrated in footlamberts should not be called a *brightness* meter. If correctly calibrated it is a *luminance* meter. A troublesome paradox is eliminated by the proposed distinction of nomenclature. The *luminance* of a surface may be doubled, yet it will be permissible to say that the *brightness* is not doubled, since the sensation called *brightness* is generally judged to be not doubled.

BRIGHTNESS CHANNEL Deprecated (see **Monochrome Channel**, Luminance Channel).

BRIGHTNESS SIGNAL See **Monochrome Signal**.

BURST PEDESTAL (COLOR BURST PEDESTAL) The rectangular pulse-like component which may be part of the color burst. The amplitude of the color burst pedestal is measured from the a.c. axis of the sine wave portion to the horizontal pedestal.

BYPASS MONOCHROME SIGNAL A monochrome signal that is shunted around the color-subcarrier modulator or demodulator.

CAMERA SPECTRAL CHARACTERISTIC The sensitivity of each of the camera color separation channels with respect to wavelength.

Note 1: It is necessary to state the camera terminals at which the *characteristics* apply.
Note 2: Because of nonlinearity, the *spectral characteristics* of some kinds of cameras depend upon the magnitude of radiance used in their measurement.
Note 3: Nonlinearizing and matrixing operations may be performed within the camera.

CAMERA TAKING CHARACTERISTICS Deprecated (see **Camera Spectral Characteristic**).

CARRIER COLOR SIGNAL The sidebands of the modulated color subcarrier (plus the color subcarrier, if not suppressed) which are added to the monochrome signal to convey color information.

CHROMINANCE The colorimetric difference between any color and a reference color of equal luminance, the reference color having a specified chromaticity.

Note: In NTSC transmission, the specified chromaticity is the zero subcarrier chromaticity.

CHROMINANCE CHANNEL In a color television system, any path which is intended to carry the carrier color signal.

COLOR BURST That portion of the composite color signal comprising the few sine wave cycles of color-subcarrier frequency (and the color burst pedestal, if present) which is added to the horizontal pedestal for synchronizing the color-carrier reference.

COLOR-CARRIER REFERENCE A continuous signal having the same frequency as the color subcarrier and having fixed phase with respect to the color burst. This signal is used for the purposes of modulation at the transmitter and demodulation at the receiver.

COLOR COORDINATE TRANSFORMATION Computation of the tristimulus values of colors in terms of one set of primaries from the tristimulus values of the same colors in another set of primaries.

Note: This computation may be performed electrically in a color television system.

COLOR DIFFERENCE SIGNAL An electrical signal which, when added to the monochrome signal, produces a signal representative of one of the tristimulus values (with respect to a stated set of primaries) of the transmitted color.

COLOR EDGING Spurious color at the boundaries of differently colored areas in the picture.

Note: *Color edging* includes *color fringing*, *misregistration*, etc.

COLOR PHASE (of a given subcarrier component) The phase, with respect to the color-carrier reference, of that component of the carrier color signal which transmits a particular color signal.

COLOR PHASE ALTERNATION (CPA) The periodic changing of the color phase of one or more components of the color subcarrier between two sets of assigned values.

Note 1: In the NTSC system, the color phase is changed after every field.
Note 2: It is recommended that the term *color phase alternation* be used in place of the terms *oscillating color sequence* and *flip-flop*, which have been used with this same meaning.

COLOR PICTURE SIGNAL The electrical signal which represents color picture information, consisting of a monochrome component plus a subcarrier modulated with color information, excluding synchronizing signals.

COLOR SUBCARRIER The carrier whose modulation sidebands are added to the monochrome signal to convey color information.

COLOR SYNC SIGNAL See **Color Burst**.

COLOR TRANSMISSION In television, the transmisson of a signal wave for controlling both the luminance values and the chromaticity values in a picture.

COMPATIBILITY The nature of a color television system which permits substantially normal monochrome reception of the transmission by typical unaltered monochrome receivers designed for standard monochrome.

COMPOSITE COLOR SIGNAL The color picture, including blanking and all synchronizing signals.

CONSTANT LUMINANCE TRANSMISSION A method of color transmission in which the carrier color signal controls the chromaticity of the produced image without affecting the luminance, the luminance being controlled by the monochrome signal.

DELAY DISTORTION That form of distortion which occurs when the envelope delay of a circuit or system is not constant over the frequency range required for transmission.

ENVELOPE DELAY The first derivative of the phase shift with reference to the frequency.

Note: If the phase is measured in radians and the frequency in radians per second, the *envelope delay* will be in seconds.

FIELD One of the two (or more) equal parts into which a frame is divided in interlaced scanning.

FLIP-FLOP Deprecated (see **Color Phase Alternation**).

GAMMA In a color or monochrome channel, or part thereof, the coefficient expressing the selected evaluation of the slope of the used part of the log vs. log plot relating input (abscissa) and output (ordinate) signal magnitudes as measured from the point corresponding to some reference black level.

Note 1: As the log vs. log plot is usually not entirely straight in the used region, it is necessary to formalize that evaluation of the slope, for example, by the use of a value at a particular point, maximum, mean, or other value. The method of evaluation must be stated.
Note 2: At some points the signal may be in terms of light intensity or light transmission.

GAMMA CORRECTION The modification of a transfer characteristic for the purpose of changing the value of gamma.

LUMINANCE Luminous flux emitted, reflected, or transmitted per unit solid angle per unit projected area of the source.

Note 1: Usual units are the lumen per steradian per square meter, the candle per square foot, the lambert, the millilambert and the footlambert.
Note 2: This quantity is also called *photometric brightness*.

LUMINANCE CHANNEL In a color television system, any path which is intended to carry the luminance signal.

Note: The *luminance channel* may also carry other signals, for example, the carrier color signal, which may or may not be used.

LUMINANCE SIGNAL A signal wave which is intended to have exclusive control of the luminance of the picture.

LUMINOSITY Ratio of photometric quantity to corresponding radiometric quantity in standard units (lumens per watt).

LUMINOUS FLUX The time rate of flow of light. When radiant flux is evaluated with respect to its capacity to evoke the brightness attribute of visual sensation, it is called luminous flux, and this capacity is expressed in lumens.

MATRIX, *noun*. In color television, an array of coefficients symbolic of an operation to be performed, which operation results in a color coordinate transformation. (This definition is consistent with mathematical usage).

MATRIX, *verb*. In color television, to perform a color coordinate transformation by computation or by electrical, optical, or other means.

MATRIXER (MATRIX UNIT, MATRIX CIRCUIT, ETC.) A device which performs a color coordinate transformation by electrical, optical, or other means.

MODULATED COLOR SUBCARRIER See **Carrier Color Signal**.

MOIRE In television, the spurious pattern in the reproduced picture resulting from interference beats between two sets of periodic structures in the image.

Note: *Moires* may be produced, for example by interference between regular patterns in the original subject and the target grid in an image orthicon, between patterns in the subject and the line pattern and the pattern of phosphor dots of a three-color kinescope, and between any of these patterns and the pattern produced by the carrier color signal.

MONOCHROME BANDWIDTH (of the signal) The video bandwidth of the monochrome signal.

MONOCHROME BANDWIDTH (of the monochrome channel) The video bandwidth of the monochrome channel.

MONOCHROME CHANNEL In a color television transmission, any path which is intended to carry the monochrome signal.

Note: The *monochrome channel* may also carry other signals, for example, the carrier color signal which may or may not be used.

MONOCHROME SIGNAL 1. In monochrome television transmission, a signal wave for controlling the luminance values in the picture but not the chromaticity values. 2. In color television transmission, that part of the signal wave which has the major control of the luminance of the color picture and which controls the luminance of the picture produced by a conventional monochrome receiver.

MONOCHROME TRANSMISSION In television, the transmission of a signal wave for controlling the luminance values in the picture, but not the chromaticity values.

OSCILLATING COLOR SEQUENCE Deprecated (see **Color Phase Alternation**).

PICKUP SPECTRAL CHARACTERISTIC The set of spectral responses of the device, including the optical parts, which converts radiation to electric signals, prior to any nonlinearizing and matrixing operations.

RECEIVER PRIMARIES The colors of constant chromaticity and variable luminance produced by the receiver, which when mixed in proper proportions are used to produce other colors.

Note: Usually three *primaries* are used—red, green and blue.

STATIONARY CPA AXIS A fixed reference phase with respect to which a carrier color signal of constant chrominance makes equal and opposite angles for successive fields, this reference phase being the same for all chrominances.

TAKING CHARACTERISTIC See **Camera Spectral Characteristic**.

ZERO SUBCARRIER CHROMATICITY The chromaticity which is intended to be displayed when the subcarrier amplitude is zero.

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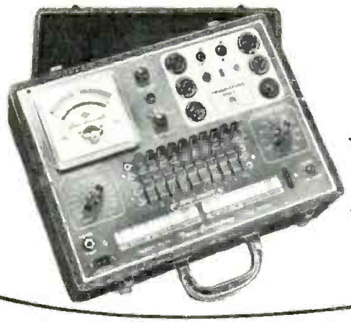

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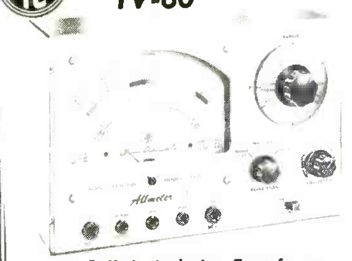

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CHAPTER 5

TEST EQUIPMENT FOR COLOR TV

Test Equipment For Color 113

Test Equipment and Servicing 116

Dot Pattern Generator For Color and Monochrome 117

Test Equipment for Color

What test equipment do you need to install a color TV set? What are the differences among the various types?

By

ROBERT G. MIDDLETON

Chief Field Engineer
Simpson Electric Co.

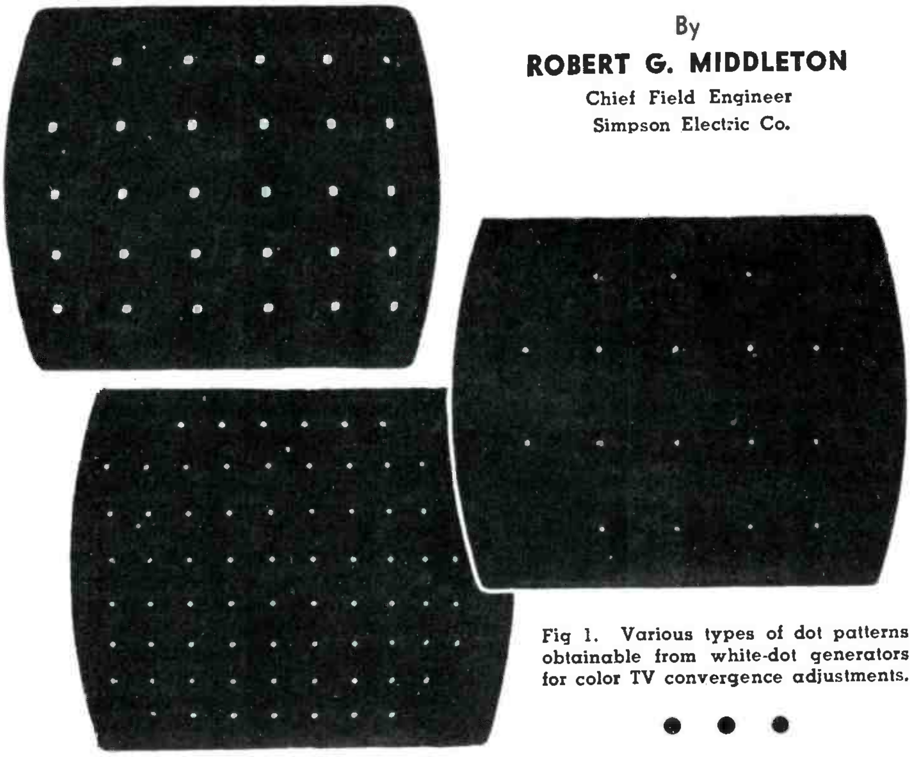


Fig 1. Various types of dot patterns obtainable from white-dot generators for color TV convergence adjustments.

• • •

COLOR TV servicing and installation requires several new types of test equipment and field experience shows that the characteristics and capabilities of the new instruments are not completely understood in all cases. It is the purpose of this article to indicate what test instruments are needed and how they should be used.

At this time, the service technician is more concerned with the installation of color TV receivers than with their maintenance. Installation men are not concerned with repair procedures, and assume that the receiver is capable of providing proper performance when the controls are correctly adjusted, otherwise the installation man will return the receiver for repair or replacement.

The really essential new instrument for the color TV installation man is the white-dot generator. This instrument is required to provide the necessary information regarding misconvergence of the color picture tube. Although other types of pattern generators can be used, it is generally recognized that the white-dot generator gives the most useful data.

White-dot generators may supply either large dots or small dots; they may provide numerous dots in the pattern, or a small number of dots; they may generate their own horizontal or vertical sync pulses, or it may be necessary to "borrow" sync from the receiver under test; they may provide modulated r.f. output which can be applied directly to the antenna input terminals of the receiver, or they may only provide a video-frequency output which must be injected into the receiver circuits at some point after the picture detector. Retrace blanking may or may not be provided.

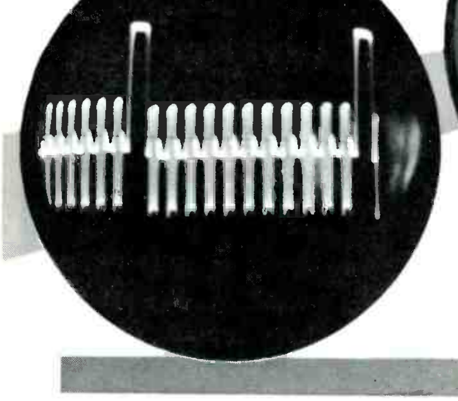
Fig. 1 shows the difference in appearance of the pattern when large dots are used and when small dots are used. White-dot generators are available which provide front-panel control of dot size, so that the operator can use a dot size of his own choice. Some receiver manufacturers recommend large dots, while others recommend medium or small-sized dots. Individual preferences of operators also differ, and the same operator may prefer large dots when the room lighting is bright or when he must utilize a mirror for viewing the screen, while he may prefer small dots when he can work directly in front of the picture tube, and when the room lighting is dim.

It is a fact that very small dots show up small misconvergences to better advantage than large dots, although the small dots are dimmer and more difficult to observe. Some receiver manufacturers discourage the use of very small dots on the basis that the operator may attempt to obtain impossibly accurate convergence, and thereby waste his time.

Questions often arise as to whether round dots or square dots are better. Actually, the dot shape provided by service generators is a square or rectangular dot, which only appears round when the picture tube is defocussed by setting the contrast and/or brightness control too high. It is hardly necessary to point out the error of such adjustment of these controls.

The difference in appearance of the dot pattern when a small number of dots are utilized, as compared with a large number of dots, is shown in Fig. 1. Although it is usually desirable to use a large number of dots to check convergence at different parts of the CRT screen, difficulties may be encountered in the early stages of convergence when a large number of dots are used. The difficulty comes about from the fact that some large-screen

Fig. 2. Output from a keyed rainbow generator as seen on the screen of a wide-band scope. Note horizontal sync pulses.



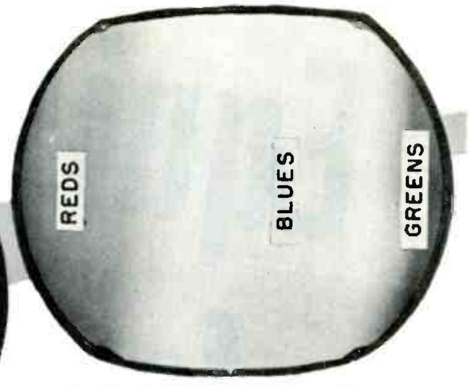


Fig. 3. Typical rainbow display on a color TV tube. The actual display, of course, is in color. Absence of a hue indicates trouble in the associated chrominance channel of the color TV set.

picture tubes may go far out of convergence when the convergence controls are badly misadjusted; in such a case, the red-green-blue triads may be so widely spaced that adjacent triads overlap and cause confusion in a pattern having a large number of dots. Hence, the operator may need to start convergence procedures with a relatively small number of dots, and to make the final convergence with a larger number of dots.

It is convenient to have sync pulses furnished by the generator, as an additional lead does not then need to be run from the generator to tap off sync from the receiver sweep circuits. Unless blanking is provided, horizontal smear will appear in the white-dot pattern, due to dot pulses being caught and stretched on retrace. While background smear is not serious from the standpoint of convergence procedure, the smear is a distraction and annoyance.

Remember that convergence of the three-gun picture tube is a tedious and time-consuming procedure, and that the operator needs every bit of assistance possible from his generator. Experienced installation men do not need to be told of the demands placed on time and tempers by convergence procedures—the newer color TV receivers provide as many as 17 convergence controls, all of which interact to some extent.

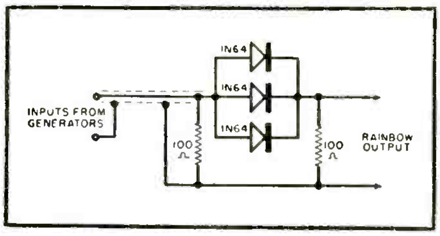
Color-Bar Generators

In the event that the technician cannot time his installation so that it coincides with a color TV program transmission, he must utilize some source of color-signal generation, or make a "callback" to set up the color phase and color intensity controls when a color program is available. Hence, the color signal generator is frequently a "must" for installation work.

The simplest source for obtaining a color pattern is to use a modulator output cable, such as the "Chromatic Probe." This is used in conjunction with conventional signal generators and will cause a rainbow pattern to be displayed on the screen of the color picture tube. Although it leaves something to be desired in the direction of accuracy, saturation, etc., the rainbow pattern does give the installation man sufficient data that he can "get by." To generate a rainbow pattern, the FM and AM generators which feed the probe (see Fig. 4), are adjusted as follows: The AM generator is tuned to 3.58 mc. (the color subcarrier frequency) and the FM generator is tuned to the picture carrier frequency of the channel to which the receiver is set (this should be a vacant channel, to avoid beat interference). The FM generator is operated as a conventional signal generator by reducing the sweep-width control to zero and by turning off the blanking switch.

The output of the probe is fed to the antenna input terminals of the color set. It will be observed that the setting of the contrast control has no affect on the rainbow pattern, but that the pattern becomes bright or dim as the color intensity and brightness controls are varied in the color TV receiver—these latter controls are usually operated approximately three-fourths of maximum for the rainbow display. When the AM generator is set exactly to 3.579545 mc., a single hue appears on the screen of the color picture tube, since the rainbow signal is then zero-beating with the color subcarrier oscillator in the receiver. Next, as the frequency of the AM generator is reduced by one horizontal scan (15,750 cps), one complete rainbow appears on the picture tube. The rainbow pattern is characterized by

Fig. 4. Circuit diagram of a "Chromatic Probe" used with conventional AM and FM signal generators to produce a rainbow pattern on the screen of a color tube.



reds, blues, and greens, but lacks the brighter colors, such as yellow; rainbow colors are always dim and bluish, as compared with true color displays, obtained from specialized generators.

Proper setting of the color phasing control of the TV set is indicated when the color sweep is shifted to the standard position on the screen of the picture tube—as the color phasing control is varied, the spectrum moves left or right. The standard position is that which displays a dim orange at the extreme left-hand edge of the screen, merging rightward into the reds, then into the blues to the right of center-screen, and finally into greens at the extreme right-hand edge of the screen.

Note that a standard rainbow is obtained only when the AM generator is operated *below* the color subcarrier frequency. A rainbow also appears when the AM generator is tuned 15,750 cps above 3.579545 mc., but this display is reversed, *i.e.,* the reds appear at the right-hand side of the screen, and greens appear at the left-hand side. Any number of rainbows up to 30 or 40 can be obtained by tuning the AM generator farther away from the color subcarrier frequency. Standard practice is to utilize a single rainbow with the signal set one horizontal scan below the subcarrier.

Compact rainbow generators for installation work are available, and they avoid the bulkiness of conventional alignment equipment. These contain the necessary signal generators and connectors, and operate in much the same manner as described for the "Chromatic Probe."

Some more elaborate rainbow generators contain sync and burst signals in the chrominance output, as illustrated in Fig. 2. In this arrangement, the rainbow signal is keyed into groups by means of a multivibrator contained in the generator. This type of signal displays rainbow stripes, instead of a continuous chrominance sweep, and is easier to interpret. The first group following the horizontal sync pulse is utilized by the color sync circuits in the receiver, while subsequent groups appear on the screen of the picture tube as rainbow stripes. The horizontal sync pulse provided in the signal stabilizes the pattern, and crystal control of the chrominance signal and the picture carrier signal greatly increases the accuracy of indication.

When a sound carrier is also provided in the output signal from the generator, additional operating facility is obtained, since the operator may then adjust the fine-tuning control accurately to eliminate the 920-kc. beat between sound and chroma. Many color TV receivers are sensitive to adjustment of the fine-tuning control and do not provide true color reproduction unless proper adjustment is made.

Note in Fig. 2 that the simpler types of keyed rainbow generators provide the chrominance signal at black level; for this reason, the hues obtained are not standard. Standard hues are obtained only when the chrominance signal is combined with suitable values of *Y* (black-and-white video) signal. More elaborate keyed rainbow generators provide a single *Y* output with the chrominance signal, and this *Y* signal can be varied in level by means of a front-panel control. In generators which have no *Y* signal available, the brightness control of the receiver must be advanced to a suitable position to provide an artificial equivalent of a *Y* signal. Of course, it is possible to find some setting which will provide a standard color for *one* stripe, such as blue or red.

A rainbow generator is useful, not only for adjustment of the color phasing control during installation procedures, but also for troubleshooting the chrominance circuits. For example, consider the rainbow display illustrated in Fig. 3. The display is characterized by reds, blues, and greens, as indicated. In case the *R-Y* detector channel in the color TV receiver is faulty, the reds disappear from the pattern, being replaced by blank raster. Likewise, if the *B-Y* detector channel is faulty, the blues disappear from the pattern, leaving the reds and greens. Lack of input signal to the *G-Y* matrix causes the greens to disappear from the pattern, leaving the reds and blues only. Of course, more complex indications are obtained from other types of chrominance circuit faults and familiarity with these symptoms is gained by experience in service work.

In summary, a rainbow generator will show whether a color TV receiver is capable of reproducing a color signal (no pattern is obtained if the chrominance circuits are "dead"), serve as a guide in adjusting the color phasing control properly, and indicate the nature of major faults in the chrominance circuitry.

The NTSC color-bar generator is the most elaborate and expensive form of color signal generator and provides an output which is essentially the same as transmitted by a color TV transmitter during test pattern time. Varied outputs are generally available from the NTSC type of generator to facilitate different types of tests. The proportions of the signal output from an NTSC color-bar generator are illustrated in Fig. 5. Note carefully that the chrominance signals are not centered on black level, but are superimposed upon definite values of *Y* signal.

This type of signal provides fully saturated and true colors on the screen of the picture tube. Yellow and white bars are available, for example, and the operation of the receiver chrominance circuits is fully indicated. An NTSC color-bar generator may provide both modulated r.f. output and video-frequency output.

Fig. 6 illustrates the appearance of an *R-Y* signal from an NTSC color-bar generator. The output contains horizontal sync, burst, and a crystal-controlled chrominance signal properly phased for *R-Y* response. Since most present-day color TV receivers incorporate *R-Y* and *B-Y* detectors, the advantage of having individual *R-Y* and *B-Y* outputs for bench tests is apparent. An NTSC generator may also provide individual *G-Y* signals for matrix tests; they all provide *I* and *Q* signals.

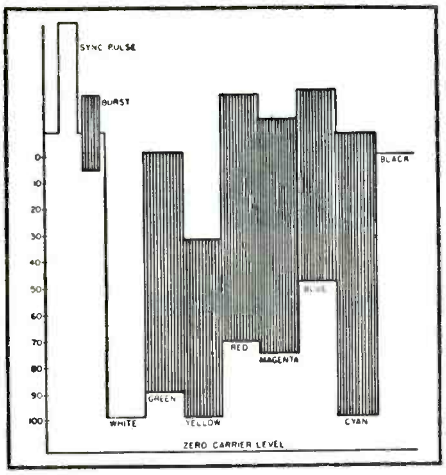


Fig. 5. Composite video signal output of one NTSC color-bar generator. The color tube display resulting from this signal has distinct vertical color bars.

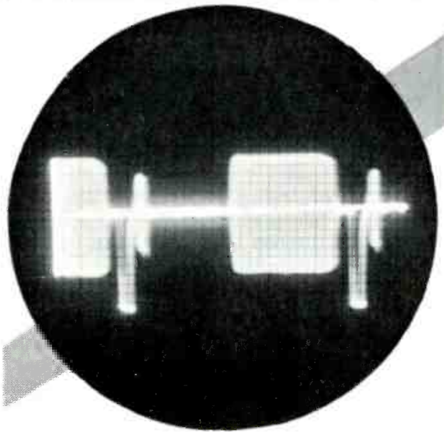
An NTSC color-bar generator produces standard colors, which appear in a regular sequence when the color phasing control is properly adjusted, as shown in Fig. 7. If the color phasing control is incorrectly adjusted, the entire color spectrum shifts, so that the bars do not appear in proper color sequence. The NTSC color signal is considerably more useful than a rainbow signal for troubleshooting work, because it gives more direct information concerning circuit action.

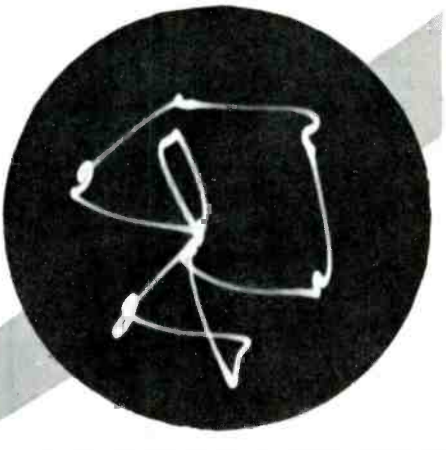
If the *R-Y* detector channel is inoperative, the red bar appears as a gray, the yellow bar appears green, the magenta bar appears blue, and the white bar appears cyan. Or, if the *B-Y* detector channel is inoperative, the blue bar appears gray, the cyan bar appears green, the white bar appears magenta, and the magenta bar appears red. If the *G-Y* matrix channel is inoperative, the green bar appears gray, the yellow bar appears red, the white bar appears magenta, and the cyan bar appears blue.

The *R-Y* and *B-Y* outputs of an NTSC color-bar generator tests the color circuits of a TV set in the following manner. When the color detectors are operating properly, the *R-Y* detector circuit develops maximum output on an *R-Y* signal from the generator and zero output on a *B-Y* signal; the *B-Y* detector will develop maximum output on a *B-Y* signal and zero output on an *R-Y* signal. The color picture tube will display only the *R-Y* bar for the first case and only the *B-Y* bar for the second case. If these conditions are not obtained, the trouble is usually due to misadjustment of the quadrature transformer, or to capacitor failure in the color subcarrier circuits.

When the operator views the output from an NTSC generator on the screen of a wide-band scope, he cannot distinguish the difference between an *R-Y*, *B-Y*, or *G-Y* signal when sawtooth sweep is used. However, if the output from the *R-Y* detector is applied to the vertical channel of the scope, and the output from the *B-Y* detector is applied to the horizontal input of the scope, a chrominance phase display is obtained, as shown in Fig. 8. The transient distortion in the pattern is due to inaccuracies of receiver response and will differ from one receiver to another. Of course, transient distortion in the scope amplifiers can mislead the operator in this regard.

↓ **Fig. 6. Appearance of an R-Y signal from a color-bar generator, as seen on a scope.**





↑ **Fig. 8. Vector phase display obtained on an oscilloscope connected to a color TV set. A color-bar generator furnishes the input to the set. See text.**

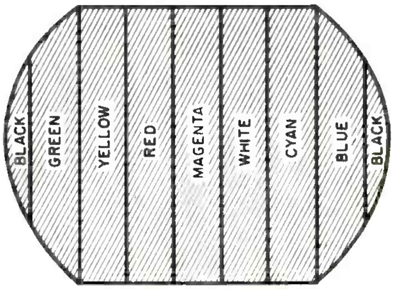


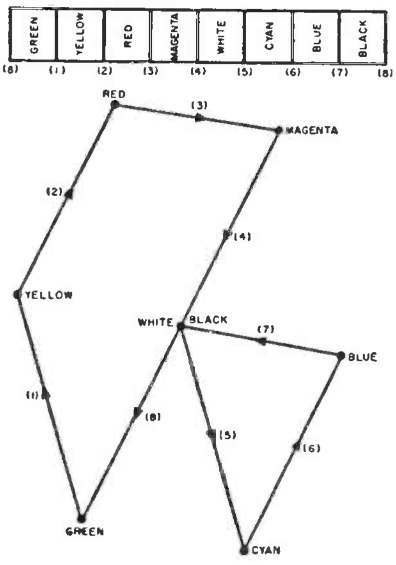
Fig. 7. Typical color sequence provided by one NTSC color-bar generator when the color phasing control is set correctly. →

The chrominance phase display corresponding to an NTSC color-bar signal for the case of distortionless receiver circuits and scope amplifiers is diagrammed in Fig. 9. This diagram deserves some attention, inasmuch as it provides the bench man with a wealth of direct data concerning chrominance circuit operation. As the color phasing control is turned, the vector display rotates on the scope screen. As the color intensity control is turned, the display expands or contracts accordingly. The length of each vector from the center (black) is proportional to the chrominance voltage for that color. The angle of each vector with respect to the horizontal axis is equal to the phase of the chrominance voltage for that particular color.

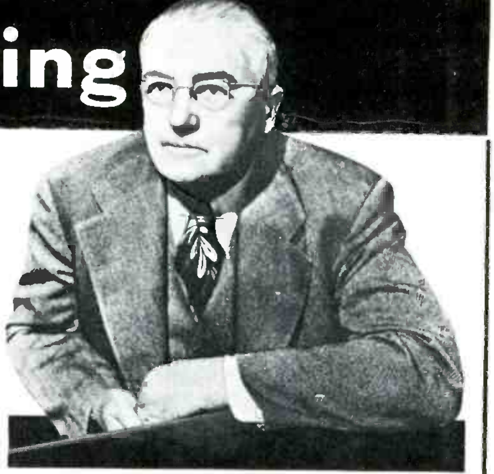
If the angles do not appear correctly in the vector display, the phase of one or both of the color subcarriers is incorrect—this latter point is determined by observing which color phases appear correctly and which do not. If the lengths of the vectors do not appear in proper ratios, the output voltages from the color detectors (either or both) are incorrect, or the output voltage from the *G-Y* matrix is incorrect. Again, this localization is made by observing which vector lengths are out of proportion.

Which color test instruments will be required by your shop depends upon how much color TV service work you are anticipating. While the amount of color TV servicing and installation is limited at present, those who are prepared to handle such jobs will get the lion's share when the market opens up. —30—

Fig. 9. The vector display shown here corresponds to the bar pattern above it. This is a correct display; if the receiver circuits were faulty, the display would be different. See Fig. 8.



Test Equipment and Servicing



By RAY R. SIMPSON

The author, founder of Simpson Electric Co., Chicago, is celebrating his 50th year in the electronic instruments field. He began his career in 1906 when he went to work for the old Jewell Electric Co., a firm he later headed. In 1934 he organized the firm which bears his name. Today, Simpson Electric Co., with Ray Simpson as chairman of the board, has three plants — in Chicago; Aurora, Ill.; and Lac du Flambeau, Wis. — and is one of the largest manufacturers of panel meters and radio-TV test equipment.

Predictions as to the increase in the test equipment and servicing industries with the rise of color TV.

COLOR television will bring new techniques and the necessity to learn them, new testing instruments, and new plant investment.

To get an idea of just how soon a radical new development like color television can make its way into almost every American home we need only take a backward glance at the servicing industry. Since 1920, it has worn seven league boots as standard equipment to keep up with the entertainment demands of our people. The man who serviced dad's two-tube radio set in 1920 owned about $25 worth of testing equipment. His electronic education, picked up in his "ham" days, was good enough for the day, but he still spent roughly four hours on the average service job. Today, the average black-and-white TV service job takes only a half hour, but the practical engineer who is the modern service technician owns or uses at least $1500 worth of test equipment.

Another indication of growth is found in my own division of the industry, designing and manufacturing the test equipment. In 1920, our entire industry yearly sales amounted only to $50,000, while today, five of the largest manufacturers combined do a $25,000,000 yearly business. Based on growth figures of only the past few years, I believe supplying the 100,000 service technicians in the United States with specialized testers to meet the challenge of color television is going to be a bigger than $50,000,000 industry by 1960, a two-fold increase in four years.

Concretely, the need for new equipment to service a new dimension, color, will mean the production of 25,000 tube testers, 50,000 oscilloscopes, and 100,000 specialized colorscopes, color-bar generators, and variable dot generators—names which will become as much a part of servicing jargon as tube tester or v.o.m.

The biggest service tool in the service kit of 1920 was a voltmeter used to measure the output of the batteries used to power the old radio sets. It cost about $10. The advent of de Forest's vacuum tube added simple tube testers to the kit, and by the mid-thirties, the conscientious service technician carried a signal generator in his field case to make alignment tests of the larger console radios of the period.

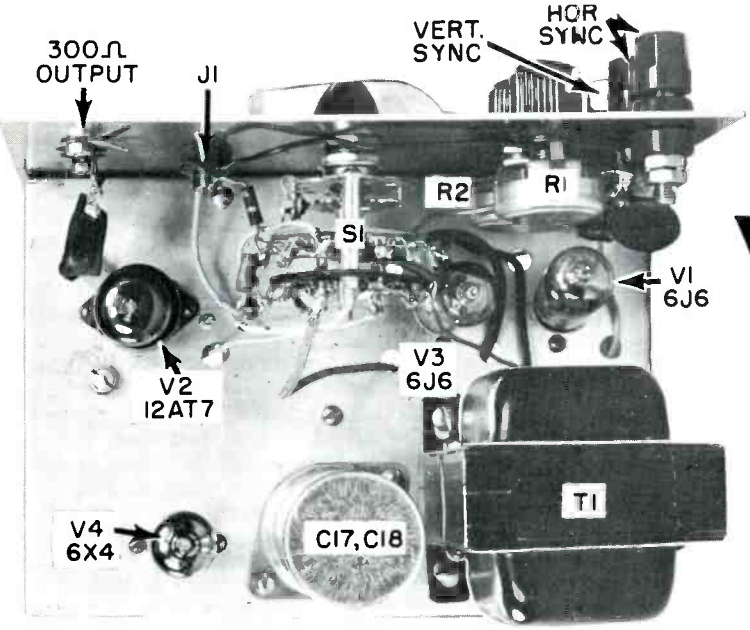
Radios, of course, became less complicated, but television introduced video, synchronizing, and sweep circuits, and problems of proper picture adjustment. The electronic instrument field met the service technician's black-and-white TV needs with advanced sweep generators, signal generators, marker generators, oscilloscopes, and high voltage probes, as well as by refining the conventional meters and making them more sensitive. With the experience gained with these instruments and TV circuitry, the service technician should be able to keep the color sets operating. But he'll need new testers and the ability to use them to do it. His own increased plant expense will, of course, be reflected in the prices he charges for color servicing, but I believe the public will accept this just as they will accept and are accepting the much higher set costs of color television.

In addition to producing new instruments, many companies in our field are distributing educational literature on color servicing and a few are conducting nationwide service technician meetings where color servicing with the new instruments is explained and demonstrated.

I've indicated a pretty optimistic growth picture for the service technician and my own industry, because I can't see how we can do anything but grow. Each new electronic development will have its counterpart in new ways of measuring, controlling, and servicing that development. —30—

DOT PATTERN GENERATOR FOR COLOR AND MONOCHROME

Fig. 1. Top view of the pattern generator showing the parts layout. Note how the video amplifier-r.f. oscillator tube is located on the left side of the chassis, away from the vertical and horizontal multivibrator tubes on the right.



By

WALTER H. BUCHSBAUM

Television Consultant

RADIO & TELEVISION NEWS

Here's an instrument which is invaluable for color TV servicing and is easily built from standard parts.

OF GREAT IMPORTANCE in color TV receivers are the d.c. and dynamic convergence adjustments which determine correct color registry. In addition, the vertical and horizontal linearity controls must also be set much more accurately than in black and white receivers. For this reason service technicians will need a pattern generator which produces horizontal and vertical bars as well as a white dot pattern.

In this article we present a simple pattern generator which can be constructed by anyone familiar with radio and TV. All parts used are standard items and a minimum of alignment is required.

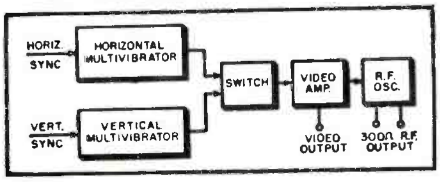
This pattern generator is useful for current black-and-white TV service work since it furnishes modulated r.f. as well as a video signal for four different patterns. A switch selects either the white dot, crosshatch or grid, vertical bar, or horizontal bar pattern. Internal or external vertical and horizontal synchronization is possible.

Circuit Operation

As can be seen from the block diagram in Fig. 2, the unit consists of four major sections. The horizontal multivibrator, running at a multiple of the horizontal scanning frequency, generates narrow vertical bars on the picture-tube screen. Operating at some multiple of the vertical scanning frequency, the vertical multivibrator produces horizontal bars on the screen. By means of a switching network, the outputs of these two pulse generators are fed to a gating and video amplifier tube. The output of this stage modulates the r.f. oscillator which covers channels 2 to 6 and has a 300-ohm balanced output. If the video signal itself is desired, it can be taken off through a separate terminal on the front panel and applied directly to the second detector or video amplifier in the TV set. For r.f. operation, a short length of 300-ohm twin-lead is connected from the pattern generator to the antenna terminals of the TV set. Any of the low frequency TV channels can be used.

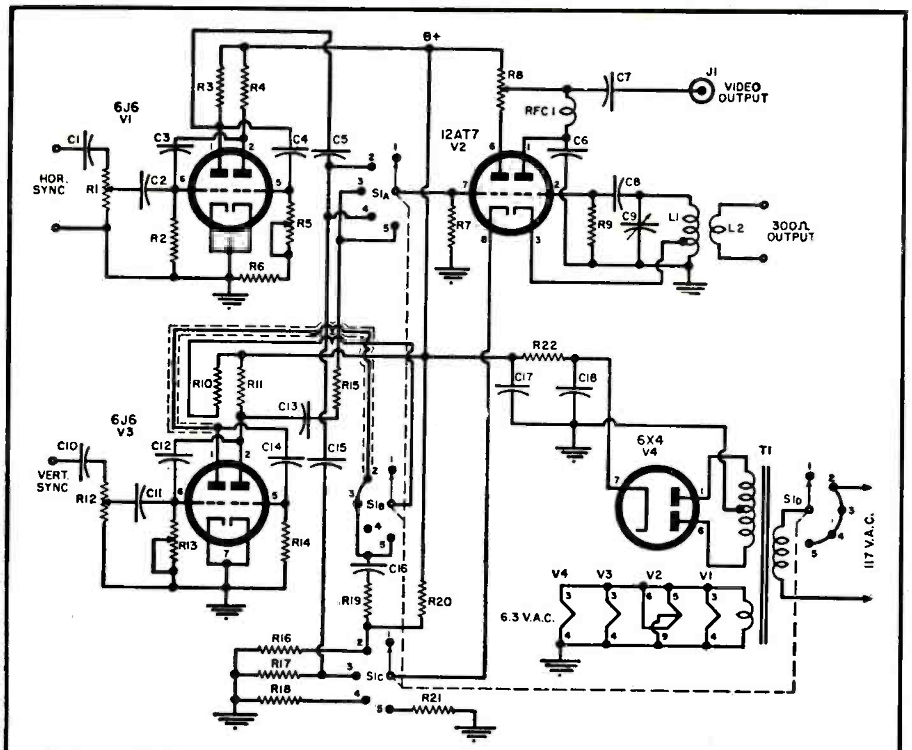
The detailed circuit diagram and parts list of the pattern generator is shown in Fig. 3. V_1 is a 6J6 used as the horizontal multivibrator and operates usually at about 157 kc. or some other multiple of 15,750 cps. The external synchronizing signal is applied to the multivibrator through C_1 and R_1 which permits adjustment of the sync pulse amplitude. Usually it is only necessary that a lead be clipped on to the wire going to the horizontal deflection yoke coils of the TV set. The flyback pulse picked up is sufficient to lock in the multivibrator and produce stable vertical bars on the screen. A simple plate-coupled multivibrator circuit is used which produces rectangular waves of unequal widths. R_5 controls the frequency of the multivibrator and allows setting it for any desired number of vertical bars.

Fig. 2. Block diagram of the pattern generator described in this article.



V_3 in Fig. 3 is the vertical multivibrator. This stage can be synchronized by means of the vertical pulse of the TV set. R_{12} allows adjustment of the sync pulse amplitude while R_{13} determines the frequency and, therefore, the number of horizontal bars on the screen. Again, a simple plate-coupled multivibrator circuit is used, producing a rectangular waveform. The coupling networks which feed the vertical pulse to the switching network introduce some differentiation and help sharpen the narrow pulse. This results in a fairly thin bar on the screen.

The switching network consists of a rotary four-pole, five-position switch. One pole or section is used as the a.c. "off-on" switch and the other three sections provide the four different patterns. Before going into details of the switching system, consider the type of



R_1, R_{12}—500,000 ohm pot
R_2, R_6, R_{16}—8200 ohm, ½ w. res.
R_3, R_4, R_{10}, R_{11}—22,000 ohm, 1 w. res.
R_5—100,000 ohm pot
R_7—47,000 ohm, ½ w. res.
R_8—10,000 ohm wirewound pot
R_9, R_{19}—15,000 ohm, ½ w. res.
R_{18}—50,000 ohm pot
R_{14}—180,000 ohm, ½ w. res.
R_{15}—270,000 ohm, ½ w. res.
R_{17}—2700 ohm, ½ w. res.
R_{18}—220 ohm, ½ w. res.
R_{20}—82,000 ohm, ½ w. res.
R_{21}—2200 ohm, ½ w. res.
R_{22}—820 ohm, 2 w. res.
C_1—.001 μfd. cond.
C_2, C_6—100 μμfd. cond.
C_3, C_8—10 μμfd. cond.
C_4—56 μμfd. cond.
C_5, C_{15}—22 μμfd. cond.
C_7—.1 μfd. cond.
C_9—5-45 μμfd. var. cond.
C_{10}—.01 μfd. cond.
C_{11}—.002 μfd. cond.
C_{12}—.0015 μfd. cond.
C_{13}—120 μμfd. cond.
C_{14}—.0056 μfd. cond.
C_{16}—.005 μfd. cond.
C_{17}-C_{18}—40/40 μfd., 350 v. elec. cond.
L_1—7½ t. #21 en. closewound ¼" dia., tapped at 1½ t.
L_2—3 t. #21 hookup wire, closewound around L_1
RFC_1—R.f. choke, 3.3 μhy., 1 w.
S_1—4-pole, 5-pos. switch (Centralab #1415 or Mallory #1325L)
T_1—Power trans. 230-0-230 @ 50 ma.; 6.3 v. @ 2.5 amp. (Stancor PC8418 or equiv.)
J_1—Output jack
V_1, V_8—6J6 tube
V_2—12AT7 tube
V_4—6X4 tube

Fig. 3. Complete schematic diagram and parts list for the dot and bar pattern generator. Easily-obtained, standard parts are used throughout this unit.

signals required for each position. Taking the last position first, horizontal bars are generated when only the output of the vertical multivibrator reaches the grid of the video amplifier. Therefore, in position 5, S_{1A} receives the differentiated vertical pulse through C_{13} and R_{15}. The latter resistor is used to avoid overloading the video amplifier grid. In position 5 the cathode of V_2, the video amplifier, goes to ground through R_{21}.

When vertical bars are desired we switch to position 4 and now only the signal from the horizontal multivibrator, V_1, is required. To avoid stray pickup from the vertical multivibrator, V_3, this stage is disabled by switch section S_{1B} which eliminates plate voltage from one half of the tube in position 4. Since more video gain is required for the weaker horizontal pulses, R_{18} is now connected as cathode resistor for V_2.

So far the switching system is quite simple, but it becomes slightly more complicated when we want to obtain a grid pattern. For this type of signal the vertical and horizontal signals should be amplified equally, without interference to each other. In switch position 3 the vertical pulse goes to the grid of V_2 through C_{13} and R_{15} while the horizontal pulse is applied to the cathode of V_2 through C_5 and C_{15}. The purpose of this is to further differentiate the horizontal pulse, and is especially effective since it feeds into the cathode resistor R_{17} which is only 2700 ohms. As a result, both the vertical and horizontal bars appear equally wide and equally strong, producing a good grid pattern.

The circuit required for the dot pattern is obtained in switch position 2. In order to produce white dots, the video signal must contain horizontal pulses only during the brief duration of the vertical pulse, and the vertical pulse should only be amplified during the period of the horizontal pulse. In other words, only the intersection of the horizontal and vertical bars should be visible. In conventional dot generators this effect is achieved by using a 6AS6 or similar gating tube and applying each signal to one of the active grids. Since 6AS6 tubes are fairly expensive and low cost as well as simplicity is desired here, we have arranged the video amplifier so that it doubles as the gating tube. The horizontal pulses are applied through C_5 to the grid of V_2 when the switch is in position 2. Vertical pulses are applied through C_{16} and R_{19} to the cathode of V_2. Note that here the vertical pulses are taken from the opposite polarity plate of the multivibrator. The reason for this is that a negative-going pulse is required to gate the video amplifier.

S_{1C} in position 2 connects the V_2 cathode to a voltage divider, R_{16} and R_{20}, which applies a fixed cathode bias of about 12 volts. This cuts off the tube and allows no signal to pass. The gating action occurs when a negative polarity vertical pulse overcomes the fixed bias and permits a short burst of horizontal pulses to pass.

The first position of the selector switch is used to shut off the a.c. power as is evident from the connection of S_{1D}. A simple, full-wave power supply is used here. It supplies 125 volts d.c. and has a current drain of about 35 ma.

The second triode section of V_2 is an r.f. oscillator, capacity tuned from 50 to 90 mc. to cover the low-band TV channels. Plate modulation is used here which permits a single amplitude control, R_8, to vary both the video output signals and the modulation percentage. The drawback of this arrangement is that changing the output control will also vary the oscillator frequency slightly. Actual tests have shown that this variation is less than 1 mc. and the TV receiver bandwidth is usually such that readjustment of the fine tuning control at the TV set compensates sufficiently. The r.f. output is obtained by means of a three-turn coil wound on the same form as the oscillator coil.

Construction

The chassis layout in Fig. 1 is simple and straightforward. A standard 5" x 7" x 2" aluminum chassis was used. There does not appear to be any critical lead length or location for either the vertical or horizontal multivibrator, but it was found necessary to shield the lead from pin 1 of V_3 to switch section S_{1B} to prevent stray pickup in the dot-pattern circuit. It is also advisable to locate the 12AT7 away from the vertical multivibrator for the same reason. In addition, the r.f. oscillator section should be isolated somewhat. In Fig. 1 is shown the r.f. output lead which consists of a piece of 300-ohm twin-lead going from L_2 to the 300-ohm terminals. Some readers may prefer to omit the terminal strip and bring out a long 300-ohm lead for direct connection to the TV set.

All resistors used are 10% values; paper and tubular or flat ceramic condensers are used throughout. No difficulty should be encountered if mica condensers are used, but it is not advisable to connect condensers having a negative temperature coefficient into the multivibrator circuits.

When the generator is first turned on, set the two frequency control potentiometers R_5 and R_{13} to an approximate midpoint position and check the output of the video amplifier on an oscilloscope. In switch position 2, dot pattern, only a faint signal may be visible unless a sensitive, wide-band scope is used. The grid pattern, switch position 3, will appear like the scope picture of Fig. 4 when the oscilloscope is set for about 600 cps. In this illustration the large, wide pulse is the vertical multivibrator output while the smear near the base line actually consists of the higher frequency horizontal pulses.

Turning the selector switch to position 4, we obtain the horizontal pulses only. When the scope frequency is adjusted to about 25 kc., the waveform shown in Fig. 5 should be observed. Each sharp spike represents one of the vertical lines on the screen. In order to see the sharp point as clearly as in Fig. 5, the oscilloscope should have a bandwidth of at least 1 mc., otherwise a rounded waveshape similar to a sine wave will appear.

The pattern obtained in switch position 5 is similar to that of position 3, except that no horizontal pulses appear and the baseline will be free from the fuzz shown in Fig. 4. When the output amplitude control is set for maximum, the peak-to-peak voltage at the video terminal will be approximately 20 volts on all switch positions except position #2. For the dot pattern the video amplifier operates with slightly reduced gain and because of the sharp, short burst of horizontal pulses the oscilloscope picture shows a peak-to-peak voltage of about 15 volts.

The final step in adjusting the pattern generator is to check out the r.f. oscillator. To make sure it is oscillating, check the grid bias with a decoupled v.t.v.m. probe. While a 5 to 45 $\mu\mu$fd. air-trimmer type condenser is used here, a somewhat larger value may be used and plates removed to make the range. L_1, the oscillator coil, can be stretched or squeezed together to provide for full coverage from channels 2 to 6. L_2 can be varied by changing its coupling with the tank circuit. The correct coupling is obtained when approximately equal output is achieved on all channels. One way to check this is by means of a 300-ohm crystal detector, with its output connected to the oscilloscope. About 0.5 volt of signal should be obtained on the scope and this should remain substantially constant when the tuning condenser is varied over the band.

Using the Pattern Generator

Switch position 5 generates horizontal bars which can be fed directly to the video output amplifier in the TV set, or the r.f. signal can be introduced at the antenna terminals. When the horizontal-bar pattern is applied at the TV receiver antenna terminals, simply tune the set for any channel between 2 and 6 and tune the pattern generator for a good screen pattern. A typical horizontal-bar pattern is shown in Fig. 6.

In some instances it will be found that the TV set does not readily lock-in with the bar pattern or, when the pattern is applied to the picture-tube grid, no sync action at all takes place. To make the bar stand still, clip a lead from the vertical sync terminal to either the vertical deflection yoke leads, the yoke terminal, or the terminals of the vertical output transformer. This will lock the multivibrator in the generator to the receiver vertical sweep, assuring absolute synchronization. The sync amplitude control, R_{12} in Fig. 3, helps to adjust the sync signal for best lock-in.

Horizontal bars are usually used to check the vertical linearity, and the method used is the same for monochrome and color receivers. Adjust the height and vertical linearity controls until the picture is slightly smaller than the screen. Count the number of horizontal bars and expand the sweep until the top and bottom bars are just within the picture tube mask. Adjust linearity and height until the spacing between bars is equal and the same number of bars is still visible.

For checking horizontal linearity, the vertical bars shown in Fig. 8 are obtained in switch position 4. In general, the same connection as for the horizontal-bar pattern is used. For good synchronization it is helpful to clip a lead from the horizontal sync terminal to either the high voltage lead or one of the leads going to the horizontal yoke coils. Usually the capacitive pickup from such an arrangement is sufficient for stable sync.

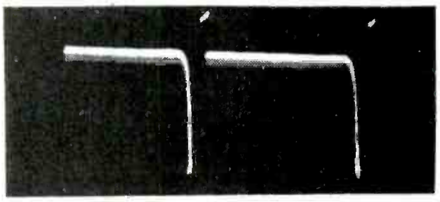


Fig. 4. Oscilloscope waveform obtained at the video output with the switch in position 3 furnishing the grid pattern.

Fig. 5. With the selector switch in position 4 the output waveform shows a sharp spike for each vertical bar.

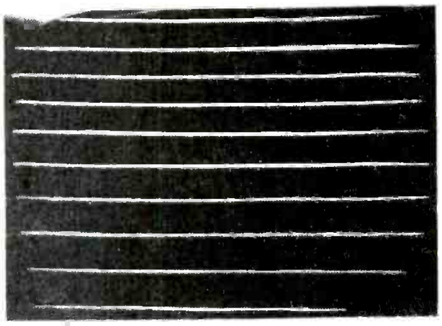
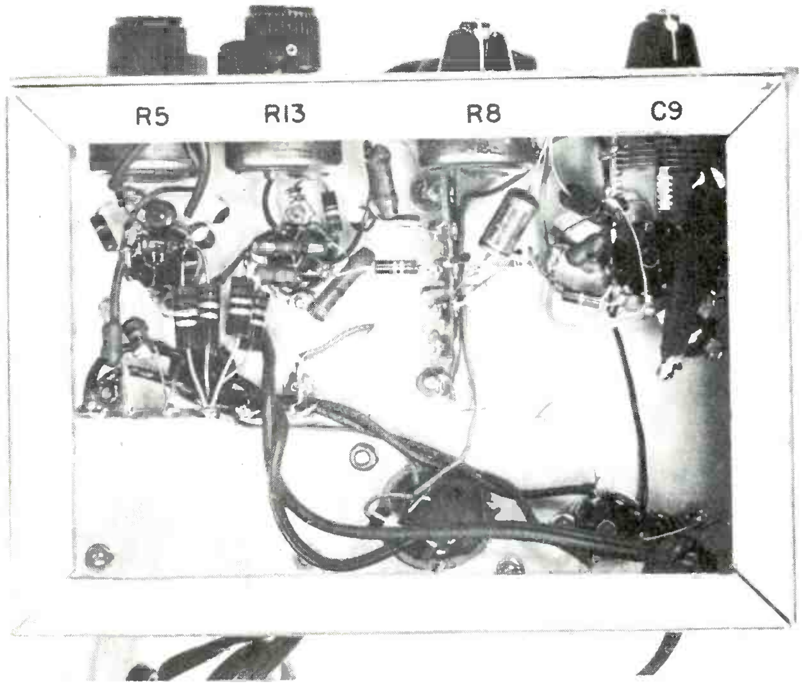


Fig. 6. Horizontal bar pattern obtainable from the generator in position 5.

Fig. 7. Bottom chassis view. Ten per-cent tolerance resistors and paper and tubular or disc ceramic condensers are used throughout, except for the oscillator trimmer and power supply electrolytic filter condensers. See the parts list.



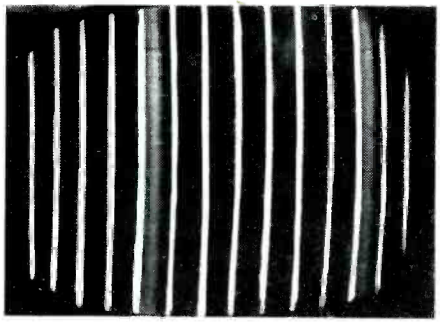


Fig. 8. Vertical bar pattern with the generator selector switch in position 4.

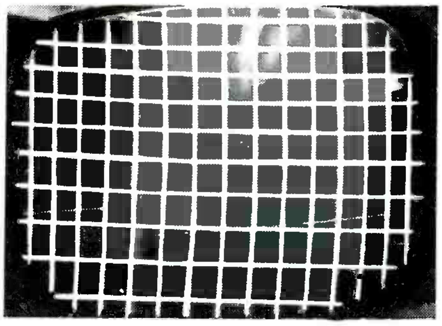


Fig. 9. Grid or crosshatch pattern used for linearity adjustments, position 3.

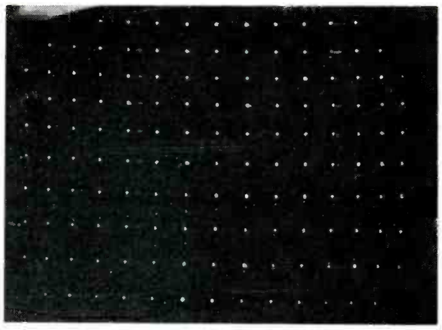


Fig. 10. White dot pattern for color TV convergence adjustments, switch set at 2.

The sync control, R_1 in Fig. 3, regulates the sync pulse amplitude. It is important to set the horizontal frequency control to get a stable, fixed number of vertical bars as shown in Fig. 8. The procedure for adjusting horizontal linearity is similar to that outlined for the vertical sweep section. Pincushioning or other yoke distortion will appear as bent, bulging, or wavy vertical bars.

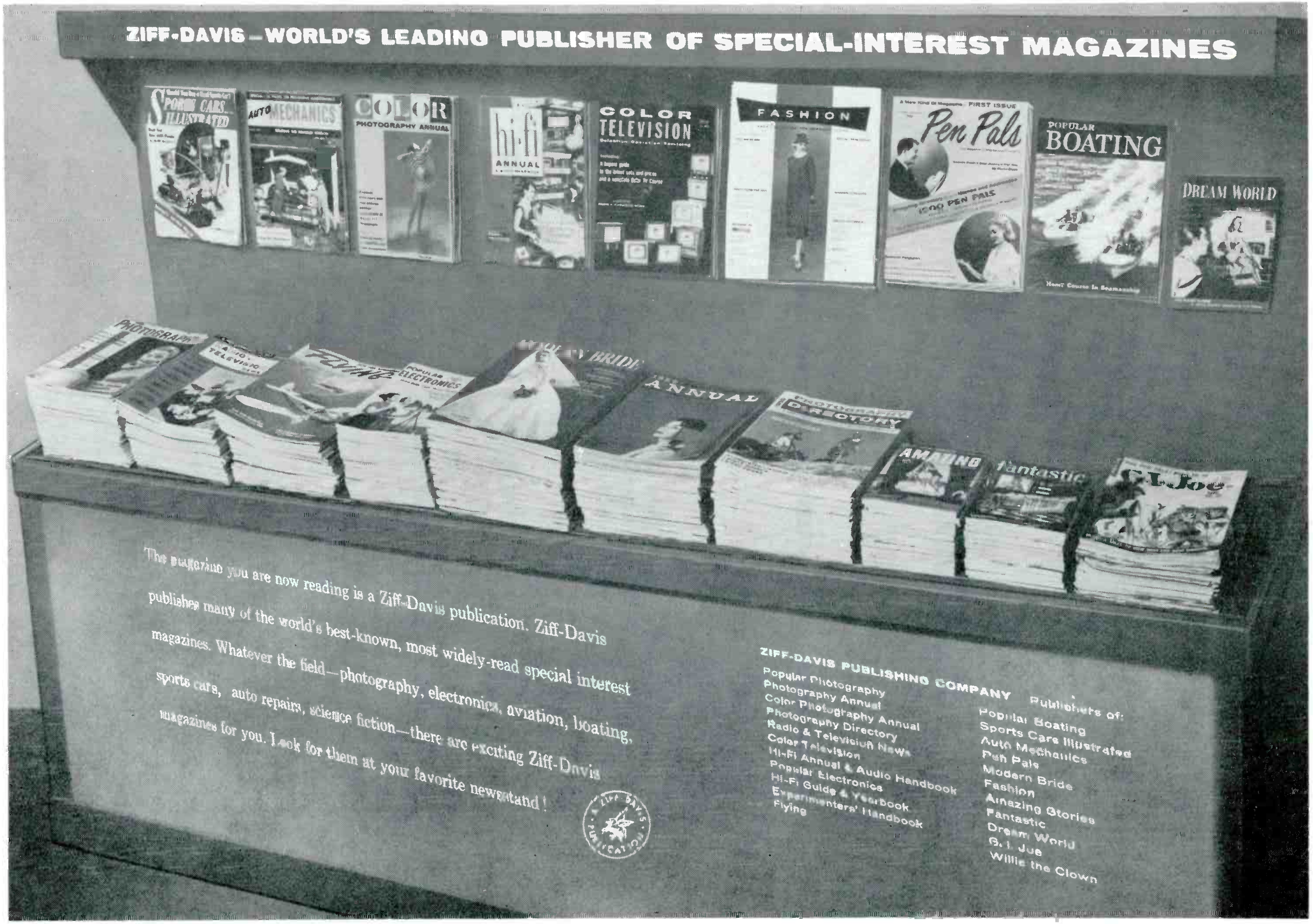
For a rapid check of both vertical and horizontal linearity the grid or crosshatch pattern can be used. As Fig. 9 shows, this type of pattern tends to accentuate any non-linearity and therefore allows more accurate adjustment. Just compare the squares in the center of the screen with the squares at the sides or corners. In Fig. 9, it is apparent that the horizontal sweep is compressed at both sides while the vertical sweep is expanded at the bottom and compressed at the top.

The great utility of the pattern generator described here lies in the fact that it produces white dots as shown in Fig. 10. This white-dot pattern is of great help in adjusting convergence on shadow-mask type color picture tubes such as the 15GP22 and its larger cousins, as described in the article beginning on page 96 in this book. The dot pattern will produce white dots only when proper convergence is achieved. When convergence is off, two or three colored dots will appear.

The dot signal can be introduced either through the antenna or through the video stages, as with the other patterns. To obtain only the desired dots, set the video gain controls for maximum and adjust the brightness control until the screen is completely black, except for the white dots.

Because it is possible to synchronize the pattern generator to the receiver sweep circuits, rather than the other way around, the video signal can be applied anywhere in the video circuit without loss of sync. This permits signal tracing the video section of receivers and also allows using the generator instead of a station signal for channels 2 through 6. When an intermittent defect appears and some doubt exists as to whether it is in the antenna or in the receiver, use the r.f. signal from the generator to see whether the intermittent is really in the set or not.

To use the signal-tracing method of troubleshooting in the r.f. or i.f. section, just connect the pattern generator, set for horizontal bars, and use a crystal detector with earphones to trace the loud buzz through the various stages. Since the video signal for horizontal bars is about 600 cps, it provides a low-frequency buzzing which can be easily identified through earphones or any signal tracing equipment. The amplitude of the video signal can be controlled by the output control, R_8 in Fig. 3, but the r.f. amplitude has to be adjusted either by the receiver gain control or else by the amount of detuning or the method of coupling. In many instances the author found that it is merely sufficient to bring a clip lead from the generator r.f. terminals near the TV receiver to obtain strong, stable patterns. —30—



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- Fantastic
- Dream World
- G. I. Joe
- Willie the Clown

CHAPTER 6

COLOR CONVERTERS, WHEELS, PROJECTION, AND STUDIOS

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Build Your Own TV Color Converter

Fig. 1. Receiving a color show on a large-size movie screen using the color converter described in this article with a black-and-white set.

Part 1: This color TV converter can be used with three projection units or a three-color picture tube and a second-hand black-and-white chassis.

By **JAY STANLEY**

WHEN black-and-white TV first became a reality, the whole thing was something of a deep, dark mystery to most radio service technicians of the era. But a few brave souls took the plunge, built their own sets, and had the thrill of getting out ahead of most of their competitors and in on the ground floor of a tremendous industry.

Color TV is off to a better start. Many manufacturers are offering courses and a lot of articles have been written about the subject so that the studious can, in a fairly short time, acquire some knowledge of color TV. But, as in all things, there is no substitute for experience with actual equipment on which you have no qualms about experimenting. The cost of present-day color TV sets is high enough to discourage a lot of service technicians (and most consumers) from owning such a receiver.

This article is a practical answer to that problem. Here is step-by-step data for building a color television system. Actually, the original chassis was designed and built by two Denver service engineers; Larry Costa and Paul Dontje.

The unit described in this article is a *color converter* which can simply be hooked onto a conventional (but carefully selected) black-and-white TV set. It can be used to drive a three-unit projection system, or with a bit more circuitry, a three-gun color picture tube.

A look at the block diagram in Fig. 2 and the circuit diagram of the color converter in Fig. 3 will reveal that it is surprisingly simple when compared to many color TV sets. The secret lies in the fact that the set uses a narrow-band system, with .6 megacycle bandpass limiting. This is possible because demodulation is on the *R-Y* and *B-Y* axes instead of the alternative *I* and *Q* axes. The *I* and *Q* system is a wide-band one.

Thanks to the narrow-band system, circuitry is much simpler. Likewise, setup, adjustment, and servicing are also much easier. Don't let the "narrow band" worry you. Color quality is impaired so little that it can only be discerned when a narrow-band and a wide-band set are operated side-by-side—and even then it is difficult to see the difference.

Before covering actual construction of the color chassis, let's trace a signal through this circuit to get an overall idea of how it works. As a starting point, we'll begin with the signal which normally drives the grid of the picture tube in the TV set—a signal which is the composite video output, carrying both the black-and-white and the color information. This signal can be supplied by any really good black-and-white set which has an i.f. bandpass of 4.1 megacycles or more—and maintains this bandpass right through the video amplifier stages. Many of the older TV chassis, built from 1947 to 1949 (split-sound sets), were capable of this bandpass when carefully aligned. The set used here was a *Philco* 1001 chassis, but an *RCA* 630 or an *Admiral* 30A1 (and some others) will work just as well. These are obtainable second hand from many TV dealers.

The composite signal goes to the grid of V_1, the first video amplifier on

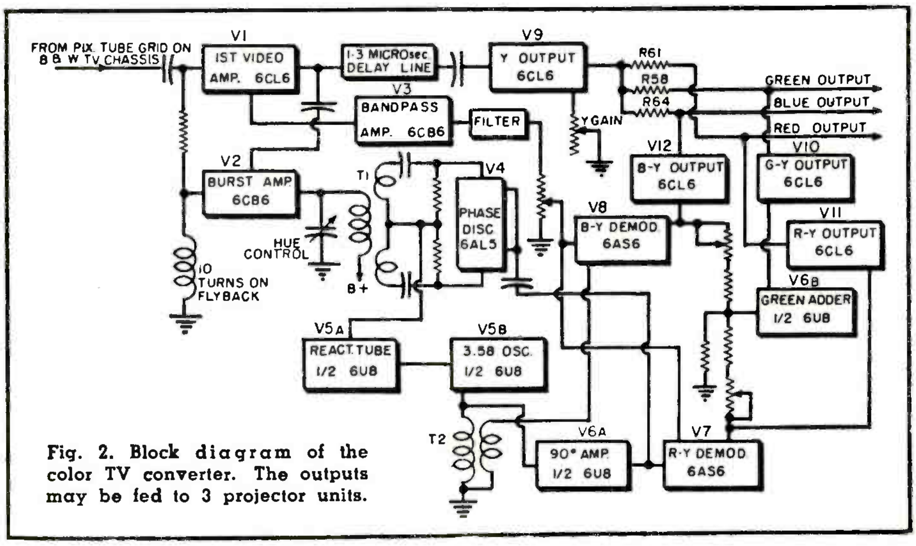
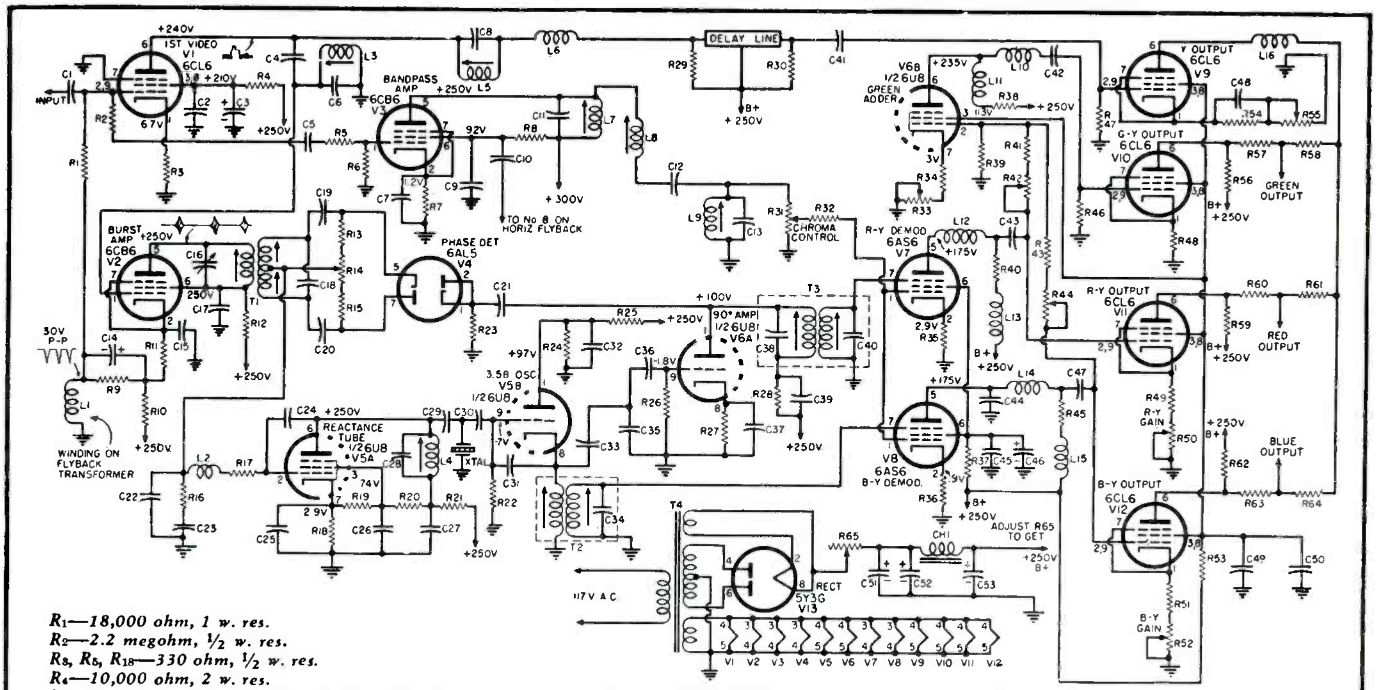


Fig. 2. Block diagram of the color TV converter. The outputs may be fed to 3 projector units.



R_1—18,000 ohm, 1 w. res.
R_2—2.2 megohm, ½ w. res.
R_3, R_5, R_{18}—330 ohm, ½ w. res.
R_4—10,000 ohm, 2 w. res.
R_6, R_{16}, R_{24}, R_{40}, R_{58}, R_{61}, R_{64}—15,000 ohm. ½ w. res.
R_7, R_{27}, R_{32}, R_{34}, R_{35}, R_{36}, R_{49}. R_{51}. R_{64}—100 ohm, ½ w. res.
R_8—82,000 ohm, 1 w. res.
R_9—12,000 ohm, 1 w. res.
R_{10}, R_{13}, R_{15}—220,000 ohm, ½ w. res.
R_{11}—220 ohm, 1 w. res.
R_{12}—2200 ohm, ½ w. res.
R_{14}, R_{42}—100,000 ohm pot
R_{17}, R_{28}, R_{29}, R_{30}—1000 ohm, ½ w. res.
R_{19}—10,000 ohm, 1 w. res.
R_{20}—22,000 ohm, 2 w. res.
R_{21}—2200 ohm, 1 w. res.
R_{22}—150,000 ohm, ½ w. res.
R_{23}—10,000 ohm, ½ w. res.
R_{25}—18,000 ohm, 2 w. res.
R_{26}—100,000 ohm, ½ w. res.
R_{31}—500 ohm pot
R_{33}, R_{50}, R_{52}—2000 ohm pot
R_{37}, R_{53}—10,000 ohm, 5 w. res.
R_{38}, R_{56}—4700 ohm, ½ w. res.
R_{39}—22,000 ohm, ½ w. res.
R_{41}—39,000 ohm, ½ w. res.
R_{43}—33,000 ohm, ½ w. res.
R_{44}—500,000 ohm pot
R_{45}—15,000 ohm, 1 w. res.
R_{46}, R_{47}—1 megohm, ½ w. res.
R_{48}—150 ohm, ½ w. res.
R_{55}—1500 ohm pot
R_{57}—8200 ohm, 1 w. res.
R_{59}, R_{62}—4700 ohm, 1 w. res.
R_{60}, R_{63}—8200 ohm, ½ w. res.
R_{65}—550 ohm, 25 w. adj. res. (Adjust to give 250 v. from power supply "B+" output.)
C_1, C_{41}, C_{42}—.1 µfd., 400 v. cond.
C_2, C_{25}—.01 µfd. button ceramic cond.
C_3, C_{46}, C_{52}—20/20/60 µfd., 350/350/450 v. elec. cond. (Sprague TVL 3725)
C_4—4.7 µµfd. ceramic cond.
C_5—150 µµfd. ceramic cond.
C_6—22 µµfd. silver mica cond.
C_7, C_{15}, C_{17}, C_{26}, C_{27}, C_{32}, C_{37}, C_{39}. C_{45}. C_{48}, C_{49}—.01 µfd. disc ceramic cond.
C_8, C_{44}—47 µµfd. silver mica cond.
C_9—470 µµfd. mica cond.
C_{10}—.001 µfd., 1600 v. paper cond.
C_{11}, C_{13}—250 µµfd. silver mica cond.
C_{12}—14.7 µµfd., made up of two condensers: a 10 µµfd. and a 4.7 µµfd. ± 5% ceramic cond.
C_{14}—2 µfd., 150 v. elec. cond.
C_{16}—3.5 to 20 µµfd. midget-type variable cond (Phase control)
C_{18}—10 µµfd. silver mica cond. (In trans. can)
C_{19}, C_{20}—.01 µfd., 400 v. cond.
C_{21}—10 µµfd. silver mica cond.
C_{22}—.02 µfd. paper cond.
C_{23}—.22 µfd., 400 v. paper cond.
C_{24}—2.2 µµfd. ceramic NPO cond. ±5%
C_{28}—5 µµfd. NPO cond. ±5%
C_{29}, C_{30}—100 µµfd. silver mica cond.
C_{31}—47 µµfd. ceramic NPO cond. ±5%
C_{33}—500 µµfd. silver mica cond. ±10%
C_{34}—27 µµfd. silver mica cond. (In trans. can)
C_{35}—.002 µfd., 600 v. cond.
C_{36}—100 µµfd. silver mica cond. ±10%
C_{38}—100 µµfd. silver mica cond. (In trans. can)
C_{40}—390 µµfd. silver mica cond. (In trans. can)
C_{43}, C_{47}—.1 µfd., 400 v. paper cond.
C_{50}, C_{51}, C_{53}—40/10/80 µfd., 450 v. elec. cond. (Sprague TVL 3792)
Xtal—3579.5 kc. crystal (Peterson PR Z-2)
L_1—See text
L_2—20 µhy. r.f. choke
L_3—90 t. #36 en. closewound on Miller 1470A form (Cromco L-6)
L_4—105 t. #36 en. closewound on Cambridge Thermionic ½ x 2" form (Cromco L-1)
L_5—4.5 mc. trap, 75 t. #36 en. closewound on Miller 1470A form (Cromco L-5)
L_6, L_{16}—120 µhy. peaking coil
L_7—29 t. #30 en. scramblewound 3/16" on ¼" Cambridge Thermionic form (Cromco L-2)
L_8, L_9—78 t. # 36 en. scramblewound 3/16" on Cambridge Thermionic ⅜" x 1" form (Cromco L-3)
L_{10}, L_{12}, L_{14}—1000 µhy. peaking coil (Cromco P-1000)
L_{11}, L_{13}, L_{15}—500 µhy. peaking coil (Cromco P-500)
CH_1—1 hy., 300 ma. filter choke
T_1—90 t. #40 d.s.c universal wound, 5/32" wide (pri.); 60 t., each, universal wound, 5/32" wide (sec.) wound on coil form from Miller 1466 i.f. trans. (Cromco T-1)
T_2—18 t. #30 en. closewound (pri.); 90 t. #36 en. closewound (sec.) wound on form from Miller 1466 i.f. trans. (Cromco T-3)
T_3—60 t. #30 en. closewound (pri.); 26 t. #26 d.c.c. and en. closewound (sec.) wound on form from Miller 1466 i.f. trans. (Cromco T-4)
T_4—Power trans. 370-0-370 v. @ 275 ma.; 6.3 v. @ 7 amps.; 5 v. @ 3 amps. (Stancor P-6315 or equiv.)
Delay Line—See text
V_1, V_9, V_{10}, V_{11}, V_{12}—6CL6 tube
V_2, V_3—6CB6 tube
V_4—6AL5 tube
V_5, V_6—6U8 tube
V_7, V_8—6AS6 tube
V_{13}—5Y3G tube

Fig. 3. Complete schematic diagram and parts list for the TV color converter designed to be used with a black-and-white set.

the color chassis. See Fig. 3. The luminance or *Y* signal is picked up at the plate of the first video amplifier in the color chassis, passes through a 3.58 megacycle trap (L_5-C_8), and is fed to a 1.3 microsecond delay line, which insures that the luminance information and the color signals arrive at the output at the same time. From the delay line, the signal goes to the grid of the *Y* output tube (V_9). From the plate of this tube, the signal goes through the matrix resistors, R_{58}, R_{61}, and R_{64}, where the *Y* signal and the color-minus-*Y* signals are mixed to provide green, red, and blue output.

The color-burst signal is also obtained from the plate of V_1 and is fed to the grid of the burst amplifier, V_2. This tube is keyed on only during retrace, the keying being accomplished by means of a 10-turn coil wound on the flyback transformer in the black-and-white TV set chassis. (See Fig. 4.) By this means, the color burst, which is on the back porch of the horizontal sync pulse, is amplified—but no other 3.58 megacycle signals get through.

The output of the burst amplifier goes to the phase discriminator transformer T_1, the secondary of which is also supplied with a comparison signal from the plate of the 90-degree amplifier, V_{6A}. The output of the phase detector is a d.c. correction voltage which is fed to the reactance tube, V_{5A}; this tube, in turn, controls the frequency and phase of the 3.58-megacycle oscillator, V_{5B}. In this way, the local 3.58 mc. oscillator is locked in exact phase and frequency with the transmitted color burst to supply the synchronous demodulators with the missing color subcarrier, the sidebands of which only are transmitted—the carrier being suppressed at the transmitter.

From the cathode of the 3.58 megacycle oscillator, the signal takes two paths. A signal directly from the cathode goes to the 90-degree amplifier which shifts its phase 90 degrees for proper demodulation in the *R-Y* demodulator. The secondary winding of transformer T_2, however, feeds the

B-Y demodulator directly with no phase shift.

The *B-Y* demodulator and the *R-Y* demodulator receive their color signals from the bandpass amplifier (V_3) and filter, which has a bandpass of 1.2 megacycles (from 2.9 mc. to 4.1 mc.) and passes *only* the color subcarrier sidebands. This automatically drops out the low-frequency *Y* signal.

In the *R-Y* and *B-Y* demodulators, the missing carrier is restored and demodulated to produce the *R-Y* and *B-Y* signals. The *B-Y* signal, taken directly from the plate of V_8, goes to the grid of the *B-Y* output tube, V_{12}. The output of this tube, in combination with some of the *Y* signal, supplies blue.

The *R-Y* signal from the plate of the *R-Y* demodulator goes to the grid of V_{11}, which, in similar fashion to that of the *B-Y* output stage, supplies the red output signal.

The output of the *R-Y* and *B-Y* demodulators is fed to the grid of the green adder, V_{6B}, through a set of resistors. This tube is simply a phase inverter at which the negative signals from the demodulators combine in proper proportion and invert to form the positive *green-Y* signal. This is fed to the *G-Y* output for addition with the luminance signal as described previously for the other two colors.

The outputs terminate in jacks along the end of the chassis, making the three color signals and the *Y* signal readily available for different experimental hookups. Most of the controls are inserted on the rear of the chassis since many of them are setup controls which are left alone once adjusted. Two controls, chroma and phase, are used for minor adjustment during reception, and it is desirable to make them readily available. No "color killer" controls or circuits are needed—simply turning down the chroma control puts the set in shape to receive black-and-white.

In actual construction of the converter, the first step is to round up the needed parts. The careful builder can, by following the data given in the parts list, "roll his own" coils. A real help in doing this is the setup shown in Fig. 5 which provides approximately the same loading as the converter circuits. This allows the coils to be wound with considerable accuracy without actually inserting them in the circuit. The signal generator should preferably be a 3.58-mc. crystal oscillator. A standard d.c. voltmeter will give a clear-cut indication of resonance. This circuit, however, will indicate when the signal generator is tuned to one-quarter or one-half of the resonant frequency, so if a variable frequency oscillator is used, always switch to the next higher band to make certain that you are actually on the fundamental. The physical layout for the windings of T_1 is shown in Fig. 6.

For those who want to buy coils already wound, the designers of the color converter, Costa and Dontje, will supply coils, and their part numbers are given in the parts list under *Cromco*. Write to *Cromco,* in care of P. Dontje at 7020 W. 38th Ave., Wheatridge, Colo.

The color chassis measures 10 x 14 x 3 inches. The layout is purposely crowded in order to keep leads short and point-to-point. No trouble has been experienced from stray capacity, even though some of the signal carrying leads are longer than were desired.

The chassis illustrated in Figs. 7 and 8 has a cut-out for a *Norelco* video amplifier chassis, to allow use with a single-projection unit and a color wheel. The chassis will eventually be used in this fashion although, at present, three *Norelco* projection units are utilized. There are a couple of other extra holes on the chassis for parts which circuit development later proved unnecessary.

In building, all transformers and tube sockets were mounted first, also terminal strips, filter condensers, and controls. Following usual construction practice, heaters were wired in, and then "B+" voltage leads completed. Finally, the r.f. wiring was put in

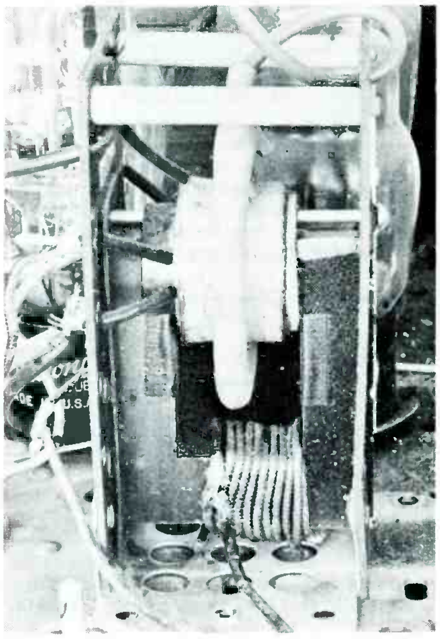


Fig. 4. A ten-turn winding on the flyback transformer keys the burst amplifier on for the proper operation of the 3.58 megacycle color synchronization circuits.

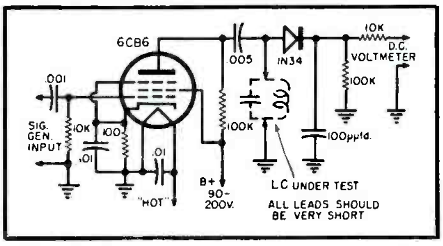


Fig. 5. A test setup which is useful in preparing the coils used in converter.

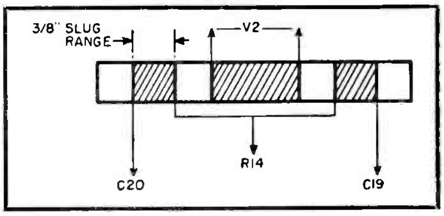


Fig. 6. The physical layout of the phase discriminator transformer windings.

Fig. 7. Top view of the color converter. Note where the crystal is mounted so as to minimize temperature variation effects.

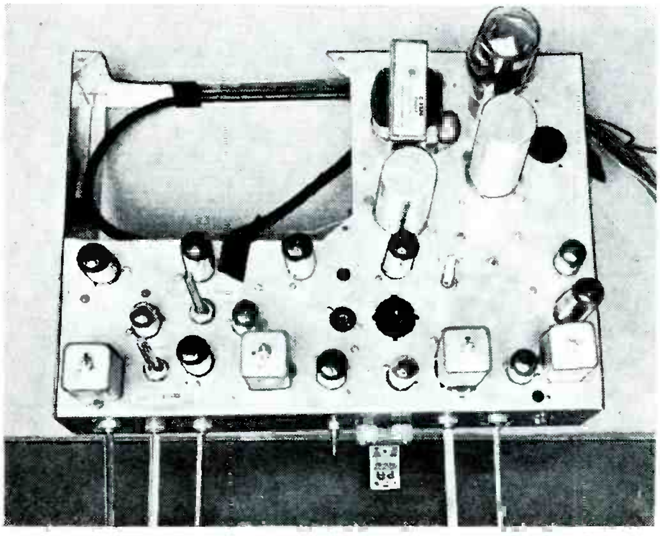
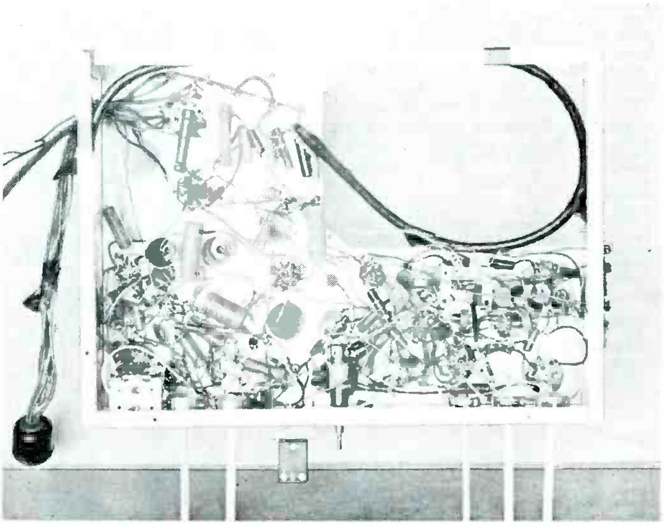


Fig. 8. Bottom view of the converter chassis. The black cable running around the cutout is the delay line in the Y circuit.



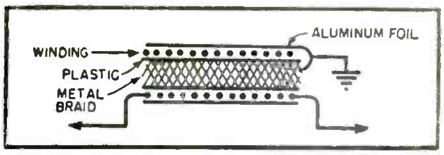


Fig. 9. Details on the construction of the time delay line used in the Y channel. The line is made from a piece of coaxial cable from which the center conductor has been removed and an external winding added.

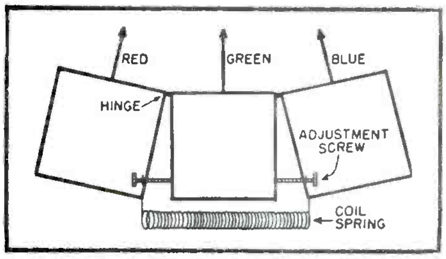


Fig. 10. Three TV projection units can be set up as shown here and used with the converter to give colored TV pictures.

Important: All resistors carrying fairly heavy loads were grouped on terminal strips below the power supply section, as far from tuned circuits as possible, to avoid the possibility of heat causing detuning of circuits. This is a vital matter in a color set because detuning and accompanying shift will cause color contamination.

The crystal is mounted alongside the chassis where it is out in the open and "runs cool"—again to avoid frequency shift.

The heavy black lead which loops around under the chassis is the delay line. Fig. 9 shows how this component is constructed from a 23-inch piece of RG-59/U coaxial cable. As shown, the center wire lead, and its polyethylene sheath, is pulled from the cable, leaving only the metal braid and its plastic cover. These two pieces serve as the foundation of the delay line. First, they are slipped *temporarily* over a metal rod to provide sufficient stiffness for winding. This winding, which should be put on accurately with a lathe, is made of No. 36 enameled wire. It is wound for a length of 22 inches, 128 turns-per-inch. As shown in the drawing, the leads connect to opposite ends of this coil winding. The winding itself is covered with a layer of *very thin* dielectric paper (pulled from old condensers) and this, in turn, is covered with a layer of aluminum foil. The latter is grounded to the inside braid as shown in the drawing, being careful not to short the winding to the grounding foil. Tape completely.

Wiring a set as complicated as this is a job in which even an expert can go astray. One bit of insurance is to tape a piece of vellum (a kind of semi-transparent drawing paper available at any art store or engineering supply house) over the diagram, and then draw in each lead with a colored pencil as it is done. This process is a little tedious—but not as tedious as trouble-shooting for built-in errors. Once the set is wired, the chassis can be given a rough check by comparing pin voltages with those shown in the diagram of Fig. 3.

When the color chassis is completed, the next step is to tie it to the *Norelco* projection units. These are the standard type, readily available from electronic parts jobbers. The hook-up requires three.

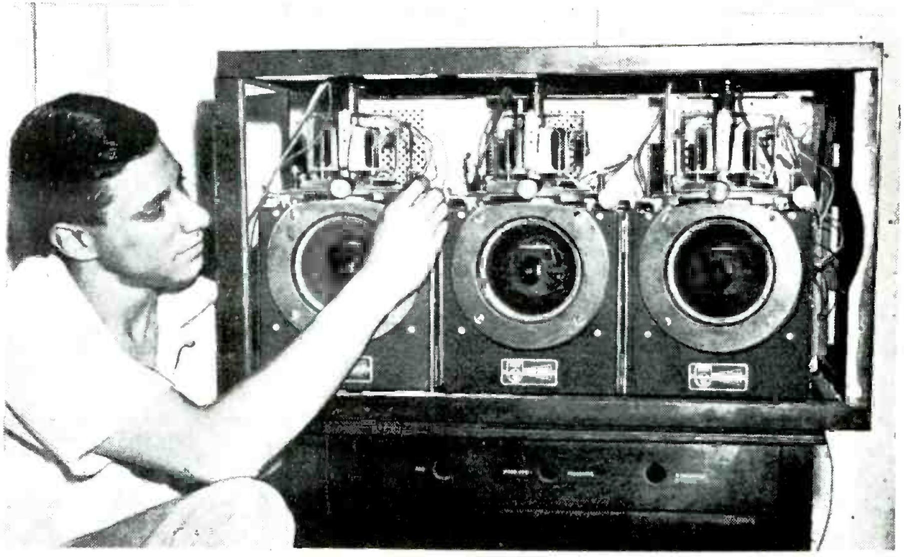
As shown in Figs. 10 and 11, the units are mounted side by side, as close together as possible, with hinges between them. Then the chassis are spring-loaded, as shown in Fig. 10, and adjustment screws provided so that the outer two projection units can be pointed in slightly—so that the images from all three units fall on top of each other on the screen. The fact that the units are some distance from the screen, and that the middle unit (green) carries 59% of the illumination, makes the very slight "keystoning" of the two outer units a theoretical rather than a practical worry.

Each of the units has a colored filter in front of it. (Colored Plexiglas was found to work the best—even better than photo filters.) The vertical and horizontal adjustments on the projection units, plus the mechanical position of the projection housings themselves, are all utilized to get the best possible registration of the projected images.

Both vertical and horizontal sweep voltages for the three projection units are picked up from the black-and-white chassis. The vertical sweep is used to drive the vertical yokes on the *Norelco* units—and the yokes are connected *in series*. The horizontal yokes are driven *in parallel*. Doing this will probably require substituting a different output transformer for that originally in the set. In the receiver described here, an *RCA* 231T1 transformer is used with the proper tap to provide the correct impedance match. The grids of the *Norelco* units are driven by the color output signals from the color converter chassis.

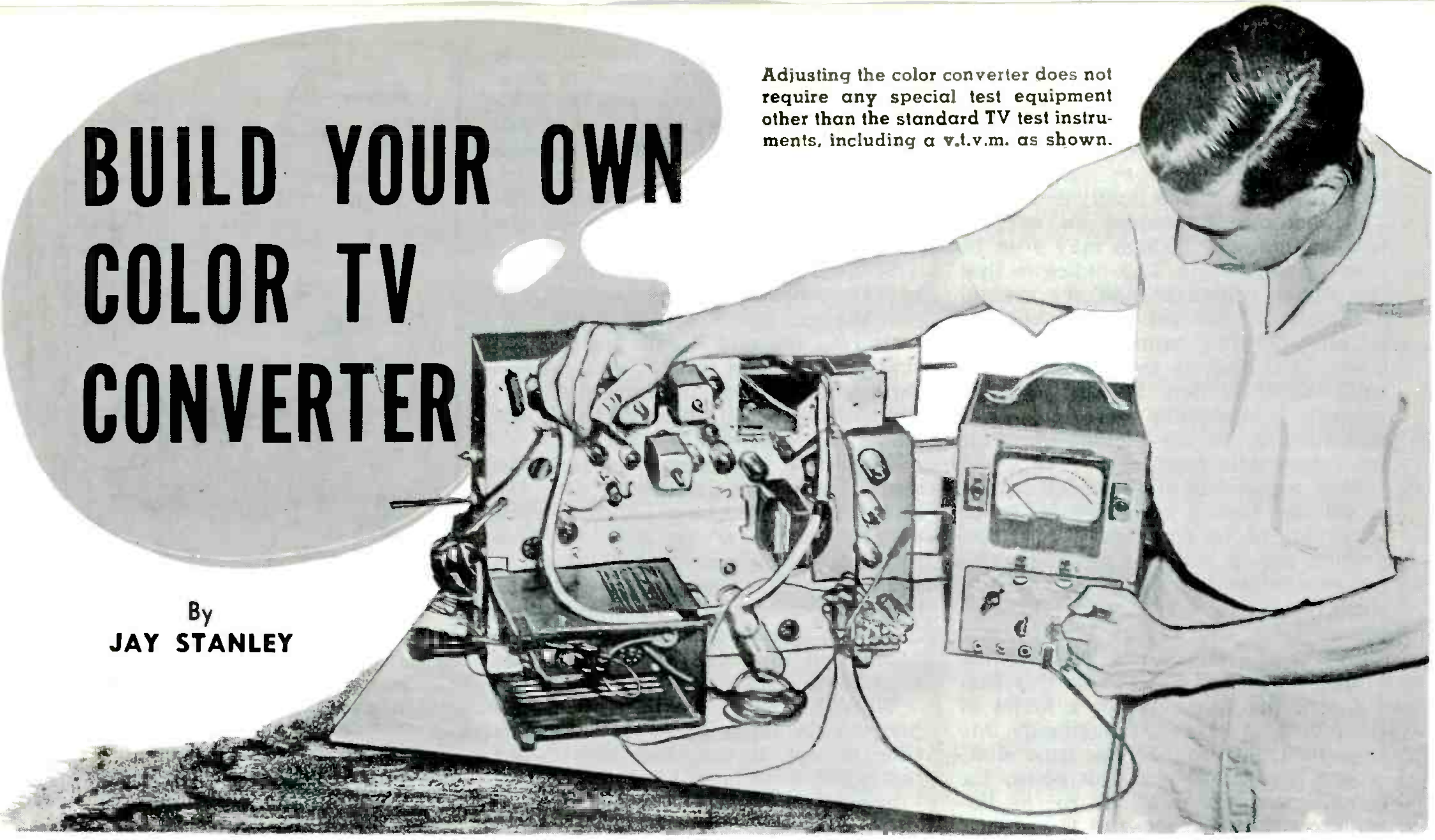
If everything checks out OK, we're ready for the final step—tuning up the chassis.

Fig. 11. Front view of the three projection units set up for use with the color converter described in this article. Color filters made of Plexiglas are mounted directly in front of each projector. Touch-ups are provided for registration.



BUILD YOUR OWN COLOR TV CONVERTER

By
JAY STANLEY



Adjusting the color converter does not require any special test equipment other than the standard TV test instruments, including a v.t.v.m. as shown.

Part 2. Complete step-by-step tune up instructions for the TV color converter described last month, including hints for using a 3-gun tube instead of projectors.

THIS article covers a step-by-step procedure which will enable you to get the color converter described in the preceding article appearing in this book going. Essentially, it is a procedure which will get adjustments so close to the ideal that final, minor adjustments can be made with a color broadcast tuned in.

First, equipment. You'll need a *good* signal generator, one capable of tuning the 3.58 megacycle range with very little drift after the initial warmup. Also needed are a v.t.v.m. fitted with an r.f. probe, a standard service-type scope, and a sweep generator which will sweep from 1 megacycle to 5 megacycles.

To begin with, align the black-and-white TV chassis as close as possible to the ideal i.f. curve shown in Fig. 1A. Be certain to avoid sharp corners on the i.f. response curve (Fig. 1B) which can introduce highly undesirable phase shift.

Next, make certain that the set receives black-and-white pictures through the color tubes. This will enable you to determine that the *Y* channel is working, and will allow you to get brightness, focus, and convergence of the three projection tubes in proper adjustment. Unless the brightness controls, for example, are at something like the proper level, color alignment is virtually impossible.

Now, we're ready to start.

Connect the signal generator (with a 10-$\mu\mu$fd. capacitor in series with the "hot" lead) to the first video amplifier grid in the black-and-white set. Tune in a black-and-white picture, and make certain that the picture is in proper horizontal sync. Then, pull out an i.f. tube to keep any stray signals from reaching the video detector. Set the signal generator as close to 3.58 megacycles as possible, preferably with crystal calibration. When you get it reasonably close to the proper frequency, you should see some indication of color on the raster—in the form of random streaks and shapes.

Now, pull out the 6U8 oscillator and reactance tube on the color converter chassis, and connect the v.t.v.m. with the r.f. probe to pin 5 of the color burst amplifier, V_2, 6CB6, and tune the burst take-off coil, L_8, for maximum. Remove the probe. (Note: All parts numbers refer to Fig. 3 in the December article.)

Next, ground pins 1 and 2 of the 6AL5 phase detector, V_4. Set the v.t.v.m. on the d.c. voltage scale (50-volt scale or higher), connect it to pin 5 of the 6AL5, and tune T_1, the phase discriminator transformer (both slugs), for maximum d.c. voltage. When this is done, remove the ground from the 6AL5 pins 1 and 2.

Replace the 6U8 reactance tube, pull out the burst amplifier, V_2, and connect the voltmeter with probe to pin 7 of the *B-Y* demodulator (V_8, 6AS6). Tune both slugs of the crystal output transformer, T_2, for maximum reading. You will notice that as you tune the primary of this coil (turning the slug clockwise) you will start toward a maximum reading, and then the oscillator will overload and stop oscillating. Back the slug out a few turns from this point, and the oscillator will be stable. The secondary of the crystal output transformer will tune through a normal peak.

Now, connect the v.t.v.m. with probe to pin 7 of the *R-Y* demodulator (V_7, 6AS6) and tune the output transformer of the 90-degree amplifier, T_3, for maximum.

Replace the burst amplifier tube, and once again pull the 6U8 oscillator-reactance tube. Connect the sweep generator (sweeping from 1 mc. to 5 mc.) to the grid of the first video amplifier tube in the black-and-white TV chassis. Turn the chroma control, R_{31}, to minimum, and connect the scope through a demodulator probe to the "hot" end of the chroma control. Tune the band-pass amplifier (V_3) plate coils for the resonance curve shown in Fig. 1C. Markers should be provided by the signal generator, still connected to the grid of the video amplifier in the black-and-white set.

Disconnect the sweep generator, leaving the signal generator attached, and replace the 6U8 oscillator tube. At this point, it is a good idea to recheck for horizontal sync by tuning the black-and-white chassis to a TV broadcast.

For the next step, turn the chroma control full open and the signal generator to maximum output (unmodulated). Carefully tune the signal generator back and forth around 3.5 megacycles, and you will observe a pattern of color bars shifting around on the raster. You will notice that as you approach the crystal oscillator frequency in the converter, this pattern will become a definite series of color bars, lying horizontally. As you get still closer to the exact frequency, you will note that the bars will become fewer and fewer, and finally disappear. The raster will assume an over-all tone of one color, which may even be simply an off-white. This indicates that the signal generator and the crystal oscillator in the set are *locked together*. (If you cannot achieve this effect, that fact is evidence that the color sync section is not working properly.) Carefully note the *exact* dial reading on the signal generator for future reference.

Now comes one of the most critical of all the tuning adjustments, so be very careful to do it exactly as described. *Slowly* tune the signal generator to a *lower* frequency than that of the crystal. "Slowly" cannot be emphasized too much, for there is real danger that you will pass right by the proper frequency. As you do this tuning, you will begin to see a series of color bars which move diagonally into a vertical pattern. If you tune slowly and carefully about this point, the signal generator will lock to the difference frequency between the crystal and the horizontal sweep frequencies.

Note carefully that as you tune below the crystal frequency there are quite a number of these "lock-in" points. Also, that the *lower* the frequency, the greater the number of bars. (The signal generator locks in at even multiples of the horizontal sweep frequency away from the crystal frequency.) Only the *first* lock-in point *below* the crystal frequency is the proper adjustment, and the only one which makes it possible to phase and align the color demodulators.

Keeping the signal generator locked to this point (as mentioned previously, the generator must be stable) the next step is to add the scope. Set the horizontal sweep in the scope to approximately twice horizontal frequency and switch it for external sync. The sync is obtained by clipping a lead to the "hot" deflection yoke wire (*over* the insulation—no direct connection).

Next, establish horizontal sync pulses by holding the lead to the input of the scope's vertical amplifier *close* (again, no connection) to the horizontal output plate lead in the black-and-white TV set chassis. Set the horizontal gain and horizontal centering of the scope to put these "pips" on two of the vertical calibrating marks on the scope face. See Fig. 1D.

Now, clip the input of the scope's vertical amplifier to the blue output. By carefully tuning the phase control, C_{16}, and the secondary slug of transformer T_2, you will be able to position the sine wave as shown in Fig. 1E. Note that the positive peak of the sine wave should fall halfway between the two previously established horizontal sync points (180 degrees) shown in Fig. 1D.

Changing no settings, connect the scope to the red output. Now tune the output of the 90-degree amplifier plate transformer, T_3. *Important,* the positive peak of the red output must fall *exactly* where the blue went through the zero axis, as shown in Fig. 1F. This establishes the all-important 90-degree phase difference between the *R-Y* and *B-Y* signals.

Still changing no scope settings, connect the scope to the green output. Adjust the red, green, and blue add controls (R_{42}, R_{33}, and R_{44}) to position the sine wave so that its zero axis crosses through the point 29 degrees to the right of the point where the blue was maximum positive. (See Fig. 1G.)

Disconnect the scope, leaving the signal generator attached. On the screen you should have bands of color running vertically. You should be able to adjust the phase control to get a pattern which is orange on the far left, blending into red, then blue, and finally green. When you have reached this point, you are ready to try a color broadcast!

With the color signal tuned in, adjust the plate coil, L_4, of the reactance tube to lock in the color signal. At this point, objects will become colored —even though bananas may look blue! Then adjust the phase control, and the color gain controls, for the most natural coloring in the picture. Once the color gain controls are set properly, correct coloring can be obtained by using the phase control only. This is the external color control available in some form on all color TV sets.

The chroma control affects the saturation of color, and is set to the taste of the individual viewer. One caution: if this control is set too high, the picture becomes garish and very grainy.

Just one more thing. The delay line may need some adjustment. This can be done by observing the color picture. If the color information seems to fall to the right-hand side of the black-and-white image, the delay line is too short. However, if you have made it 22" long, the color will probably fall very slightly to the left of the black-and-white image. Trim the line a few turns at a time until the color picture and the black-and-white picture are perfectly superimposed.

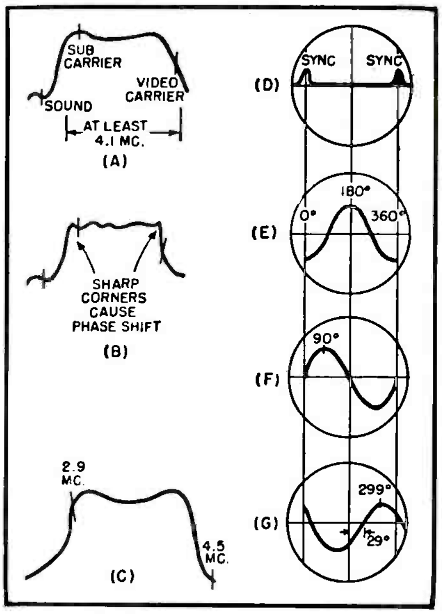


Fig. 1. Oscilloscope waveforms obtained during the various steps of the tune up procedure as described in the text. (B) is an incorrect waveform to be avoided.

3-Gun Tube

Either the 3-unit projection arrangement or a single projection unit with a color wheel provide the simplest way to get going with your color converter. However, if you desire to use a 3-gun tube, the *RCA* tri-color kinescope is available at some parts distributors, and here is the data you'll need.

First of all, because of the unequal phosphor sensitivity of the 3-gun tubes, it is necessary to make a slight change in the *Y* signal adding matrix to supply the unequal video drive required on the three grids. This is shown in

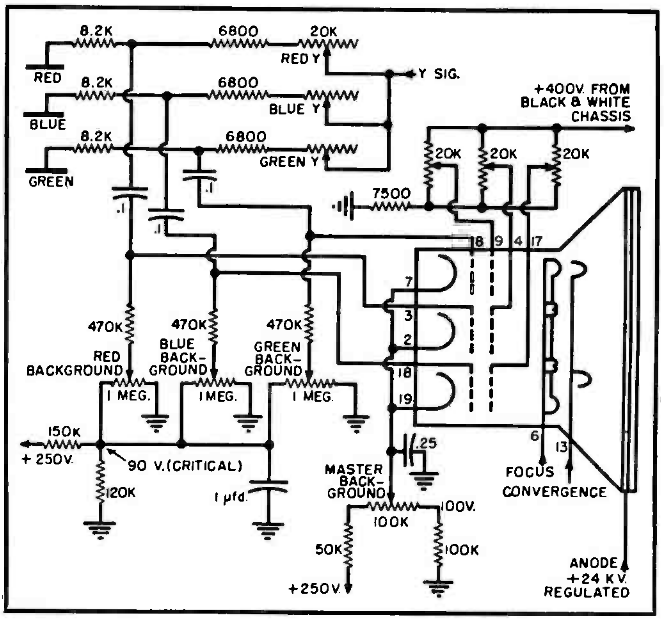


Fig. 2. Additional circuitry that must be included in the converter when it is used with a three-gun color TV tube.

Fig. 2. It is also necessary to add individual background and master background controls, as well as red, blue, and green screen controls, which control the transfer characteristics of the three guns so that a black-and-white picture may be maintained at any brightness setting.

Set-up procedures for the matrixing and background adjustments are adequately described in instruction bulletins available with the 3-gun tube. *Caution:* before attempting to set up the system for a black-and-white picture, it is necessary to pull the two color demodulators from their sockets in order to avoid any confusion until experience is gained with the various adjustments.

The complications from using the 3-gun tube arise from the need for regulated anode, focus, and dynamic convergence voltages. A practical way to build these stages is to use the standard *RCA* circuitry, specifically that given in the service data for the *RCA* Model CT-100 color receiver. The circuits used include (refer to CT-100 diagram) V_{127}, the 6SN7GT horizontal oscillator, V_{126}, the 6CD6 horizontal output (with modifications); V_{121}, the 3A3 high-voltage rectifier; V_{124}, the 1X2B focus rectifier; V_{125}, the 6AU4GT damper; V_{120}, the 6BD4 shunt regulator; and V_{119}, the 12AU7 vertical convergence amplifier.

Of course, if you utilize *RCA* circuits, you must use the standard *RCA* parts, including a tri-color yoke and the matching horizontal flyback transformer. Also needed are a complete set of dynamic convergence components, a purity coil, and the shielding recommended for the tube.

If you are building your system around the black-and-white *Philco* chassis described in the previous article, you will find that the horizontal oscillator has much too long a flyback time to drive the *RCA* transformer properly. It is necessary, then, not only to change the horizontal output stage circuitry, but also, the horizontal oscillator circuit should be modified to conform with the *RCA* circuit. The sync to the horizontal oscillator can still come from the same point in the *Philco* 1001 chassis, however.

When using the *RCA* horizontal output transformer, the keying pulse for the burst amplifier may be taken off terminals "C" and "D." Terminal "E" supplies the horizontal dynamic convergence voltage. Terminal "G" is grounded, as in the original *RCA* circuit. Terminal "F" is left blank, and the rest of the circuitry in the entire dynamic convergence and high-voltage sections should conform with the *RCA* circuit. The 400 volts necessary to drive this set-up may be obtained quite readily from the black-and-white chassis you are using.

The grid circuit for the horizontal output tube (6CD6) is modified in order to eliminate the need for a minus 30 volts. (Refer to CT-100 diagram.) The modification consists of simply changing the grid return resistor, $3R_{268}$, from 47,000 ohms to 470,000 ohms, and grounding the cold end. The cathode resistor, $3R_{263}$, should be changed from 12 ohms to 100 ohms, 2 watt, and bypassed with an 8-μfd., 150-volt capacitor. The screen grid can be supplied from the 250-volt "B+" supply in the converter chassis.

The next requirement will be to obtain the current needed by the purity coil. This can be supplied by paralleling the 20-ohm purity adjustment potentiometer, $2R_{106}$, with the coil, and putting it in series between the output of the choke and the "B+" in the converter chassis.

The vertical convergence voltage can be supplied to the input of the vertical convergence amplifier, V_{119}, without making any changes in the vertical output circuit that you already have in your black-and-white chassis. Again referring to the CT-100 diagram, connect one end of the .47-μfd. capacitor, $1C_{212}$, to the red wire on the existing vertical transformer. The end of the .1-μfd. capacitor $1C_{210}$ (in the vertical amplifier shape circuit of the *RCA*) goes to the plate or blue lead of the existing vertical output transformer. The end of $1C_{211}$, .22-μfd. (also in the vertical amplifier shape circuit), goes to the cathode of the vertical output tube.

The remainder of the connections in the vertical convergence circuits should be hooked up exactly as shown in the *RCA* schematic. The green-and-yellow leads from the existing vertical output transformer should be tied directly to the vertical deflection windings on the deflection yoke. This eliminates any need for vertical centering circuits.

Note: terminal 5 of the flyback is not used.

The "B+" 400 volts from the black-and-white chassis goes to the fuse, $3F_{101}$, which feeds the cathode of the shunt regulator, 6BD4, the plus end of $3C_{221}$, 20-μfd. capacitor, and one end of the horizontal centering control. This gets the "B+" voltage into the rather involved circuit.

Two more things. Once the tube is set up for proper black-and-white reception, the color mixing circuits operate exactly the same as for the 3-unit projection system described previously. Adjustments needed to converge the tube are covered in the technical data now widely available.

—30—

Projection Color TV with a Color Wheel

By **JAY STANLEY**

Fig. 1. The complete projection color TV receiver showing the color converter described in the two previous articles in this book, in the upper compartment and the color wheel and switch in the lower. The complete 6-tube keyer chassis mounts in the cut-out section of the converter.

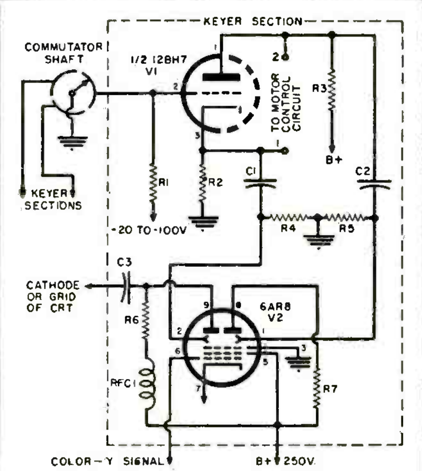
In response to requests from readers — here is how you may use a color wheel and one projection unit with the color TV converter described in the two previous issues.

THE original model of the color converter described in the previous articles in this chapter in this color televisionbook was designed for use with a 3-unit projection system. This is by far the simplest way to get a color set going—but of course it is a somewhat cumbersome way to do the job. For this reason, many readers have asked for data on using one projection unit and obtaining the color with a color wheel.

This article outlines such a system, as shown in Fig. 1. It is *not* intended as a step-by-step construction article but, rather, will present a method that has been developed from experimental work with a color wheel system so that the experienced technician can, in working out his own layout, avoid many of the pitfalls which may otherwise plague him.

In theory, a color-wheel system is quite simple. First, there needs to be a switching system between the red, green, and blue outputs and the picture tube, so that the proper output can be switched to the picture tube at the proper time. This must coincide with the time when that section of the color wheel is in front of the tube. For example, when the color converter is delivering a red signal to the projection tube the red segment of the color wheel should be in front of the tube so that a red image is projected.

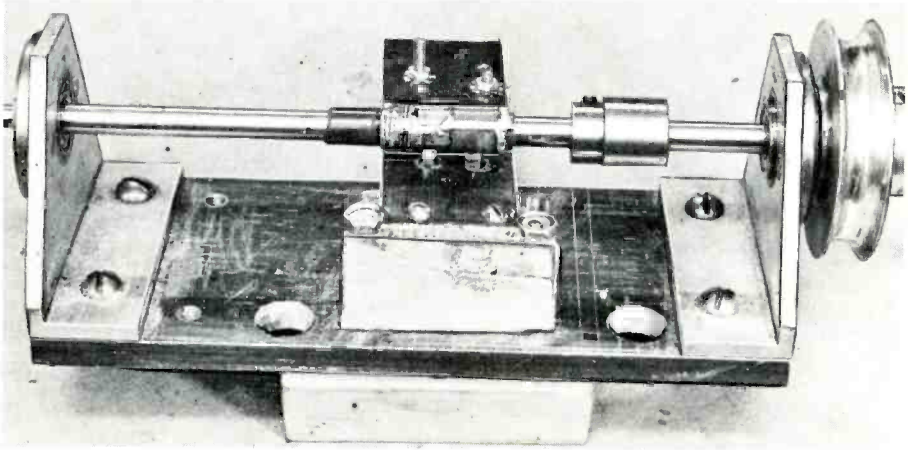
Of course, this switching action can start with a rotary switching device on the shaft of the color wheel, as shown in Fig. 3. But the difficult part of the job comes from the need to sync the color wheel so that it stays exactly in step with the vertical sync frequency of the set. This is necessary to make certain that the "crossover" point (when changing from one color to the other) occurs during retrace, and not



R_1—100,000 ohm, ½ w. res.
R_2, R_3—2700 ohm, 1 w. res.
R_4, R_5—2.2 megohm, ½ w. res.
R_6, R_7—4700 ohm, 1 w. res.
C_1, C_2—.25 μfd. capacitor
C_3—.1 μfd. capacitor
RFC_1—1000 μhy. r.f. choke
V_1—½ 12BH7 tube
V_2—6AR8 tube

← Fig. 2. Schematic diagram and parts list of one of the keyer sections used for selecting the right color signal to go with the color filter in front of the projector. Three keyers are required.

Fig. 3. Commutator-type switch on the shaft of the color wheel used for breaking the color signal into a field sequential one to operate properly with the color wheel. The switch shown here is an example of what may be used, the constructor should use his ingenuity to devise one that is precise and practicable.



during the regular scanning time. If the latter happens, a bar works up and down on the screen, much like a vertical blanking bar.

In an early model of the color-wheel system, it was decided to let the wheel run at random speed, switching the output with commutator contacts on the shaft of the color wheel. But trouble with "crossover" points and noise difficulties led to abandoning the system. However, if the bugs could be worked out, the system would be wonderfully simple in both circuitry and parts.

Subsequent work has been based on the use of a saturable reactor. The vertical sync signal is picked up from the grid of the vertical output stage (or any other convenient point in the vertical system) and applied to a phase detector, driving a d.c. amplifier which, in turn, varies the d.c. potential on a saturable reactor. The reactor controls the speed of the color-wheel motor, with the result that it keeps in sync with the vertical sweep of the TV set, so that the "crossover" occurs during the retrace when it is not visible on the screen.

As shown in Fig. 2, the switching starts with a commutator, the rotary shaft of which is grounded. The "rotating" ground is applied to the grids of three keyer amplifier tubes in turn. Each of the keyer amplifiers feeds the deflector elements of a 6AR8 tube—a wonderful new type developed especially for color work. In effect, this tube is a voltage-controlled single-pole, double-throw switch, and at the same time an amplifier.

Here is how the switching takes place. The commutator segment, as it grounds the grid of the keyer amplifier, removes the bias voltage and allows a pulse of plate current to flow. The output is taken off across R_2 in the cathode circuit and is positive with respect to ground. This positive voltage is used to switch the 6AR8 from one plate, which is idling (no output), to the plate which is driving the CRT cathode.

The color minus *Y* signal is fed to the control grid of each of the three 6AR8's, one for each color. As the commutator rotates, it will switch the output to the live plate of each tube in turn. The net result is a sequential color signal applied to the CRT that is in step with the segments of the color wheel. The commutator cannot be used directly for switching the inputs to the CRT as the noise level from the sliding contacts is prohibitive, and of course, with a 1 megacycle video signal present at this point, it cannot be bypassed. However, the indirect switching method outlined, makes it possible to bypass the commutator segments with a small capacitor (.001 μfd.) and get rid of the high-frequency noise, the only noise present. Even this small capacity will round the edges of the switching signals somewhat, but these are hidden in retrace anyway.

The symmetrical output from one of the keyer amplifier tubes (points 1 and 2 in Fig. 2) is applied to a shaping network to form a narrow pulse which is fed to the phase detector and compared with the vertical saw-tooth present on the grid of the vertical output tube (see Fig. 4). The resulting correction voltage is then applied to a

R_1, R_2—100,000 ohm, ½ w. res.
R_3, R_7—470,000 ohm, ½ w. res.
R_4—1 megohm, ½ w. res.
R_5—10 megohm, ½ w. res.
R_6—68,000 ohm, ½ w. res.
C_1, C_2—.01 μfd. capacitor
C_3—.25 μfd. capacitor
C_4—.002 μfd. capacitor
C_5—.04 μfd. capacitor
C_6—4 μfd., 450 v. elec. capacitor
V_1—6AL5 tube
V_2—12AU7 tube
V_3—6CU6 tube

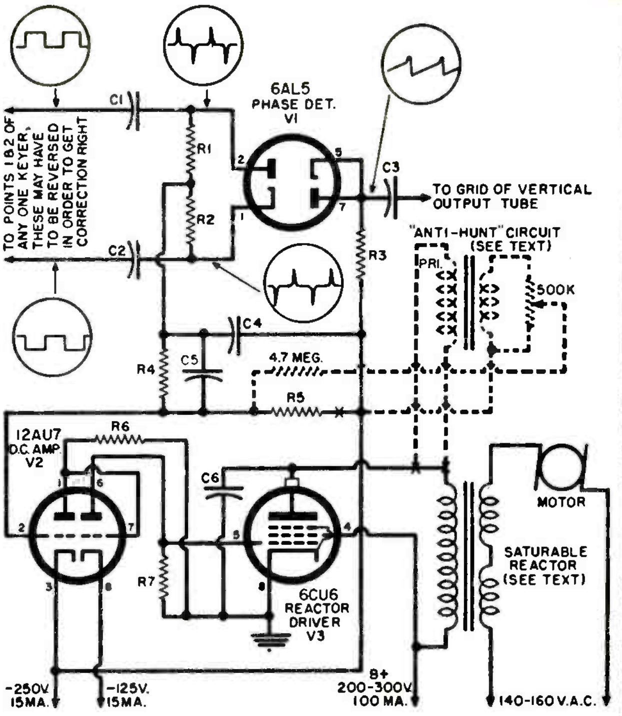


Fig. 4. Schematic diagram and parts list for the color wheel motor speed control circuit. The input is derived from one of the keyer sections, select the one that moves the bar between color wheel filters out of the picture.

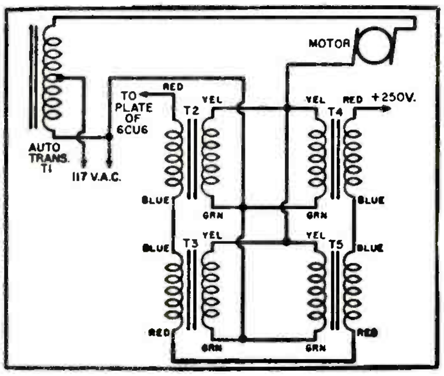
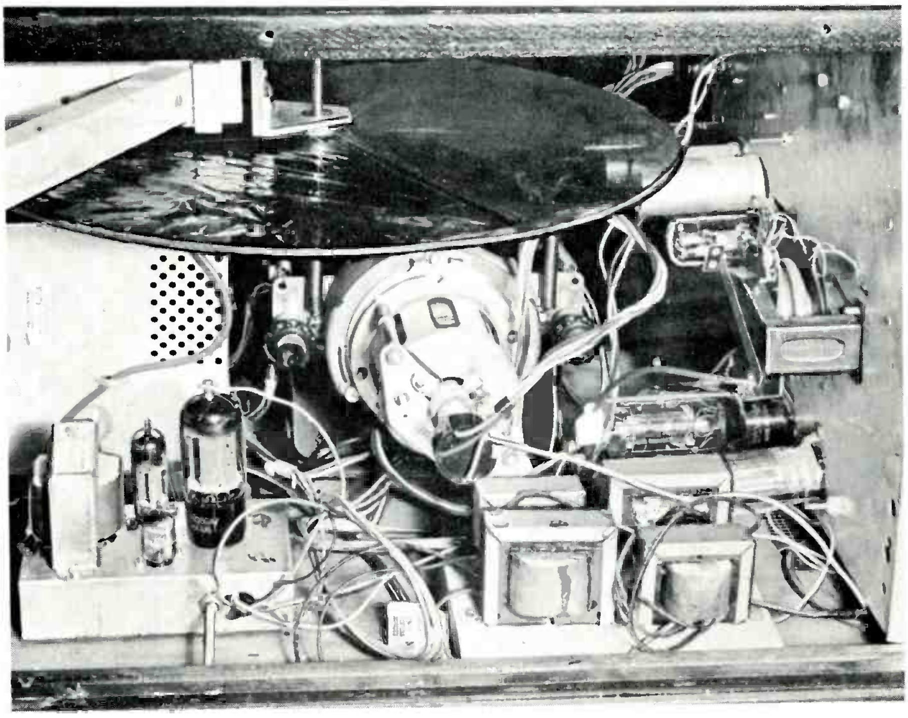


Fig. 5. The four vertical output type transformers are connected as shown here to form a saturable reactor which controls the speed of the color wheel motor in conformity with the signal from the motor control circuit shown in Fig. 4. ➡

Fig. 6. View of the color wheel and associated circuitry. Note the saturable reactor and motor control chassis in the foreground. The regular deflection chassis furnished in the original Norelco projection television receiver is on the right.



d.c. amplifier system that runs negative with respect to ground in order to have a negative-going bias that will vary between zero and minus 25 volts on the grid of the 6BQ6 (or 6CU6), a husky tube type needed to handle the relatively heavy current required for control of a saturable reactor.

A saturable reactor is a device in which one winding will control the inductance of a second winding. The reactor is placed in series with the motor which drives the color wheel. If the d.c. in the primary increases, the inductance of the secondary decreases, allowing more current to flow, and the motor to speed up, and *vice versa*. The motor itself is fed from an autotransformer which steps up the line voltage 25 volts or so, because even with the minimum inductance of the type reactor to be described in this article, there will still be considerable voltage drop. The circuit used for this portion of the converter is shown in Fig. 5.

The saturable reactor shown in Figs. 5 and 6 uses readily-available transformers. Four TV type (six would be even better) vertical output transformers of the kind which have individual primary and secondary windings work very well. The autotransformer types are not satisfactory. It is of the utmost importance that the transformers used be matched, *i.e.*, of the same manufacturer's part number. The reason is that the a.c. which will be induced in the primary winding (the d.c. control winding in this case) in each transformer must be canceled out by its mate. Connect all of the secondaries in parallel and pay close attention to the winding directions to make certain that all are the same. (For example, for RETMA coded units, connect all green leads to green, and yellow to yellow.) The primaries are all connected so that the pairs are series-opposed to a.c., *i.e.*, connect the red lead of transformer T_3 to its mate's (T_5) red lead, and connect the two blue leads to the next pair of transformer's blue leads. After the paralleled secondaries are connected in series with the motor and a.c. is applied, no, or very little a.c. voltage should appear between the ends of the combined primaries.

Caution: If an a.c. voltage of any magnitude *does* appear, recheck connections. The direction of d.c. to the primaries makes no difference as they are merely connected between "B+" and the plate of the 6CU6 control amplifier.

Incidentally, when using the 6AR8's in the color switching system, it is advisable to do away with the individual color amplifiers in the color chassis described in the color converter article starting on page 123 and extending to page 126 in this book, as the gain of the 6AR8's is rather high and makes the amplifier unnecessary. Too much gain may cause instability.

The output from the *Y* amplifier should be disconnected from the matrix resistors and fed directly to the grid of the CRT. The color signals go to the cathodes and are matrixed within the picture tube.

The color wheel itself should have any multiple of 3 sections (6, 9, etc.) However, for projection use in front of the corrector lens, a 3-section wheel about 16" in diameter is best. Such a wheel gives longer useful projection time for each color without overlap of individual colors. The speed of the wheel is easily determined as a single section should cover the lens during one vertical field time, *i.e.,* a three-section wheel should run 1200 rpm, a six-section wheel 600 rpm, etc. These speeds are a close approximation to those actually required because during a color broadcast, the field frequency is not quite 60 cycles. It may be desirable to drive the color wheel by means of a small V-belt drive, preferably fitted with one variable pitch pulley in order to bring the wheel close enough to the proper speed so that the automatic control system takes over.

It may be necessary to try different keyer amplifier outputs for the phase detector so as to get the "crossover" point into retrace. Try first one and then the other, and settle for the one which moves the "crossover" bar out of the visible portion of the raster.

It is strongly urged that fully saturated color filters *not* be used on this projection system. Doing so may reduce brilliancy. Instead, use ordinary-colored red, green, and blue Cellophane. Fasten these filters to a disc of clear plastic. Also, keep the weight of the wheel as low as possible in order to reduce any tendency for the automatic control system to "hunt." This is a difficult problem to correct and the heavier the wheel the more inertia there is to overcome, with the result that the wheel will overshoot the control, then slow down, then undershoot, then repeat the cycle.

Fortunately, there is an electronic circuit that may be used to correct for this defect. The suggested circuit is shown dotted in Fig. 4. The transformer is a vertical output type. It is important, of course, that the secondary be connected so as to give negative feedback. If it should be hooked up incorrectly, the d.c. amplifier will probably motorboat at a very slow rate that may be varied by turning the "anti-hunt" control (500,000 ohm pot). This circuit works on the idea that the rate of change of the correction voltage must agree with all the variables in the system, including weight of wheel, etc. The transformer only has an output when the current to the reactor is changing, and this output is directly proportional to the rate of change. The 500,000 ohm control taps off the amount of voltage necessary to properly control this change rate. In short, "anti-hunt" is time-controlled inverse feedback.

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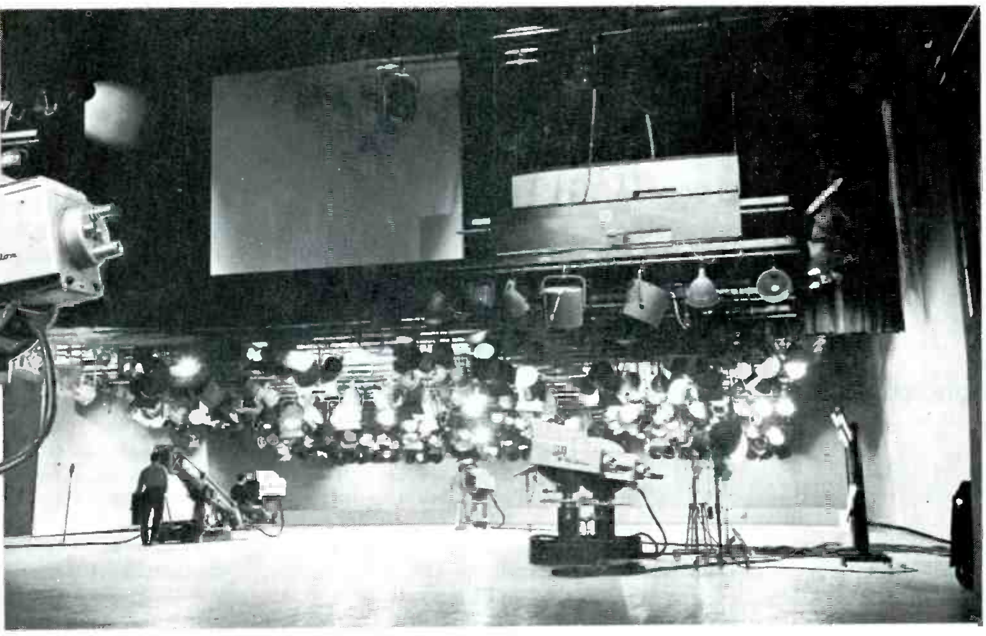
One of the four RCA color cameras in use at NBC's Burbank studio. Each of these color camera chains contains three RCA image orthicon tubes. Each camera has a lens turret which will permit use of four different lenses.



Over-all view of the NBC color studio in Burbank. There are 1260 lighting outlets, located on the lighting pipe battens and in outlet boxes along the walls. About 1000 lighting fixtures, in sizes from 500 watts to 5000 watts, have been incorporated.

NBC's New Burbank Color Studio

THE National Broadcasting Company's $3,716,000 color studio in Burbank, California has a number of unique features which provide special facilities to meet the demand of colorcasting and the production of the network's series of "Color Spectaculars."

A control building, alongside the color studio proper, is a two-story structure containing all of the control functions for the existing studio as well as facilities for future expansion. The video control room contains a video console, black-and-white and color monitors, scopes, a special video equipment rack, and auxiliary camera equipment.

Each video engineer can talk *via* phone to his own cameraman separately or can hook into a conference circuit.

Signals for the cameras go into the switching system. This newly-designed system permits optimum transmission of the color signal and makes possible special video effects as well as providing simpler and surer operation through the use of a preset system.

This preset feature permits the technical director to do all camera switching with one hand. This includes both previewing and program switching. The operation entails presetting the camera or remote signal by pushing the appropriate preset button. This presetting displays the picture on a color monitor. When the director wishes to put this shot on the air, he either pushes the cut bar, which is similar to a typewriter space bar, or he pulls either the dissolve handle or the special effects handle to transfer to that picture by means of a lap dissolve or by special effect. He is now ready to preset another camera and transfer it to an "on-the-air" status by one of the three means available to him.

In the program control room a monitor housing is fastened to the wall in front of the director's console. This housing contains black-and-white monitors connected to each camera's output as well as black-and-white monitors which are patchable to other signal sources within the studio.

The network emphasizes that the most noteworthy features are the provisions for color progress. —30—

Flexible design, which anticipates future developments in colorcasting, makes this new facility a "Television Dream City"

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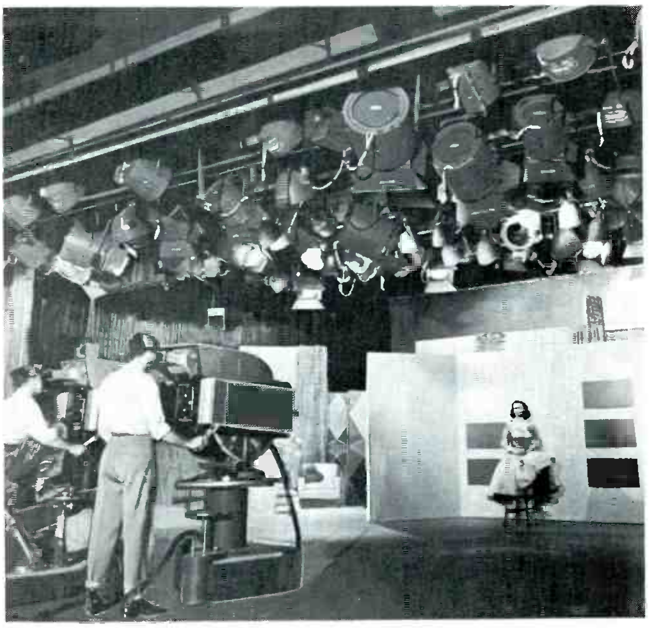
The run-through on a colorcast includes setting up the cameras and presetting the special switching system. Live subjects and various color swatches are used for making needed adjustments.



"VITASCAN"* for Color TV

A flying-spot scanner with phototube pickup simplifies color TV studio equipment.

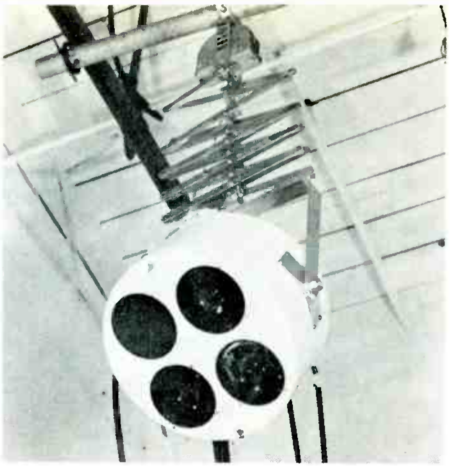


Fig. 1. One of the clusters of photomultiplier tubes used in the "Vitascan" system. Four tubes are employed in each cluster.

COLOR television was given another boost recently with the announcement of the *Du Mont Vitascan* Color Studio Scanner. The *Vitascan* utilizes a beam of light from a cathode-ray tube "flying spot scanner" to scan persons, objects, or action and then picks up the reflected scanned light by means of photomultiplier tubes. These tubes convert the light into an electrical signal which may be passed on to a regular standard color transmitter for broadcast.

Color pictures produced by this equipment are electronically identical with standard color pictures produced by other methods, and result in a standard NTSC color signal. Therefore, any regular color studio or transmitter equipment may be used to broadcast the signal.

The *Vitascan* principle can best be described as a conventional television pickup system in reverse. Here the light source is a flying-spot cathode-ray tube which develops an extremely bright raster—much brighter than that in cathode-ray picture tubes used in television sets. This light source replaces the camera in a conventional pickup system.

Light from the flying-spot tube is directed by means of a mirror and lens system into the studio and onto the scene being televised and focusing is accomplished in much the same manner as with a regular camera. As this light travels over the scene, point-by-point and line-by-line, it is reflected at each instant from the point on which it is shining. This reflected light is picked up by clusters of photomultiplier tubes which are arranged in groups of four throughout the studio.

To separate the light into three primary colors, the photomultiplier tubes are equipped with selective filters which allow only the desired color to pass. In each cluster of four tubes, one is equipped with a green filter, one with a blue filter, and two with red filters. Two are used for red because the light source is deficient in this end of the spectrum and the phototubes are less sensitive to red than to the other colors. The photomultiplier tubes convert the three colors into electrical signals, amplify these signals many thousands of times, and pass them on to conventional color transmitting equipment.

Color registration is no problem with this system, because the scanning operation has already taken place before the light is split up into its three colors.

Since the *Vitascan* system operates by picking up reflected light from the object being scanned, the light source must be rigidly controlled and very little ambient or stray light can be allowed to reach the pickup tubes. Such light would cause "noise" in the picture. Thus, there is no longer any necessity for the heavy lighting load now required in color television studios. Actors and actresses perform in much greater comfort, and the air-conditioning load is reduced tremendously.

However, some studio lighting is necessary, because the light from the flying-spot scanner is insufficient for normal illumination. To solve this lighting problem advantage is taken of the vertical retrace blanking period, when the flying-spot scanner is blanked out. Stroboscopic studio lights are employed, and are synchronized with the system in such a manner that they flash on only during blanking periods and are turned off when scanning is taking place. In this way, over-all studio illumination is achieved without interfering with the scanning process. Intensity of this illumination can be adjusted to any value.

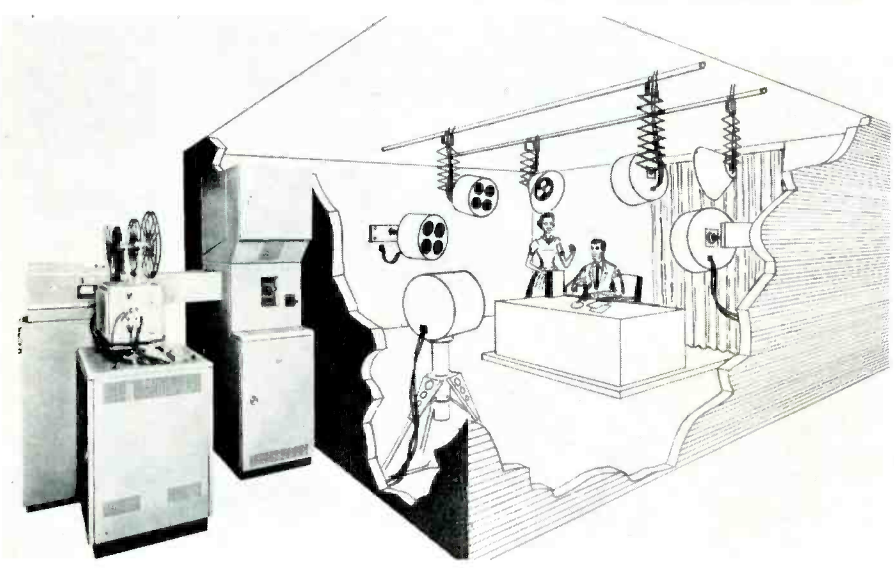
As mentioned before, several groups of photomultiplier tubes are employed in a studio. Each group of four is assembled into a "scoop" or "bucket," as shown in Fig. 1. The outputs of these scoops are fed to a central control panel, where they are mixed in the proper proportions to produce the desired picture.

These scoops perform a function very similar to that of studio lights used with conventional equipment. In other words, most of the various lighting effects can be obtained by proper scoop location and orientation, and by mixing the scoop outputs in the correct proportion.

Vitascan is expected to fulfill the urgent need of TV stations throughout the country for a dependable means of originating their own live color programs and commercials at minimum expense. In addition, it provides an easy, inexpensive method for producing live closed-circuit telecasts in color, such as televising of sales meetings. The equipment may also be used as a monochrome pickup for black-and-white studio programs, thus providing standby facilities for stations having a limited number of cameras.

Du Mont emphasizes that this system is intended to be an invaluable supplement to live color pickup equipment, and should not be compared point-by-point with conventional TV. Each has its own advantages. *Vitascan* uses a controlled light source; therefore, in its present form, it is not intended for use where light cannot be controlled. -30-

Fig. 2. Proposed studio layout employing the "Vitascan" system. A fixed or portable flying-spot scanner may be used, with a number of "scoops" arranged throughout the studio. General illumination is provided by synchronized stroboscopic lights.



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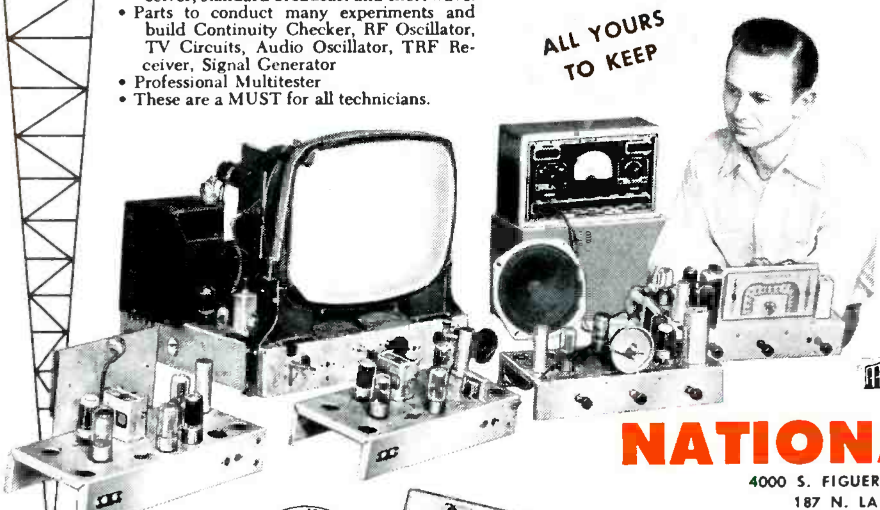

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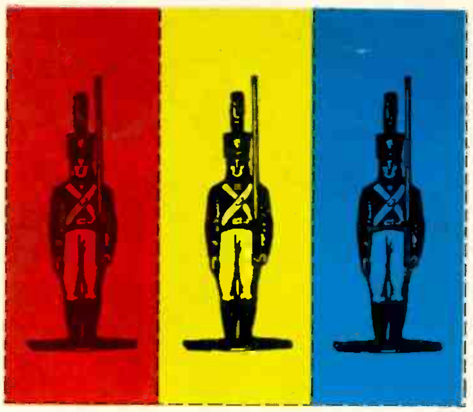

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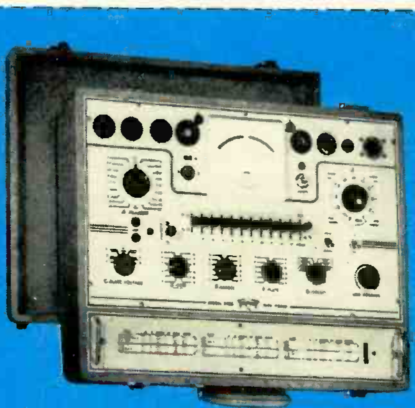

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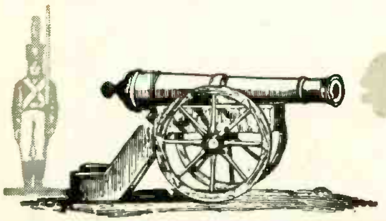

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