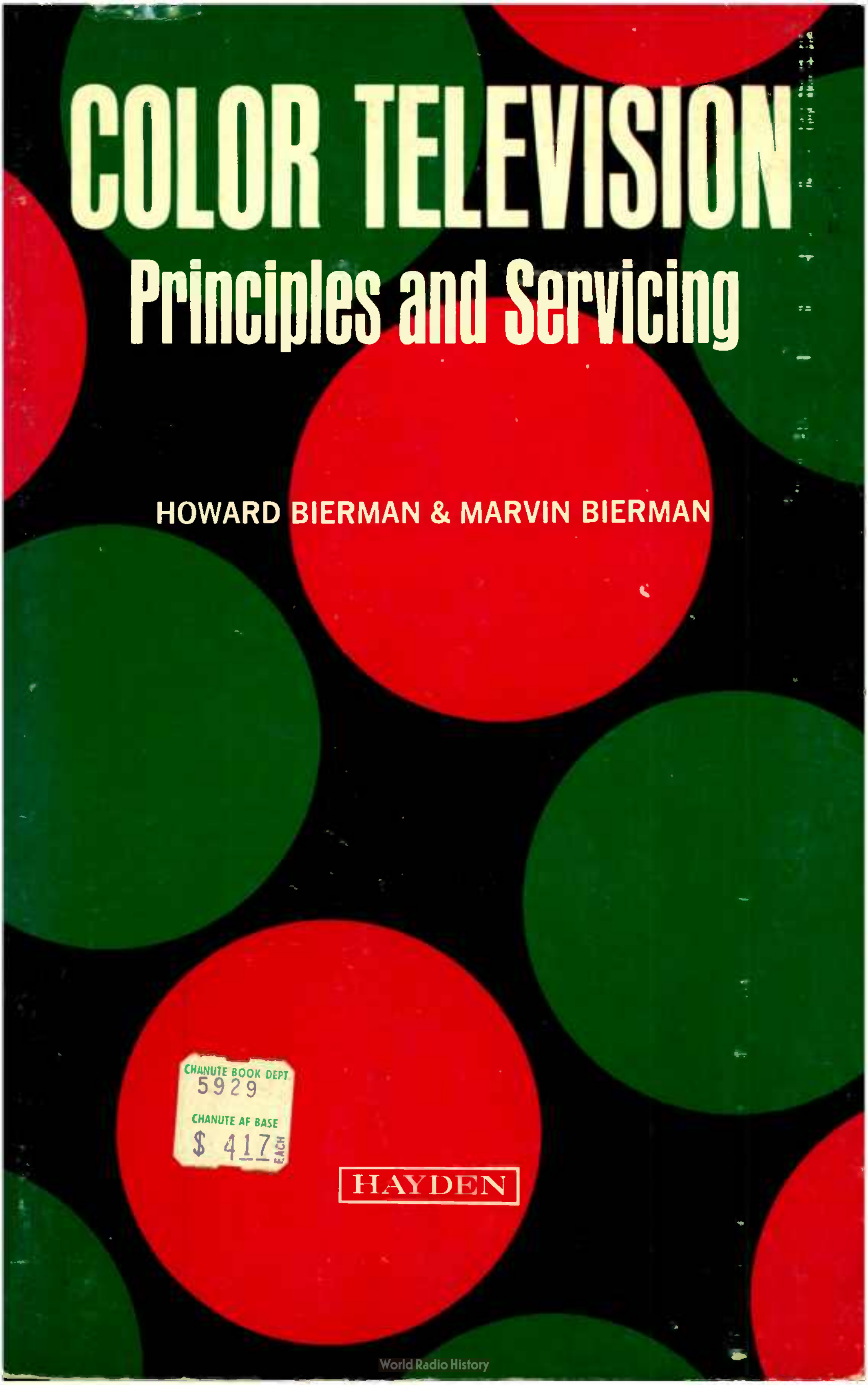

COLOR TELEVISION

Principles and Servicing

HOWARD BIERMAN & MARVIN BIERMAN

HAYDEN

Color Television

principles and servicing

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Preface

Sales of color TV sets continue to flourish as consumers experience added viewing enjoyment of movies, variety shows, and sports in full color. Few potential customers can pass a series of color TV receivers on display in their local department store and not be overwhelmed by the contrast with nearby black-and-white sets. Thus, the temptation to own a color set has always been high; steadily increasing sales are the result.

Price in today's inflationary economy has been, is, and will be the key factor in the decision to buy a color set or get by with an existing black-and-white receiver. Although prices have not been reduced dramatically, they have been level despite improved features such as automatic tuning, high brightness picture tubes, and the use of reliable solid-state devices and integrated circuits. The elimination of multiple knobs on the color set by new "one touch" designs has overcome customers' concerns about their competence to adjust a color set; this factor too has had a share in sales increases.

The exploding growth of color TV sales has created a need for a large number of competent technicians who can analyze color receiver faults, make proper repairs, and perform purity and convergence touchup adjustments when required. Just as radio technicians needed education and training to achieve proficiency in TV servicing, so is a knowledge of colorimetry, color TV circuitry, and specialized test instruments essential to today's TV technician. The sophisticated circuitry and complex picture tube accessory adjustments of a modern color set minimize the opportunity for "tube pullers" or "knob twiddlers" to maintain satisfactory receiver performance or operate a profitable service business.

This book attempts to simplify the complexity by introducing the study of color (colorimetry) and the characteristics of the human eye, relating how these influence the choice and design of the present color TV transmission system. The generation of the color TV signal is traced, as is the concept of phase modulation.

Receiver circuitry is presented by comparing new color TV circuits with similar black-and-white arrangements wherever possible. Tube, transistor, and integrated circuit (IC) configurations are described and illustrated to provide familiarity with the most recent trends in circuit designs.

The structure of the three-gun picture tube, heart of the color TV system, is explained, and the key accessories required to produce quality color reception are detailed. The step-by-step procedures for tube degaussing, purity and convergence adjustments, and gray-scale tracking are included.

Since special color TV test instruments are needed by the service technician, various criteria for selection are discussed. The different types of available color bar/dot generators are noted along with their advantages. Special probes for high voltage and demodulator checks are described, along with degaussing coils, magnifiers, and bias supplies. The vectorscope, a relatively new tool for phase alignment, is explained along with waveform analysis.

Troubleshooting a color TV receiver can be frustrating and time consuming, often fruitless, unless an organized approach is taken. A logical approach is presented, beginning with a technique to isolate black-and-white receiver troubles from strictly chrominance or color problems. From this starting point, various sections of the color receiver can be rapidly identified as faulty or satisfactory. A listing of symptoms with causes and remedies is included in the form of detailed troubleshooting charts. Signal tracing, using a color-bar generator and oscilloscope, is illustrated, along with key scope patterns to be monitored.

Eighteen color photographs are included to illustrate color TV faults; referenced sections in the text explain the troubles and procedures for their correction.

A clear understanding of the color TV system is the basis of knowledge on circuitry and servicing. A clear understanding of color TV circuits and servicing procedures can be the basis of a sound business.

HOWARD BIERMAN and MARVIN BIERMAN

New York, N.Y.

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Color Television

principles and servicing

1

Introduction

SERVICING COLOR TV

When television first appeared on the market over twenty-five years ago, radio technicians were confronted with a "make or break" decision in the servicing industry. An exploding product acceptance of television was responsible for TV sets being purchased as rapidly as manufacturers could deliver them to their retail outlets. As sales of TV sets soared, a pressing demand developed for installation and service technicians capable of doing a professional job to prevent the public from becoming disenchanted with the new electronic miracle.

Despite the occasional bad publicity directed at a few irresponsible and dishonest TV technicians, the total acceptance today of TV as the mainstay of home entertainment is a tribute to the TV service industry. But considerable time and effort in learning new circuits, setup adjustments, and alignment techniques were first demanded from the radio specialist interested in becoming a competent TV technician.

Today's color TV receivers require an equal amount of study on the part of the TV technician who wants to assume the responsibility of color TV service. Although color TV is surely less of a mystery to a TV serviceman familiar with black and white circuits than TV used to be to a radio serviceman, the complexity of many color receiver designs dictates a good basic knowledge of colorimetry, color mixing, and alignment techniques, not to mention new service techniques. Also, he must become familiar

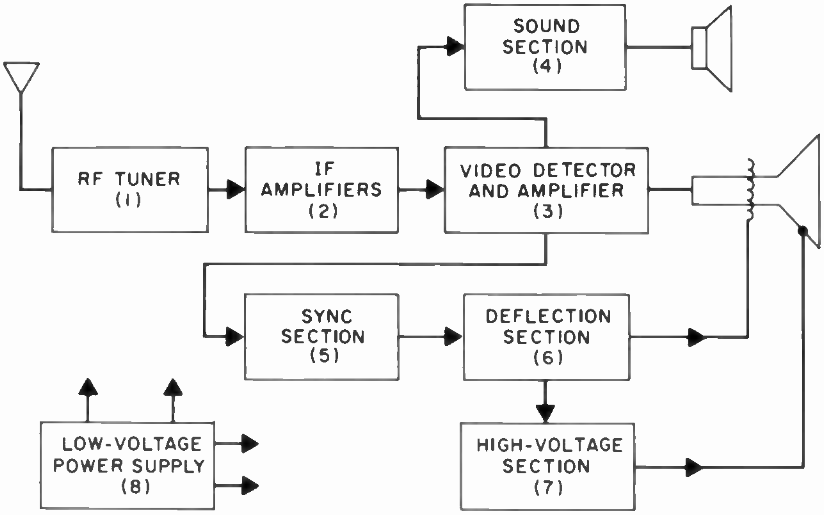

Fig. 1-1 The basic black-and-white TV receiver.

with the use of such specialized color equipment as the color bar generator, dot/crosshatch generator, vectorscope, and other new instruments.

COMPATIBILITY OF COLOR AND BLACK-AND-WHITE TV

Compatibility was a key factor in the decision a quarter of a century ago to proceed with RCA's all-electronic color TV system rather than a CBS approach involving electromechanical scanning. The CBS system had been demonstrated to have color pictures of acceptable quality; the bulky rotating discs on the outside of the prototype receivers had been replaced by moving drums within the cabinet; and styling drawbacks had been overcome. But the CBS system involved transmission of color information and sync pulses that would have made it impossible for existing black-and-white sets to receive the color programs without set modification by technicians. The RCA approach, adopted by the National Television Standards Committee (N.T.S.C.), permitted owners of black-and-white sets to view color telecasts (in black-and-white, of course) without any such modifications.

The system in effect today is fully "compatible," meaning that the following criteria are met:

1. Color receivers deliver quality color pictures from color transmissions.

2. Color receivers deliver satisfactory black-and-white pictures when black-and-white material is transmitted. Color receivers automatically adjust to either color or black-and-white, depending on the material transmitted.

3. Black-and-white receivers produce satisfactory monochrome pictures on their screen without any modification.

BLACK-AND-WHITE TV RECEIVERS

The monochrome receiver has the task of receiving the weak incoming signals containing video, sound, and sync pulse information and amplifying, detecting, and processing to deliver a picture on the kinescope and sound from the speaker.

The basic elements of a monochrome TV receiver (see Fig. 1-1) are the following:

1. RF tuner–The RF amplifier-tuned circuits select the desired channel and reject all others. The weak incoming signals are amplified and, together with the locally generated oscillator, are combined in the mixer stage to produce the video and sound IF signals. The bandwidth of the tuner must be at least 6 MHz wide and relatively flat.

2. IF section–A two- or three-stage IF section provides additional amplification for the video and sound signals. Again bandwidth is rather critical if quality picture detail is to be achieved.

3. Video detector and amplifier section–The video and sound IF signals are demodulated at the video detector, and several volts output is produced. The video amplifier provides the final additional gain to deliver the 50 to 100 volts demanded at the kinescope grid or cathode for sufficient picture contrast.

4. Sound section–The video detector output includes 4.5 MHz intercarrier sound IF which is demodulated and then applied to an audio preamplifier and power output stage.

5. Synchronization (sync) section–Sync pulses are transmitted to keep the scanning action of the electron beam at the receiver kinescope in step with the beam travel at the station camera system. The receiver sync section separates the sync pulses from the video information and then routes the horizontal and vertical pulses to their respective deflection sections.

6. Deflection section–Horizontal and vertical movement of the kinescope electron beam is provided by the sweep or deflection system. A horizontal oscillator, operating at 15,750 Hz and followed by a power amplifier and deflection yoke assembly, moves the beam from left to right and rapidly returns it to the left again. Simultaneously, a 60-Hz vertical

oscillator and amplifier arrangement moves the beam from the top of the screen to the bottom, then rapidly back to the top. A horizontal automatic frequency control (A.F.C.) system is used to maintain steady horizontal sync despite noise bursts or signal variations; since the vertical system is less susceptible to disturbances (because of its much lower operating frequency), it requires no A.F.C.

7. High-voltage section—The sharp, high-aptitude pulses occurring at the horizontal output transformer during each horizontal return from the right to the left side of the screen (retrace) is sufficient to develop 15 to 20 KV high voltage. A high-voltage rectifier and filter capacitor converts the sharp pulses to the proper d-c for application to the kinescope.

A damper tube is used in conjunction with the horizontal deflection and high-voltage sections to reduce horizontal nonlinearity and also to develop a "boosted B+" for the defection amplifiers.

8. Low-voltage power supply—The normal 115-volt a-c from the wall outlet is converted to appropriate d-c and filament voltages by this section. Many portable TV sets today avoid a power transformer so as to minimize cost as well as weight. Several hundred volts d-c is developed by means of half-wave voltage doublers; filament voltages are obtained by means of series-stringing heaters connected to 115 volts. Console models, which are more expensive and usually contain larger screen kinescopes with heavier deflection demands, generally use conventional power transformer design. Fuses or circuit breakers are included in the event of component or tube shorts.

A BASIC COLOR TV SYSTEM

Colors, as well as shades from black to white, can be reproduced on a color kinescope by combining proper amounts of three primary colors (to be discussed in detail in a later chapter). Conversely, any color can be separated into proportional amounts of three primary colors.

The principles of a color TV system are shown in Fig. 1-2. Three cameras are used, one equipped with a red filter, another with a green filter, and the third with a blue filter. Only light of its particular primary color can pass to each camera. Effectively then, the blue camera responds only to objects with blue content, its camera output being proportional to the brightness of the blue areas. Similarly, the red and green camera outputs depend on the red and green picture content. For example, when scanning a yellow flower, there would be output from the red and green cameras while the blue camera delivered no output since yellow is produced by combining red and green.

If three existing TV channels were allocated for such a system, one channel could carry the red video information, the second the blue, and

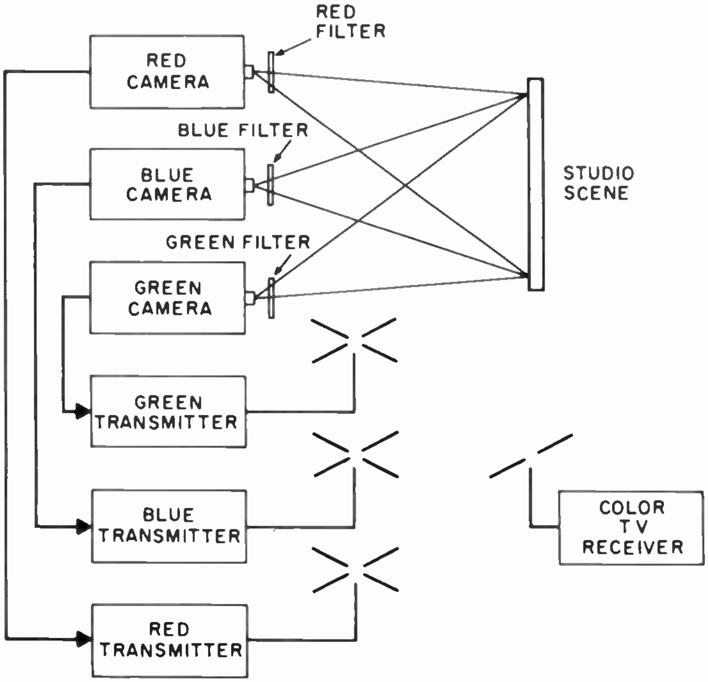

Fig. 1-2 A basic color TV system.

the third the green. A specially-designed wideband receiver could accept and amplify the signals and recover the separate red, blue, and green video intelligence and produce three pictures on three kinescopes, each equipped with a color filter. The three color images, each with its own primary color picture, could then be superimposed by mirrors and lenses to deliver a color TV picture. Among the obvious objections to such a simple system are the following:

1. Excessive bandwidth requirements.
2. Lack of compatibility—Existing black-and-white receivers would not be able to produce a satisfactory picture from such a color transmission scheme.
3. High costs—Transmitting and receiving equipment for wideband operation (12 MHz for this system) would be prohibitive.

THE BASIC COLOR TV RECEIVER

A number of additional sections must be added to the basic black-and-white block diagram to illustrate a color receiver. In addition to new

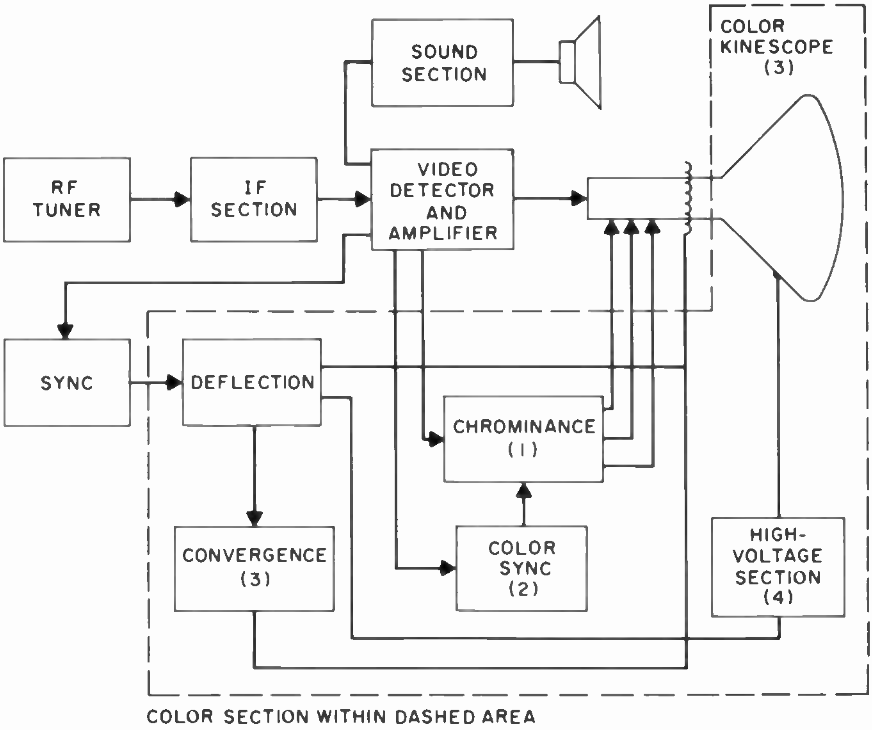

Fig. 1-3 The basic color TV receiver.

sections, RF and IF bandwidth responses are more critical and deflection/high-voltage demands are greater. The major sections of a color receiver are shown in Fig. 1-3.

Chrominance section The chrominance information, in the form of amplitude- and phase-modulated signals, are routed from the video section to a bandpass amplifier. Here the chrominance is separated from the video and amplified prior to application to two phase-sensitive demodulators. One phase demodulator is fed the input chrominance sidebands and one 3.58-MHz reference oscillator signal at a particular phase; the other demodulator is fed the identical input chrominance and a 3.58-MHz signal with a second phase relative to the first. The resultant outputs are color-difference signals which are combined with the video (or luminance) signal at the kinescope to produce proper drive to the red, blue, and green guns of the kinescope.

Color sync section Demodulation of the transmitted chrominance signal involves phase comparison. The station transmits a "burst" signal, a short interval series of 3.58-MHz sine waves, which convey the reference signal used at the transmitter modulator. The color sync section has the task of turning this first input into a constant-amplitude, continuous-wave 3.58-MHz signal that stays in specific phase and frequency lock with the 3.58-MHz reference oscillator at the station.

The color sync section includes a burst amplifier, which separates the "burst" signal from the composite video, and a crystal-controlled 3.58-MHz oscillator. The inputs of both these stages are compared for phase and frequency in a phase-detector circuit. Any variation produces a d-c output which is fed to the grid of a reactance tube in a manner that corrects any difference between the two. The net result is a continuous 3.58-MHz sine-wave output for application to the two demodulator stages.

Color kinescope and convergence assembly The color TV receiver provides three video color signals for application to three separate guns in a shadow-mask picture tube. The color kinescope includes a screen containing over one million phosphor dots, precisely arranged in groups. One third of the phosphor dots emit red light when bombarded by electrons; the intensity of the red light is determined by the number of electrons, which is a function of the red color signal. The second group of dots throughout the screen emit blue light and the third group, green light. The eye resolves the total effect of the individual color dots and creates a color picture for the viewer. Three separate pictures, in the three primary colors (red, blue, and green) are displayed on the color kinescope. To accurately register the three images, beam landing at the kinescope screen is adjusted and maintained by convergence circuits and controls.

High voltage Color sets operate with kinescope anode potentials of 25 KV or higher to provide adequate color saturation and brightness. Because of the three guns and the need to overcome electron losses at the shadow-mask plate in front of the phosphor-dot screen, the high-voltage supply must provide 1 ma compared to only 100 μamps in a black-and-white set. High-voltage regulation becomes necessary to prevent scene brightness changes under this high current demand. Thus, a high-voltage regulator tube must be added to avoid changes in picture size and convergence (registration of the three-color pictures) as brightness varies.

Review Questions

1. What does "compatibility" mean?
2. List the major sections of a black-and-white TV receiver.
3. List the major sections of a color TV receiver.
4. What is the frequency of the color-reference oscillator?
5. Why is high-voltage regulation necessary in a color TV receiver?

2

Colorimetry

NATURE OF LIGHT

While most hi-fi hobbyists are familiar with the concept that pure tones are depicted as sine waves, they usually do not realize that light waves are effectively very high-frequency sinusoidal signals. Those light waves that are seen by the human eye vary in frequency from 385 x 10^6 MHz, at the violet end of the visible band, to 790 x 10^6 MHz, at the red end. Just outside the visible band are ultraviolet and infra-red waves. Very often these sine waves are defined in terms of wavelength rather than frequency, and the relationship between the two is:

$$\text{Wavelength} = 300{,}000{,}000 \text{ meters}/f$$

where f is in cycles per second (Hz).

The frequency, and therefore the wavelength, of each color is different, and the eye is able to translate each different frequency into its unique color. Because the response of one person's eyes may differ from another's, two people can see the same frequency as different colors. This normal variation is why color TV receivers are equipped with a "tint" or "hue" control, allowing the viewer to adjust for an acceptable color (normally skin or flesh tone). It would not be unlikely to find among a group of people watching a color TV presentation that some would agree that the skin colors were a proper shade while others would argue that there was too much green or too much red. The distribution of various

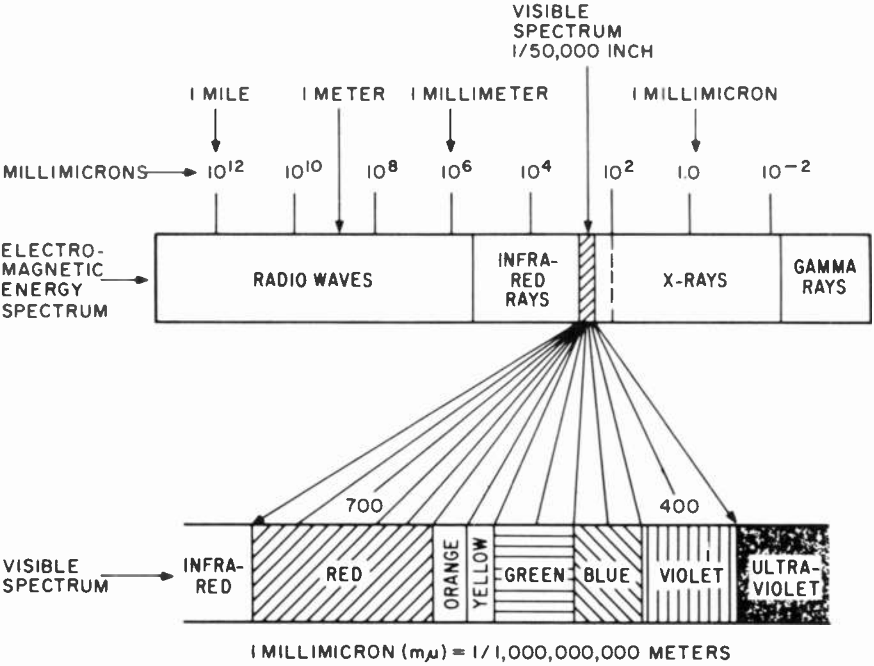

Fig. 2-1 Distribution of electromagnetic energy with an expanded view of the visible portion of the spectrum.

radiant waves in the frequency spectrum is shown in Fig. 2-1. The frequency of radio waves is low enough to allow their wavelengths to be expressed in meters or millimeters. Light waves are so high in frequency that their wavelengths must be expressed in millionths of a millimeter; in order to facilitate the description of the wavelengths in the light-wave region, the term "mu" (millimicron) is used ("mu" is the Greek letter μ). A millimicron is 1/1,000,000,000 of a meter. Translating to the English system from the metric, a wavelength of 500 millimicrons is the same as 1/50,000 inch.

FACTORS INFLUENCING "COLOR"

All readers are familiar with the problem of matching a "red" thread to a "red" garment. Invariably, the store clerk will display cherry, maroon, raspberry, pink, and a host of other variations of "red" thread spools. The end result is that the buyer usually has to bring the garment to the store for the desired match.

From the preceeding discussion we can recognize that a more scientific approach is available. Since each "color" has its own unique wavelength, labeling the garment with its wavelength, say 650 mu, and each thread spool with its wavelength would allow the buyer to select the spool marked "650 mu," assuring him of a perfect match. Wavelength, however, is not the only factor which defines a color. Relative "brightness" and "saturation" also contribute to characterizing it.

"Brightness" is easily illustrated by considering the appearance of an automobile tail light at night. The red lens around the bulb permits only the color "red" to be seen by the driver behind. If the car battery is weak, the "red" will be dim, and if the battery is fully charged, the "red" will be bright. The wavelengths of both "reds" are the same since the red lens is unchanged, yet the colors appear different because of the difference in brightness.

"Saturation" is a measure of the vividness of a color. Most readers will recall experiments in which sunlight is passed through a prism, generating a rainbow pattern. Such experiments show that white light is composed of, and can be broken down into, equal amounts of energy at all visible wavelengths. Conversely, the combination (or "addition") of equal amounts of energy at all visible wavelengths will create white. The saturation concept is easily explained by visualizing a flashlight beam, with a red lens over the bulb, projected on a piece of paper. The color would be red, with the same wavelength as the lens filter and a brightness level related to the power consumed in the bulb. If a second flashlight beam, this one covered with a clear lens, is superimposed on the first beam, the resultant color would be pink (see Fig. 2-2). The wavelength has not changed since

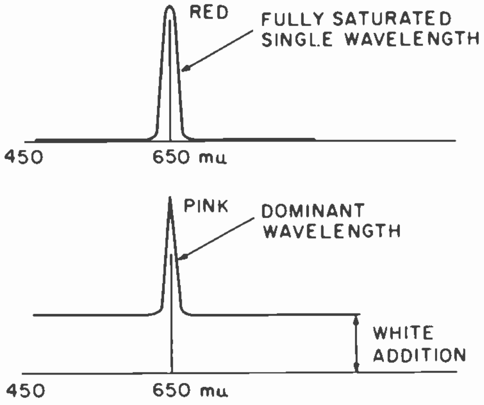

Fig. 2-2 The addition of white to a vivid red desaturates the latter to pink.

the original lens is the only one used, yet the color has changed. (Note that the brightness also increases because of the additional energy contributed by the second light source.)

Color must therefore be defined in terms of wavelength, brightness, and saturation for a full description. White is not considered a color, since it has no dominant wavelength and is considered "desaturated." Its only characteristic, being "colorless," is brightness. In relative terms, it might be described by a layman as "white" when bright, "grey" or "dark grey" if less bright, and "black" with no brightness. A more technical term to describe "colorless" is "monochrome."

Full or 100-percent saturation means that only one wavelength is seen by the eye. The addition of white to this single wavelength introduces all other wavelengths and makes the original wavelength merely dominant rather than singular. The higher the ratio of white to the dominant wavelength, the lower the saturation level. In layman terms, the addition of white makes the color less vivid. The technical term is "desaturated." For example, vivid red is a saturated color whereas pink, formed by adding white to the vivid red, is desaturated, or pastel.

RESPONSE OF THE EYE

The preceeding discussion of brightness was correct as stated but must be modified by the brightness response of the eye. Returning to the example of the flashlight with a clear lens, a viewer will note a significant decrease in brightness when a red or green lens is placed over the bulb. The electrical power to the bulb is obviously unchanged, yet the loss of brightness is evident. This result is due to the fact that the eye has a frequency response curve similar to that of a tuned circuit in a receiver (except for the frequencies involved), namely, unequal responses to all frequencies (colors). As shown in Color Plate 1, yellows and greens are brighter to the eye than reds and blues; this difference means that for the same amount of radiated energy, a green object will appear brighter than a red one.

DEFINING THE TERM "COLOR"

The three factors which fully define a color are wavelength, brightness, and saturation. (The common term "hue" is used in color TV rather than wavelength.) The essentials to remember are as follows:

1. "Monochrome" (white, grey, black) has no dominant wavelength and 0-percent saturation.
2. "Vivid" colors are 100-percent saturated (only one wavelength).
3. "Soft" or "pastel" colors are desaturated (less than 100-percent

saturated) by the addition of all other wavelengths (white) to the dominant wavelength.

4. "Brightness" is both a function of the light energy transmitted from the object and the relative response of the eye to that wavelength.

ADDITIVE AND SUBTRACTIVE PROCESSES

Two fundamental processes are used to produce colors, one in which the eye is directly presented with a combination of several colors that the eye resolves into the final color, and the other in which one or more colors are extracted from white (or another color) before being transmitted to the eye. The first is called the *additive process,* and the second is called the *subtractive process.* In both cases, specific colors are selected as "primary" colors for developing all other colors; however, the primaries for the additive process are not the same as those chosen for the subtractive process.

As shown in the example of the additive process (Fig. 2-3), red and green beams of equal intensity are partially superimposed over each other. Where the colors overlap, the eye sees the color yellow. When a third color, blue, is added as shown in Fig. 2-4, the area in which all three are combined appears white; where green and blue combine appears cyan; and where red and blue combine appears magenta. If unequal amounts of the three original colors, which are the primaries in the additive system, are combined, the center will *not* be white, nor will the other results be as described above. Rather, the resultant colors will display the predominance of the stronger color. Thus by combining either two or three of the primary colors, and by varying the relative proportions of the primaries used, other colors can be generated from the primaries. The additive system is used in color TV and is explained in further detail in later chapters.

The subtractive system, although not used for color TV presentation, is discussed here for comparison with the additive system. The pro-

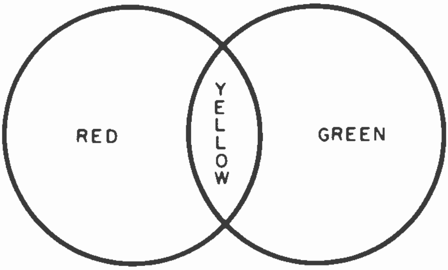

Fig. 2-3 When equal amounts of red and green are combined in the additive process, yellow is produced.

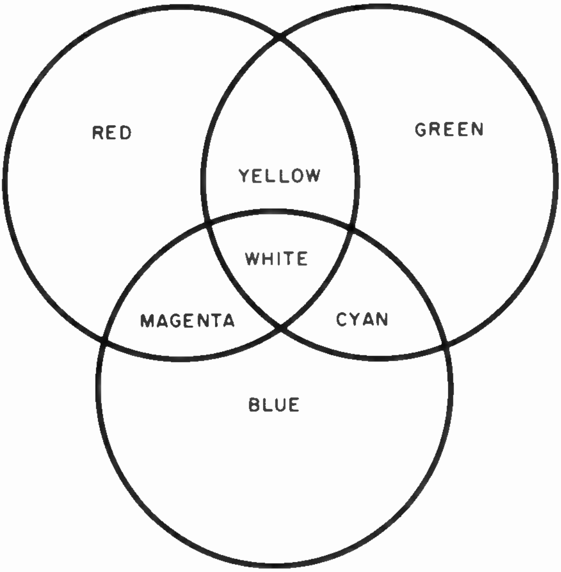

Fig. 2-4 Adding blue to yellow (red, plus green) in equal amounts produces white.

cess relies on the principle of absorption of all but one hue and reflection or passage of that one hue to the eye. As shown in Fig. 2-5, a white light is passed through a green filter. The filter absorbs all but the green hue and allows the green to be transmitted to the eye. If red and blue are passed through the green filter (Fig. 2-6), no light will reach the eye because the filter will absorb the red and blue inputs. Printed material uses the same general principle in that a page of green lettering against a white back-

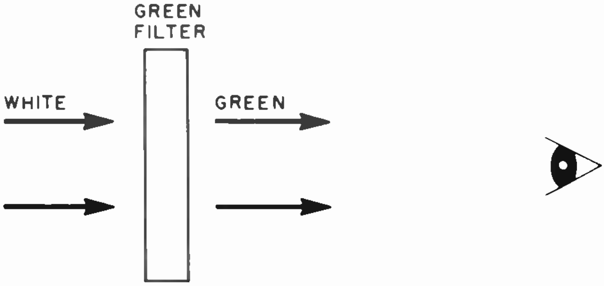

Fig. 2-5 When white light is passed through a green filter, only green is transmitted to the viewer.

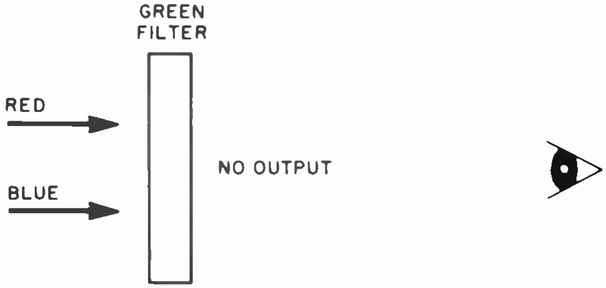

Fig. 2-6 When magenta, a combination of red and blue, is passed through a green filter, no output will appear.

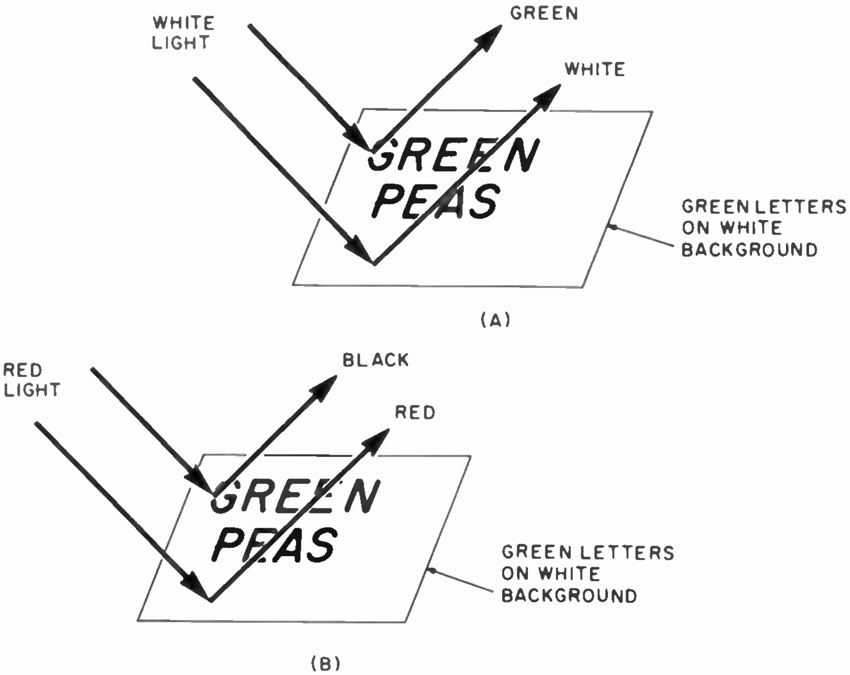

Fig. 2-7 In the subtractive process, white light projected on a white sheet with green lettering (a) would display green lettering on a white background. When a red light source is substituted for the white source (b), the viewer would see black letters on a red background.

ground, as shown in Fig. 2-7(a) would look as just described when white light is imposed on the page. The green ink would absorb all but the green, reflecting green to the eye; the white background would absorb no hues and reflect white back to the eye. Now, if a red light was used as a source, as shown in Fig. 2-7(b), the green lettering would absorb the red and the lettering would appear black. The background would reflect back the red source, and the viewer would believe that he was seeing black lettering on a red paper. Another example which shows how the subtractive process is dependent on the light source is the familiar experience of garments appearing one color inside a store (under tungsten or fluorescent lamps) and a different color when outside in sunlight.

CHARACTERISTICS OF THE EYE

A preceding discussion disclosed that the eye responds differently, in terms of relative brightness, to different colors. Another characteristic of vision, which is used to advantage in TV transmission and reception, is its persistence. The viewing image is composed of two frames, each taking 1/60 second, one scanning the even lines (2, 4, 6, etc.) and the other the odd lines (1, 3, 5, etc.); the eye resolves these two images into one without a flicker.

Two other characteristics of the eye which are important for color TV are the eye's inability to see small areas in true color and its resolution of various interference patterns.

While conducting early viewing tests on color TV receivers, it was noted that the eye sees large areas (over 3/8-inch square on a 21-inch screen) in true color. As the image area is decreased, the eye will resolve the color, depending on its actual hue, as either orange or cyan (bluish-green). When the area reaches 1/8-inch square and smaller, the eye loses its ability to resolve the hue at all and the image is seen as white or grey, in other words, in terms of brightness only. How these factors are used in selecting circuit bandwidths will be covered in a later chapter.

Regarding pattern discrimination, TV horizontal scan lines can be seen spaced apart when viewed closely; as the eye moves away from the screen, it becomes more and more difficult for the eye to detect the individual lines and soon the lines blend into one continuous image. The eye finds it even more difficult to individually resolve adjacent lines that are diagonal rather than vertical or horizontal. This important characteristic of the eye is used to advantage in selecting color signal frequencies and will be covered in a later chapter. For the moment, the reader can appreciate that interference patterns, if they must exist, would be less noticeable if they were in the form of diagonal lines rather than vertical lines.

REQUIREMENTS OF COLOR TV SYSTEM TO MEET EYE'S DEMANDS

As seen from the preceding discussions, the characteristics of the human eye are significant factors to be considered when developing a color TV system. Recalling black-and-white TV theory, image area is related to signal frequency, that is, large images are represented by low video frequencies and small images (fine detail) are represented by high video frequencies.

To summarize, the eye is essentially color-blind when viewing fine detail, sees medium detail as either orange or cyan regardless of their true color, and sees large areas in their true colors. More specifically, the *color* of fine detail (1/8-inch square or less area on a 21-inch screen) is not transmitted at all; the *color* of medium detail (over 1/8-inch up to 3/8-inch square) is transmitted as either orange or cyan; the *color* of large areas (over 3/8-inch square) is transmitted fully. Note that the word color is italicized to emphasize that while fine-detail *color* is not transmitted, fine-detail black-and-white *is* transmitted.

Relating the above definitions of size to frequencies, fine detail refers to signals of 1.5 MHz and higher, medium detail to signals from 0.5 MHz up to 1.5 MHz, and large areas to signals below 0.5 MHz.

To clarify the discussion of medium detail, past statements that either orange or cyan are transmitted rather than true color does not mean that the transmission is arbitrary. Rather it is related to the true color, and as will be shown later, true colors such as red and yellow are transmitted as orange, and true colors of green and blue are transmitted as cyan.

Review Questions

1. What color is generally used as a reference by the home viewer to adjust the "tint" or "hue" control?
2. In terms of a meter, how large is a "millimicron"?
3. What is the abbreviation for the term "millimicron"?
4. Name the three factors that define a color.
5. What factor is a measure of the vividness of a color?
6. Define the expression, "desaturated color."
7. What colors appear to have the highest brightness to the eye?
8. Is the "subtractive" or "additive" process used as the basis for color mixing in the color TV system?

9. What color is formed by combining red and green?; red and blue?; blue and green?
10. What is meant by "persistence of vision"?
11. Describe what happens to "color" as image size becomes smaller and smaller.

3

The Color TV System

Two fundamental problems required solution before a color system would be approved by the FCC; the first was that the color information had to be transmitted within the same 6-MHz frequency band allocated for monochrome transmission, and the second was that the transmitted color signal had to present an adequate monochrome picture on existing black-and-white receivers without the use of special, costly auxiliary equipment.

CHANNEL ALLOCATION

Prior to the advent of color TV, each TV channel was (and still is) allocated a bandwidth of 6 MHz, with the lowest VHF frequency channel (channel 2) operating from 54 to 60 MHz and the highest VHF frequency channel (channel 13) operating from 210 to 216 MHz (see Fig. 3-1). The frequencies from 88 to 174 MHz are assigned to other services, so that a frequency gap exists between channel 6 and channel 7. UHF channels 14 through 83 operate from 470 to 890 MHz with the same 6-MHz bandwidth.

The 6-MHz bandwidth allocation has the picture carrier located 1.25 MHz above the low end of the channel and the sound carrier located 4.5 MHz from the picture carrier, or 5.75 MHz from the low end of the channel. The picture carrier is amplitude-modulated by the video information, and at 100-percent modulation the amplitude of the video sidebands is 50 percent that of the carrier; at lower-percentage modulation, the relative amplitude of the sidebands will be correspondingly lower. Video signals up to 0.75 MHz have both their upper- and lower-sidebands modulated equally; video signals above 0.75 MHz have their lower sidebands attenuated, as shown in the Fig. 3-1, in order to minimize interference with the lower adjacent channel. Compensation for this attenuation is made at the receiver.

The sound carrier is frequency-modulated, with the maximum frequency excursion from the sound carrier being 25 KHz; therefore the bandwidth for the sound portion of the channel is 50 KHz.

The importance of these requirements is that the standard TV channel could not be altered to accommodate color information; rather, some method of transmitting the additional color data had to be found in the existing 6-MHz band. Referring back to Chapter 2, we know that color signals up to 0.5 MHz are required to create true colors, and that color signals from 0.5 MHz to 1.5 MHz are needed to create the orange or cyan for medium-sized areas. How these color signals are injected into the existing 6-MHz band will be covered in Chapter 4.

COMPATIBILITY

A prime requirement for color TV system approval was that it be "compatible" with existing monochrome, or black-and-white, transmission and reception. Basically this meant that transmission of color-TV program

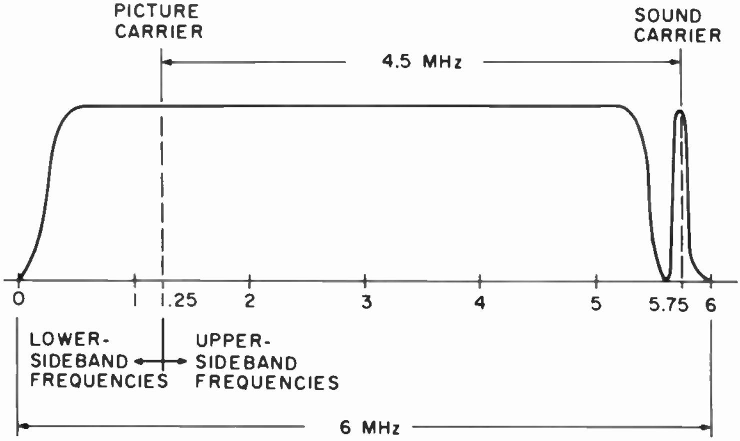

Fig. 3-1 Each TV channel occupies a 6-MHz bandwidth, with picture and sound carriers separated by 4.5-MHz.

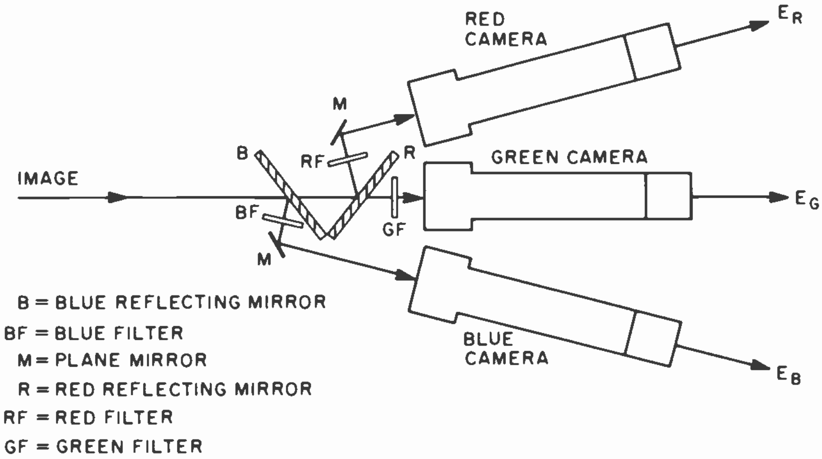

Fig. 3-2 In this basic 3-color TV system, filters and mirrors separate the scene into three primary color signals.

material would be received on existing monochrome receivers without the addition of supplementary equipment in the home and without loss of picture quality. Likewise, color-TV receivers had to be able to receive monochrome transmission and present an acceptable black-and-white picture on their screen (termed reverse compatibility) without auxiliary equipment on the color receiver.

BASIC THREE-CAMERA SYSTEM

A basic three-camera color system is shown in Fig. 3-2. By means of filters and mirrors, each camera receives a signal corresponding to its assigned color (E_R for red, E_G for green, E_B for blue). For example, if the optic system is viewing an American flag, all cameras will have an image for the white areas of the flag since the red, green, and blue filters will all allow white to pass through. The red camera will have, in addition, an image corresponding to the red stripes since the red filter will allow the red to pass through onto the camera face; the green and blue camera will not have an image corresponding to the red stripes since the green and blue filters will absorb the red rather than pass it through. Correspondingly, the blue camera image will have the blue background of the stars, while the red and green cameras will not. Summarizing, the image on the red camera will contain the red and white stripes plus the stars, the blue camera will have the white stripes and stars, plus the blue background, and the green camera only the white stripes and stars. The camera tubes generate electrical signals at the areas on which light impinges, with output amplitudes a function of the image brightness.

THE LUMINANCE SIGNAL

Neither the E_R, E_G, nor E_B signals alone are adequate in terms of content for a black-and-white receiver, so a means must be devised to develop a brightness signal for monochrome receivers. In addition, this brightness signal is used in the color receiver for depicting fine detail; referring back to Chapter 2, color information is not transmitted for fine detail; therefore brightness is the only signal used to display such detail. The brightness signal, called the luminance signal and identified as E_Y is developed from the color camera outputs in accordance with the equation,

$$E_Y = 0.30\ E_R + 0.59\ E_G + 0.11\ E_B \tag{3-1}$$

If E_R, E_G, and E_B are adjusted to equal each other ($E_R = E_G = E_B = E$) when the cameras are focused on a white object, Eq. 3-1 becomes

$$E_Y = 0.30\ E + 0.59\ E + 0.11\ E = 1.0\ E \tag{3-2}$$

Thus, the luminance (or brightness) of white is unity. As can be seen from Eq. 3-1, the relative brightness of any color will be less than 1.0. Comparison of Eq. 3-1 with Color Plate I, which shows the brightness response of the eye, reveals that the coefficients for the equation were obtained from the brightness response curve of the eye to various colors.

COLOR BAR CHART

The response curve of the eye in Color Plate I reveals that the eye gives the brain the impression that a green object (525 mu) has twice the brightness of a red object (626 mu), although the real brightnesses, as measured by a photoelectric cell, are the same. This data is used for developing the luminance signal by means of a matrix circuit at the transmitter which conforms to Eq. 3-1. To show how the E_Y signals are mathematically derived, we will first compute E_Y for the primary colors.

For *red,* where $E_R = 1.0$ and $E_G = E_B = 0$,

$$E_Y = 0.30\,(1.0) + 0.59\,(0) + 0.11\,(0) = 0.30$$

For *green,* where $E_G = 1.0$ and $E_R = E_B = 0$,

$$E_Y = 0.30\,(0) + 0.59\,(1.0) + 0.11\,(0) = 0.59$$

For *blue,* where $E_B = 1.0$ and $E_R = E_G = 0$,

$$E_Y = 0.30\,(0) + 0.59\,(0) + 0.11\,(1.0) = 0.11$$

Thus, to the human eye, green has almost twice the brightness of red, and almost six times the brightness of blue.

For nonprimary, vivid (saturated) colors, the same formula and method of computation are used; here are some examples:

For *yellow* (red plus green), where $E_R = E_G = 1.0$ and $E_B = 0$,

$$E_Y = 0.30\,(1.0) + 0.59\,(1.0) + 0.11\,(1.0) = 0.89$$

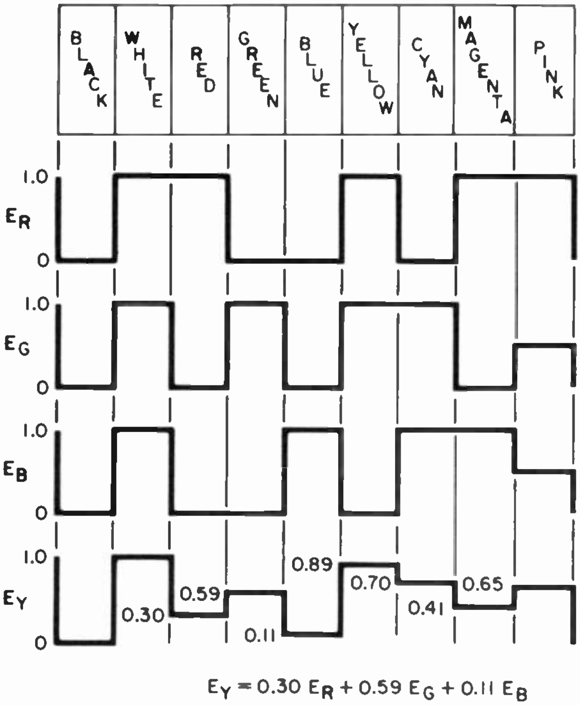

Fig. 3-3 Color bar chart illustrates how E_R, E_B, E_G, and E_Y are developed for various saturated colors and for a desaturated color (pink).

For *cyan* (blue plus green), where $E_G = E_B = 1.0$ and $E_R = 0$,

$$E_Y = 0.30\,(0) + 0.59\,(1.0) + 0.11\,(1.0) = 0.70$$

For *magenta* (red plus blue), where $E_R = E_B = 1.0$ and $E_G = 0$

$$E_Y = 0.30\,(1.0) + 0.59\,(0) + 0.11\,(1.0) = 0.41$$

For desaturated colors where white has been added to dilute the color, we again use the same formula but account for the amount of white added. Pink is made up of red plus white; the values of E_R, E_G, and E_B and the method of computing E_Y are as follows:

For *pink* (50-percent desaturated red), where $E_R = 1.0$, $E_G = 0.5$, and $E_B = 0.5$,

$$E_Y = 0.30\,(1.0) + 0.59\,(0.5) + 0.11\,(0.5) = 0.65$$

If we added more white, for a desaturation of 70 percent, the values would change as follows:

For *pink* (70-percent desaturated red), where $E_R = 1.0$, $E_G = 0.70$, and $E_B = 0.70$,

$$E_Y = 0.30\,(1.0) + 0.59\,(0.7) + 0.11\,(0.7) = 0.79$$

Note that as white is added to red, the luminance (E_Y) value goes up. This is to be expected since adding white will increase the relative brightness to the eye. Figure 3-3 shows how the E_Y signal is derived from the E_G, E_B, and E_R signals.

COLOR DIFFERENCE SIGNALS

So far we have seen that four video signals must be transmitted; the three color signals (E_R, E_G, and E_B) plus the luminance signal (E_Y) that is used for monochrome receivers and the fine detail of color receivers. The number of signals can be reduced to three, which greatly simplifies color transmission, by the use of color-difference signals. Color-difference signals, as the name implies, are composed of the difference between the color signal and the E_Y signal. The ($E_R - E_Y$) signal is calculated as follows:

Since $E_Y = 0.30\,E_R + 0.59\,E_G + 0.11\,E_B$ (from Eq. 3-1),

$$E_R - E_Y = 1.0\,E_R - (0.30\,E_R + 0.59\,E_G + 0.11\,E_B) \qquad (3\text{-}3)$$

$$= 0.70\,E_R + 0.59\,E_G + 0.11\,E_B \qquad (3\text{-}4)$$

By the same technique, calculations show that

$$E_G - E_Y = 0.41\,E_G - 0.30\,E_R - 0.11\,E_H \qquad (3\text{-}5)$$

$$E_B - E_Y = 0.89\,E_B - 0.30\,E_R - 0.59\,E_G \qquad (3\text{-}6)$$

To illustrate how we can reduce the needed signals from four to three, assume that we transmit ($E_R - E_Y$) and ($E_B - E_Y$). The signal ($E_G - E_Y$) can be obtained in the receiver if ($E_R - E_Y$) and ($E_B - E_Y$) are known from the equation,

$$(E_G - E_Y) = -0.51\,(E_R - E_Y) - 0.19\,(E_B - E_Y) \qquad (3\text{-}7)$$

Mathematically, the proof is as follows. From Eq. 3-1,

$$E_Y = 0.30\,E_R + 0.59\,E_G + 0.11\,E_B$$

Readjusting the E_Y term,

$$0.59\,E_Y + 0.30\,E_Y + 0.11\,E_Y = 0.30\,E_R + 0.59\,E_G + 0.11\,E_B \qquad (3\text{-}8)$$

Rearranging terms,

$$0.59\,E_Y - 0.59\,E_G = 0.30\,E_R - 0.30\,E_Y + 0.11\,E_B - 0.11\,E_Y \qquad (3\text{-}9)$$

Multiplying both sides by -1 and rearranging again,

$$0.59\,(E_G - E_Y) = -0.30\,(E_R - E_Y) - 0.11\,(E_B - E_Y) \qquad (3\text{-}10)$$

Dividing both sides by 0.59,

$$(E_G - E_Y) = -\frac{0.30}{0.59}\,(E_R - E_Y) - \frac{0.11}{0.59}\,(E_B - E_Y) \qquad (3\text{-}11)$$

$$(E_G - E_Y) = -0.51\,(E_R - E_Y) - 0.19\,(E_B - E_Y) \qquad (3\text{-}12)$$

Note that $(E_R - E_Y)$ can be obtained by taking the E_Y signal, inverting it, and adding it to E_R. The value of $-0.51\,(E_R - E_Y)$ can be obtained by attenuating the $(E_R - E_Y)$ signal by 0.51 and inverting the result.

To summarize, if E_Y, $(E_R - E_Y)$, and $(E_B - E_Y)$ are transmitted, the receiver can create $(E_G - E_Y)$. In a subsequent chapter we will see how these signals are used in the receiver. It is obvious now that if we were to add, say, $(E_R - E_Y)$ and E_Y at the red gun of a color tube, we would get

$$(E_R - E_Y) + E_Y = E_R$$

namely the red signal. We could do the same with the other color-difference signals to get E_G and E_B.

LUMINANCE SIGNAL BLENDING

The following example is presented to show possible problems in colorcasting if proper color combinations are not considered at the studio. Assume that an orange-colored plate is resting on a green-colored place mat on a white counter; the display on a color receiver would be quite pleasing. However, the relative brightness of green (at 500 mu) is exactly the same as that of orange (at 600 mu); this fact can be verified from Eq. 3-1. The end result on a black-and-white receiver would thus be a bright background (for the white counter top) with a somewhat darker outline

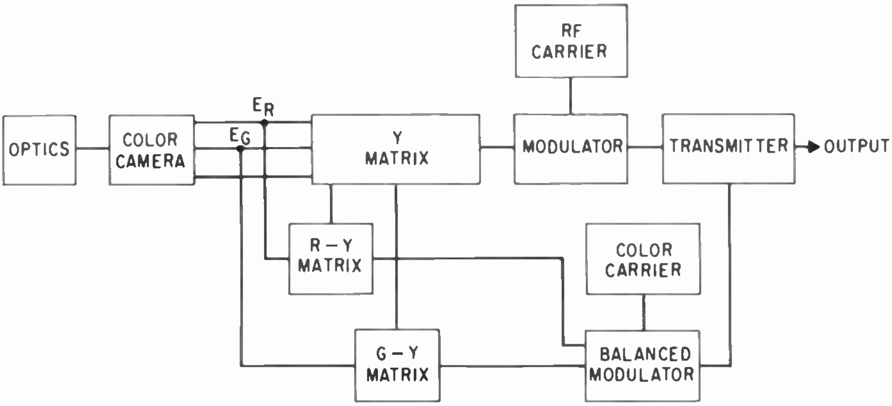

Fig. 3-4 In the basic TV transmitter matrix, E_R, E_G, and E_B signals are combined with E_Y to produce color-difference signals.

representing the mat. The plate would blend with the mat and would not be seen on monochrome receivers. A review of the brightness response curve of the eye (see Color Plate I) shows that many such combinations exist, and care must be taken at the studio so that the colors of scenery, costumes, etc., are not lost when converting the brightness of the colors into luminance signals.

MATRICES

Figures 3-4 and 3-5 show the basic block diagrams of matrices which could be used at the transmitter and receiver to develop the luminance and

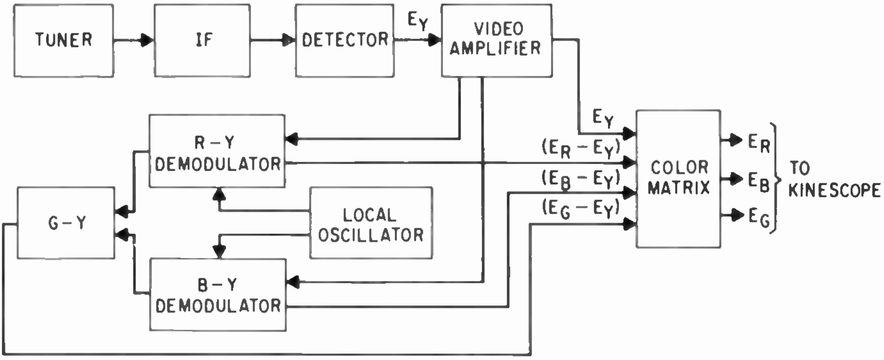

Fig. 3-5 At the color receiver, the color-difference signals are combined with luminance signal E_Y to recreate the E_R, E_B, and E_G color signals.

color signals. At the transmitter, E_R, E_G, and E_B are combined to form E_Y in the Y-matrix. The E_Y signal is combined with the color signals to develop $(E_R - E_Y)$ and $(E_B - E_Y)$ in those respective matrices; the signals then modulate the carrier. At the receiver, the E_Y signal is demodulated to feed the video amplifier stages; the $(E_R - E_Y)$ and $(E_B - E_Y)$ color-differences signals, after being demodulated and processed to form $(E_G - E_Y)$, are fed to their respective color guns. In actuality, the (R – Y) and (B – Y) signals are not used as shown, but this will be explained in a later chapter.

Review Questions

1. Define the term "compatibility" and explain its significance to the requirements for a color TV system.
2. Indicate the relative proportion of red, blue, and green camera outputs used to form the luminance or brightness signal.
3. Calculate the brightness signal (E_Y) for a vivid cyan.
4. Calculate the brightness signal (E_Y) for a 50-percent saturated cyan.
5. Explain why the brightness signal for a desaturated color (such as 50-percent saturated cyan in Question 4) is higher than that of a vivid color (such as vivid cyan in Question 3).
6. What is the advantage of using color-difference signals rather than color signals in the color TV system?
7. What signal is used to provide fine-detail information on a color TV picture tube?

4

Color TV Transmission

As discussed previously, one of the requirements in developing a practical color TV system was that existing monochrome receivers had to receive colorcasts in black-and-white without the need for auxiliary equipment. A second requirement, related more to the transmitter than to the receiver, was that the existing frequency allocation and 6-MHz bandwidth for each channel would not be altered since this would necessitate replacement or modification of tuners, IF strips, and video sections of all monochrome receivers in the field, to say nothing of the extensive modifications required at the transmitters. The challenge was then to devise a system which could fit the color information into the existing band.

WAVEFORM ANALYSIS

Before going into system details, a brief review of waveforms is necessary. It can be shown mathematically that any complex (or nonsinusoidal) wave is composed of sine and/or cosine waves of the same frequency as the complex wave, plus additional sine and/or cosine waves at integral multiples of the frequency of the complex wave. Those sine and cosine waves at the same frequency as the complex wave are called *fundamentals,* and the integral multiples are called *harmonics.* In other words, a complex wave at a carrier frequency, f_c, can be considered to consist of a multitude of sine and cosine waves at frequencies of f_c, $2f_c$, $3f_c$, ...

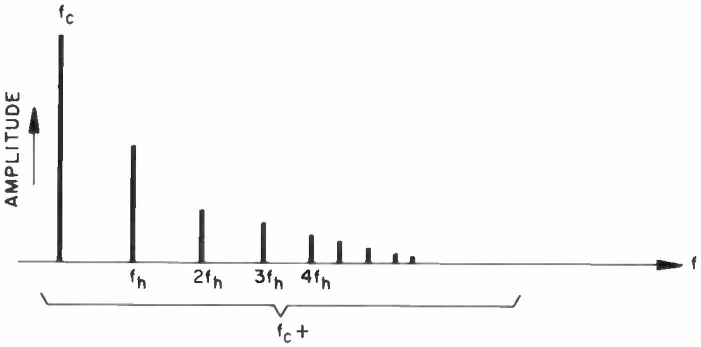

Fig. 4-1 The lower harmonics usually have the highest amplitude levels in a complex waveform.

FREQUENCY INTERLEAVING

Applying this concept to monochrome transmission, the video information appears between horizontal sync pulses, and this composite signal can be considered analogous to the complex wave mentioned above. Referring to Fig. 4-1, the complex wave will have sine and/or cosine waves

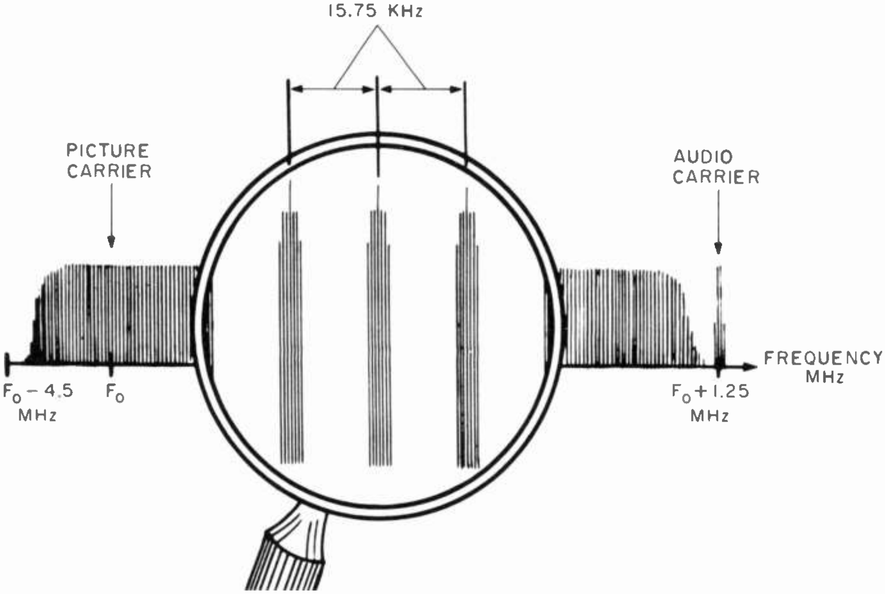

Fig. 4-2 Video information is concentrated at discrete frequency intervals, namely, the horizontal and vertical scanning frequencies.

at f_h (horizontal scan frequency), $2f_h$, $3f_h$, etc. Generally, the amplitude of the sine and cosine waves are such that the fundamental is strongest, the second harmonic weaker, and so on, with the highest harmonic having the least amplitude.

It then becomes evident that energy is transmitted only at the carrier and sideband frequencies, namely f_c, $f_c \pm f_h$, $f_c \pm 2f_h$, $f_c \pm 3f_h$, etc., and that no energy is transmitted at the frequencies between (see Fig. 4-2). These unused regions are therefore logical places to inject the color information. This method of signal insertion is called "frequency interleaving" or "frequency interlacing."

The paramount question is where to locate the carrier for the color information. If it is placed close to the video carrier, as shown in Fig. 4-3, the low-order harmonics of the video and low-order harmonics of the color will both be relatively large in amplitude, and strong inference between the two will develop an objectionable beat pattern. Locating the color carrier away from the video, as shown in Fig. 4-4, will produce strong low-order video harmonics beating with weak high-order color harmonics as well as weak high-order video harmonics beating with strong low-order color harmonics; in both cases a weak beat pattern will be produced, which is desirable.

In Chapter 2 it was mentioned that the eye sees true color only up to about 0.5 MHz; from about 0.5 MHz to 1.5 MHz, the eye sees either cyan or orange; after 1.5 MHz, the fine detail is seen only as gray, white,

Fig. 4-3 Locating the color carrier adjacent to the video carrier will produce strong interference patterns.

Fig. 4-4 Placing the color carrier further from the video carrier tends to reduce interference effects.

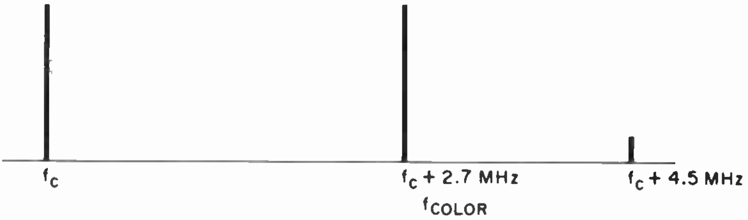

Fig. 4-5 The color carrier could be placed 2.7 MHz away from the video carrier to allow equal amplification of the 1.5 MHz "medium-size" detail signals.

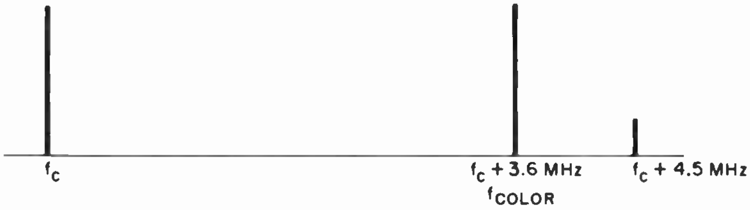

Fig. 4-6 The final choice for the color carrier is approximately 3.6 MHz away from the video carrier. This selection offers the best compromise of color fidelity to the eye with least objectionable interference.

or black, and no color information need be transmitted since it will not be recognized by the eye.

Referring to Figs. 4-5 and 4-6, the color carrier could be located 1.5 MHz from the end of the video band, or 2.7 MHz from the video carrier. While both the upper and lower sidebands of the color signal would be equally amplified, a relatively strong beat pattern would be produced by interaction of the video sidebands and low-order color sidebands. Another choice would be to locate the color carrier 0.6 MHz from the end of the video band or 3.6 MHz from the video carrier. This would provide equal amplification of the low and high color sidebands up to 0.6 MHz, but only single-sideband amplification of the color sidebands from 0.6 to 1.5 MHz. The loss of one sideband causes a small phase change in the demodulated signal, but since the eye sees only cyan or orange in this band anyway, the phase change is not significant. The color carrier is therefore located approximately 3.6 MHz from the video carrier, and the resultant beat pattern is small. The exact spacing is 3.579545 MHz.

The visual effect of the beat pattern on the eye is minimized by

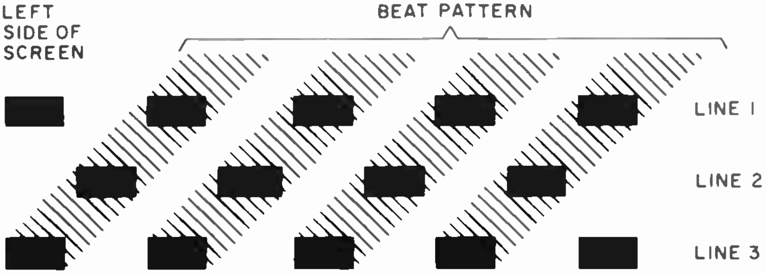

Fig. 4-7 Minimum beat pattern interference is obtained when the adjacent line signals are on a diagonal.

placing the pattern on a diagonal, as discussed in Chapter 2. This is accomplished by locating the color information exactly between the monochrome video information and by the proper selection of the horizontal scan frequency, as will be discussed later.

As shown in Fig. 4-7, a desirable situation for minimizing the beat signal would be to have the pattern at a 45-deg angle from the vertical. This situation can be created by having line 2 start out 180 deg out-of-phase with line 1, line 3 start out 180 deg out-of-phase with line 2, etc.

When the output on line 1 and all other odd lines is maximum positive, line 2 and all other even lines immediately below will be maximum negative. This situation will create the effect desired, namely a 45-deg diagonal beat pattern on the screen. The reader is cautioned to relate this technique only to the beat pattern; the image of the desired signal is placed on the screen in the normal line-to-line additive way.

As shown in Fig. 4-8, the color carrier must be located somewhere halfway between the video sidebands, say between nf_h and $(h + 1)\ f_h$. The video sidebands nf_h and $(h + 1)\ f_h$ must be integral multiples of f_h from

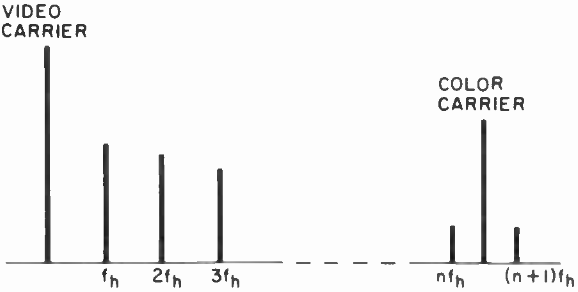

Fig. 4-8 The color carrier must be located at an off-multiple of half-line frequency to reduce interference effects.

the discussion of complex wave formation and even integral multiples of $f_h/2$ (since $f_h = 2f_h/2$, $2f_h = 4f_h/2$, etc.). Therefore the color carrier must be located at some odd multiple of $f_h/2$ since it is located halfway between the video sidebands (which are at even multiples of $f_h/2$).

Beat patterns are created when two signals, say f_m and f_c, combine. The result of heterodyning, or beating, a set of pure sine-wave signals at frequencies f_m and f_c are the original signals f_c and f_m, plus a signal at $(f_m + f_c)$ and a signal at $(f_m - f_c)$. If f_m is an even multiple of $f_h/2$ and f_c is an odd multiple of $f_g/2$, the two beat signals must be at an odd multiple of $f_h/2$. For example, if $f_m = 400\ f_h/2$ and $f_c = 431\ f_h/2$, the beats will be at $f_m \pm f_c$, or $831\ f_h/2$ and $31\ f_h/2$.

Combining the information developed above, the color carrier should be (1) about 3.6 MHz from the video carrier, and (2) at an odd multiple of $f_h/2$.

In addition, since the color sidebands will tend to beat with the sound carrier (which is 4.5 MHz from the video carrier) and the sound sidebands, an additional requirement would be to have the sound carrier at an even multiple of $f_h/2$. Thus the beat between color sidebands and sound carrier would be at an odd multiple of $f_h/2$, which is desirable.

Mathematically, the carrier frequencies can be written as follows:

$$f_{color} = n_{odd} \times (f_h/2) \approx 3.6 \text{ MHz} \tag{4-1}$$

$$f_{sound} = n_{even} \times (f_h/2) = 4.5 \text{ MHz} \tag{4-2}$$

Black-and-white transmission utilizes a horizontal scan rate, f_h = 15,750 Hz. Referring to Eq. 4-2,

$$n_{even}\ (15{,}750/2) = 4{,}500{,}000 \text{ Hz} \tag{4-3}$$

The term n_{even} is calculated to be 572.06, which is not an integral multiple of f_h when f_h = 15,750 Hz. If the equation is rewritten so that f_h is the unknown and n_{even} is taken at 572, the expression becomes

$$f_h/2 = 4.5 \text{ MHz}/572 \tag{4-4}$$

$$f_h = (2 \times 4.5 \text{ MHz})/572 \tag{4-5}$$

$$f_h = 15{,}734 \text{ Hz} \tag{4-6}$$

The vertical scan frequency, f_v, is related to f_h by the equation,

$$f_v = f_h/\text{No. of lines per field} \tag{4-7}$$

Since there are 525 horizontal lines in one frame, or 262.5 lines per field, if f_h = 15,734 Hz, then

$$\begin{aligned} f_v &= 15{,}734/262.5 \\ &= 59.94 \text{ Hz} \end{aligned} \tag{4-8}$$

Referring back to Eq. 4-1, and using $f_h = 15{,}734$ Hz,

$$f_{color} = n_{odd} \times (15{,}734/2) \tag{4-9}$$

If n_{odd} is chosen as 455,

$$\begin{aligned} f_{color} &= 455 \times (15{,}734/2) \\ &= 3.579545 \text{ MHz} \end{aligned} \tag{4-10}$$

Summarizing, during transmission of color programs the sound carrier is 4.5 MHz from the video carrier (the same as monochrome) and the color carrier is 3.579545 MHz from the video carrier. Beat patterns on the screen are minimized by virtue of the large spacing between video and color sidebands, and by the fact that the beats which do exist are at an odd multiple of half-line frequency. The horizontal line frequency is 15,734 Hz and the vertical is 59.94 Hz during color transmission as compared to 15,750 Hz and 60 Hz, respectively, during monochrome transmission. These changes do not make it necessary for the viewer to adjust the horizontal and vertical hold controls on his receiver since the 16-Hz change in horizontal frequency is well within the range of the receiver horizontal AFC circuits, and the vertical oscillator in the receiver is triggered very slightly later during color transmission.

BALANCED MODULATION

Basic fundamentals of amplitude modulation reveal that if a carrier wave at a frequency of f_c is modulated by a sinusoidal signal at f_m, the resulting envelope can be shown mathematically to be composed of three components, one at f_c, one at $f_c + f_m$, and the third at $f_c - f_m$. However, the amplitude of f_c is always larger than the two sidebands, which are equal in amplitude to each other. These sidebands contain the signal information desired; the carrier wave itself contains no information about the modulating signal. As an example, consider the transmission of an unmodulated carrier; when retrieved at the receiver and detected, no modulation is noted (which is proper). When the carrier is modulated at the transmitter, the signal reaching the receiver is demodulated and that demodulation contains the information which is supplied to the speaker or picture tube. In terms of efficient operation, the question can be raised as to why we should bother to transmit the carrier, since the information is only in the sidebands. Since the carrier always has a large amplitude compared to that of the sidebands, relatively high energy levels of this carrier are transmitted with no useful information being detected at the receiver. The answer lies in the fact that the receiver must be given information on the center frequency of all sidebands and it is the sidebands that convey the intelligence; therefore the carrier must be transmitted.

In the case of color TV transmission, the video carrier is transmitted (along with the video sidebands), and the question can be raised whether it is necessary to transmit the color carrier as well. Since the color sidebands can be identified by their relationship to the video carrier as easily as to the color carrier, the answer is that the color carrier need not be transmitted. The virtues of not transmitting this second carrier are that the transmitter need not send out high-power color carrier energy which is not used in the receiver and that the elimination of this energy source avoids strong beats with high-order video sidebands.

The system of transmitting only sidebands without the carrier is called *balanced modulation*. The details of circuit operation are more pertinent for transmitter texts, but the significant characteristic is that the carrier is supressed. When no modulating signal is present, the transmitter radiates no power; when a modulation signal is applied, only the upper and lower sidebands are transmitted, without the carrier.

BURST SIGNAL

The suppression of the color carrier does pose one problem, namely, the hue of the color signal is related to the relative phase of the color carrier. A sample of the carrier is therefore transmitted as part of the sync signal, as shown in Fig. 4-9, and is called the *burst signal.*

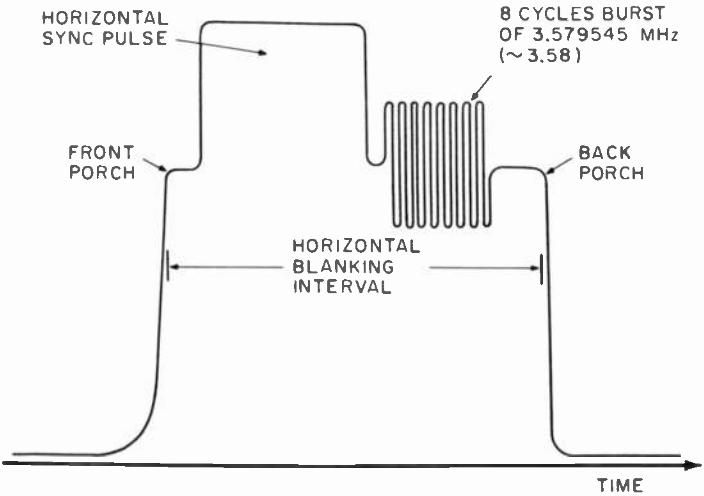

Fig. 4-9 A sample of the color carrier, or "burst," is transmitted on the "back porch" of the horizontal sync pulse.

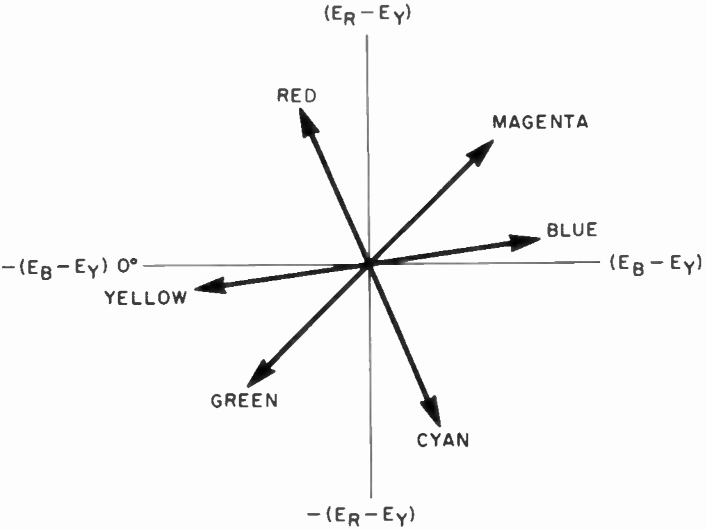

Fig. 4-10 Primary (red, blue, and green) and complementary (cyan, yellow, and magenta) colors displayed in the form of vectors.

COLOR VECTORS

In Chapter 2 it was shown that color is defined fully by its hue, saturation, and brightness. In Chapter 3 it was shown that the brightness (E_Y) and the color-difference signals could be computed for all colors; since E_Y contains the brightness data on the colors, the color difference signals must contain the hue and saturation information.

If two color-difference signals $(E_R - E_Y)$ and $(E_B - E_Y)$ are drawn as quadrature (90-deg) axes as shown in Fig. 4-10., a vector can be drawn for any given color. For example, the color red is defined as

$$(E_R - E_Y) = (1.0 - 0.3) = 0.7 \tag{4-13}$$

$$(E_B - E_Y) = (0 - 0.3) = -0.3 \tag{4-14}$$

Likewise, green is defined as

$$(E_R - E_Y) = (0 - 0.59) = -0.59 \tag{4-15}$$

$$(E_B - E_Y) = (0 - 0.59) = -0.59 \tag{4-16}$$

The third primary color, blue, is defined as

$$(E_R - E_Y) = (0 - 0.11) = -0.11 \tag{4-17}$$

$$(E_B - E_Y) = (1.0 - 0.11) = 0.89 \tag{4-18}$$

The vectors for each primary color are shown in the figure. Also shown are the vectors for the complementary colors for each primary. If the $-(E_B - E_Y)$ line is considered as the reference, or 0 deg, as shown, with rotation clockwise, the angle of the vector and its length can be used to identify the color. The angle that the vector makes with the reference relates to the hue, and the length of the vector relates to the saturation.

During transmission, the chrominance signal is added to the luminance signal. The horizontal sync pulse is well past the kinescope cut-off point, and the signals must drive the kinescope in a positive direction to display information. The luminance level of the three primary colors are as follows:

$$E_Y = 0.3 \quad \text{for red}$$
$$E_Y = 0.59 \text{ for green}$$
$$E_Y = 0.11 \text{ for blue}$$

The amplitude of the color vectors is computed by recalling that the hypotenuse of a right triangle is the square root of the sum of the squares of the legs:

$$\text{Red vector length} = \sqrt{(0.7)^2 + (0.3)^2} \approx 0.77$$
$$\text{Green vector length} = \sqrt{(0.59)^2 + (0.59)^2} \approx 0.85$$
$$\text{Blue vector length} = \sqrt{(0.11)^2 + (0.89)^2} \approx 0.90$$

The composite luminance plus chrominance signal overdrives into both the positive and negative regions; if transmission were attempted, the whiter-than-white signals would not be recognized and the negative signals would erroneously try to sync the horizontal oscillator in the receivers.

To avoid this condition, the $(E_R - E_Y)$ and $(E_B - E_Y)$ signals are attenuated at the transmitter before modulation by factors of 0.877 and 0.493, respectively. If the reader recalculates the vector lengths and adds them to the E_Y levels, he will find overshoots of 33 percent of the red and blue in the negative region, but none in the positive region for the primaries. However, since the complementary colors are mirrors for the primaries in this situation, calculations would show that yellow and cyan would overshoot by 33 percent in the positive (whiter-than-white) region. These excursions are permitted, based on tests which have shown that these overshoots do not substantially degrade picture quality.

The 0.877 and 0.493 attenuation factors at the transmitter are compensated for at the receiver, either in circuitry before the color difference amplifiers or in these amplifiers themselves.

I AND Q SIGNALS

The preceding vector diagram can be modified by adding one vector 57 deg from the reference line and a second vector extending from the first at 180 deg plus 57 deg or 237 deg. Since the first vector falls between yellow and red, its hue must be orange; since the second falls between green and blue, its hue must be cyan. An orange-cyan line has just been created and can be tied in with the orange-cyan concept related to the eye's resolution of color. (Recall that "medium" areas are seen only as orange or cyan, not in their true color.) A new pair of axes is now added to the vector diagram, one along the orange-cyan line called E_I (in-phase) and one perpendicular to E_I called E_Q (quadrature), as shown in Fig. 4-11.

All vectors which represent colors can have their components on any mutually perpendicular axes. While their computed angle from the reference line and their length were based on the (R − Y) and (B − Y) axes, the vector's projections on the I and Q axes could also be computed. If this were done, each color would have an E_I and E_Q component. If the transmitter used these axes to modulate the two balanced modulators, and the bandwidth of the E_I channel was made 1.5 MHz and the E_Q channel 0.6 MHz, conditions are set up which permit optimum transmission of color signals in terms of the requirements of the eye. Recall that the eye sees large areas (0 to 0.5 MHz) in true color; the system above transmits both E_I and E_Q and true color as available at the receiver. The eye sees medium

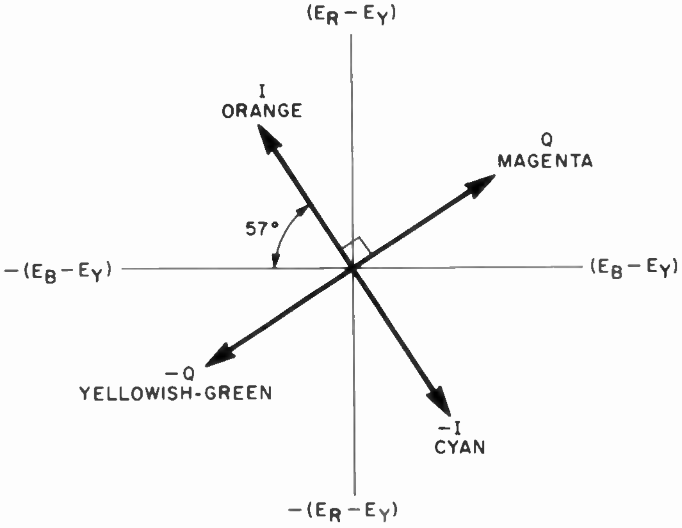

Fig. 4-11 The I-axis represents orange to cyan while the Q-axis extends from greenish-yellow to magenta.

areas (0.5 to 1.5 MHz) as either orange or cyan; the system above transmits only E_I (the orange-cyan line) and no E_Q. The eye does not see any color in fine detail (1.5 MHz and up); the system does not create E_I or E_Q above 1.5 MHz. The E_I, E_Q axes are used at the transmitter, but except for a few early receivers, have not been used for reception.

Review Questions

1. What is meant by "frequency interleaving?"
2. What is the significance of frequency interleaving to the present color TV system?
3. Indicate the frequency spacing between the color subcarrier and the video carrier.
4. Are the scanning frequencies (vertical and horizontal) identical in a black-and-white TV system and a color TV system? Explain.
5. Why is "balanced modulation" used in a color TV transmitter?
6. What is the purpose of the "burst" signal?
7. Explain how a vector can be used to represent a color TV signal.
8. What are I and Q signals and how do they relate to the color TV system?
9. Which signal, I or Q, is used to carry medium detail information?
10. Is the I or Q signal or both used for large color areas? Explain.

5

The Color TV Receiver

INTRODUCTION

Prior to about 1970, the majority of color receivers used tubes almost exclusively; they were more reliable and available at lower costs than their solid-state counterparts.

As semiconductor manufacturers sought to expand into the lucrative, high-volume market offered by the TV industry, considerable attention was directed to reduce cost and improve performance under the stringent requirements demanded by TV receiver producers. Tiny transistor radios had unquestionably acquired a well-earned reputation for long life, durability, and high performance at modest cost. But these radios operated at voltages from 12 volts and below with relatively low power output levels. In addition, the signals handled were audio or RF analog signals.

The TV receiver design, on the other hand, includes some circuits similar to those found in AM-FM sets, namely RF, IF, and audio stages. But the high voltage pulses and sweep circuit demands in the deflection system posed problems to the semiconductor suppliers.

Thus, the first solid-state devices included in color TV receivers were in the low-voltage, low-power sections. Then the TV set designers introduced power transistors and silicon-controlled rectifiers (SCR's) into the deflection and high-voltage sections. Next came the integrated circuit (IC) where a complete function, fabricated on a tiny silicon chip, replaced several transistors and their associated resistors and capacitors. Numerous sets on the market today boast several IC's, a number of transistors and SCR's, and even a few tubes. TV design engineers do not hesitate to combine IC's, transistors, and tubes on one chassis provided optimum performance at lowest cost is achieved.

All solid-state color TV receivers (except the picture tube, of course) are now on the market with a variety of IC's and dozens of transistors contained on the chassis; the price is still slightly higher than that of receivers using a combination of devices. A number of set manufacturers are already testing prototype all-IC color sets but admit that a competitively priced model is not yet available for production.

Today's technician will encounter a vast majority of receivers in the field using tubes. A fundamental grounding in circuitry and servicing techniques applicable to tube models can be conveniently transferred to solid-state principles.

TUNER AND VIDEO IF SECTION OF A COLOR RECEIVER

Although the bandpass response characteristics for the RF/IF sections are more stringent for a color receiver than a black-and-white set, relatively little difference exists in circuitry. The RF stage is counted on to provide high gain with low noise; the oscillator stage must provide sufficient output over all channels with adequate frequency stability; and the mixer stage provides the video IF output by the proper combination of the RF and oscillator signal.

For satisfactory color reception, it is imperative that the frequency response of the tuner be uniform for each channel (see Fig. 5-1a). A tilt in the response curve Fig. 5-1b or attenuation somewhere in the 6-MHz RF

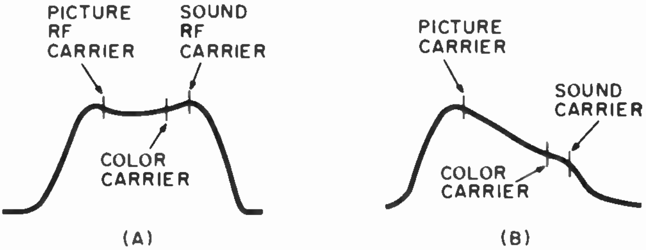

Fig. 5-1 A uniform RF tuner response as shown in (a) provides excellent tuner performance; a tilted or nonuniform response with attenuation as in (b) would seriously affect color reception.

bandpass could result in slight picture degradation in a black-and-white set; the same improper response on a color set could result in no color, weak color, or poor color sync. This is because of possible attenuation of the color sideband signals relative to the luminance or brightness signals.

Similarly, the video IF circuitry is relatively straightforward, but particular attention must be given to the video IF response curve. Most modern receivers employ nonuniform amplification near the subcarrier IF and compensate for this by tailoring the shape of the bandpass amplifier characteristic. The overall response for the chrominance signals is uniform, but particular attention must be paid to the video IF response curve in the region of the color subcarrier.

A departure from conventional video IF design in the color receiver is the takeoff for the sound IF.

SOUND IF TAKEOFF IN COLOR RECEIVERS

To understand why the sound takeoff point in a color receiver is placed before the video detector, recall that there is approximately 920 KHz separation between the sound carrier and the color subcarrier (the sound carrier is 4.5 MHz away from the RF carrier and the color subcarrier is 3.58 MHz away from the RF carrier; hence the 920 KHz separation).

If the two signals are not separated before the video detector stage, disturbing bars would appear on the screen and cause objectionable interference. To avoid this interaction, the sound IF carrier is separated from the composite video signal at the last video IF stage and before the video detector as shown in Fig. 5-2. The sound IF is then sharply attenuated by high-Q traps before reaching the video detector. The video detector also may include a 4.5 MHz trap to offer further protection against sound beat interference.

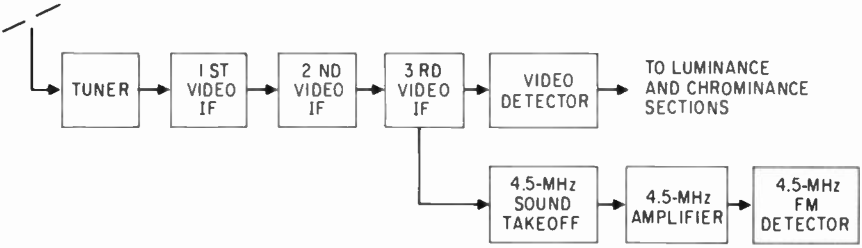

Fig. 5-2 The sound IF takeoff is located before the video detector in a color receiver to avoid video IF-sound IF interaction which would cause objectionable interference.

The sound IF removed at the last video IF is fed to its 4.5 MHz sound detector after which further amplification of the 4.5 MHz takes place before final detection of the audio intelligence.

AUTOMATIC FINE TUNING (AFT)

The fine tuning control of a TV tuner is considerably more important for color reception than for monochrome. Failure of the user to correctly set fine tuning on a monochrome receiver merely results in a poor quality picture; the intercarrier sound circuitry continues to produce undistorted sound despite the mistuning. Improper fine tuning on a color set can result in weak or washed-out color or no color at all.

Manufacturers now offer color sets with automatic fine tuning (AFT) to permit the set to do its own fine tuning. The scheme shown in Fig. 5-3 operates on the principle that the IF picture carrier results from the difference between the tuner local oscillator and the station's transmitted picture carrier, which is precisely set. Now, if the tuner oscillator frequency can be maintained at exactly 45.75 MHz above the station carrier, the tuning will be exactly correct. To accomplish this end, some means must be included in the receiver to sense the drift from this 45.75 MHz point and act to restore this exact IF. As shown in the block diagram, a signal for AFT sensing is derived from the third video IF stage. A high-gain resonant amplifier stage, tuned to 45.75 MHz, increases the level of this signal before application to the AFT discriminator. Zero output results when the discriminator input is 45.75 MHz. A d-c output will appear if the IF shifts; the polarity and magnitude of this d-c voltage depends on the degree and direction of shift. The correction voltage is fed

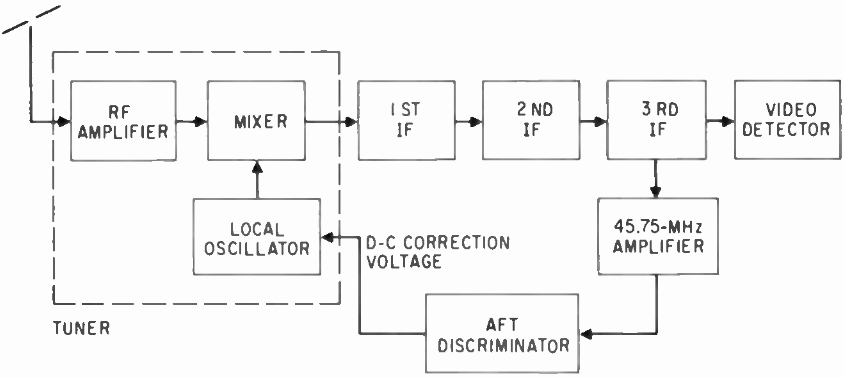

Fig. 5-3 Automatic fine tuning (AFT) compares the station's picture carrier signal with the receiver's local oscillator and corrects the local oscillator in the event that it should shift frequency.

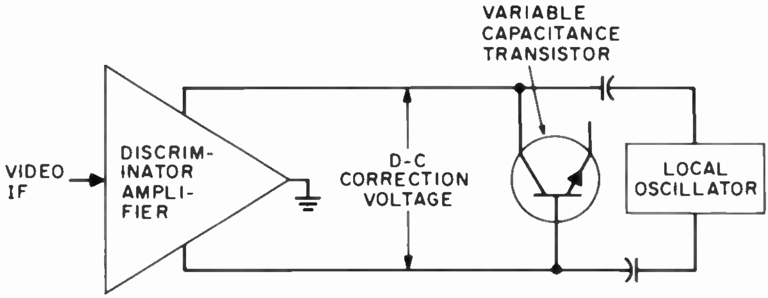

Fig. 5-4 In this integrated circuit AFT arrangement, the correction voltage is applied to a variable-capacitance transistor when oscillator drift occurs.

back to the local oscillator of the tuner where it controls its frequency in a manner that restores the exact frequency required for proper reception.

INTEGRATED CIRCUIT AFT SYSTEM

In the AFT system shown in Fig. 5-4, an integrated circuit (IC) discriminator-amplifier chip accomplishes the task of producing a d-c voltage proportional to the developed video IF. In the tuner assembly, a special variable capacitance transistor in the VHF section is fed this d-c voltage for corrective action; a varactor diode serves this function in the UHF tuner. An internally regulated power supply is included in the AFT IC system to eliminate any effects due to line voltage fluctuations.

INTEGRATED CIRCUIT SOUND SECTION

The functions of sound IF amplification, detection, audio preamplification, and drive are provided with a single integrated-circuit (IC) chip, as shown in Fig. 5-5. Basically, the IC consists of a 4.5-MHz amplifier fed from the sound detector, a 4.5-MHz ratio detector and an audio preamp-driver.

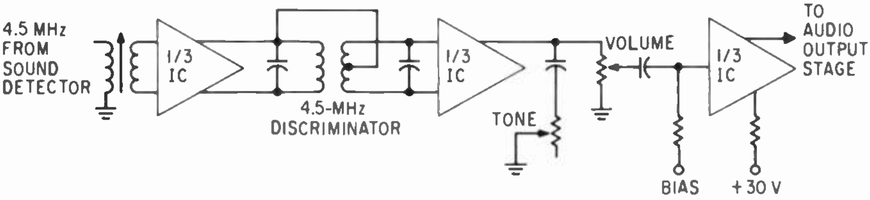

Fig. 5-5 One IC chip accomplishes sound IF amplification, detection, preamplification, and drive to the output power amplifier.

The sound IF amplifier output is fed to the discriminator transformer and applied to the IC ratio detector. The audio signal produced is coupled to the tone and volume controls and then to the driver section of the IC chip. Here sufficient current gain is provided to drive the audio output stage. Thus this IC may be considered as a three-section device, as shown in Fig. 5-5.

THE LUMINANCE OR BRIGHTNESS AMPLIFIER

The wideband detail information in a color receiver is obtained from the Y signal, which is sometimes called the *luminance* or *brightness signal.* This signal is derived at the video detector and amplified by as many as three stages of a luminance or brightness amplifier chain. The circuitry is quite similar to that employed in a video amplifier for a high-quality black-and-white set.

In the two-stage luminance section shown in Fig. 5-6, the video detector feeds the composite signal to the first video amplifier. In this stage, routing of the AGC, burst, sync, and chrominance takes place. In addition, the luminance signal is fed, through a delay line, to the second video amplifier before application to the kinescope cathodes.

In the first video amplifier, negative-going sync and blanking-pulse video signal is applied to the grid from the video detector. Should noise pulses enter the receiver, they will tend to drive the first video amplifier to cutoff and thus not be observed on the screen. Amplified positive-going pulses appear at the plate for application to the sync and AGC sections. The cathode circuit (low impedance to match the delay-line input) is the takeoff point for the luminance signal. The chrominance sidebands are coupled from the first video amplifier plate circuit by a tuned (3.58 MHz) color takeoff transformer.

The two video amplifiers are d-c coupled to maintain the proper d-c level developed at the video detector. A "brightness" control is tied to the grid of the second video amplifier, which is also d-c coupled to the kinescope cathode. As the brightness control is varied, the second video amplifier bias changes, altering its d-c plate voltage, thus changing the kinescope cathode voltage and hence the receiver brightness. The contrast control is in the cathode of the second video amplifier and varies the stage gain (and thus the luminance or Y level) by changing the degree of negative feedback. This is accomplished by moving the cathode bypass capacitor along the cathode resistor to vary the amount of degeneration.

THE DELAY LINE IN THE LUMINANCE AMPLIFIER

The luminance amplifier contains a component—the delay line—which is not found in black-and-white video amplifiers. In a color receiver,

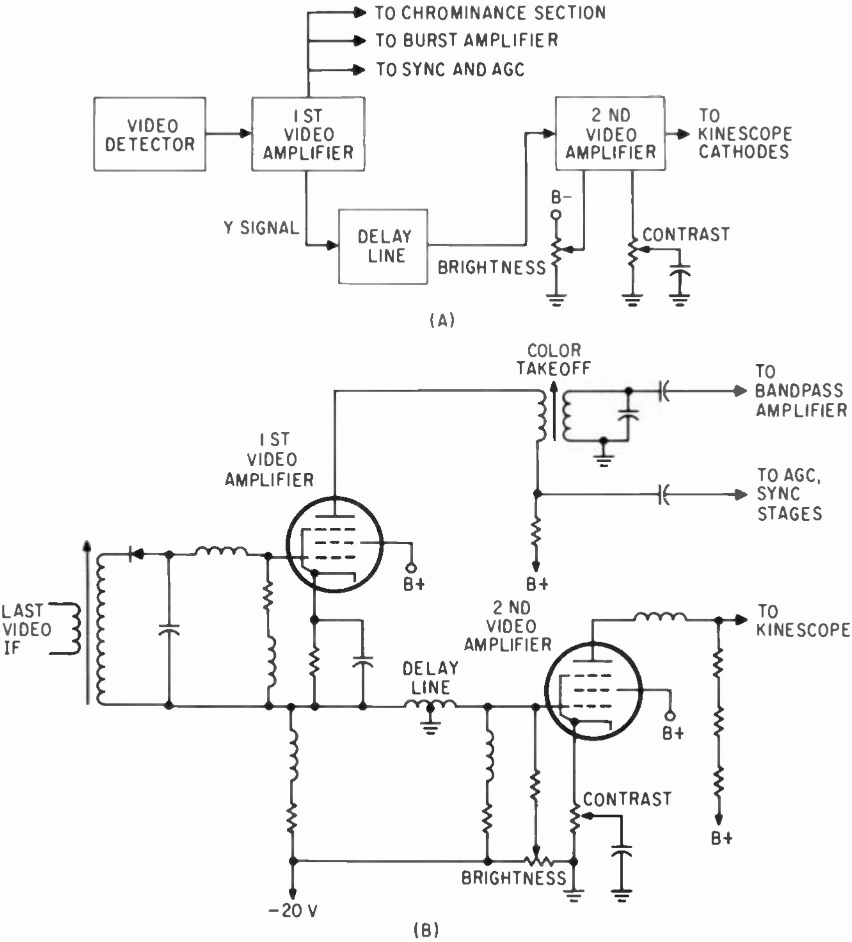

Fig. 5-6 In this two-stage luminance amplifier, a delay line is inserted between the first and second stages. Details of the block diagram (a) are shown in the schematic (b).

the luminance signal and the chrominance signal are separated at the video amplifier and are routed to different stages before they are recombined at the kinescope. However, they must arrive at the color kinescope cathodes and grids at the same time. Unfortunately, a timing error exists because the luminance signal is applied to wideband stages whereas the chrominance signal is fed to bandpass amplifiers of narrower bandwidth. The chrominance signal is thus delayed relative to luminance since time delay is inversely proportional to frequency response.

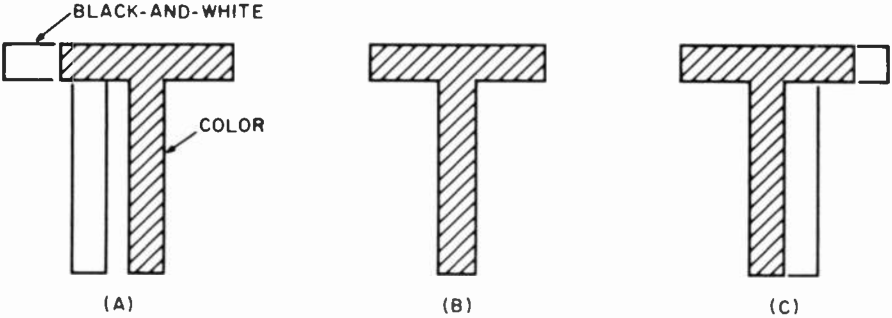

Fig. 5-7 Lack of a delay line, or insufficient delay, in the luminance channel would produce misregistration as shown in (a); excessive delay would create the pattern shown in (c). Proper delay would allow the video and color signals to arrive at the kinescope at the same time and produce the pattern in (b).

If this delay between luminance and chrominance were not corrected, these signals would not overlap on the kinescope screen and a misregistered picture would result. As an example, consider a word appearing on the screen with the letter "T" (see Fig. 5-7). Without a delay line in the luminance section, the Y signal would arrive ahead of the color signal and appear as in Fig. 5-7a. A delay line with proper delay time would register the two signals as in Fig. 5-7b. Excessive delay time would cause misregistration as in Fig. 5-7c. The delay line used in color sets is an artificial line which provides one microsecond or so delay (depending on the receiver design) in a compact assembly.

An inner conductor (which will carry the signal) is wound over a length of flexible tubing. Next, several layers of insulation are added and then a shield or braid of insulated copper wires is wound to serve as the outer conductor. The insulated copper wires are connected together at one end of the line only so that each wire of the braid acts as a capacitor with each turn of the inner conductor. A final insulation coverage is placed over the outer conductor to complete the delay-line assembly.

Delay lines are designated for a specific time delay and characteristic impedance. To avoid reflections along the delay line, it is matched in impedance at its source (generally the cathode of the first video amplifier) and its termination (often the contrast control).

THE CHROMINANCE SECTION

The output of the first video amplifier (Fig. 5-8) contains a bandpass transformer tuned to 3.58 MHz. The chrominance sidebands are thus separated from the composite video and applied to a one- or two-stage bandpass amplifier section. The takeoff transformer plus the interstage coupling between bandpass amplifiers provide selectivity for the signals between 3.0 and 4.2 MHz (approximately 0.5 MHz on either side of 3.58 MHz). Signals below this frequency are attenuated, as are the 4.5 MHz sound signals that could combine with the chrominance sidebands and produce objectionable interference on the kinescope screen.

Burst pulses are amplified, along with the chrominance signals, in the first bandpass amplifier and are then fed to the burst amplifier. Gain of the first bandpass amplifier is controlled by an automatic-color-control (ACC) voltage developed at the phase detector to minimize color saturation changes caused by variations in input signal strength.

The second bandpass amplifier stage includes a saturation or color-intensity control to permit the viewer to adjust color vividness to his particular liking. A d-c voltage from the color-killer stage is applied to the grid of the second bandpass amplifier. In the absence of color, this color-killer stage will bias off the second bandpass amplifier and thus prevent the appearance of color noise or snow on the screen.

From the second bandpass amplifier, the amplified chrominance sideband signal is fed to two demodulators to recover the transmitted color (hue and saturation) intelligence. Outputs from the demodulators, whether they be R - Y, B - Y, X, or Z designs, are next fed to R - Y, B - Y color difference amplifiers. Here the G - Y signal is formed by the proper combination of R - Y and B - Y.

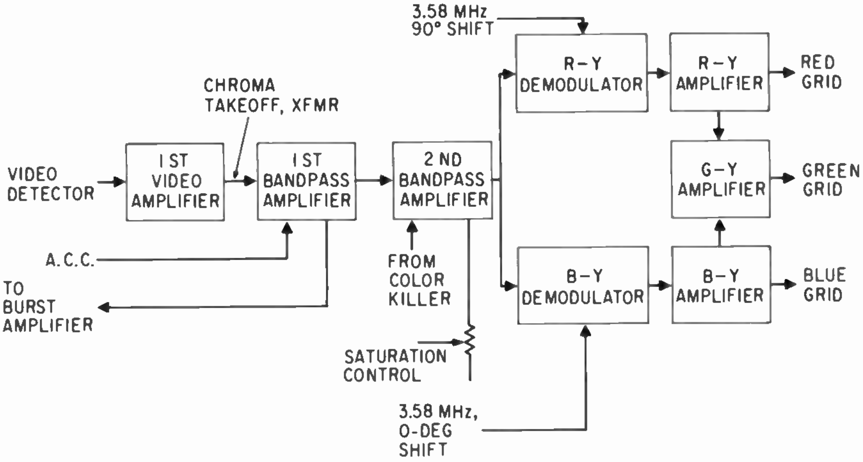

Fig. 5-8 Block diagram of the chrominance section.

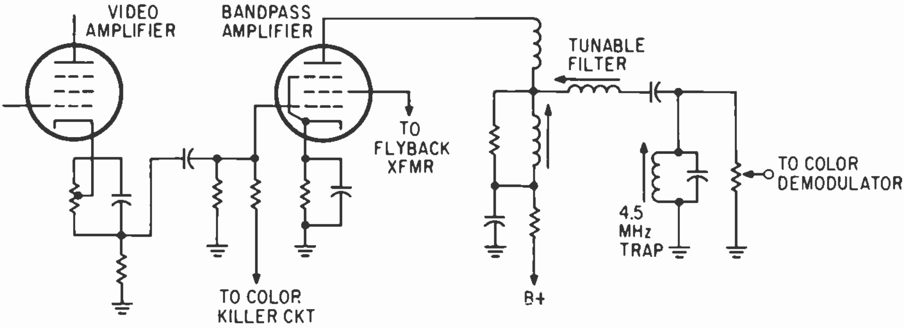

Fig. 5-9 Schematic diagram of the bandpass amplifier.

Finally, the mixing or matrixing of the luminance or Y signal with the color-difference (R - Y, G - Y, and B - Y) signals takes place in the kinescope. The three grids are fed their respective color-difference voltages while the cathodes are supplied with appropriate amounts of the Y signal for each gun.

THE BANDPASS AMPLIFIER

The chrominance sidebands appearing in the region of the 3.58 MHz subcarrier frequency are separated from the composite video signal by the bandpass amplifier. The high-frequency video components, extending from 3.0 to 4.2 MHz (0.6 MHz on either side of the color subcarrier), are filtered from the first video amplifier while the lower range of video signals are routed to the second video amplifier.

In the single-stage bandpass section illustrated in Fig. 5-9, the composite video signal is fed to the grid of a pentode. The plate circuit contains a turnable filter section to obtain the proper response, as shown. A sound trap is shunted across the chroma output to minimize interference from the heterodyning of the 4.5-MHz sound IF and the 3.58 MHz sidebands. The color intensity, or saturation, control is placed between the bandpass output and the input to the two demodulators. The pentode screen is connected to a winding on the flyback transformer; during retrace time, a negative-going pulse is applied to cut the bandpass amplifier off. This action is necessary to prevent the color burst signal, which occurs during retrace, from passing to the demodulators and then to the picture tube. The burst signal would develop a yellowish-green color which would cover the entire screen since it would be applied as the beam sweeps from the right- to the left-hand side of the screen during retrace.

The bandpass amplifier also includes provisions for application of a "killer" bias to eliminate objectionable color noise during black-and-white transmission. A color-killer circuit, to be described later, is coupled to the bandpass amplifier and automatically cuts off the bandpass amplifier in the absence of a burst signal (during monochrome transmission).

BANDPASS AMPLIFIER RESPONSE CURVES

A flat-topped response curve symmetrical about the 3.58-MHz color subcarrier is desired as an overall response from the tuner to the demodulator inputs. One approach to achieve this aim is to use a video IF response which is flat up to 4.2 MHz (see Fig. 5-10a) and then include a symmetrical bandpass amplifier response as shown in Fig. 5-10b. The resultant response is shown in Fig. 5-10c. This obvious approach has the disadvantage

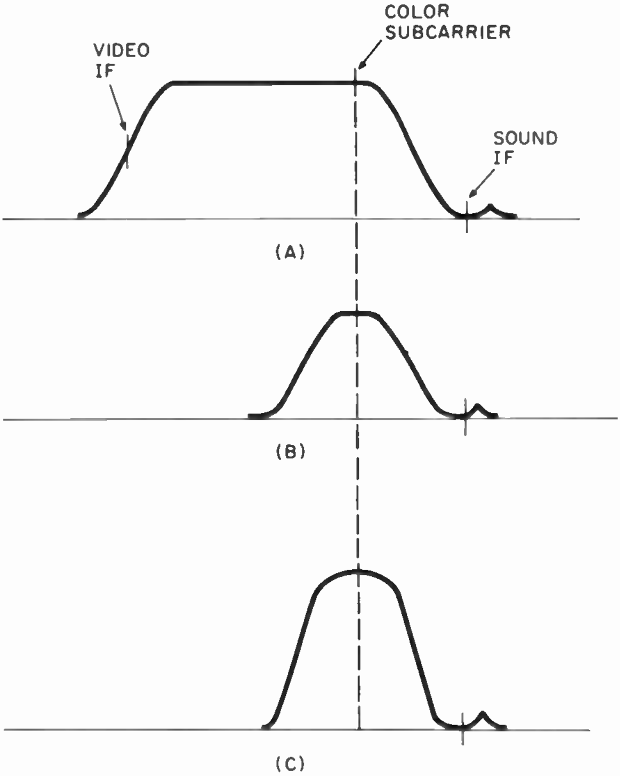

Fig. 5-10 One approach to achieving the uniform flat response from tuner to color demodulator output is the use of symmetrical response curves in the IF (a), and bandpass (b) amplifiers to obtain the overall response (c).

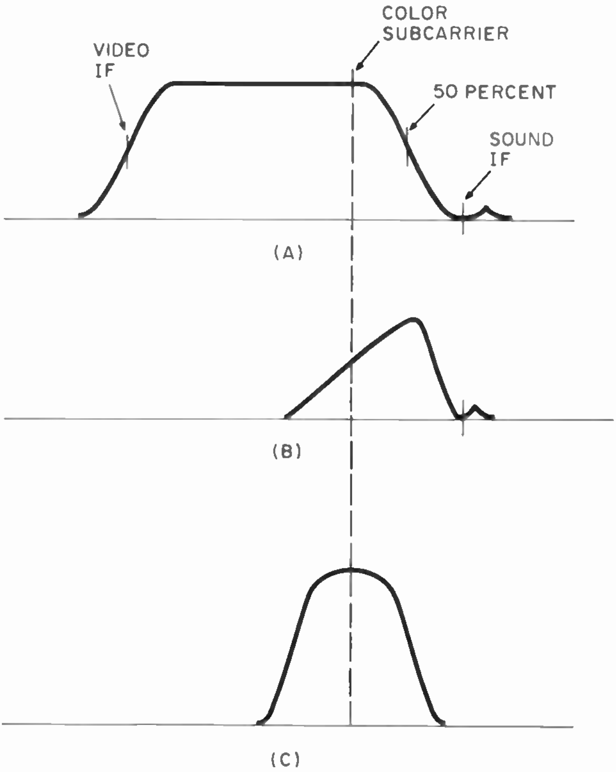

Fig. 5-11 An alternative bandpass amplifier arrangement uses a sloping IF response (a) which is compensated by a reverse slope response in the bandpass amplifier (b) to produce the uniform response (c).

of requiring additional IF stages to achieve the needed gain-bandwidth requirements. In addition, considerable precautions are required to avoid strong beat interference between the sound IF carrier and the chrominance sidebands.

Another method to accomplish the same end result makes use of a sloping video IF response with the color subcarrier at the 50-percent level, as shown in Fig. 5-11a. The bandpass amplifier response is then tailored as shown in Fig. 5-11b to produce the desired overall response shown in Fig. 5-11c.

THE COLOR KILLER

During reception of black-and-white programs, it is desirable to disable the chrominance section automatically. Noise or high-frequency video signals are then prevented from producing extraneous color dots or streaks on the screen.

The color-killer stage is fed from the phase detector, as shown in Fig. 5-12, and is connected to the control grid of the bandpass amplifier. Note that the negative d-c output side of the phase detector arrangement is fed to the color-killer grid. When a color station is being received, the combination of burst and the 3.58-MHz oscillator signal will develop a negative voltage across R1 sufficient to cut off the color-killer stage. The flyback pulses, applied to the plate, will not cause plate current flow and thus no voltage will appear at the bandpass amplifier grid as a result of color-killer action.

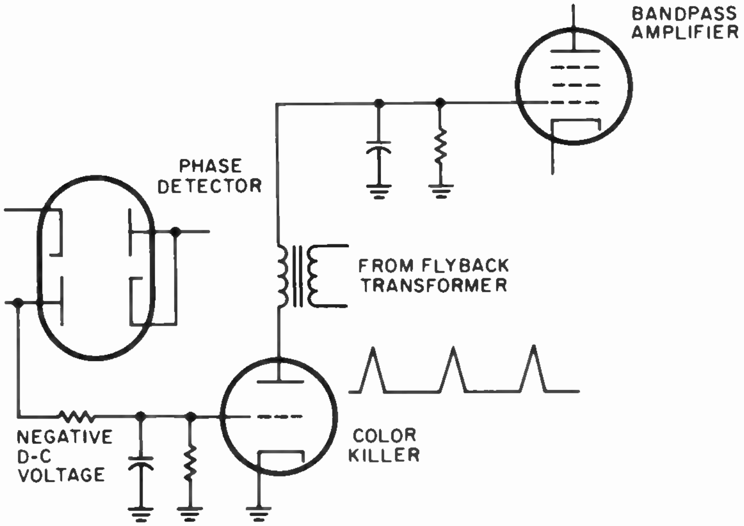

Fig. 5-12 The color-killer stage automatically cuts off the bandpass amplifier during black-and-white transmission.

When a black-and-white program is received, burst is not present. The negative d-c voltage developed across R1 by only the 3.58-MHz oscillator will not be sufficiently great to cut off the color-killer stage. Now, the positive-going flyback pulses will find a complete return path through the color-killer stage and develop a negative bias of sufficient amplitude to cut off the bandpass amplifier.

To summarize, burst will act during colorcasts to cut off the color killer and thus allow the bandpass amplifier to conduct. During black-and-white programs, the color killer conducts and causes the bandpass amplifier to become nonconducting, thus preventing extraneous signals from passing to the demodulators.

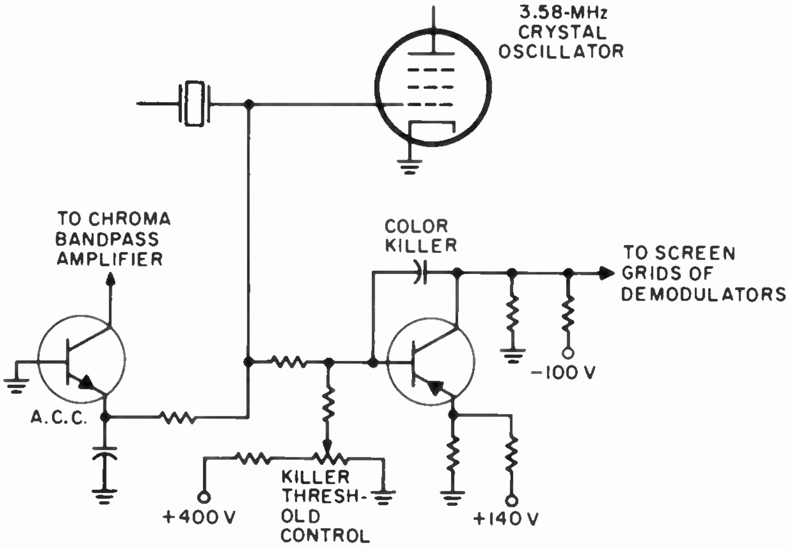

Fig. 5-13 This solid-state color killer circuit is driven into saturation during color transmission, allowing the bandpass amplifier to conduct.

TRANSISTOR COLOR-KILLER CIRCUIT

The color-killer circuit in Fig. 5-13 operates as a simple on/off switch with the transistor either fully saturated or completely cut off. The PNP transistor, operating in a common emitter arrangement, is base-biased by the negative voltage developed by the 3.58-MHz oscillator and the setting of the killer threshold control. The emitter voltage is set to 2.5 volts by a voltage divider. Collector voltage is obtained from a voltage divider connected across a −100-volt supply.

Under no color transmission conditions, about 3.5 volts negative exists at the 3.58-MHz oscillator grid, which leads in turn to about 3 volts positive on the color-killer base (by voltage divider action). The difference between the base and emitter is 0.5 volts (base positive), and the collector voltage under this condition of cut off is 20 volts negative—sufficient to bias off the demodulators by virtue of negative screen voltage. When color burst appears at the oscillator grid, its voltage rises to 8 volts negative, changing base voltage to about 1.5 volts positive. The base-to-emitter bias is now sufficient to drive the transistor from cutoff to saturation. The collector voltage rises to a positive voltage, allowing the demodulator stage to function.

AUTOMATIC CHROMA CONTROL (ACC)

Automatic chroma control (ACC) and automatic gain control (AGC) are combined in color receivers to maintain a constant contrast and saturation level at the picture tube.

The ACC control voltage is derived from the phase-detector stage. The detected d-c voltage level is determined by the two a-c voltages applied—the 3.58 MHz oscillator signal and burst. However, the 3.58-MHz signal is taken from the local oscillator and is constant in amplitude while burst is a function of the level of the incoming chrominance signal. The negative d-c voltage at the phase-detector output is thus proportional to the burst level. A strong incoming color signal develops a relatively high negative voltage. A weak color signal produces a lower negative d-c voltage.

The ACC bias is applied to a variable-gain bandpass amplifier stage. A strong incoming color signal produces a high negative bias (not sufficient to cut off the bandpass amplifier) and places the tube at a low-gain operating point. A weak color signal develops a small negative bias that allows the bandpass amplifier to operate at maximum gain.

The net result of this arrangement is a fairly constant chrominance level regardless of weak or strong reception.

CHROMINANCE DEMODULATION

After the video detector stage, the chrominance or color information exists as sidebands of the 3.58-MHz subcarrier; thus further detection or demodulation is necessary before application to the color kinescope.

First, the chrominance sideband signals are separated by the bandpass amplifier and then sent to two color demodulators. Why two? Recall that at the transmitter two color signals (I and Q) were each individually amplitude-modulated with their particular frequency and phase carrier; then the two modulated carriers were combined to produce a single chrominance signal for transmission. At the receiver this single chrominance signal must be separated back into *two* individual color signals by *two* demodulators.

Although the transmitter uses I and Q axes to develop the resultant chrominance signal, it is not necessary for the receiver to restore the single chrominance signal to I and Q signals. This situation exists because of the relationship between the I/Q signals and the color-difference signals (R - Y), (B - Y), and (G - Y).

$$I = -0.27(B - Y) + 0.74(R - Y)$$
$$Q = 0.41(B - Y) + 0.48(R - Y)$$

Without going through the complex mathematical derivations, the color-

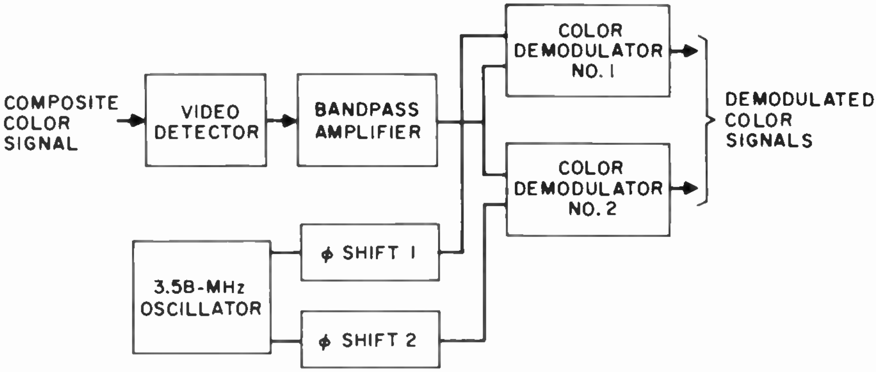

Fig. 5-14 Block diagram of the color demodulator section.

difference signals can be individually obtained by the proper proportion of I and Q signals.

$$(R - Y) = 0.62Q + .96I$$
$$(B - Y) = 1.7Q - 1.1I$$
$$(G - Y) = 0.64Q - 0.28I$$

Thus, it is possible to demodulate along the (R − Y), (B − Y) axes rather than the I, Q axes as long as the conversion or trigonometric relationships are known. Also the (R − Y), (G − Y) axes may be selected. In fact, other axes can be, and are, used in modern color receiver designs.

COLOR DEMODULATORS

Color demodulators are basically phase-amplitude detectors. On schematic or block diagrams they may be referred to as synchronons detectors, chroma detectors, or color detectors.

The function of this section of the color receiver is to recover the color video signals from the 3.58-MHz sidebands developed after the video detector stage. Note in Fig. 5-14 that the 3.58-MHz chrominance signal encounters two detector sections in the receiver. The chrominance signal is separated from its RF carrier (along with the Y or luminance signal) at the video detector; then it is routed, via the bandpass amplifier, to the two color demodulators, where phase detection will take place. As discussed previously, two color demodulators are required at a receiver to develop two separate color signal outputs. Each demodulator requires two inputs for proper operation: (1) the 3.58-MHz chrominance sidebands, and (2) a 3.58-MHz CW signal of a particular phase relative to the transmitted burst. The 3.58-MHz signal is locally generated in the receiver and is precisely locked in phase and frequency with the transmitter 3.58-MHz carrier by a color AFPC system (*a*uthomatic *p*hase and *f*requency *c*ontrol). Each of the two demodulators will be fed this 3.58-MHz CW signal with a carefully adjusted phase relationship relative to burst and to each other.

DEMODULATOR AXES

Early color receivers used I and Q demodulator axes with the I axis 57 deg from burst and the Q axis 90 deg from the I axis. The I demodulator in such a receiver would be fed the 3.58-MHz color sidebands plus the locally generated 3.58-MHz CW signal passed through a phase-shifting network to establish a 57-deg difference from reference burst. Similarly, the Q demodulator would receive the same 3.58-MHz color sidebands plus the locally generated 3.58-MHz CW signal with a 90-deg phase separation relative to the I CW signal.

Many receivers in use today contain (R - Y) and (B - Y) demodulators and the relative phase relationships are 90 deg, or quadrature, as shown in Fig. 5-15. Note that the -(B - Y) axis is the same phase as the in-

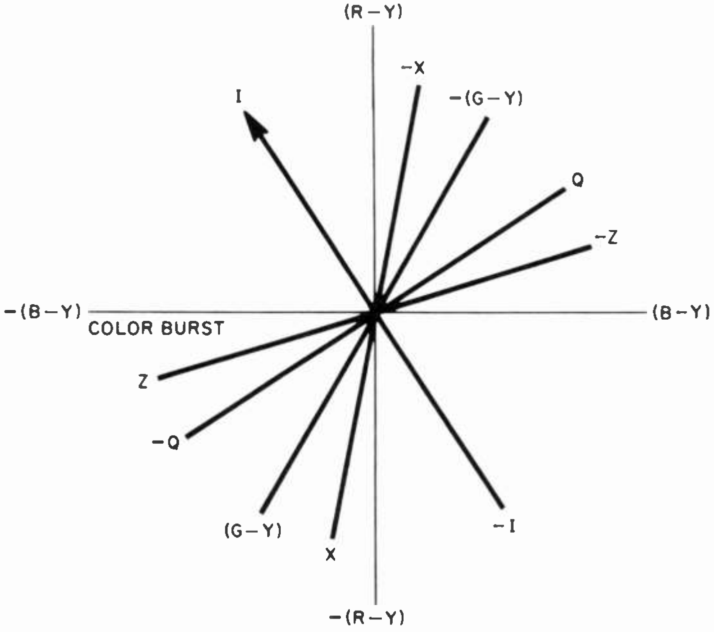

Fig. 5-15 Various axes can be used for color demodulation as long as the receiver circuits are designed to restore the proper color signal relationships.

coming reference from the transmitter (burst). There are receivers designed for still simpler circuitry, and these demodulate along the (R - Y), (G - Y) axis with the phase relationships shown.

Finally, a rather unique demodulator design to produce the three color-difference signals with a minimum of circuitry and cost uses two axes labeled X and Z. These axes fall close to the (R - Y), (B - Y) axes; the X axis is at 281 deg and the Z axis is at 343 deg. Don't be confused about the flexibility of the receiver design in the selection of the demodulator axes. The purpose of the demodulator section is to produce color video voltages for application to the color kinescope. Even though the transmitter used I and Q signals to develop the transmitted sidebands, recall that these signals were constructed from color-difference signals developed at the camera output. Thus, as long as the demodulator section produces proper color video signals, accurate color reproduction will result.

COLOR DEMODULATOR CIRCUITS—PENTAGRID DETECTOR

One of the earliest types of synchronons detectors used pentagrid converters with the 3.58-MHz chrominance sidebands coupled to the control grid and the 3.58-MHz CW signal or subcarrier (with appropriate phase shift) fed to grid No. 3. Remember that a color-demodulator section contains two demodulators. Let's see how a single demodulator stage works.

The 3.58-MHz CW subcarrier at the No. 3 grid may be considered as a gate, allowing the tube to conduct only during the positive half-cycles; the tube is nonconducting when this grid is driven negatively. Thus, with no chrominance signal present (Fig. 5-16a), the plate current consists of half-cycle pulses with the average value shown. This average-value plate current corresponds to no-signal input condition. Now assume that a chrominance signal is applied with a phase similar to that of the subcarrier. Since the control grid is at its most positive point when the grid No. 3 input is also at its maximum positive level, plate current pulses will be high, with an average value as shown.

Next assume a chrominance input whose phase is 180 deg away from the subcarrier. The control grid signal will then be at its lowest level when the grid No. 3 voltage is maximum; low plate current pulses will be obtained with a correspondingly low average value. In an actual circuit, the 3.58-MHz components are filtered at the demodulator output, and thus only the varying average level (or color signal) is left. For an in-phase condition (Fig. 5-16b), a high average plate current results, causing a low plate voltage output. (Recall that high plate current causes a large drop across the plate load resister and therefore low plate output voltage.)

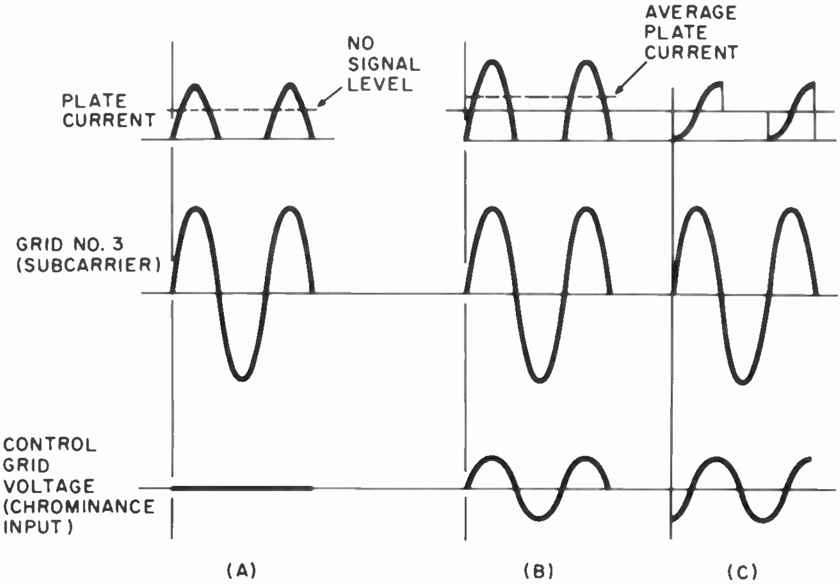

Fig. 5-16 Pentagrid detector operation with no chrominance input (a), chrominance signal in phase with the reference subcarrier (b), and out-of-phase by 90° (c).

Next, consider a 90-deg out-of-phase chrominance signal, as shown in Fig. 5-16c. During the positive swing on grid No. 3, the control grid voltage is changing from negative to positive by an equal amount. The net effect is to cause an equal decrease and increase that is relative to the no-signal condition with the average change zero. Thus, the 90-deg out-of-phase condition results in an average plate current level equal to the no-signal condition. Similarly, a 270-deg out-of-phase chrominance input signal would produce the same average plate current as a no-signal condition.

To summarize, this single demodulator stage is supplied incoming chrominance, with the phase angle dependent on the color being broadcast. Also supplied to the demodulator is the 3.58-MHz subcarrier with its appropriate phase. When both signals are in phase, a low plate voltage output results. A 180-deg difference results in a high plate voltage output. A 90- or 270-deg phase relationship does not cause a change relative to the no-signal condition. Chrominance signals of a phase other than these described will produce output voltages somewhere between the minimum (in-phase) and maximum (180-deg) voltage levels. The polarity of the output is thus dependent on the phase of the incoming chrominance relative

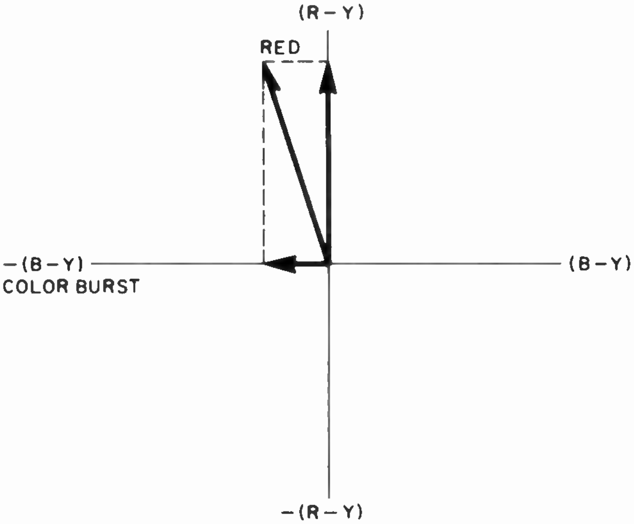

Fig. 5-17 An example of demodulating a color signal representing a red area in the scene.

to the established subcarrier phase. The amplitude of the output depends on the level of the chrominance input. Note that a large chrominance input signal on the control grid would produce more plate current flow than a small chrominance signal at the grid. This factor establishes the demodulator as both phase- and amplitude-sensitive.

A second demodulator stage would be included in a complete demodulator section. Its control grid would also receive the incoming chrominance signal, but its grid No. 3 would be fed a 3.58-MHz subcarrier with a different phase than that fed to the first demodulator. This fact explains how it is possible to develop two separate components from the single chrominance input.

A pentode can also be used in a similar arrangement, with the subcarrier applied to the suppressor grid and the chrominance signal applied to the control grid. The operation of the detector closely follows that just described.

A DEMODULATOR EXAMPLE USING (R – Y), (B – Y) AXES

Consider a receiver with its demodulator axes selected as (R – Y) and (B – Y). The (B – Y) demodulator grid No. 3 would be fed a 3.58-Mhz subcarrier with a 180-deg phase shift relative to burst. The (R – Y) demodulator would have a 90-deg phase shift relative to (B – Y). Now as-

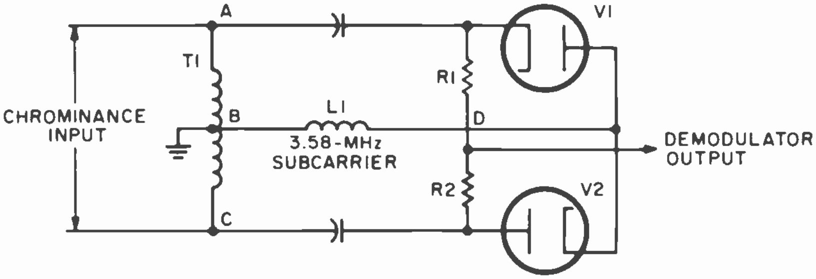

Fig. 5-18 Circuit of a balanced diode chrominance detector.

sume that a chrominance signal arrives corresponding to the color red, or about 75 deg relative to burst, as shown in Fig. 5-17. Consider the (R - Y) demodulator first. The incoming chrominance signal is only 15 deg out of phase with the (R - Y) subcarrier, and thus a rather large output change would appear from the (R - Y) stage. The (B - Y) demodulator, however, receives the same chrominance signal, which is 75 deg (close to the 90-deg situation) out-of-phase with its subcarrier, and there only a small output change would take place. Nevertheless, both demodulators would develop output. Portions of the (R - Y) and (B - Y) outputs would be combined in a separate adder stage to produce (G - Y). The three color-difference signals would then be amplified (if necessary) and applied to the color kinescope for final combination or matrixing with the Y, or luminance, signal. If all circuits are functioning properly, the (B - Y) addition to Y and the (G - Y) addition to Y would both drive the blue and green guns to cut off, and only red would be displayed.

COLOR DEMODULATOR CIRCUITS—DIODE DETECTORS

A balanced diode arrangement is shown in Fig. 5-18 to represent a single demodulator circuit. The chrominance sideband signals are applied from TI to diodes V1 and V2, connected in series. Since the transformer is centertapped, equal but opposite voltages are fed to each diode. The 3.58-MHz subcarrier is fed through LI to both diodes. Thus each diode will conduct by an amount proportional to the vector sum of the two a-c voltages applied across its cathode and plate. Of course, each diode will only conduct when its plate is positive with respect to its cathode.

Let's examine how the phase relationship between the incoming chrominance and the 3.58-MHz subcarrier affects output, as shown in Fig. 5-19. Vector AB is the chrominance signal fed to V1, BC is the chrominance signal fed to V2, and BD is the subcarrier voltage. Diode V1

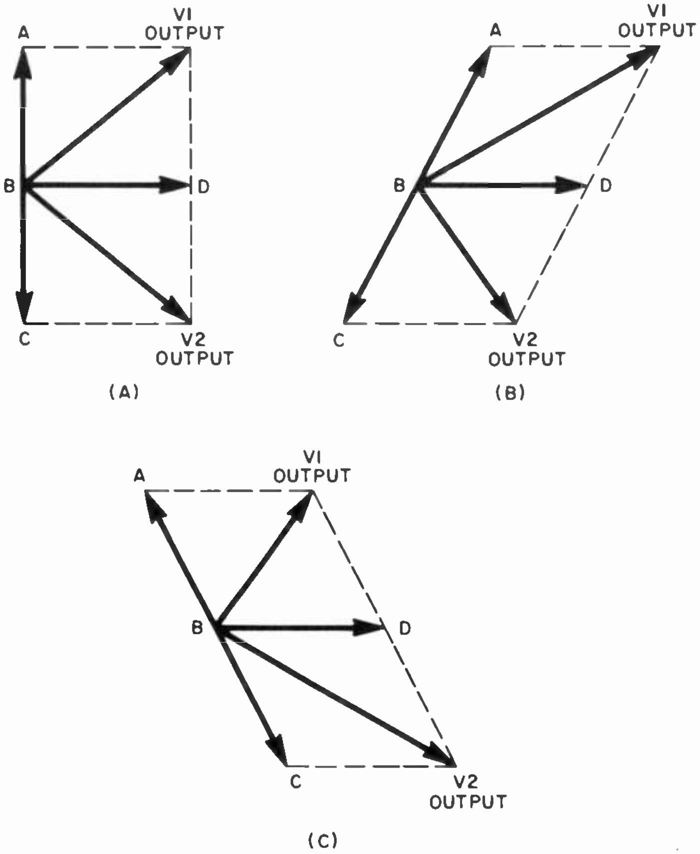

Fig. 5-19 When the center-tapped chrominance signal (AB, BC) is 90 deg out of phase with the subcarrier BD, resultant vectors V1 and V2 cancel and no output appears (a). With a phase shift other than 90 deg as in (b) and (c), V1 and V2 outputs do not cancel and a resultant output appears.

thus is affected by AB and BD, whereas V2 output depends on BC and BD. When the incoming chrominance signal is 90 deg out of phase with the subcarrier, zero output will result since both diodes will conduct equally and the total resultant will be zero (Fig. 5-19a). As the chrominance signal changes in phase, an unbalance in diode conduction will take place and output will appear (Fig. 5-19b and c).

The polarity of the output will depend on which diode conducts more heavily, a function of relative phase. Also note that the amplitude of the output is a function of the level of the chrominance input signal; the larger the input, the larger its vector (AB, BC) and the larger the output. This again demonstrates the fact that a color demodulator is sensitive to the phase (output polarity) and the amplitude (output level) of the incoming chrominance signal.

COLOR DEMODULATION—X, Z ADDERS

A popular arrangement used in some RCA receivers makes use of the X, Z axes located close to the (R - Y), (B - Y) axes. A unique three-tube adder design, using a common cathode resistor, produces the proper (R - Y), (B - Y), and (G - Y) color-difference voltages with a minimum of components (see Fig. 5-20).

The Z axis lies between -(B - Y) and (G - Y), and thus the Z demodulator output contains some -(B - Y) as well as (G - Y). Similarly, the X axis exists between (G - Y) and -(R - Y), and these components appear at the X demodulator output. Both X and Z signals appear across the common cathode resistor in the adder; the grid of the (G - Y) adder triode is grounded. The location of the X and Z axes are chosen so that a (G - Y) signal appears at this adder plate. At the (B - Y) amplifier, fed by the Z de-

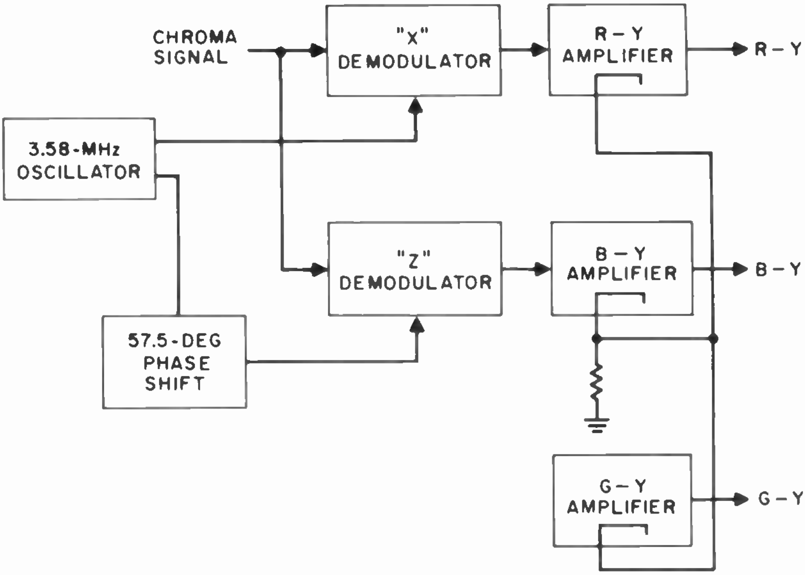

Fig. 5-20 An X-Z demodulator arrangement used to minimize components and thus receiver cost.

modulator, -(B - Y) and (G - Y) appear. But some (G - Y) appears across the common cathode resistor, and the (G - Y) components cancel in the (B - Y) adder; thus only (B - Y) appears at the plate. Similarly, the (R - Y) adder receives -(R - Y) and (G - Y) at its grid from the X demodulator. The (G - Y) component at the common cathode cancels the (G - Y) grid component, and only (R - Y) appears at the (R - Y) output.

This clever arrangement, using X and Z axes for demodulation, offer the advantages of (1) equal gain for each adder stage, (2) identical components in each plate, grid, and cathode circuit, and (3) less sensitivity to changes in component value due to aging.

SOLID-STATE DEMODULATORS

One solid-state demodulator design has chroma sidebands fed to the base of each of the two transistors (Fig. 5-21). The 3.58-MHz reference signal is applied to the emitters, with one emitter having an 80-deg phase shift by means of an L-C network.

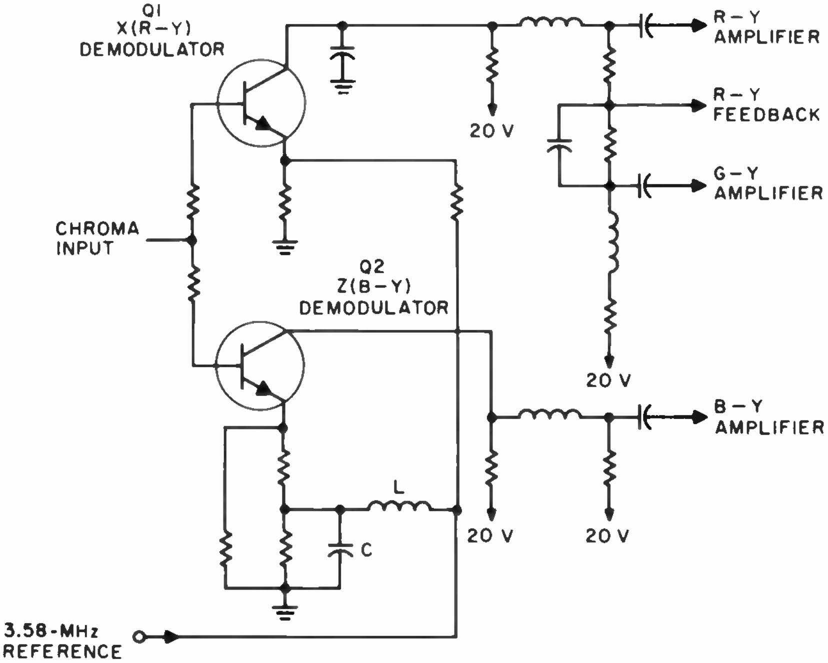

Fig. 5-21 In this solid-state color demodulator, chrominance input is fed to the transistor bases with the subcarrier reference coupled to the emitters.

The large-amplitude 3.58-MHz reference signals develop outputs at each collector load that are a function of the relative phase of the chroma signal at the base. A low-pass filter is provided at each collector to eliminate the RF components and produce the R - Y or red signal at the output of Q1 and the B - Y or blue output at Q2.

This X - Z demodulator design also includes small amounts of the R - Y and B - Y signals, which are fed back to their respective bases. Finally, a portion of the R - Y output is fed to the G - Y amplifier after being shifted in phase by L and C. This R - Y component is combined with a B - Y signal before G - Y amplification. The R - Y and B - Y demodulator outputs are routed to their proper amplifiers to be further amplified before application to the color kinescope.

MATRICES IN COLOR RECEIVERS

At the color transmitter, various arrangements of resistors are used to develop the proper I and Q signals to apply to the modulator stage. At the receiver, similar arrangements are needed to combine the chrominance signals—whether they be I/Q, R - Y/B - Y, R - Y/G - Y, etc.—with the luminance (Y) signal to produce color voltages at each gun of the kinescope. The mixing network to perform this function is called a *matrix*.

Modern receivers use a variety of demodulator axes, but none make use of I/Q, the economy of the circuitry being the key factor. Recall that the I section requires 1.5-MHz bandwidth whereas all other designs use narrow (0.5-MHz) bandwidth. Matrixing the early I/Q receivers was involved because of the following relationships between the I/Q signals and the final color voltages:

$$R = Y + 0.62Q + 0.96I$$

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

$$G = Y - 0.64Q - 0.28I$$

The proportional voltages are developed by resistive voltage dividers; the negative values are obtained with the use of phase inverters.

Modern receivers, using various demodulators ending up with R - Y, B - Y, and G - Y color-difference signals, combine these voltages with the luminance voltage (Y) at the kinescope itself. Thus, the red signal (R) is developed by applying the Y signal to the kinescope cathode while the R - Y signal is fed to its grid. Similarly, the blue and green signals are combined within the kinescope.

To compensate for differences in phosphor efficiency, different levels of Y signal are fed to each cathode. The red phosphor, being the least efficient, requires the greatest drive; the video amplifier plate load is thus highest for the red cathode. Blue is the most efficient and thus its plate load is tapped at the lowest point along the resistive divider.

A matrix is used in the demodulator section as well. Here, two demodulators are employed to develop any two of the color-difference signals, such as R - Y and G - Y. A matrix is employed to form the G - Y signal by using this relationship:

$$G - Y = 0.51\,(R - Y) - 0.19\,(B - Y)$$

It would make little difference if two other signals were selected since matrixing would easily provide the third.

THE COLOR SYNCHRONIZATION SECTION

To avoid the objectionable interference at the receiver that would result from the interaction between the 3.58-MHz chrominance subcarrier and the 4.5-MHz sound IF, the chrominance subcarrier is deliberately removed at the transmitter. However, to reproduce the correct colors at the receiver picture tube, it is necessary to provide the color demodulator circuits with a 3.58-MHz oscillator injection signal that is identical to that used at the transmitter.

To fulfill this demanding requirement, eight or nine cycles of the 3.58-MHz transmitter oscillator reference is sent on the back porch of each horizontal sync pulse and is called "burst." It is the function of the color sync section to compare this brief sample of the transmitter reference with a locally generated 3.58-MHz signal. Should any phase or frequency difference exist, a correction voltage results that is then used to correct the local oscillator until it exactly matches the transmitter oscillator characteristics. Note the similarity between the color sync section and the horizontal AFC function in a black-and-white set.

As shown in Fig. 5.22, the burst gate separates the burst signal from the composite signal. The amplified burst is then fed to the phase-detector section together with the 3.58-MHz signal developed by the crystal oscillator. The phase detector senses any difference in phase or frequency between the two and generates a d-c voltage whose level and polarity depends on the direction and degree of deviation.

The d-c voltage is then applied to a reactance tube connected across the oscillator tuned circuit where proper corrective action takes place.

In this manner, the short "burst" representing the 3.58-MHz reference signal serves to develop a continuous 3.58-MHz signal of identical phase and frequency. Finally, the 3.58-MHz oscillator is followed by tunable phase-shifting networks to supply proper injection signals to the two chrominance demodulators.

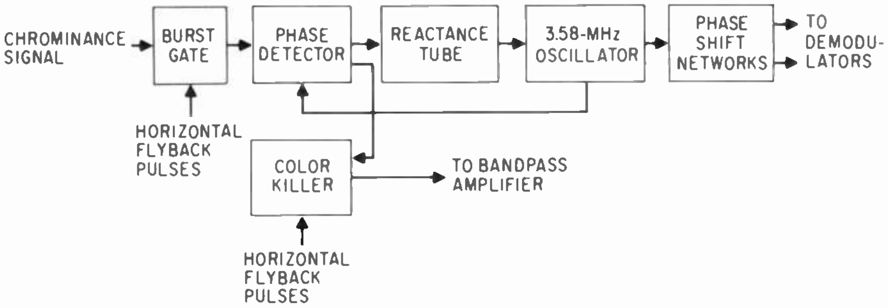

Fig. 5-22 Block diagram of the color synchronization section.

THE BURST AMPLIFIER

The burst amplifier in a color receiver separates the color burst from the composite color signal just as a sync separator in a monochrome receiver separates sync from video.

During active trace time, the burst amplifier is kept cut off. During the retrace interval, when the color burst signal is appearing on the back porch of the horizontal sync pulse, the burst amplifier is turned on. The output of the burst amplifier, or burst gate as it is sometimes called, consists of amplified color sync pulses.

A typical burst amplifier stage is shown in Fig. 5-23. Chrominance information from the video section or bandpass amplifier is fed to the control grid, which is biased from a −15-volt source. The stage is normally cut off and conducts only when the high-level, positive-going flyback pulse arrives at the control grid during retrace time. At this time, of course, color burst is present during transmission of a color program. The output of this circuit therefore consists only of burst, the eight or nine cycles of the 3.58-MHz signal that is precisely timed with the reference oscillator used for modulation at the transmitter.

SOLID-STATE BURST AMPLIFIER

Burst from the collector of a transistor bandpass amplifier (Fig. 5-24) is coupled to the base of the burst amplifier. Also fed to this base is a 15-volt, positive-going pulse from the horizontal output transformer. The flyback pulse is timed to gate on the burst amplifier during the burst interval by virtue of the delay imposed by CI and RI. Thus, only during the brief interval of flyback pulse gating can the burst amplifier conduct. Emitter bias is set by R2, C2, with some degeneration by R3 to achieve

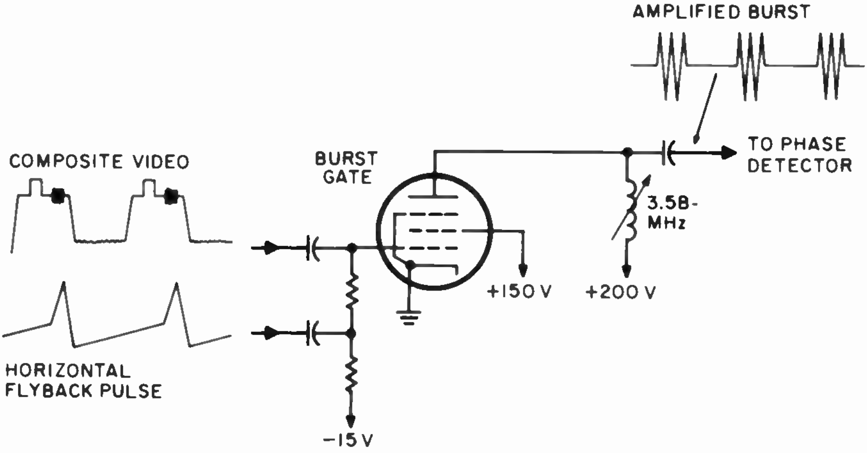

Fig. 5-23 The burst amplifier function is to separate the color burst reference from the composite video.

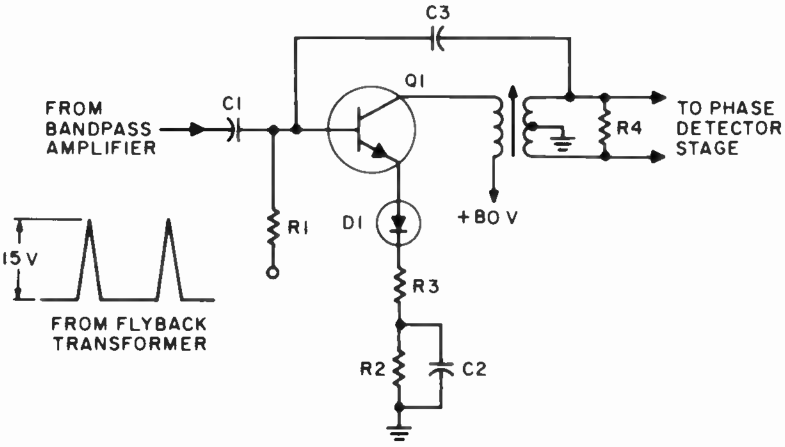

Fig. 5-24 Flyback pulses applied to the base triggers the transistor on during retrace time, allowing burst to appear at the collector output.

stability. To cancel the effect of interval capacitance between collector and base, capacitor C3 acts as a neutralization component. Diode D1 is included to prevent the developed bias voltage from exceeding the reverse emitter-base breakdown voltage.

COLOR AFPC PHASE DETECTOR

The sample 3.58-MHz signal from the transmitter (burst) is compared with the locally generated 3.58-MHz oscillator output at the color phase detector. Any difference in phase or frequency between the two creates a d-c voltage which is used to force the local oscillator to match the transmitter signal.

As shown in Fig. 5-25, burst is applied to the primary of transformer T and two equal-amplitude, opposite-phase burst voltages appear at the phase-detector diodes. The diode output elements are tied together and are connected to the local 3.58-MHz oscillator. Phasing arrangements are designed in the receiver so that the 3.58-MHz oscillator voltage is 90 deg from the burst signals.

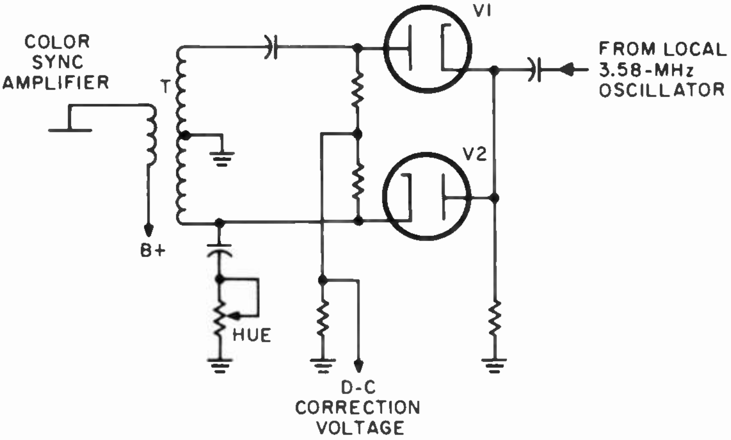

Fig. 5-25 In a color AFPC system, transmitter burst is compared with the receiver 3.58-MHz oscillator. Any error develops a voltage which is used to correct the receiver's oscillator.

Consider the "in-sync" condition (Fig. 5-26a) when the two signals being compared are identical in phase and frequency. Diode V1 receives a 0-deg burst signal on its plate and a 90-deg local oscillator voltage on its cathode, producing the resultant vector shown. During conduction of V1, the d-c voltage developed across R_L will be negative with respect to ground. Diode V2 will receive the same local oscillator voltage on its plate plus a 180-deg burst signal at its cathode to produce the resultant shown. During V2 conduction, a positive-going d-c voltage will be developed across R_L. Since both diodes produce equal but opposite d-c voltage across

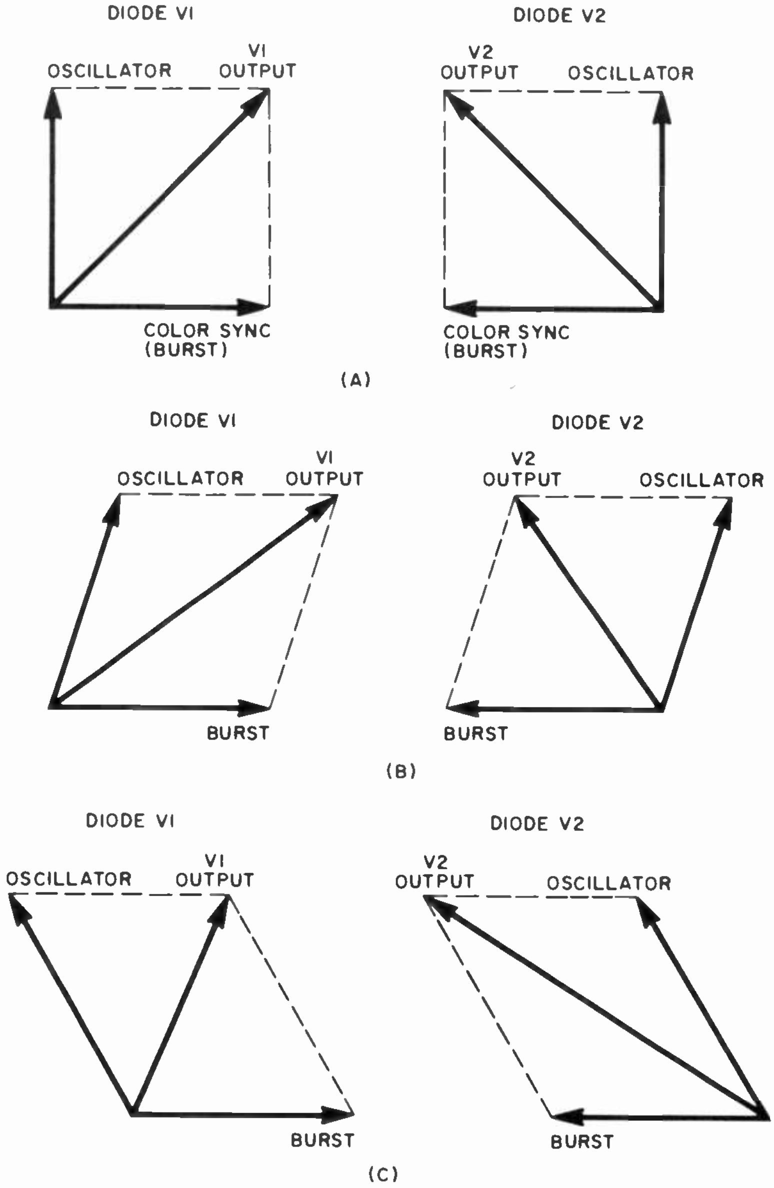

Fig. 5-26 Color AFPC operation when burst and receiver oscillator are in sync (a), when the oscillator frequency is too low (b), and too high (c).

R_L, the final correction voltage developed by the phase detector is zero, a situation which would be expected under "in-sync" conditions.

Now assume that the local oscillator drops slightly in frequency. The burst signal vectors remain unchanged, of course, and their vectors also remain the same. However, the local oscillator vectors will be less than the original 90 deg, as shown in Fig. 5-26b. Now since the resultant vector produced by each diode is slightly different, V1 conducts more than V2. Since the d-c voltages produced are unequal, with the output of V1 exceeding that of V2, cancellation does not take place. A negative d-c voltage (with respect to ground) is developed by the phase detector for corrective action at the reactance tube.

If, on the other hand, the local oscillator shifts to a slightly higher frequency, its vector representation leads its "in-sync" condition to produce the situation shown in Fig. 5-26c. Now V2 will conduct more heavily than V1 and produce a positive d-c correction voltage.

Thus it can be seen that the polarity of the correction voltage depends on whether the local oscillator shifts above or below the burst reference. The amount of d-c correction is proportional to the amount of deviation; a slight shift in frequency develops a small d-c voltage whereas a large drift would produce a higher correction voltage.

THE 3.58-MHz SUBCARRIER OSCILLATOR

A tuned-plate, tuned-grid arrangement is commonly used in color sets with a quartz crystal as the resonant element. The 3.58-MHz subcarrier oscillator output will be properly phase shifted and then applied to each of the chroma demodulator stages. Unless there is a subcarrier signal, demodulation cannot take place. A 3.58-MHz oscillator with improper phase and frequency relative to burst would result in incorrect colors on the screen of the color tube.

THE REACTANCE TUBE

By means of the reactance tube, the d-c correction voltage from the AFC phase detector keeps the local 3.58-MHz oscillator in phase and frequency lock with the transmitter burst signal. The reactance tube acts as inductor or capacitor (depending on the circuit arrangement) shunted across the 3.58-MHz local oscillator tuned circuit. The magnitude of the d-c correction voltage determines the tuning effect of the reactance tube on the oscillator.

When the 3.58-MHz oscillator drifts off its correct value relative to burst, the d-c voltage developed at the phase detector is applied to the grid of the reactance tube.

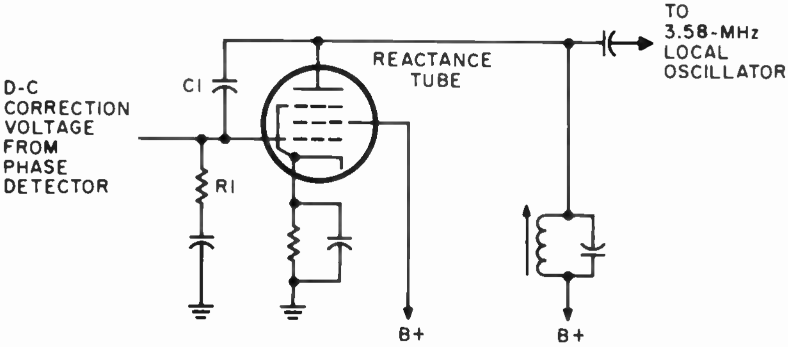

Fig. 5-27 A reactance tube arrangement which acts as a capacitor across the 3.58-MHz oscillator tuned circuit.

As shown in Fig. 5-27, C1 (2 MMF) is connected between the plate and control grid. Due to its low capacitance value, its capacitive reactance is high compared to that of R1 (22 K). The sequence of reactance tube operation is as follows:

1. A portion of the 3.58-MHz oscillator output is applied to the R1-C1 network.
2. Since XC1 is much larger than R1, the current through the network leads the 3.58-MHz oscillator voltage by 90 deg.
3. The a-c voltage drop across a resistor must be in phase with the current through it. Therefore the a-c voltage across R1 also leads the 3.58-MHz voltage by 90 deg.
4. Note that the voltage across R1 is applied to the control grid of the reactance tube. Since the grid voltage drop across R1 leads the 3.58-MHz voltage by 90 deg, so also must the reactance tube plate current. (Remember that the grid voltage and the plate current are in phase.)
5. The net effect therefore is a leading current source shunted across the 3.58-MHz oscillator. This is equivalent to a capacitor (which draws a leading current) shunted across the 3.58-MHz oscillator.

The 3.58-MHz oscillator is adjusted to exactly match burst when zero d-c correction voltage is at the reactance tube grid. If the 3.58-MHz oscillator drifts, a d-c correction voltage at the reactance tube grid changes the amount of leading current drawn, an action equivalent to changing the value of the shunting capacitor. For example, if the d-c correction voltage changes from zero (in sync condition) to some positive value due to a rise in frequency, the reactance tube will draw more current, effectively increasing the capacitance value across the 3.58-MHz oscillator. The oscillator will therefore be lowered in frequency until exact lock with the 3.58-MHz reference burst is established. Similarly, a decrease in subcarrier oscillator frequency would develop a negative d-c correction voltage to lower the reactance tube plate current. This would be equivalent to less capacitance and would allow the oscillator frequency to rise until the precise value is reached.

AUTOMATIC TINT CONTROL

A viewer may tolerate an orange-tinted apple or a greenish banana on his color set, but he will be annoyed enough to get up and adjust the hue or tint control if his favorite ballplayer's face is purple. Flesh tones are critical since the viewer is constantly aware of the proper hue and his eyes are highly sensitive to this color.

Incorrect flesh tone appearance can be due to subjective adjustment of color cameras at the studio, variations in video tape equipment, and/or differences in color film used by movie companies.

One approach to automatic color tint correction is RCA's Accutint. To review the I and Q signals for one moment, recall that they appear in vector form as shown in Fig. 5-28a, with burst at zero degrees. The I vector falls at 57 deg, or orange, the Q signal at 147 deg, or magenta, and -Q at 327 deg, or yellow-green. Flesh tones are a pastel shade of orange, and thus the I signal is critical.

Should burst be displaced for some reason, all vectors are effectively rotated. Thus flesh tones could turn green or magenta depending on the direction of shift. The effect of the vector rotation is the same as adding a component of the Q signal. For example, if burst is shifted counterclockwise, as shown in Fig. 5-28b, the effect is the same as adding -Q to the I vestor, producing a greenish tint to the flesh tones. In the Accutint system Q output is deliberately reduced by half by shifting the R - Y demodulator axis closer to the I axis, and the B - Y demodulator axis closer to the I axis.

With this arrangement any transmission errors that would have a marked effect on the I axis position have considerably less effect. Another way of analyzing this scheme is that the receiver becomes less sensitive in the region of flesh tones.

A disadvantage of this approach is the occasional viewer complaint that dark greens appear blue and light greens appear yellow. Grass and trees may show up slightly bluish at times, but this is considerably less annoying than improper flesh tones.

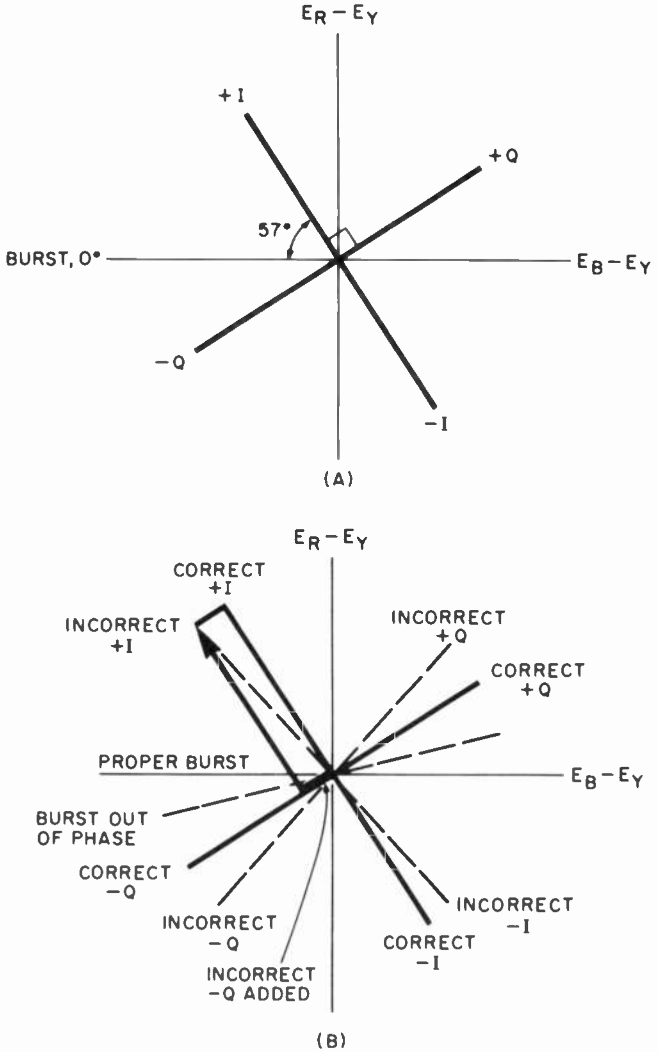

Fig. 5-28 The I and Q axis, correctly shown in (a), are effectively shifted in the receiver when burst is changed in phase, as in (b).

COLOR SYNC SYSTEM USING CRYSTAL RINGING

A less expensive approach to color sync makes use of a crystal ringing circuit to provide the exact 3.58-MHz signal required for the demodulators (see Fig. 5-29).

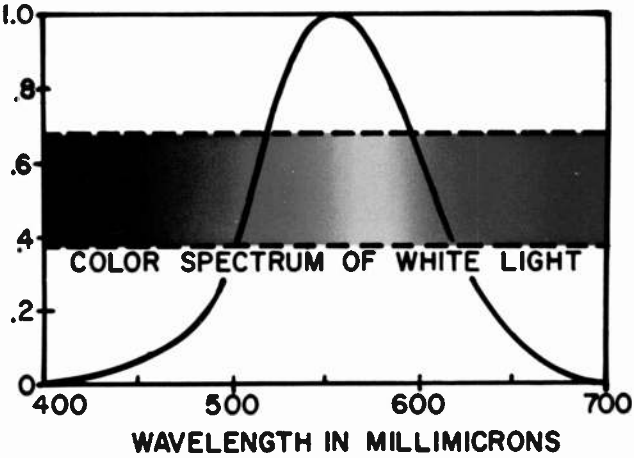

Plate I The color spectrum.

Plate I is reprinted from *Fundamentals of Television*, by Walter H. Buchsbaum, Hayden Book Company, Inc. (John F. Rider Publisher).

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Plate II Color scene with proper adjustment of the control resulting in normal skin tones.

Plate III Color screen showing purplish skin tones caused by a different adjustment of the control.

Plate IV Color scene showing greenish skin tones caused by yet another adjustment of the control.

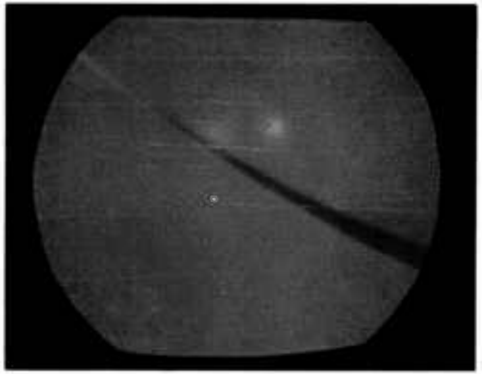

Plate V Effect of convergence on purity, showing a well-converged (center dot as seen by a double exposure) pure red field.

Plate VI Effect of convergence on purity, showing the lack of purity (the purple streak in the middle) when only convergence was misadjusted (the red dot moved over).

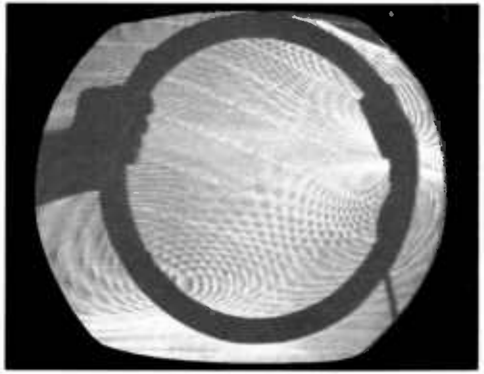

Plate VII Effect of degaussing coil on raster.

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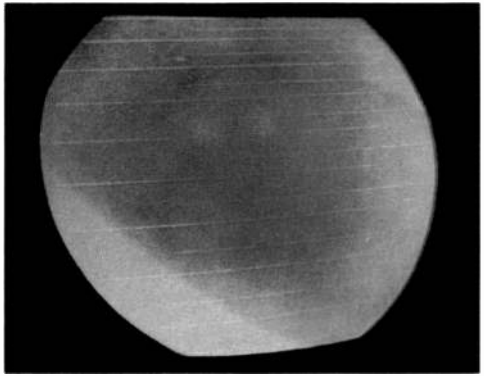


Plate VIII Complete lack of purity, with only the red gun operating and both yoke and purity magnets misadjusted.

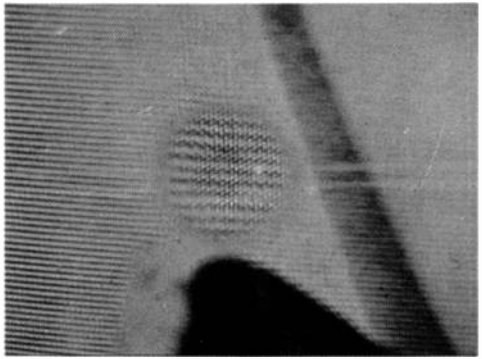
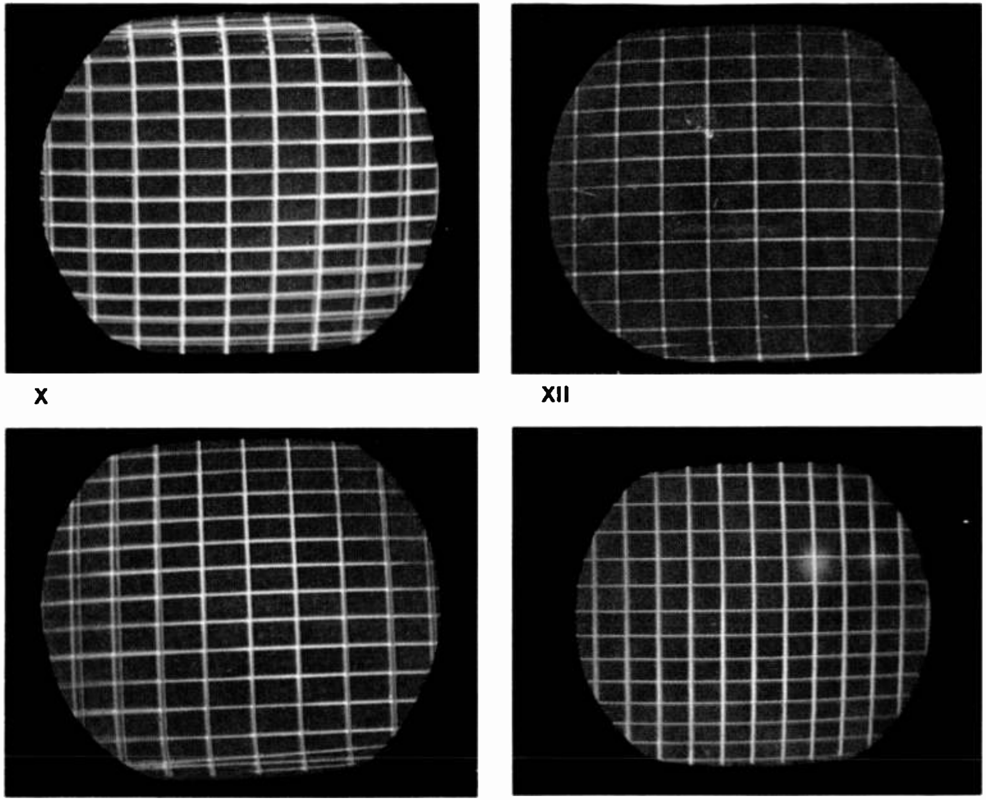


Plate IX Phosphor dots made sharp under magnifying glass by use of cellophane tape.



X

XII

XI

XIII

Plates X-XIII Effect of the cross-hatched pattern of dynamic convergence adjustments, the first photograph showing the center only converged, and the others (top-to-bottom, left-to-right) successive adjustments bringing one area after another into proper convergence.

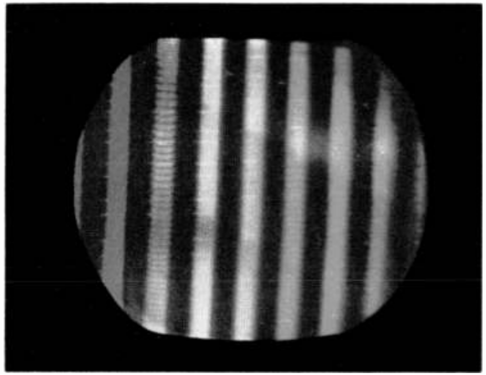


Plate XIV CRT screen with rainbow generator display.

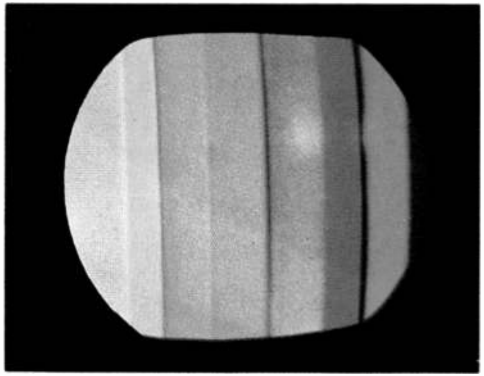


Plate XV Normal colors produced by an NTSC color bar generator, their order being white, yellow, cyan, green, magenta, red, and blue.

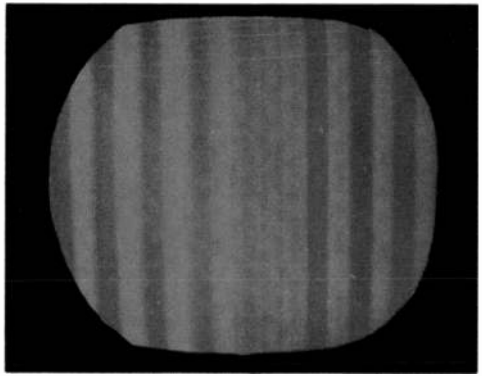


Plate XVI CRT screen with color bar signal applied and green and blue guns shorted (correct phase present).

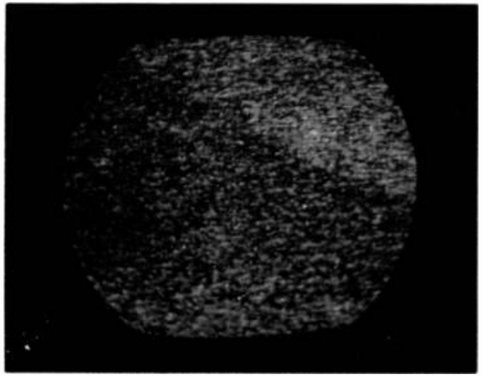


Plate XVII Confetti, or colored snow (color killer inoperative).

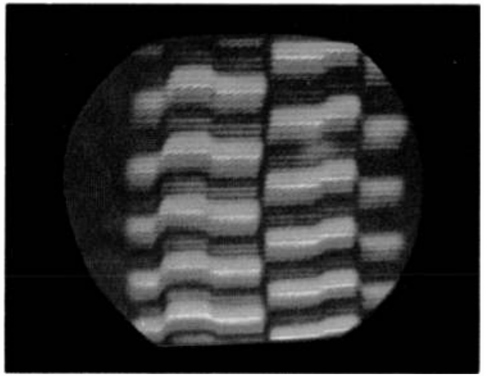


Plate XVIII Scene out of color sync –the barber pole effect.

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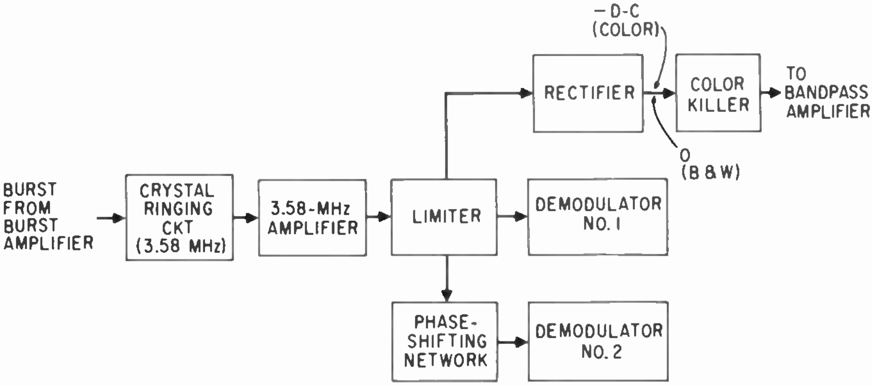


Fig. 5-29 In crystal ringing design, color sync occurs when each horizontal sync pulse causes the high-Q 3.58-MHz oscillator circuit to oscillate or "ring."

Color burst, appearing during each horizontal scan interval, is amplified and fed to the input of a 3.58-MHz quartz crystal. The sharp pulse causes the crystal to "ring" or oscillate; the high-Q, low-loss characteristic of the crystal permits it to oscillate with only slight amplitude reduction until the next burst pulse arrives. A trimmer capacitor is included in the crystal circuit to permit adjustment for the precise 3.579545-MHz frequency desired.

An amplifier to increase the 3.58-MHz crystal output is followed by a limiter to eliminate the slight amplitude fluctuations caused by the ringing arrangement. The limiter output may be fed directly to one of the two demodulators; the second demodulator would receive its 3.58-MHz input from the limiter, followed by a suitable phase-shifting network.

Provisions for a color killer are relatively simple. Part of the ringing circuit output is fed to a rectifier which develops a negative d-c output when input is provided. During color reception, burst appears and causes the crystal to oscillate, providing output from the limiter. Sufficient negative voltage is developed to cut off the color-killer stage, thus allowing the bandpass amplifier to operate. During black-and-white transmission, no burst is available to initiate crystal ringing, no output appears from the limiter, and no bias is developed to cut off the color killer. Thus the color killer cuts off the bandpass amplifier.

COLOR TINT AND SATURATION CONTROLS

The color sync section in the receiver contains a tint or hue control to act as a master phase control. This viewer control allows for variation in personal preference relative to key colors, such as flesh tones. It also makes it possible for the viewer, without the aid of a service technician, to correct for a slight phase shift in the color burst section due to component aging or changes in d-c voltages due to line-voltage fluctuations. (See Color Plates II, III, and IV for the effect of the tint control on flesh tones.) The tint control is generally associated with the color burst tuned circuits and varies the phase of the arriving transmitted burst before application to the AFPC system where it exercises final control of the 3.58-MHz oscillator. In other designs, the phase of the corrected 3.58-MHz oscillator is varied by this control. In either case, the end result is to shift the phase angles of the 3.58-MHz reference signals applied to the chrominance demodulators and thus change the colors reproduced on the screen. The saturation or color control varies the intensity or vividness of color in the same manner as the contrast control sets the intensity of a black-and-white picture. This control is generally placed in the bandpass amplifier stages or at the input to both demodulators.

HIGH-VOLTAGE REGULATION FOR COLOR RECEIVERS

The horizontal deflection power for a color receiver averages about 25 watts, with 25 KV at the picture tube when the beam current for the three guns totals 1 ma. As the brightness level of the televised scene varies, the beam current demand also varies and causes the d-c high voltage to vary likewise. Of course, as high voltage varies, picture height and width also change.

Although black-and-white sets also experience such variations, color receivers require circuitry to maintain constant high voltage. First, the condition is less critical in monochrome sets since beam current is lower (perhaps 100 microamps) and high voltage is generally less than 20 KV. Thus loading variations are less pronounced. Second, and very important, beam convergence—both static and dynamic—in a color receiver is precisely adjusted at a specified high voltage. If beam current demands were not smoothed by some type of regulator, the picture size would vary and proper convergence would appear and disappear to the considerable annoyance of viewers. Also consider the affects of flyback transformer pulse variations on such circuits as AGC and sync, where the pulse levels are used as reference points. So some scheme must be included in a color receiver to regulate high voltage. Two popular approaches are (1) shunt regulation and (2) bias feedback.

HIGH-VOLTAGE SHUNT REGULATORS

Basically, a shunt regulator is a tube placed in parallel with the color CRT across the d-c high-voltage output. Together, their combined current demands determine the load across the high-voltage transformer and thus the value of the d-c high voltage.

As the brightness of the scene varies, the individual current through each will change, but the combined current will remain essentially constant, thus maintaining a steady d-c level.

As shown in Fig. 5-30, a 6BK4 shunt regulator is connected to the high-voltage power supply, as is the picture tube anode. The cathode of the 6BK4 is tied to B plus while the grid is connected to B boost.

Now, assume that the televised scene suddenly becomes dark; the picture tube beam current decreases, causing the high voltage to rise. However, B boost immediately increases also as does the conduction of the 6BK4, thus countering the lower current demand of the picture tube. Since the high-voltage section is thus unaware of any change in total current demand, high voltage is unchanged.

Similarly, if a scene becomes very bright, picture tube beam current rises, causing B boost to drop. The 6BK4 conducts less, and again the total current drain is essentially constant.

The manufacturer's specified high-voltage level is set by adjusting the 6BK4 bias, using R1 with the brightness turned to minimum. A calibrated d-c high-voltage probe and voltmeter is placed across the high-voltage output. As this setting is performed, beam current is zero, and the regulator tube appears as the total load across the high-voltage supply. After the setting is made, the brightness control is varied until a fairly bright raster appears. The high-voltage reading should not vary by more than 5 percent from its initial setting.

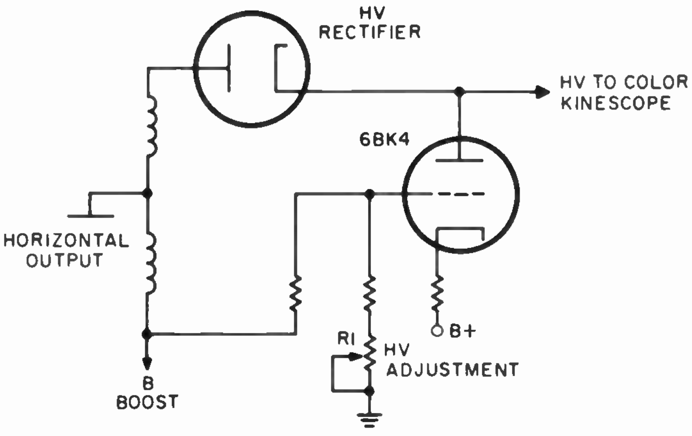


Fig. 5-30 A shunt regulator's function is to maintain a constant high-voltage output despite loud fluctuations due to brightness changes in the picture.

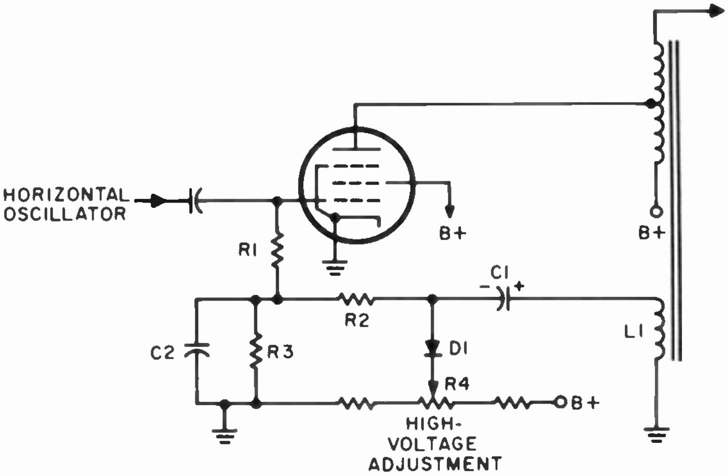


Fig. 5-31 A bias-feedback circuit permits high-voltage regulation to be accomplished at the horizontal amplifier input rather than at the high-voltage stage.

BIAS FEEDBACK HIGH-VOLTAGE REGULATORS

The shunt regulator circuit maintains constant high voltage by keeping a constant load across the flyback transformer. Recent designs make use of a feedback arrangement to vary the horizontal amplifier output according to load demands. At high brightness levels, for example, beam current is high and the horizontal deflection system delivers increased output; when brightness drops, a feedback arrangement lowers the horizontal output since the beam current needs are reduced.

As shown in the simplified schematic of Fig. 5-31, winding L1 in the flyback transformer samples a portion of the high-voltage output pulse. The feedback circuit–consisting of L1, C1, R1, R2, the horizontal output tube, and the flyback transformer T1–includes diode D1. The positive-going pulses across L1 are applied to D1 in series with C1 and C2. A threshold voltage setting R4 determines when D1 will conduct.

When the positive pulse across L1 is sufficient to cause D1 to conduct, C1 charges to a negative voltage (polarity as shown). This negative voltage is applied to the grid of the horizontal output amplifier via R2, R1, R3, and C2. Conduction of the output stage–and thus width and high voltage–are determined by the amount of negative bias developed across C1.

Assume that the brightness of a scene suddenly rises. Increased beam current would attempt to lower the high voltage caused by the increased load on the flyback. The pulse output across L1 would drop, reducing the charge developed across C1, and lowering the negative bias on the output tube. The amplifier tube current would increase, thus meeting the immediate demand for a brighter scene. Similarly, a dark scene would permit high voltage to increase, producing a larger pulse from L1 which would develop a larger negative voltage from C1 to the amplifier grid; less conduction would result since less deflection energy is required at low brightness levels.

The high voltage is set by means of R4. When it is set so that a rather low positive voltage is placed on the diode (D1) cathode, the diode conducts heavily, thus allowing C1 to charge to a rather high negative voltage, limiting conduction. High voltage is not at its peak level under this condition. As R4 is varied to apply more positive voltage to the cathode of D1, C1 charges less, the bias on the output stage is lowered, and high voltage increases.

THE AUTOMATIC DEGAUSSING CIRCUIT

Modern color sets include built-in, automatic degaussing to maintain color purity and convergence regardless of set movement relative to the earth's magnetic field. Obviously owners of color portables cannot be expected to have a technician perform a purity procedure each time the set is moved from one room to another.

When the set using the circuit shown in Fig. 5-32 is first turned on, the high initial charging current for the low-voltage filter capacitors flows through the series-parallel arrangement. Thermistor T is high in resistance (about 120 ohms), and about 60 volts a-c appears across the degaussing

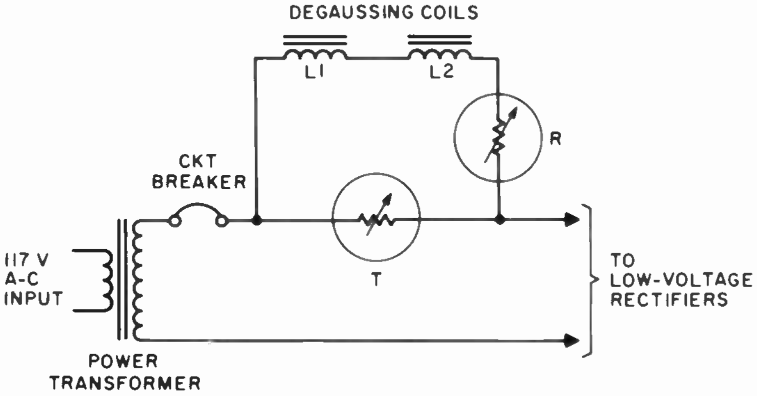


Fig. 5-32 Each time the color receiver is turned on, this degaussing circuit automatically demagnetizes the picture tube.

coil (L1 and L2) and varistor R, whose resistance is low at this time. A high a-c current flows through the degaussing coil, setting up a strong a-c magnetic field to degauss the set. After a brief time, the current through T heats it, causing its resistance to drop and thus reducing the a-c voltage across the degaussing coil and R. In the meantime, the resistance of varistor R is increasing because of the current flowing through it, and the a-c degaussing current is thus further lowered. In a matter of seconds, the degaussing coil experiences an initial a-c surge of 60 volts at about 2 amps to its steady value of less than 1 volt at less than 1 ma.

With this novel arrangement, the set is automatically degaussed each time it is turned on, with the action taking place before the raster has time to be developed on the screen.

Review Questions

1. Name one advantage and one disadvantage, at present, for the use of integrated circuits in color TV receivers.
2. Is the RF tuner bandpass response for a color TV set more critical than that of a black-and-white set? Explain.
3. What is the purpose of automatic fine tuning (AFT) in a color TV receiver?
4. Explain the purpose of a "delay line" in a color TV receiver.
5. What is the function of the bandpass amplifier stage?
6. Should the color killer be on or off when a color program is being received? Explain.
7. What type of demodulation is used to recover the chrominance information from the subcarrier?
8. Is there just one set of demodulation axes that can be used in a color TV receiver? Explain.
9. State the purpose of the color synchronization section of a color TV receiver.
10. What signals are compared in a color APC section?
11. Why is a high-voltage regulator needed for a color TV receiver and not a black-and-white receiver?

6

The Color TV Picture Tube

THE SHADOW-MASK PICTURE TUBE

Although a variety of color-television picture tubes have been developed and demonstrated, the shadow-mask tube is the type used almost exclusively today. Almost any color, as well as white and shades of gray, can be obtained with this tube by additive mixing of the proper amounts of red, green, and blue light.

The screen of a 21-inch shadow-mask tube contains over 1,000,000 red, green, and blue phosphor dots, each precisely located. In the neck of the picture tube (Fig. 6-1) are three electron-gun assemblies, each quite similar to the ones found in black-and-white picture tubes. One electron gun is driven from an electrical signal corresponding to "red" information, the second gun from "green," and the third gun from "blue." At normal viewing distance, the eye cannot perceive the tiny, individual dots but sees instead a picture whose color is determined by the combined intensity of all the red, green, and blue dots at that particular moment.

To allow each gun's electron beam to strike only its respective dots, a perforated metal plate (the shadow mask) is located slightly behind the screen, as shown in Fig. 6-2. Each hole in the shadow mask is centered over one red, one green, and one blue dot; the three phosphor dots associated with each shadow-mask opening is called a *triad.* Thus there are over 350,000 shadow-mask holes in a 21-inch tube.

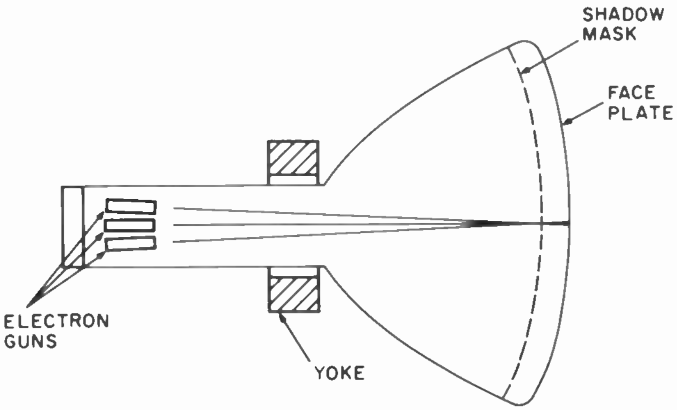


Fig. 6-1 A shadow-mask picture tube contains three electron guns, one for each of the primary colors. A shadow-mask arrangement of precisely located holes is mounted between the guns and the screen. Every hole in the shadow-mask is accurately located over a trio of phosphor dots, one for each primary color.

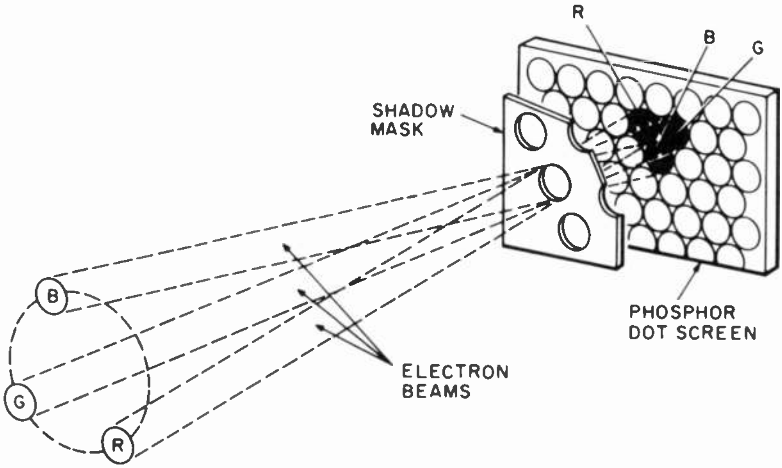


Fig. 6-2 The three electron beams pass through one hole in the shadow mask at different approach angles and strike their associated phosphor dots.

CONSTRUCTION OF THE SHADOW-MASK TUBE

The shadow mask is made from a thin sheet of metal coated with a light-sensitive material that hardens when light strikes it. A master dot pattern is placed between this sheet and a source of ultraviolet (UV) light so that the areas where holes are to appear are unexposed (Fig. 6-3). When the sheet is then washed, bare metal exists where the holes are to be located. The sheet is then dipped into an acid bath, and the acid etches holes in the shadow-mask sheet. Finally, pressure is applied to the flat

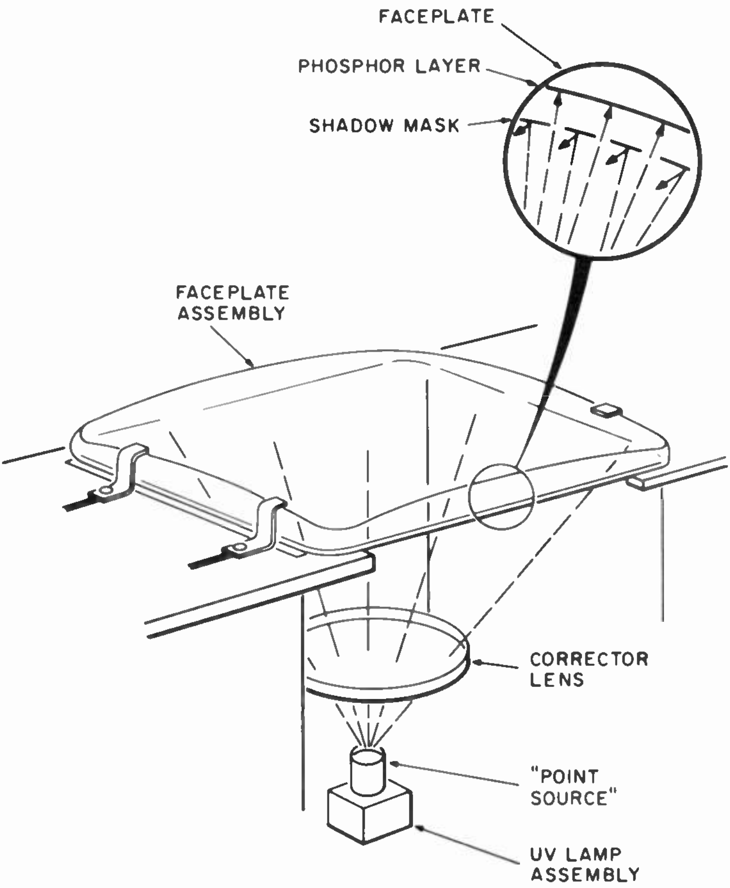


Fig. 6-3 A point-source of ultraviolet light is projected through a master dot pattern to a thin metal sheet coated with light-sensitive material; this is an early step along the production cycle of a color picture tube.

sheet to force it into a spherical shape to match the contours of the picture tube screen.

The phosphor dot arrangement for each picture-tube screen is developed using the specific shadow mask that will later be mounted in that tube. Red phosphor is deposited on the tube faceplate, and the shadow mask is carefully placed in its intended position relative to the faceplate. A point source of UV light is placed in the precise position where the red electron gun will be located in the tube. The point source of UV light exposes tiny areas on the red phosphor. The shadow mask is carefully removed, and the unexposed phosphor material is washed away, thus leaving those holes which will be energized by the red electron beam. (Note that the "red" electron beam signifies an electron beam that strikes the phosphor dots that produce red light, not a beam of red electrons!)

The shadow mask is carefully replaced in its original position; the point source of UV light is moved to where the green electron gun will be located; and the faceplate is covered with green phosphor and the process is repeated. After cleaning, the process is again repeated for a blue phosphor, locating the point source of UV light where the blue electron gun will be mounted.

In this manner, over 1,000,000 separate dots of the three primary colors will be very accurately deposited on a 21-inch picture tube face. The face is then baked; a fine aluminum film is sprayed over the back surface of the dots; the shadow mask is accurately set in its proper position; and the tube face assembly is sealed to the funnel. Finally, the three-electron gun structure is carefully set in place in the neck of the tube, and the entire tube is sealed and then evacuated.

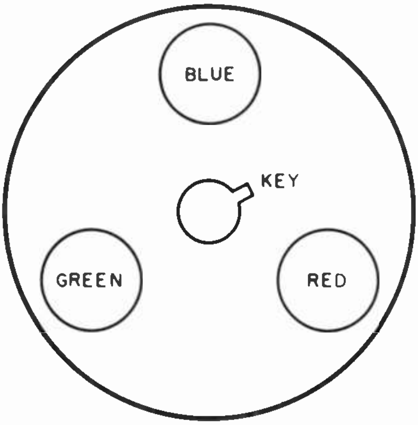


Fig. 6-4 The blue electron gun assembly is located at the top of the three gun structure when viewing the tube from the rear.

THE THREE-ELECTRON GUN ASSEMBLY

The tricolor shadow-mask tube contains three electron guns, each quite similar to that found in a black-and-white picture tube. The three guns are arranged 120 deg from each other relative to a center line through the neck of the tube, as shown in Fig. 6-4. A view of the picture tube assembly from the rear reveals the blue gun on top, with the red and green guns as shown.

The three gun assemblies are slightly tilted toward the screen of the tube so that the three energized beams will meet at one point at the center of the screen when there is no deflection energy.

COLOR PURITY–LIGHTING THE CORRECT PHOSPHOR

Manufacturing tolerances for color tubes are quite critical, and setup adjustments must be carefully performed to produce a high-quality color picture. With more than a million phosphor dots deposited on a screen, ready to display colors when bombarded by electron beams, it is obviously critical that each of the three electron gun beams be directed to the correct phosphor dot elements. Electron beams striking incorrect phosphor dots in improper locations on the picture tube screen would produce receiver performance of an objectionable quality.

Each individual electron gun must somehow succeed in directing its beam so that only its associated phosphor dots are bombarded. In other words, if the green and blue electron guns are deliberately biased to cut off, and the red electron gun is turned on, the beam from this gun must pass through each hole in the shadow mask and strike only the red phosphor dot of the appropriate triad. Doing so, it will achieve the proper purity, as shown in Fig. 6-5. To accomplish this objective, the approach angle of the beam as it leaves the gun assembly must be exactly identical to the approach angle of the light beam during the dot formation process. If the approach angle is incorrect, the beam may excite the blue or green phosphors in the triad, and improper colors will result.

Since it would be uneconomical to attempt to locate each gun in the three-gun assembly within very exact tolerances, a scheme for readjusting the angle approach using a magnetic field is used. A purity magnet, similar to the centering magnet assembly in a black-and-white set, is placed over the three-gun assembly, and proper adjustment of its field strength and the direction of the applied field enables the technician to control the beam angle approach for proper purity during receiver setup.

To check for proper purity, first the green and blue guns are biased off and the red biased on. The entire screen of the tube should appear red. The raster produced by this single gun is called a *field*. Next, a 10-power magnifier is used to examine individual dots closely at various areas over

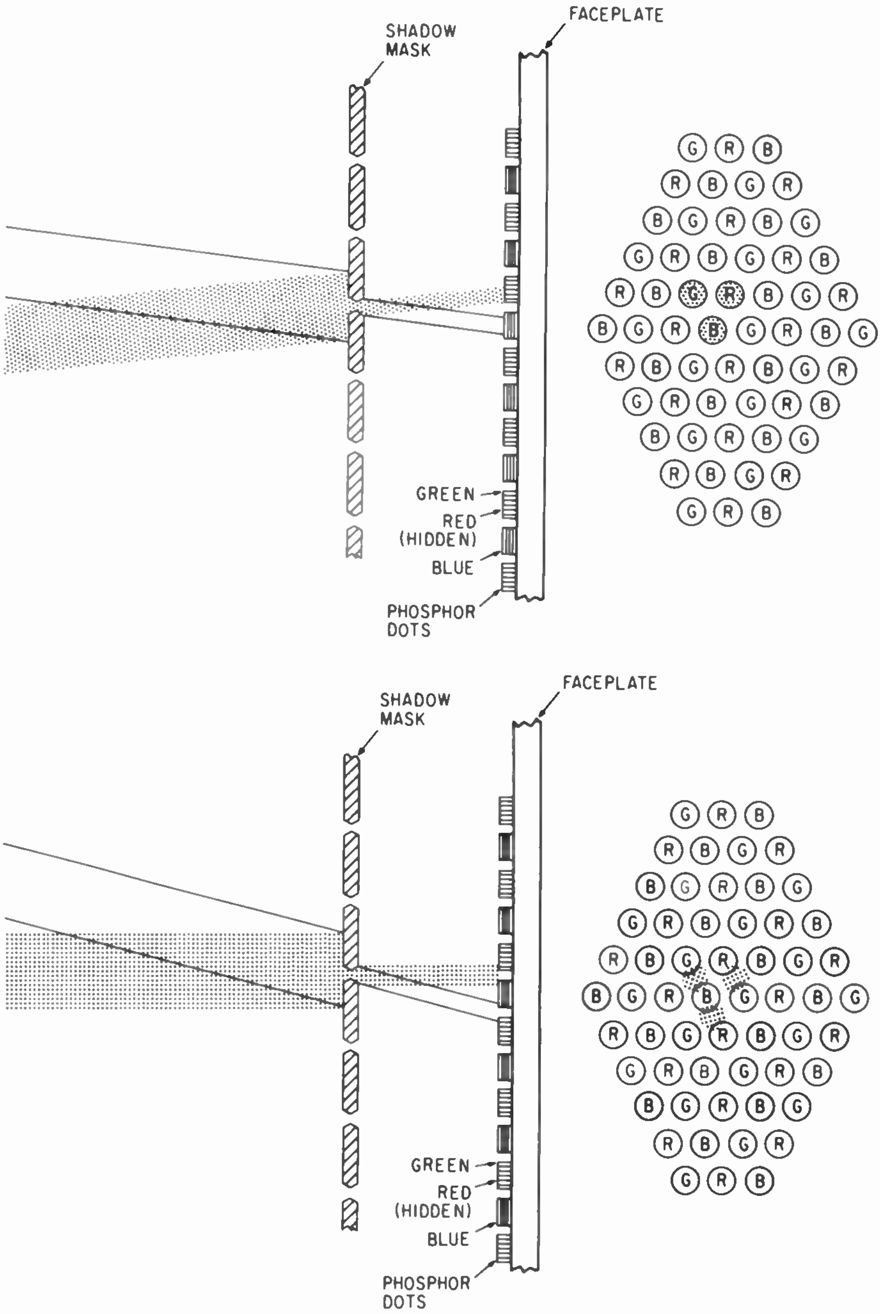


Fig. 6-5 For proper purity, each beam must pass through a hole in the shadow mask and strike its proper phosphor dot, as in (a). An error in approach angle shown in (b) causes the beam to strike its dot plus an adjacent dot resulting in poor purity.

the screen. Each red dot should be hit exactly in its center while adjacent blue and green dots are left completely untouched. A slight error in beam-angle approach would allow the red beam to hit red phosphor dots off center, producing less than full light output. A large error would enable the red beam to strike a portion of the green or blue dot as well as the red and thus display an off tint.

After the red screen is examined, the blue gun is biased on, the red and green guns are biased off, and the blue screen is observed for traces of color contamination. Finally, the brief process is repeated for a check of the green screen.

Improper purity, or traces of color other than that of the single gun biased on, are corrected by a color purity adjustment procedure to be described later.

OBSTACLES TO PERFECT PURITY

Proper purity is achieved when the electron beam passes through the hole in the shadow mask and hits its dot exactly on center. This objective is termed proper beam *landing* and is achieved only when the beam passes through its deflection center and travels to the screen in the same manner as the light source used to expose the screen during fabrication. The position of the deflection yoke and adjustment of the purity magnet are both important.

The deflection yoke position along the axis of the picture tube establishes the deflection center. Notice that the beam landing at the center of the screen is unaffected by yoke position.

Stray magnetic fields from nearby power transformers or chokes on the chassis, as well as minor variations in alignment and placement of the three electron gun assemblies during tube assembly, contribute to incorrect purity.

The earth's magnetic field is another influence on beam landing. Fortunately, the component of the earth's magnetic field that acts in a horizontal plane, the compass field, can be corrected by the purity magnet.

POSITIONING THE DEFLECTION YOKE FOR PURITY

Purity at the outer areas of the screens is greatly affected by the deflection yoke setting, which establishes the deflection center for each beam (Fig. 6-6). When the deflection yoke is properly positioned, the electron beams travel through the yoke field and are deflected at the proper angle to strike their respective dots. If the yoke is tampered with and misplaced, the beams begin their deflection at the wrong point and thus arrive at the incorrect dots when they reach the screen.

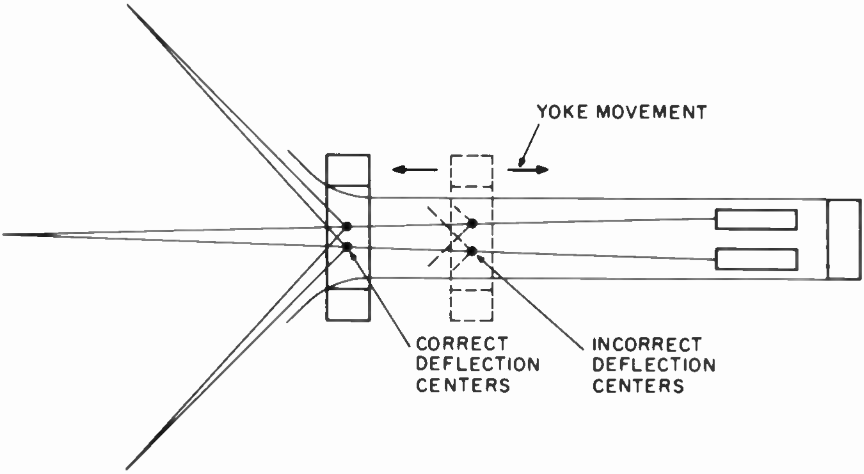


Fig. 6-6 Edge purity is achieved by sliding the yoke back and forth until the proper deflection approach angle is obtained.

To perform the deflection yoke adjustment, the green and blue guns are biased off and the red guns biased on. The yoke mounting screws are loosened, and the yoke is moved as far to the back of the tube neck as possible. The purity magnet is then adjusted until a red area is visible over the center of the screen; improper colors off center are ignored. The yoke is slowly moved forward until the entire screen, or "field," is pure red, and the yoke mounting screws are tightened. Once the red field is properly adjusted, the blue field is checked, and slight touchups are made if necessary. Finally, the green field is observed. In each case, two guns are biased off while the electron gun for the field under scrutiny is turned on.

When proper screen purity is observed for each individual field, all three guns can be biased on and individually set for the proper brightness level until a pure white raster, devoid of color contamination in any portion of the screen, is obtained.

THE COLOR PURITY MAGNET

Proper purity in the center area of the screen is obtained by use of a purity magnet assembly that is similar to the centering magnet assemblies on black-and-white sets.

Two identical ring magnets are mounted together so that they can be rotated relative to one another; the entire assembly, when placed over the neck of the picture tube, can be rotated as a unit around the neck. Each magnet has a square and a round tab representing its north and south poles. When the north pole of one ring is rotated directly behind the south pole of the second ring, the net magnet field is zero, and no force is exerted on the three electron beams. When the tabs are arranged so that both north poles are adjacent to one another, maximum flux is developed and maximum force will be applied to the three electron beams. As the tabs are rotated in positions other than complete cancellation or full reinforcement, magnetic forces from zero to maximum can be obtained. Movement by the beams resulting from the magnetic flux is illustrated in Fig. 6-7.

In addition to changing the magnetic strength by tab rotation, the direction of the applied flux can be varied by rotating the entire purity assembly as a unit. The electron beams will be moved at right angles to the magnetic flux lines, as shown.

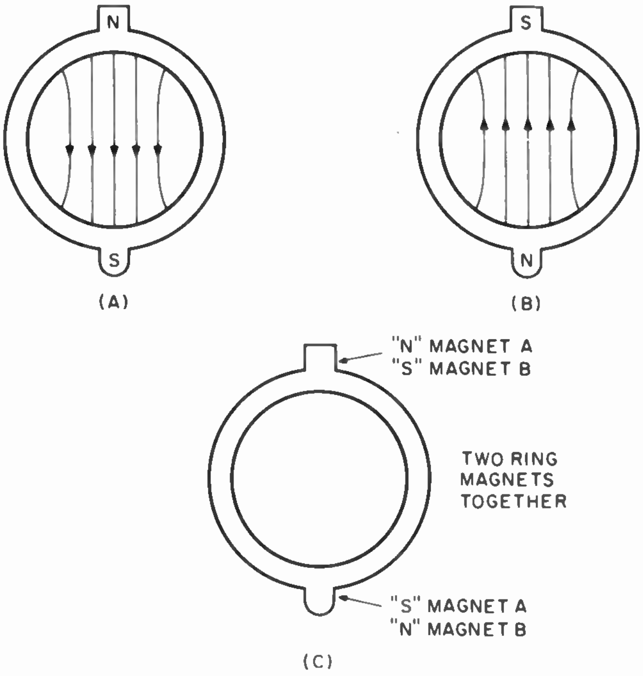


Fig. 6-7 Reversing the position of the north pole of the purity magnet assembly in (a) to that of (b) reverses the force exerted on the three electron beams. When both rings of the purity assembly are arranged so that their magnetic fields cancel, as in (c), no force is exerted on the beams.

The purity magnet is mounted behind the deflection yoke, close to the rear of the tube, and controls beam landing on the phosphor dots in the center of the screen where the yoke setting has no effect.

CONVERGENCE—REGISTERING THREE PICTURES INTO ONE

Successfully setting up three pure and individual rasters produced by three separate electron gun assemblies is the first step to a satisfactory color picture. But it is not enough by far. With three separate electron gun assemblies and three distinct phosphor dot regions, three separate rasters and pictures can be formed.

What has so far been achieved can be described simply in the following manner. Three individual pictures can be displayed on the screen, with each of the three guns properly driven by the receiver circuits. The electron beam representing the red picture information will produce a red scene of, say, a studio setting, with appropriate bright and dim regions on the screen. Similarly, the blue and green guns will display their particular scenes in their color on the screen. The net result: three separate displays, in three colors, of the same studio setting.

Assume three separate transparencies of the letter A (Fig. 6-8), with each transparency a different color. If the three transparencies are care-

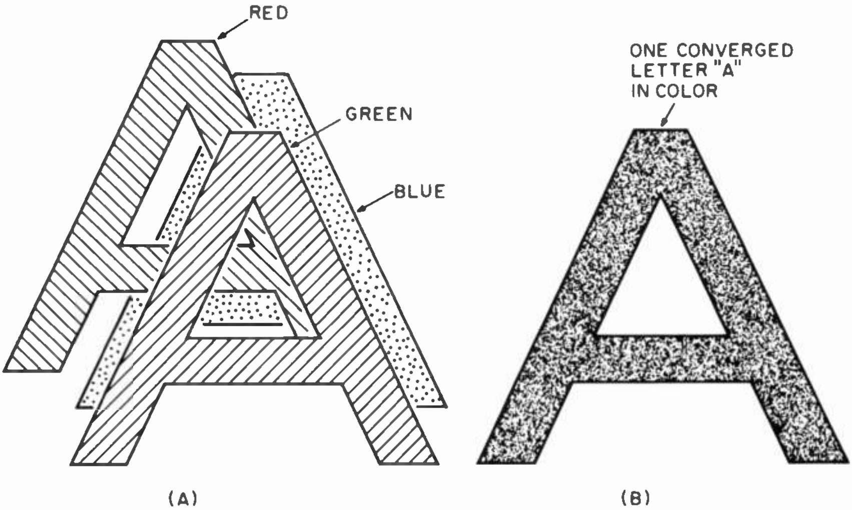


Fig. 6-8 When the three beams are misconverged, the display of the letter "A" will be as shown in (a). Proper convergence procedure will correct the misregistration until the proper display (b) results.

fully aligned, or "registered," so that all elements line up and overlap properly, an intelligible A will be observed. Consider the confusion, however, if the three transparencies were to be combined with little attention to their relative alignment!

Thus, what is known as *convergence* in a color set involves the precise registration of the elements of all three scenes over the entire area of the screen. Convergence is achieved when the three beams converge or cross over the entire screen at the same point on the plane of the shadow mask.

COLOR FRINGING–FAILURE TO CONVERGE PROPERLY

To illustrate the effect of misconvergence, consider a scene consisting of a small white square in the center against a black background. All three electron beams would be biased on during this display. Let's consider the white square alone.

The red, blue, and green guns would produce red, blue, and green squares respectively. If the three squares were precisely aligned over one another, the resultant picture on the tricolor tube would be a white square, as in Fig. 6-9a. However, suppose the green beam was just slightly deflected to the right; the resultant picture would now appear differently, as in Fig. 6-9b. At the left, there would be a magenta strip, since the green is now missing there. At the right, there would be a green strip since the green gun is hitting its appropriate dots while the red and blue dots are not being excited.

The net result is known as *color fringing,* or the presence of improper color displayed at the edges of objects. If the blue beam were also misconverged, and furthermore, if all three beams were misconverged vertically as well as horizontally, it is not hard to imagine the havoc that misconvergence can cause.

PROPER PURITY AND PROPER CONVERGENCE

Proper purity implies proper beam landing by each electron beam on its associated phosphor dot. Proper convergence assumes proper purity as well as the requirement that all three beams cross at the same point at the shadow mask.

Illustrated in Fig. 6-10 is a situation in which correct purity obtains (only two beams are shown for simplicity) and the beams pass through the same hole in the shadow mask. Assuming a white spot was being displayed, each adjacent dot in the triad would be excited to produce the correct display. Illustrated in Fig. 6-11 is a condition in which the beam landing and purity are proper but the beams do not cross at the same point at the

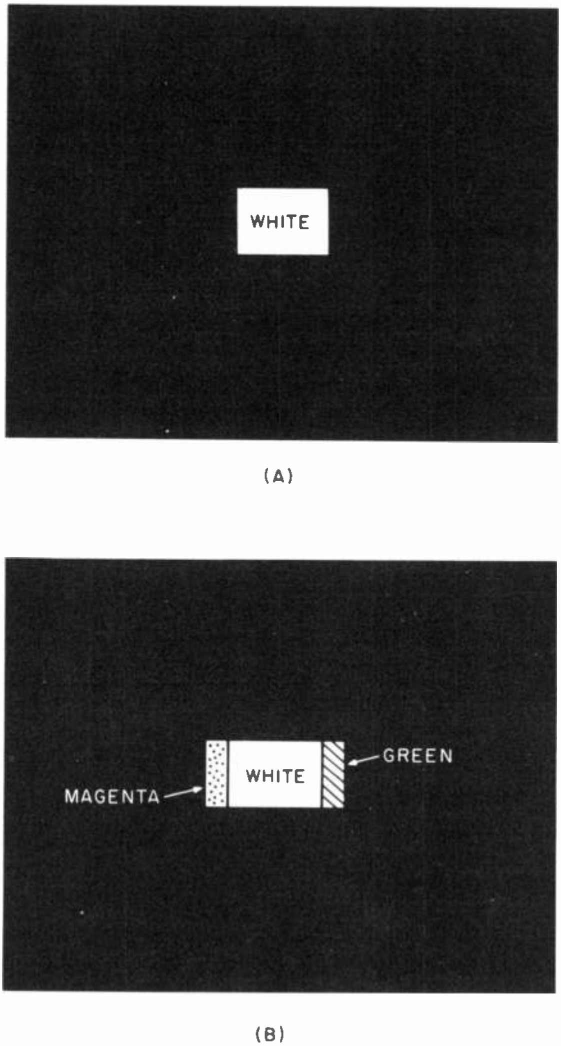


Fig. 6-9 A properly converged white square is shown in (a). A slight displacement of the green beam to the right would produce the color fringing shown in (b).

shadow mask. Instead of a white dot being formed, a yellow dot appears with a blue dot slightly below it. Convergence adjustments would be required to somehow move the blue beam up to excite the blue dot adjacent to those producing the yellow. Then a white spot would finally result. Color Plates V and VI show how purity and convergence are directly related relative to providing a properly set-up receiver.

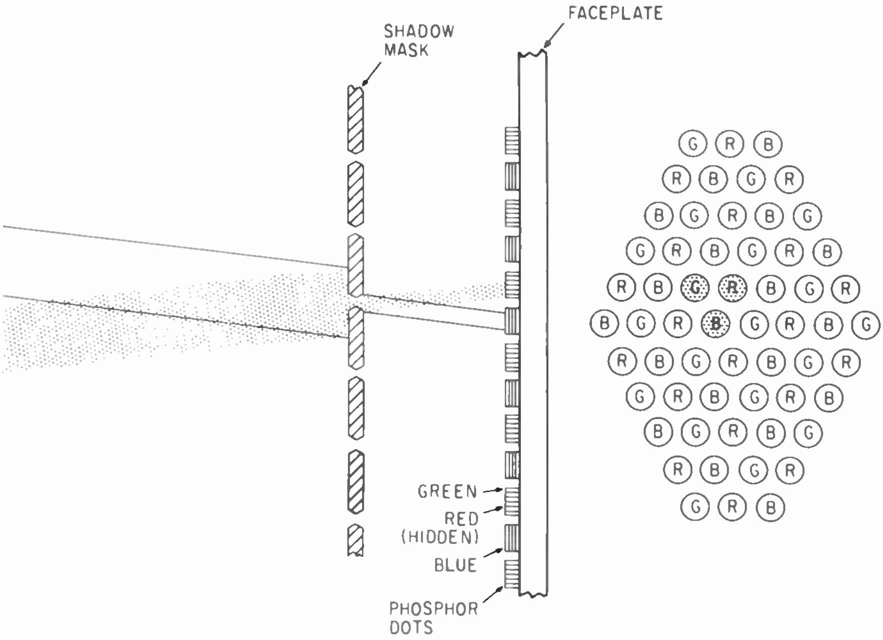


Fig. 6-10 Proper purity with proper convergence occurs when each beam passes through the same hole in the shadow mask and hits its proper phosphor dot.

STATIC CONVERGENCE FOR THE CENTER OF THE SCREEN

Magnetic fields are used to position the electron beams so that proper convergence is obtained at the screen center. A typical convergence arrangement is mounted slightly behind the deflection yoke, as shown in Fig. 6-12, or over grid 4 of the electron gun assembly, as shown in Fig. 6-13. The external convergence assembly includes permanent magnets and electromagnets—permanent magnets for static, or center-screen, adjustment and electromagnets for edge correction.

One popular static magnet approach makes use for each gun of a small permanent magnet that can be moved closer to or further from the neck of the tube. Each magnet is lined up with its internal pole piece so that magnetic flux strength varies as the magnet is moved closer to or further from the neck of the tube. In this manner, the amount of beam movement is varied. If it is necessary to reverse the direction of movement of one beam relative to the other two, the magnet is withdrawn from its plastic holder, reversed, and reinserted. As the magnet is moved in towards

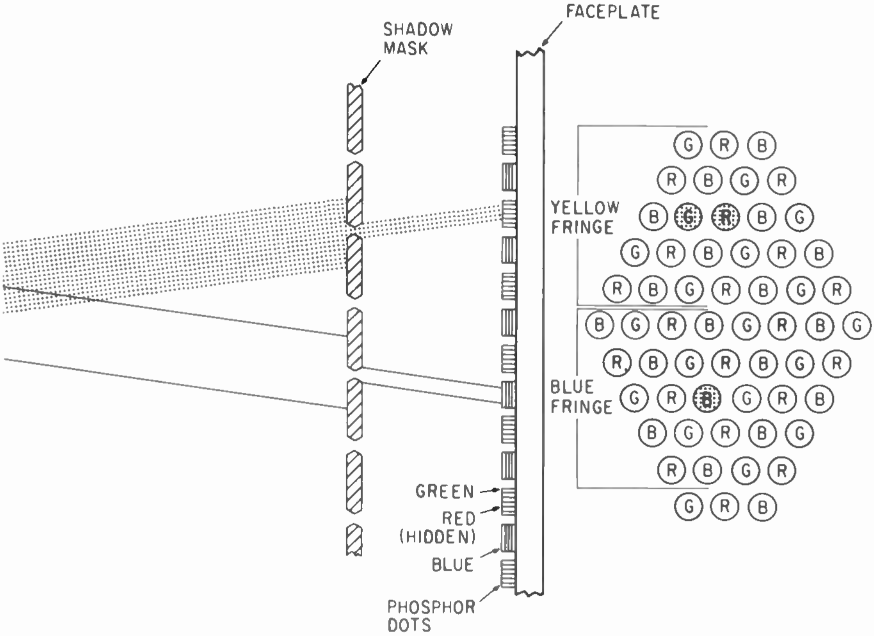


Fig. 6-11 Here purity is proper, since the beam strikes its proper dot, but convergence is incorrect since the beam passes through an adjacent hole in the shadow mask.

the neck of the tube, beam movement is increased but in a direction opposite to the previous one.

The accelerating grid (grid 4) of the electron gun assembly includes metal tabs that act as internal pole pieces to complete the magnetic path from the external magnets. An internal magnetic shield minimizes interaction between adjacent fields. As the electron beams travel through their individual gun structures, each will be separately affected by their individual convergence magnet adjustment. Note that the purity magnet adjustment affects all beams whereas the convergence magnets are arranged to control each beam separately.

ADJUSTING THE STATIC CONVERGENCE MAGNET

The action of the static convergence magnets is as follows. Assume that you are closely examining the center area of the picture tube screen and observe that the three beams are striking dots that are displaced from each other in the manner of the end points of an equilateral triangle, as in

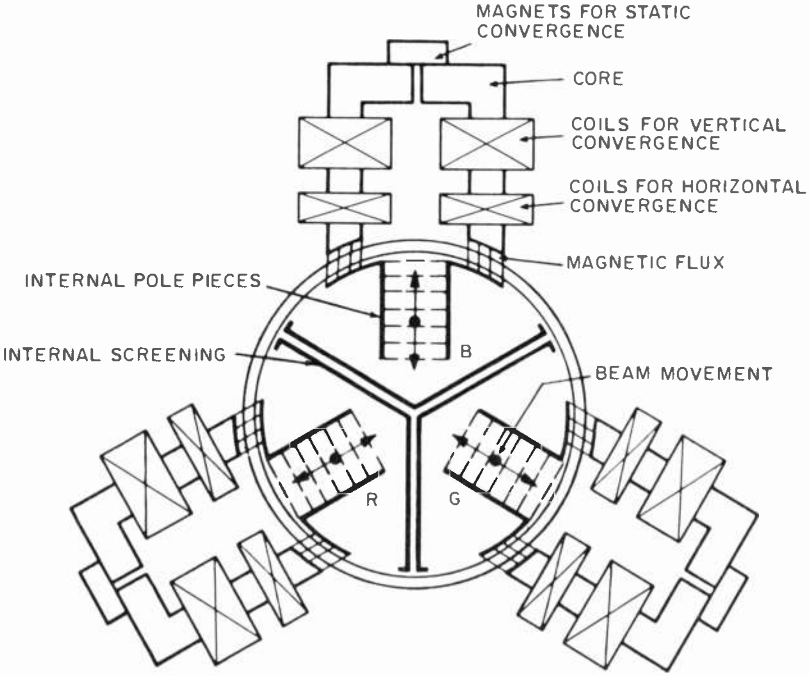


Fig. 6-12 A typical convergence assembly includes permanent magnets for static or center convergence and electromagnetic coils for dynamic convergence.

Fig. 6-14a. Adjustment of the green, red, and blue static magnets will soon bring the three beams to a common point P.

Suppose, however, that the three beams are initially in positions as shown in Fig. 6-14b. Now, adjustment of the three static magnets will fail to register all three at one point. Somehow, there must be a provision to move the blue beam laterally rather than just up or down. Such movement requires still another permanent magnet, called the blue lateral magnet, to achieve proper center-screen convergence.

THE BLUE LATERAL MAGNET

As with the three static convergence magnets, an internal pole piece (Fig. 6-15) is required in conjunction with the external blue lateral magnet. Grid 3, the focus grid, includes this element. One particular arrangement used consists of an upper rectangular tab plus a bent strip beneath it.

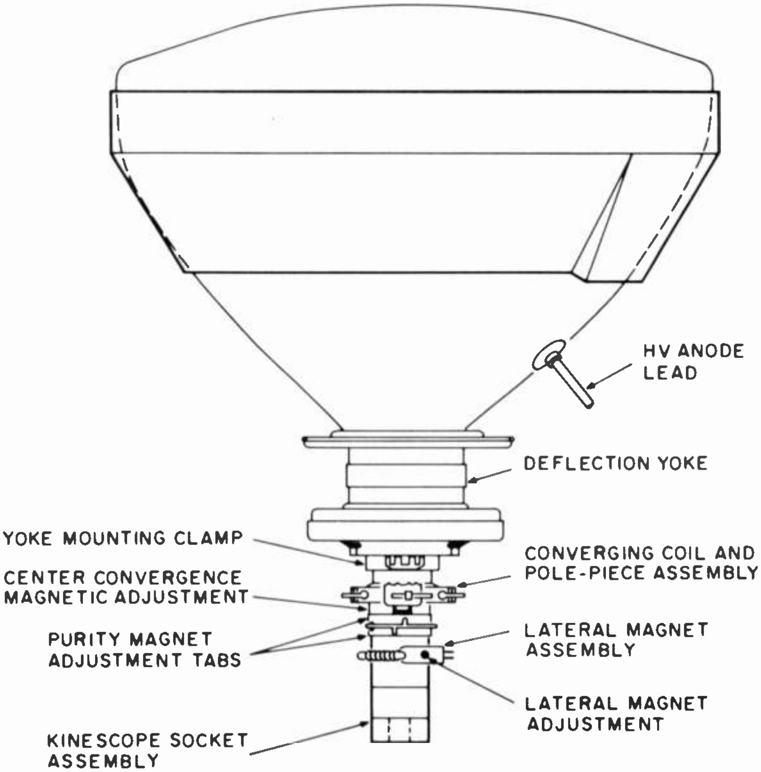


Fig. 6-13 Location of the deflection, convergence, and purity assemblies on the neck of a shadow-mask tube.

The magnetic flux lines from the external-magnet assembly flow vertically across the blue beam and thus permit horizontal or lateral positioning.

A variation on this scheme makes use of a long ceramic magnet that can be rotated around its own axis to control the amount and direction of blue lateral displacement. Other arrangements achieve static convergence. Basic understanding of the static convergence function plus the manufacturer's specific notes on his own particular scheme should be sufficient to permit proper adjustment.

DYNAMIC CONVERGENCE

Static convergence, involving correct overlap of the three beams at the center of the screen, is only the first step in achieving an acceptable color picture on a three-gun kinescope. As the three beams are deflected

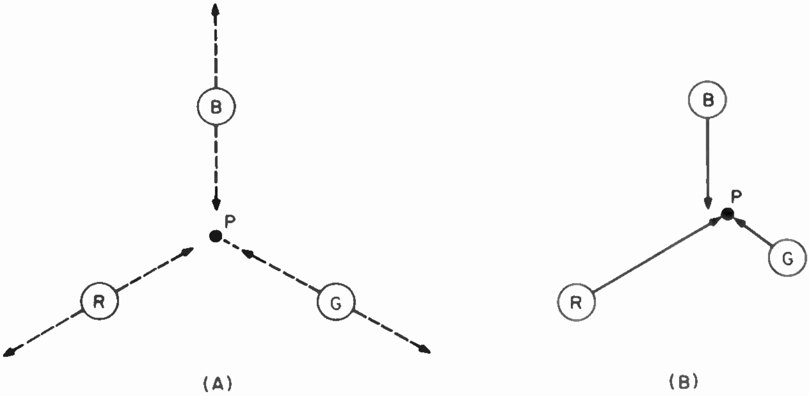


Fig. 6-14 Each of the three static convergence magnets moves its associated beam as shown in (a). However, as shown in (b), where proper center convergence cannot be obtained, some method must be included to allow the blue beam to be moved laterally.

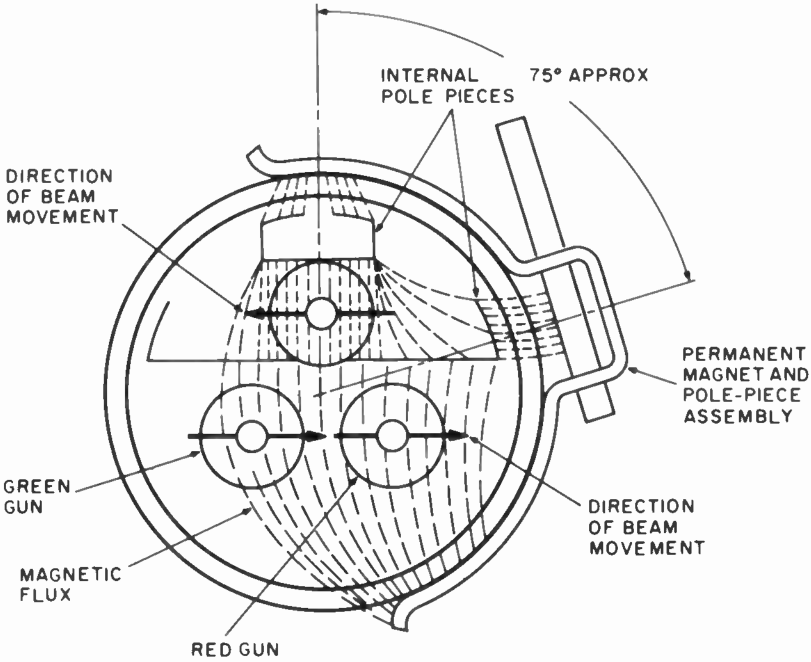


Fig. 6-15 A blue-lateral magnet assembly provides the necessary sideward beam control to achieve proper center convergence.

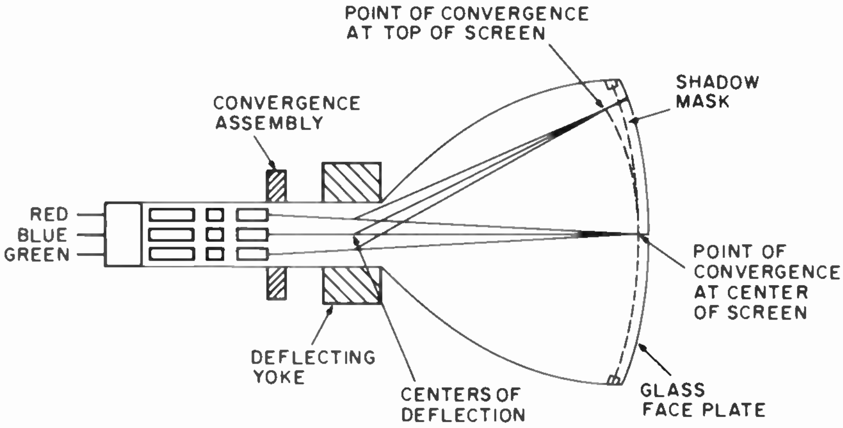


Fig. 6-16 Misconvergence occurs when the electron beams are directed in a different deflection curvature than the curvature of the faceplate and shadow mask.

away from center, the radius of curvature of the deflection system is quite curved compared to the relatively flat faceplate (Fig. 6-16). The beams tend to cross or converge before they reach the shadow mask, and dynamic correction of the three paths must be made while the beams are being swept across the screen. If this correction is not made, misconvergence will be greatest at the edges of the screen.

To obtain dynamic or active correction in step with the deflection movement of the beams, voltages are tapped from the horizontal and vertical sweep sections, shaped into particular waveforms, and applied to electromagnets mounted on the convergence assembly. Adjustments are provided to tailor the amplitude and shape of the correction voltages for each of the three beams.

Current passed through the convergence coils develops magnetic fields that alter the focal length or crossover point of the beams arriving at the shadow mask. Since misconvergence is greatest at the edges, maximum correction current is needed at these instances of beam deflection; correction current is reduced to zero as the beams approach the center of the screen. Each of the three electron beam assemblies includes its own coils for individual correction in the vertical and horizontal planes. A total of twelve dynamic convergence adjustments are found in most color receivers. Each of the three guns contain four controls to adjust vertical dynamic amplitude (1) and waveform (2) plus horizontal amplitude (3) and waveform (4).

Another cause for misconvergence at spots other than the center of the screen is brought about by the actual physical placement of the three guns. The guns are not located along the exact long axis of the tube; for example, the blue gun is above the center axis and its electron stream must travel further to the bottom of the screen than to the top. Similarly, the green and red guns must travel unequal distances to reach the upper and lower edges of the tube. Unequal red and green beam travel also exists to reach the left and right hand edges of the screen since each is off center horizontally.

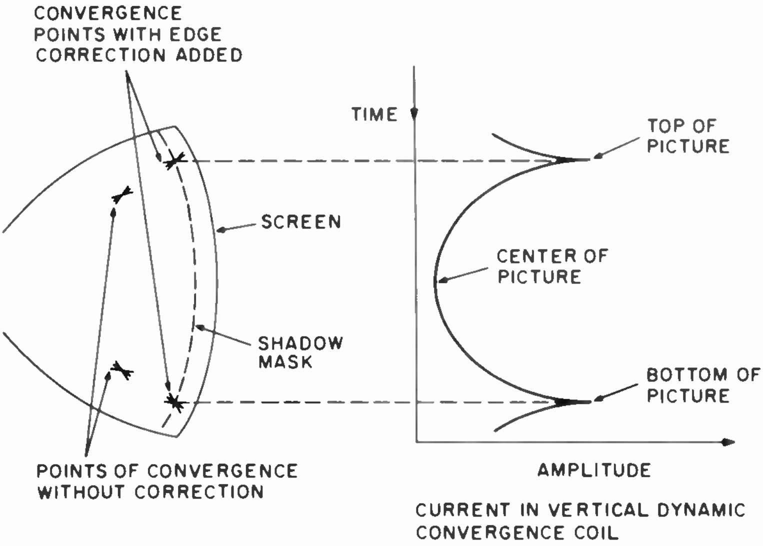


Fig. 6-17 Parabolic waveforms are required, in both the horizontal and vertical sweep section, to correct for misconvergence off center.

WAVEFORMS NEEDED FOR DYNAMIC CONVERGENCE

To obtain magnetic convergence fields that are maximum at the edges and minimum at the center, parabolic waveforms are used; they are generated by voltages from the vertical and horizontal output stages (Fig. 6-17). The magnetic fields for each gun assembly are added to the existing static fields established during static or center convergence. The net result of the combined fields is to direct all three beams through their proper holes in the shadow mask over the entire area of the screen.

To compensate for the difference in beam deflection caused by the

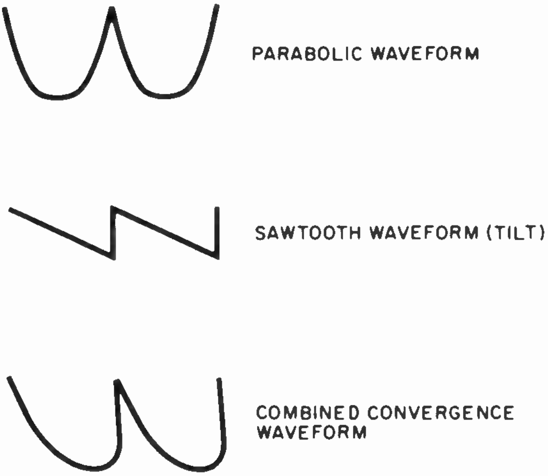


Fig. 6-18 A sawtooth waveform is added to a parabolic waveform to compensate for the off-center location of the three electron gun assemblies in the color kinescope.

off-center placement of the three guns, means must be provided to alter or distort the parabolic waveforms. For example, the blue gun is located above the tube axis and its beam travels further to reach the bottom of the screen than to reach the top. Thus greater misconvergence tends to exist near the bottom and greater correction is necessary. A symmetrical parabolic waveform would provide equal correction, which would not cure the nonsymmetrical condition. A sawtooth waveform is added to the parabolic current to solve this misconvergence error, as shown in Fig. 6-18.

Two controls are provided to adjust the correction current for each coil—"amplitude" and "tilt." The "amplitude" control governs the amount of correction current, while the "tilt" control alters the shape of the waveform to compensate for the previously discussed variations in beam movement. Recent receivers simplify dynamic convergence by connecting the red and green convergence coils in series and providing "differential tilt" and "differential amplitude" controls to correct both red and green beams simultaneously.

DEVELOPING THE VERTICAL CONVERGENCE CURRENT

In a basic circuit (Fig. 6-19) for vertical dynamic convergence, a parabolic waveform is developed at the cathode of the vertical output stage. The sawtooth current flowing through the cathode resistor is inte-

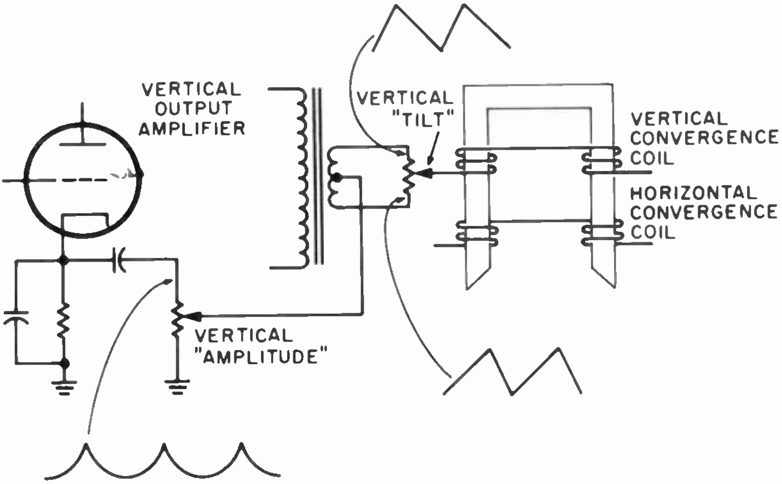


Fig. 6-19 Vertical dynamic convergence is developed at the cathode of the vertical output stage.

grated by the cathode bypass capacitor to produce the waveform shown. The "amplitude" potentiometer determined the output level of the parabolic waveform fed to the convergence coil. In addition to this parabolic signal, a sawtooth waveform from a center-tapped winding of the vertical output transformer is included. When the "tilt" control is set at mid-position, no sawtooth component is added since both halves of this winding cancel; an undistorted parabolic waveform is fed to the convergence coil at this time. Moving the "tilt" control off center provides a sawtooth component that then alters the combined waveform to be delivered to the convergence coil.

Since each gun requires its own particular vertical dynamic adjustments, three such circuits are required.

DEVELOPING THE HORIZONTAL CONVERGENCE WAVEFORM

A simple and convenient arrangement for obtaining a satisfactory parabolic waveform for horizontal correction involves the use of a resonant circuit, as shown in Fig. 6-20. At 15,750 Hz (horizontal scan rate) it is practical to use the high efficiency and lower deflection power demands offered by a resonant circuit; high-Q circuits are impractical and expensive at the low frequency (60-Hz) for vertical scan.

A short duration pulse, taken from a winding on the horizontal output transformer, is applied to the resonant circuit L1-C1 during each retrace pulse. The sharp pulse excites the resonant circuit, and a sine wave

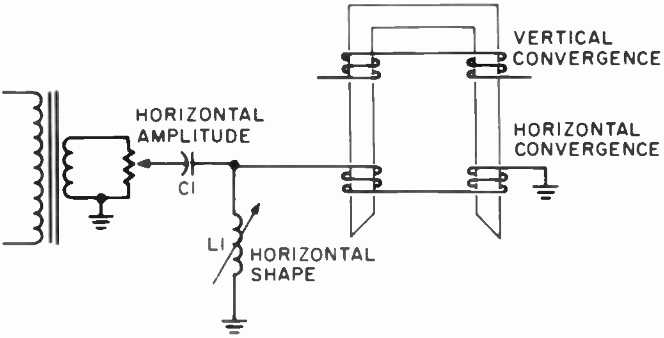


Fig. 6-20 A flyback pulse applied to a high-Q resonant circuit develops the horizontal dynamic convergence waveform.

is generated and appears across L1. Before the oscillation can decrease significantly, another pulse appears to excite the tuned circuit again. Although the sine wave is not exactly parabolic, there is sufficient correction to achieve proper horizontal dynamic convergence. An "amplitude" control varies the level of the input pulse and thus the level of the developed waveform. The variable inductance, L1, varies the frequency and phase of the developed waveform and thus affects the shape of the correction waveform during scan time.

BEFORE PERFORMING THE CONVERGENCE PROCEDURE

Before attempting the detailed procedure involved in converging a color receiver, several factors must be carefully considered. First, a definite need to perform this task must be established. Make sure that a simple degaussing step alone cannot restore proper convergence. Second, the area where misconvergence exists must be determined and the extent of the annoyance attributed to the error. For minor drift caused by normal aging, slight touchup of convergence is usually sufficient to restore satisfactory performance. A complete step-by-step convergence job should be required only if a replacement kinescope is installed or if excessive tampering with the numerous convergence controls has taken place at the hands of a layman or an incompetent technician.

Once the need for a convergence touchup or complete setup is established, the manufacturer's service notes should be obtained. The various convergence controls must be located and their particular function and interaction with other controls identified. Most manufacturers' convergence procedures are painstakingly detailed and profusely illustrated to assure a well-done job in a minimum of time.

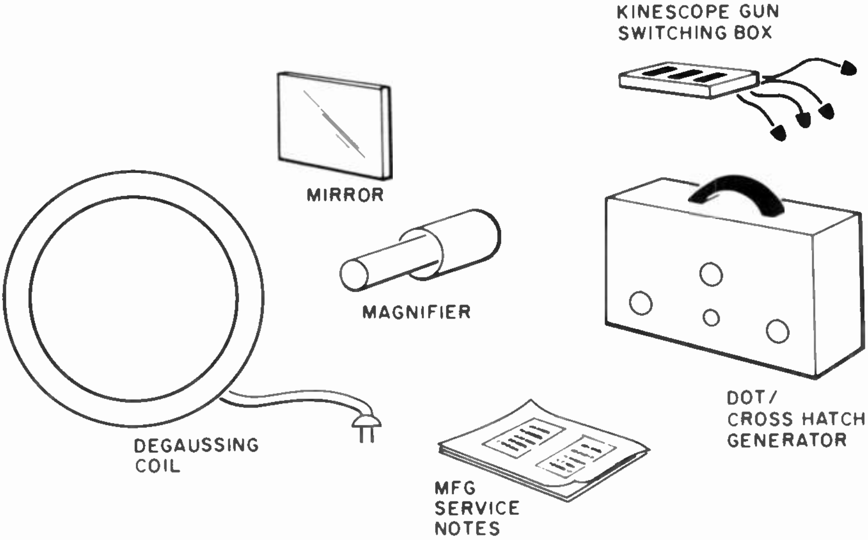


Fig. 6-21 The basic equipment required for a purity and convergence adjustment procedure.

The equipment required (shown in Fig. 6-21) includes a degaussing coil, a magnifier to check beam landing during purity adjustment, a dot/crosshatch generator to observe convergence errors and their correction as adjustments are made, and a mirror to permit the screen to be viewed while adjustments are made from the rear of the set. An additional accessory is a kinescope gun-switching box (schematized in Fig. 6-22) to allow individual guns to be turned on and off during setup adjustments.

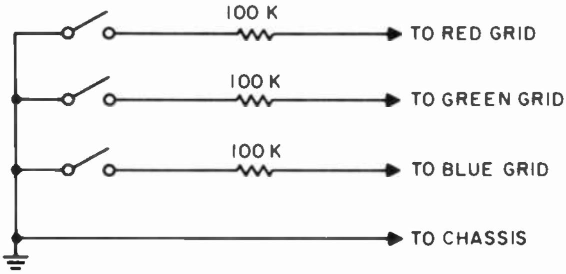


Fig. 6-22 A kinescope gun-switching box permits the technician to bias off any particular beam during the convergence procedure.

PERFORMING PURITY AND CONVERGENCE ADJUSTMENTS–DEGAUSSING

Once it has been decided that convergence readjustment is necessary, the receiver's black-and-white performance must be checked, with particular regard to width, vertical height and linearity, AGC, centering, high voltage, and focus. It would be a waste of time to complete a detailed convergence job with perfect results and then find that the picture height is insufficient. At this stage, a change in the vertical deflection system would alter the vertical dynamic convergence waveform and touchup would again be required.

Degaussing is performed by plugging the degaussing coil into an a-c outlet while holding it parallel, and close to, the faceplate of the color kinescope. (Even new sets with automatic degaussing features are usually degaussed by the technician during the installation task.) The coil is slowly rotated around the front of the set parallel to the faceplate. After a minute or two, back away from the faceplate, continuing to rotate the coil parallel to the faceplate. When ten feet or more away from the screen, rotate the coil at right angles to the screen and disconnect the degaussing coil. The receiver can be on or off during this degaussing process. See Color Plate VII for the effect of the degaussing coil on the screen.

PERFORMING PURITY AND CONVERGENCE ADJUSTMENTS–PURITY

After degaussing, purity is adjusted to obtain untinted fields for each of the three guns. Center convergence, to be described shortly, is attended to first since an improper purity setting can be reached as a result of the interaction of the purity and center convergence magnetic fields. It is recommended that you refer to manufacturers' specific notes for detailed procedure. The following steps will describe a typical setup.

Once center convergence has been set, the blue and green guns are biased off while the red gun is left on. (Kinescope gun switching boxes for easy hookup are inexpensive and available at most distributors.) The two red tabs (or the square and round tabs) of the purity magnet are overlapped (for zero magnetic field) and the yoke clamp screw loosened. The yoke is moved back to the convergence coil, and the purity magnet is adjusted by rotating the tabs with respect to each ring. Then the entire assembly is rotated around the neck of the tube until a uniform red area appears in the center of the screen. To determine the exact landing of the red beam at the center of the red phosphor dot, use a magnifier. To sharpen the display, merely paste a piece of cellophane tape over the center area of the screen. See Color Plate VIII for the resultant magnified view of the phosphor screen. The yoke must then be slowly moved forward until the entire area of the screen is red. Readjust the purity magnet, if necessary, to obtain the overall red raster. If difficulty is encountered, check static convergence and readjust before proceeding to the purity setup steps. Before tightening the yoke clamp screw, make sure the raster is not tilted. Use the magnifier to check for proper beam landing. When satisfactory purity has been obtained for the red raster, it will generally be found good for both the blue and green. However, check this fact by first biasing off the red and green and observing the blue. Finally, repeat the procedure by biasing off the red and blue guns to check for a pure green field. Refer to Color Plate IX to observe a kinescope with complete lack of purity.

PERFORMING STATIC AND DYNAMIC CONVERGENCE ADJUSTMENTS

Modern color receivers allow for considerably simpler convergence adjustments than early models because of clever circuit arrangements. Early receivers made use of dynamic controls that affected only one beam at a time; in newer models the red and green beams can be influenced by single controls. The result of newer improvements in convergence techniques enables the technician to perform this rather detailed task in a shorter time and with better final results.

The general procedure for convergence begins with the hookup of a dot/crosshatch generator to the receiver. For center convergence, a dot pattern is generally preferred. The center area of the screen is carefully observed, and the static convergence magnets are adjusted until the center dots are white with no traces of fringing. The appearance of color at the edges of dots anywhere off center is ignored at this time. Four magnets are involved—the red, the green, and the blue static, as well as the blue lateral.

Once center convergence is completed, refer to the manufacturer's service notes and follow the step-by-step procedure outlined. The key to success here lies in paying close attention to the areas affected by each control. Very little difficulty should be encountered if each control is rotated slowly and its effect observed in the area stressed by the service notes (see Fig. 6-23 as an example). If you insist on watching areas over which the particular control you are adjusting has no influence, a great deal of frustration will result with little or no improvement in receiver performance.

See Color Plates X through XIII for a step-by-step improvement as dynamic convergence corrections are made.

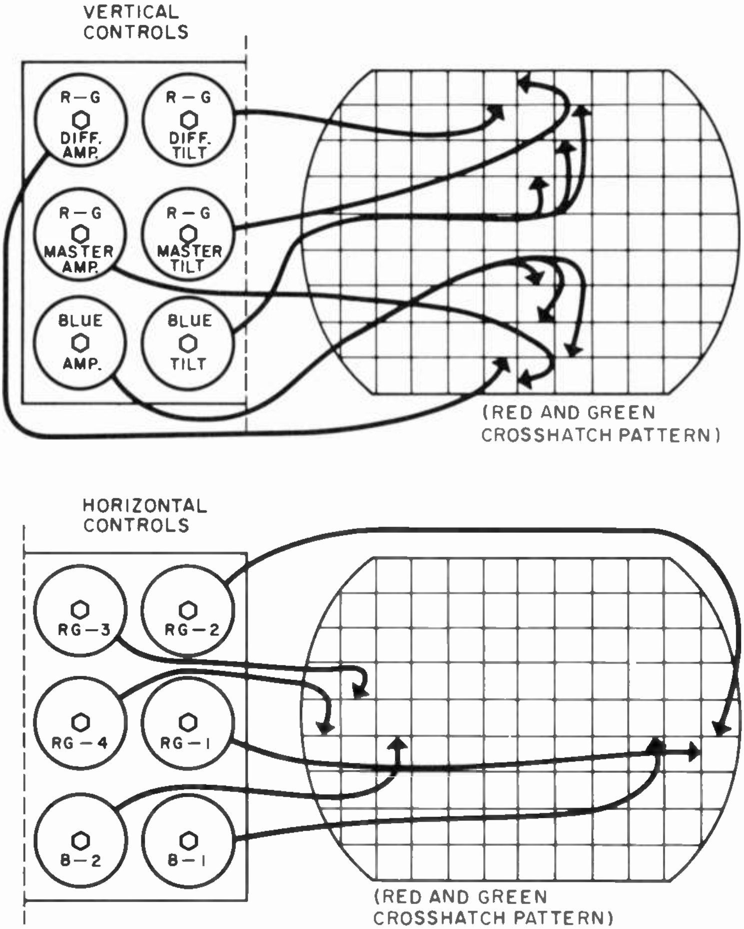


Fig. 6-23 Each dynamic convergence control has a specific effect in a certain area of the screen. Make sure to refer to the manufacturer's service notes to avoid a fruitless, time-consuming exercise.

CORRECTING CONVERGENCE TROUBLES

Color fringes at the edges of objects imply misconvergence. When the fringing is confined to the center area of the screen, static convergence is at fault; misconvergence in areas off center indicates dynamic convergence troubles (assuming center convergence is adequate).

Static and dynamic convergence adjustments are carefully detailed and profusely illustrated in manufacturers' service notes. However, there will be occasions when a convergence component or circuit failure results in inadequate beam movement or even none at all when a convergence control is varied. At this time, it is necessary to locate the defect and correct the condition to permit proper execution of the convergence procedure.

The static convergence adjustments can be severely restricted if the convergence assembly is not properly located over the internal assembly within the kinescope. (Dynamic convergence will be similarly affected, of course.) Thus, it must be determined that the convergence assembly is properly mounted on the neck of the kinescope. In most receivers, static convergence adjustment can move each beam about an inch or so.

If dynamic convergence requires touchup and a defect prevents proper adjustment, considerable effort can be wasted trying to analyze the cause. The proper procedure is to follow the service notes and watch the effect as each dynamic control is varied. At the step where a control does not perform properly, the section of the schematic diagram specifically related to this particular control must be reviewed. Then the specific components involved must be examined—using an ohmmeter to check resistance values and continuity—to pinpoint the specific trouble. It may also be necessary to use an oscilloscope to check the peak-to-peak waveforms of the circuits feeding the convergence coils.

To reproduce white or shades of gray on a color kinescope, without a dominant tint as brightness is changed, proper amounts of red, blue, and green must be mixed. As simple as this requirement may seem to be, achievement of it is made complicated by the differences in phosphor efficiency of each of the three colors. Phosphor efficiency is determined by the phosphor's ability to convert impinging beam current into light output. The red phosphor is the least efficient and therefore requires the highest beam current, as shown in Fig. 6-24. Blue is the most efficient, with green somewhere between red and blue. This difference in efficiency requires unequal beam currents from the three guns as brightness is varied from dark gray to white. Gray scale tracking involves a series of screen grid and control grid adjustments to achieve proper beam tracking as brightness is varied.

A properly adjusted receiver will display a dull gray raster (video and chrominance set to minimum) at low brightness, and then the raster will increase from gray to white as the brightness setting is increased. If gray-scale tracking is improperly performed, the raster will display a tint over the entire screen as brightness is varied.

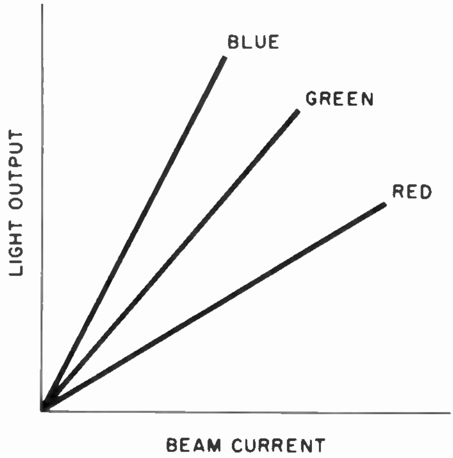


Fig. 6-24 The red phosphor is the least efficient one, and thus highest beam current is needed to achieve the same light output as for the other two primary colors.

PROCEDURE FOR GRAY-SCALE TRACKING

The gray-scale tracking procedure for a typical receiver shown in Fig. 6-25 is as follows:

1. Turn the kinescope screen and bias controls to minimum (fully counterclockwise).
2. Set the "Normal/Service" switch to "Service." This setting will ground the grid of the vertical output and provide a horizontal line for each beam across the screen. As shown, video is removed from the kinescope cathode and the cathodes are tied together since the drive controls are shorted together; thus, brightness, contrast, and drive controls have no influence at this time.
3. Advance each of the three screen controls (sequence is unimportant) until a horizontal line corresponding in color to the screen control becomes visible. If a screen control cannot produce a line in its color, leave the screen setting at maximum and slowly increase the kinescope bias control until the line appears. These settings establish equal cutoff condition for each gun with the same grid-to-cathode voltage applied to each gun.
4. Set the "Normal/Service" switch to "Normal." Tune in a station, either monochrome or color (with the saturation or color control at minimum).

5. Adjust the contrast and brightness controls for a normal picture. Then adjust the blue and green drive controls until a satisfactory black-and-white picture is obtained.

HIGH-BRIGHTNESS COLOR PICTURE TUBES

Publicity for new color sets devotes considerable attention to high-brightness color tubes achieved by two approaches: (1) application of opaque black material surrounding each phosphor dot, and (2) use of rare-earth phosphors.

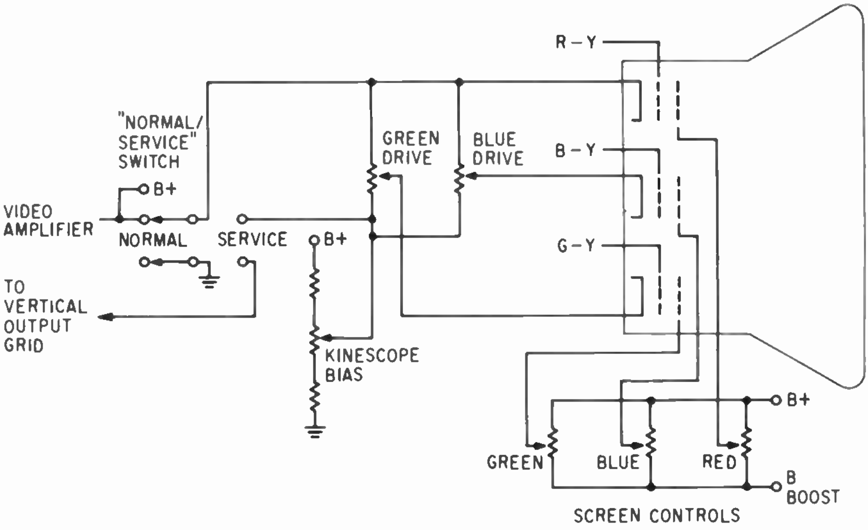


Fig. 6-25 The "Service" switch on modern color sets produces a horizontal line for each beam and allows gray-scale tracking to be simplified.

Set manufacturers have been forced to use a tinted filter glass mask between the picture tube screen and the viewer to reduce the effect of external light falling on the picture tube. Sunlight or illumination from bright lamps near the set pass through this filter, are reflected from the phosphor dot surface, and return through the glass to the viewer. The picture contrast created by the phosphor dot emission is reduced as more external light reaches the phosphor dot surface; thus the need for a low-efficiency (40 to 50 percent) tinted filter. Major picture tube manufacturers have recently developed a technique to surround each phosphor dot with an opaque black material that absorbs rathers than reflects the external ambient light. This reduction in ambient light reflection enables the tube manufacturer to use a filter glass with double the previous transmission efficiency (80 percent), thus boosting brightness considerably over that of earlier tubes using the same phosphor materials.

A second major step in improving picture tube brightness stems from research in new phosphor materials. For years sulfide-type phosphors have been used; the rare-earth phosphors now being employed offer 30 percent more brightness and contrast.

The red phosphor has been the least efficient of the three primary colors. The new europium-activated red phosphors are 20 to 79 percent brighter than earlier silver-activated zinc cadmium sulfide. In addition, the new phosphor has a narrower peak response curve, and thus the eye sees a "truer" red than that provided by the earlier phosphor, which has a broad response and thus appears as an orange-red. A final advantage in brightness improvement occurs because the new phosphor peaks at a wavelength much closer to the region where the eye is most sensitive (about 550 millimicrons).

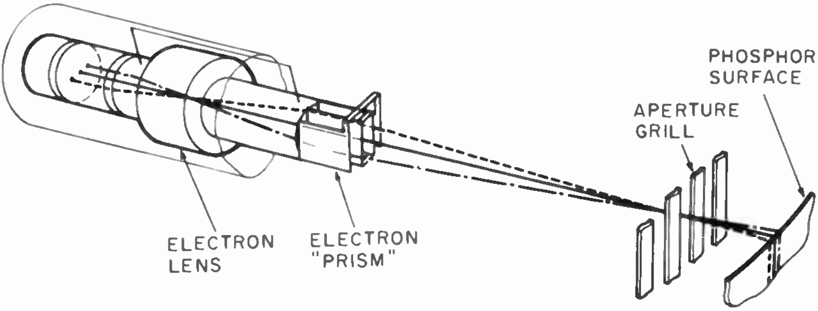


Fig. 6-26 The Sony "Trinitron" color picture tube uses only one gun to gain highest brightness (due to the omission of a shadow-mask) with considerably fewer convergence adjustments (two compared to the twelve with the shadow-mask tube).

SINGLE-GUN "TRINITRON" PICTURE TUBE

A Japanese-developed (Sony) picture tube design (Fig. 6-26) offers high brightness by virtue of the elimination of the shadow mask used in all American-made tubes. The shadow mask, placed as it is between the three guns and the phosphor dots, prevents a large portion of emitted electrons from reaching the phosphor dot screen, thus seriously reducing light output.

The "Trinitron" tube uses a single electron gun—compared to the conventional three-gun design—to generate three beams. These three beams are converged and focused by an internal optical system consisting of two large diameter electron lenses and elecroprisms.

The single electron gun emits three beams along the same horizontal plane—as opposed to the conventional delta or triangular positioning in three-gun tubes—to drastically reduce dynamic convergence and focus circuitry adjustments. Only two dynamic convergence adjustments are necessary in the "Trinitron" setup compared to the dozen required with three-gun tubes.

In place of a shadow-mask in front of phosphor dots, this tube employs an aperture grille to separate the three beams and direct them to red, blue and green phosphor strips. This novel arrangement is claimed to deliver twice as much brightness as that provided by conventional shadow mask tubes using the same phosphors.

Review Questions

1. What is a "shadow mask"?
2. How is incorrect purity displayed on a color TV tube?
3. What factors contribute to incorrect purity?
4. Describe the purity adjustment procedure.
5. What is convergence and how does it differ from purity?
6. Explain the difference between static and dynamic convergence.
7. What is "degaussing" and why is it important?
8. Describe the procedure for gray-scale tracking and state the reason for this adjustment.
9. What are "rare earth" phosphors and what is their application in color TV picture tubes?
10. State two advantages claimed for a one-gun structure compared to a three-gun.

7

Color TV Test Equipment

Color TV receivers are more complex than their black-and-white counterparts; thus new service techniques as well as new types of test instruments are required for proper troubleshooting and repair.

The two essential instruments for color servicing are the color bar generator for demodulator and chrominance checks, and the dot/crosshatch generator for performing static and dynamic convergence adjustments. Although color sets can be repaired and adjusted without these two valuable instruments, considerable service time can be expended to complete a job without them. Years ago, the technician had to purchase two separate units and carry both on service calls; today, most manufacturers offer solid-state, battery-operated units combining the color bar generator and the dot/crosshatch generator in one lightweight, compact unit.

Additional accessory service equipment includes a high-voltage probe for setting the exact voltage level on the kinescope, a grid-shunt switch for convenient display of only one or two guns at a time on the screen, a color test jig to eliminate the need for the technician to remove the customer's kinescope and yoke/convergence assembly when chassis removal is required, a degaussing coil to demagnetize the receiver before purity and convergence adjustments are performed, and a low-power magnifier to inspect the kinescope screen for proper beam landing during purity setup.

It is assumed, of course, that the service technician already possesses a wide-band oscilloscope (up to 4.5-MHz bandwidth in the vertical amplifier section), a sweep-generator with adequate marker provisions, a VTVM or VOM, and the necessary hand tools such as pliers, cutters, etc. Also, competence in the use of the equipment is assumed since a color TV receiver with its critical tuner, video IF, bandpass amplifier and sound section alignment is hardly the project to teach a technician how to use a sweep generator.

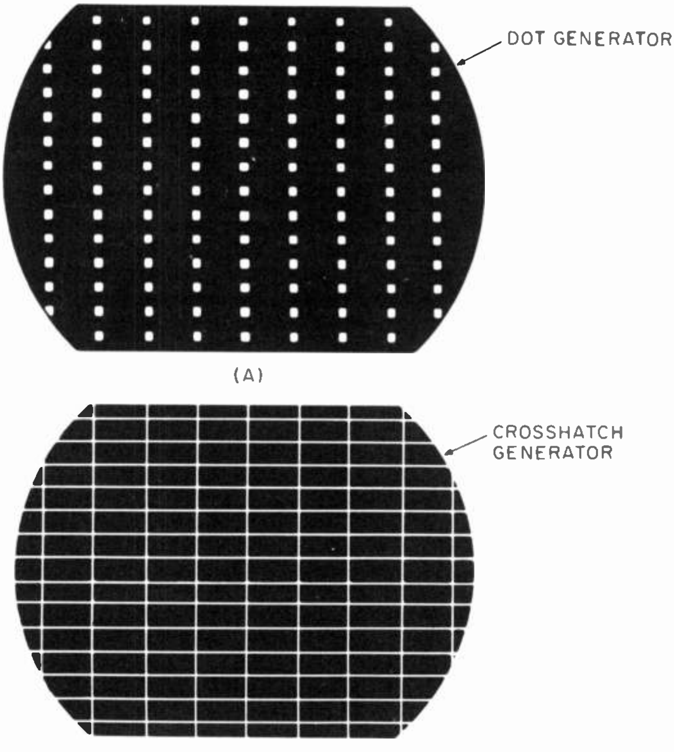
THE DOT/CROSSHATCH GENERATOR

Static and vertical dynamic convergence adjustments are necessary to register the three electron beams at the same spot on the screen without color fringing. To perform these critical adjustments, the technician must examine the entire screen to observe the effect of each control as he changes its setting. The difficulty and inconvenience of this task if station program material is used for observation is easily imagined. While the technician is attempting to concentrate on specific areas, the picture is changing in content, brightness, and contrast.

To observe color fringing and the improvements in quality as convergence controls are adjusted, it is best to view a stable, fixed pattern. Color fringing on a misconverged set will appear on a black-and-white program as well as a color program; as a matter of fact, color fringing is more noticeable on a black-and-white program. Thus, a monochrome pattern, rather than a color pattern, is used for display. Finally, color fringing is most apparent when most of the screen is dark and only a small percentage of it is illuminated with white dots or bars. Some technicians prefer a dot pattern, with vertical and horizontal rows of small white dots equally spaced over the entire screen, as shown in Fig. 7-1a. The majority of technicians, however, prefer a crosshatch pattern consisting of thin horizontal and vertical white lines, as shown in Fig. 7-1b. Color fringing will be indicated by the presence of anything other than white dots or lines in any areas of the kinescope screen.

All technical manuals for color receivers include sketches of dot and crosshatch patterns with very specific notes on how convergence controls affect various areas of the screen. It is thus relatively simple to touch up a misconverged set or even perform a major convergence setup when a new picture tube is installed if a dot/crosshatch generator is available.

A minor function of the dot/crosshatch generator is to check vertical and horizontal linearity by observing the spacing of the dots or bars. Any squeezing or stretching immediately points to nonlinearities which must be adjusted prior to the convergence procedure. Although this function of the dot/crosshatch generator may appear trivial, recall that (1) test patterns are hardly displayed any more (at least during normal day or evening hours) and that (2) any changes in vertical or horizontal linearity settings after static and dynamic convergence is completed may necessitate further convergence touchup. The utility of this instrument should be obvious.



(A)

(B)

Fig. 7-1 To converge a color receiver, technicians use a stationary-dot generator display (a) or crosshatch generator display (b) rather than a station signal that is continuously shifting.

REQUIREMENTS FOR THE DOT/CROSSHATCH GENERATOR

In order for the dot/crosshatch generator to serve its function properly, it must meet some basic requirements and these should be understood by the technician selecting one for purchase. The generator pattern, whether it be dot or crosshatch, should display a sharp transition from the black background to the white pattern and then back again. This dictates generator design in which fast rise and fall time pulses are produced and amplified in appropriate wideband circuits. Dots and crosshatch lines should maintain constant brightness over the entire screen, requiring constant pulse amplitude output from the generator.

A very important demand is the need to operate at precisely exact horizontal and vertical scanning frequencies since the high-Q circuits in the receiver horizontal dynamic convergence section will be set to the generator frequency. Should the generator sync frequency be different than the station sync frequency, misconvergence will be evident on the screen. Most dot/crosshatch generators use precision crystal-controlled oscillators to generate the proper sync signals.

Stability of the dot/crosshatch generator is important since it is most frustrating to near completion of a convergence job only to see the pattern suddenly starts to roll or jitter, necessitating hold control touchup.

Signal injection from the dot/crosshatch generator to the receiver may be achieved by two general techniques. One approach is to apply video signals to the receiver after the video detector, either by socket adapters or clip leads. Some generators provide sufficient output to permit direct application to the color kinescope while other, low-output generators require connections to the video amplifier section. These video signal generators require sync pulse information from the receiver under test to be fed back to the generator scanning circuits. In practice, the procedure is quite simple; clip leads (properly color coded and identified) are routed from the generator and merely clipped over an insulated horizontal and a vertical yoke lead to adequately couple sufficient pulses to lock the generator scanning circuits.

A more convenient type of generator provides an RF-modulated signal which is directly connected to the receiver antenna terminals; there is no need to trace video circuitry or supply sync pulse information. The RF-type dot/crosshatch generator contains complete circuitry for precise control of sync as well as generation of sharp vertical and horizontal pulses. These generators are usually preset to one particular channel (channel 3, for example) but include a convenient adjustment to reset to another channel should the preset channel be in use in the particular region where the technician works.

USING THE DOT/CROSSHATCH GENERATOR

Allow sufficient time, ten or fifteen minutes, for the receiver and generator to warm up before linearity and convergence procedures are begun. During this time, review the manufacturer's service notes for specific test steps to follow, test points for instrument connection if a video-type generator is used, and the location of each of the convergence controls. Set up a mirror in front of the receiver if necessary, and degauss the set while warmup is taking place.

If a video-type generator is used, connect the generator cable to the appropriate test points at the video defector or kinescope terminals. Also connect the clip leads for sync pulse pickup to the appropriate yoke leads (note that it is dangerous to remove the insulation from these yoke leads for direct contact); merely clip the leads to the insulation for adequate pulse coupling. When RF-type generators are used, remove the antenna

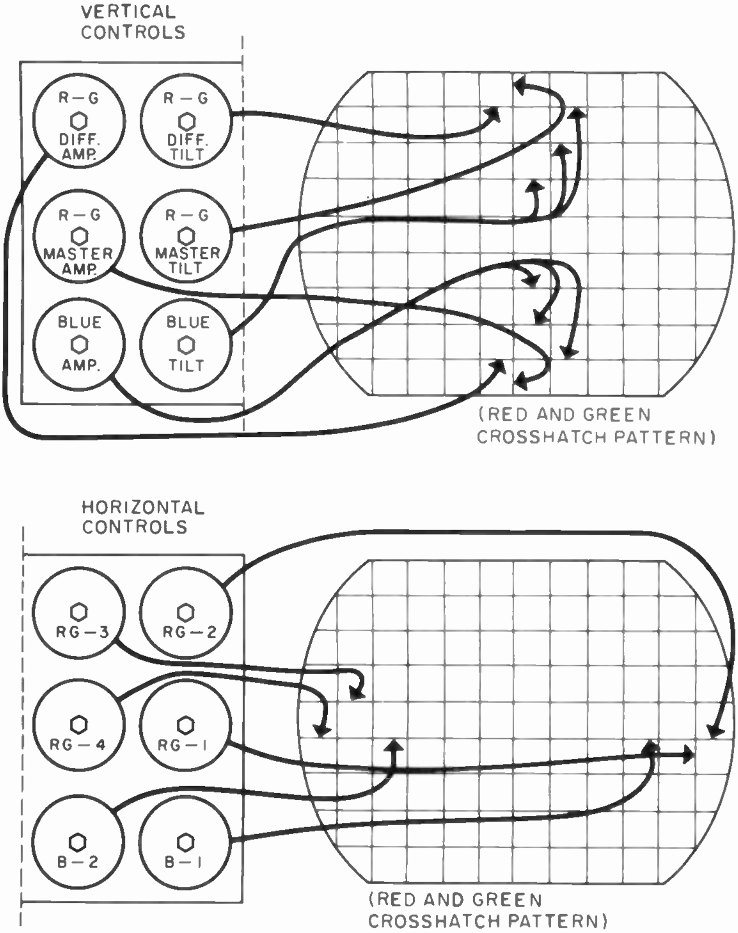


Fig. 7-2 A crosshatch pattern, as shown in most receiver manufacturer's service notes, with dynamic convergence controls related to the area of correction they affect.

leads from the set, clip the generator leads to the antenna terminals, and tune the set to the preset station of the generator.

Check the linearity of the receiver by setting the generator for a crosshatch pattern. Correct for any nonlinearities by adjustment of the appropriate height, size, or linearity controls. The brightness control should be set so that there is adequate brightness without any tendency towards blooming.

When static convergence is attempted, many technicians rely on a dot pattern and concentrate on one specific dot at the center of the screen. Once static convergence is completed, the pattern may be kept on dots or, as most technicians prefer, switched to crosshatch for the dynamic convergence procedure (Fig. 7-2).

THE COLOR BAR GENERATOR AND ITS APPLICATIONS

The chrominance and color sync sections of the color receiver involve circuitry that can be difficult to service and adjust without a stable waveform with well-defined amplitude and pattern information. Just as convergence can be tackled without a dot/crosshatch generator, so can chrominance servicing and alignment be done without a color bar generator. In both instances, the technician will invest considerable time and experience a high degree of frustration with heavy odds that the final job will be marginally completed at best.

A color bar generator enables the technician to inject a well-defined signal waveform into the chrominance and color sync sections and observe various output waveforms for evidence of distortion or signal gain. Convenient signal tracing, troubleshooting, and rapid fault isolation are the rewards for the technician who has adequately mastered the use of his color bar generator.

For example, such symptoms as loss of color or weak color can result from troubles in the antenna system, the RF/IF section of the receiver, or the chrominance section. If application of a color bar generator to the receiver produces a proper color pattern, the trouble is immediately isolated to the antenna system. If not, oscilloscope waveforms at the video detector and various chrominance section test points would rapidly isolate where partial or total loss of the color signal takes place. Most service notes contain scope waveforms, with peak-to-peak amplitude levels, of color bar signals at various stages of the receiver. Thus, the technician can quickly move his scope probe from one stage to the next, comparing waveform shape and amplitude until the defective stage and component are located.

Similarly, such symptoms as loss of color sync or weak color sync can be isolated by the injection of color sync test signals from the color bar generator. Defects in the color burst stage or the AFPC detectors can be located with signal tracing using the color bar signal and a wideband oscilloscope.

The two major service uses of the color bar generator are its display of vertical color bars on the screen to enable rapid pinpointing of demodulator defects and a simple adjustment procedure for demodulator phasing. These two applications take care of a most common complaint—incorrect color reproduction.

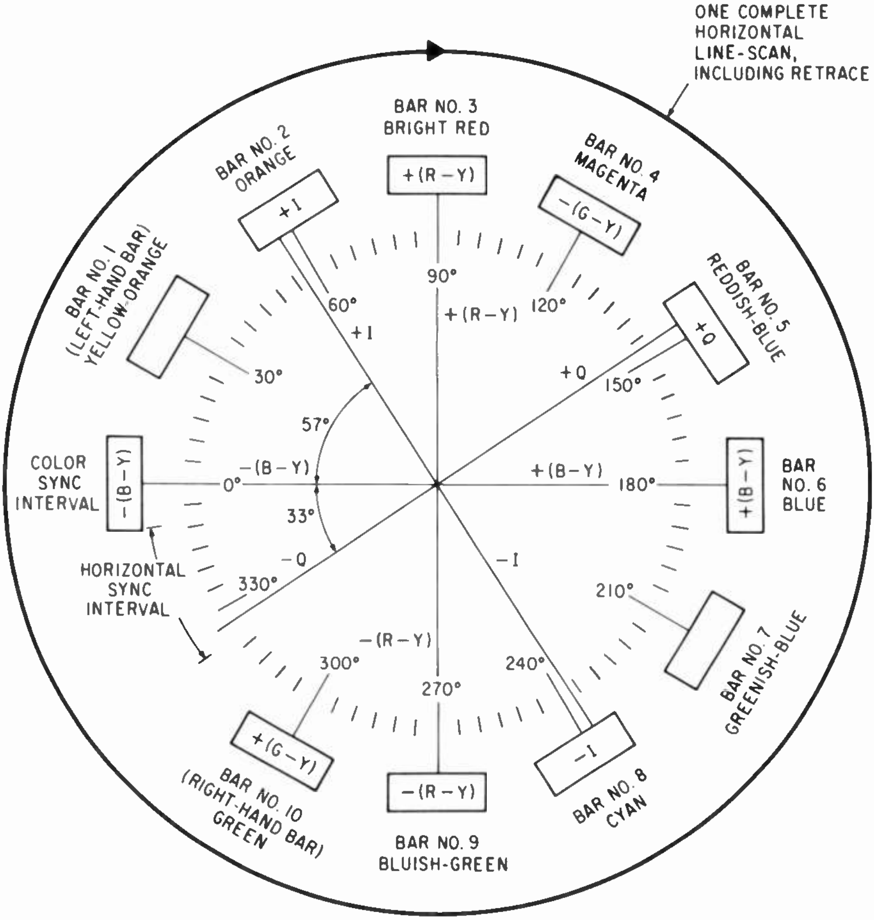


Fig. 7-3 The gated-rainbow signal produces twelve bars during its 360-deg phase travel. Due to horizontal blanking, only ten are displayed on a receiver screen.

THE THREE BASIC TYPES OF COLOR BAR GENERATORS

Three basic types of color bar generators are available—(1) the display rainbow, (2) the gated rainbow, and (3) the NTSC or saturated signal.

The display-rainbow generator produces a continuous output signal that constantly varies in phase with the 3.58-MHz oscillator in the receiver under test. The result is a pattern of vertical stripes, not distinct bars, that blend from one hue to another across the screen. An examination of such a display would indicate whether all colors are present and are thus being processed by the receiver or whether a receiver defect is failing to produce some range of colors on the screen. This type of generator is relatively inexpensive but has a rather limited use. Most generators of this type do not include color burst signals and are thus not practical for sync and demodulator adjustments.

The gated-rainbow generator is often more sophisticated than the display-rainbow type and produces a pattern of ten well-defined vertical bars of different hues (see Figs. 7-3 and 7-4). The front panel of the generator usually contains a sketch of the pattern with the sequence of hues clearly labeled. Each bar is identified with a specific phase angle so that demodulator performance can be easily judged. Since the generator is precisely gated on and off, the vertical bars represent very specific phase angles and are thus accurate and convenient for setting the phase adjustments required in the demodulator stages. Most service notes use gated-rainbow patterns to guide the technician in his work.

The NTSC (National Television Standards Committee) generator produces 100 percent saturated primary and secondary (complementary) signals. Some instruments display one color at a time while others display six colors and white. These generators are useful for signal tracing but are not as convenient for phase angle adjustments as the gated-display type because the relative phase of the primary and complementary colors do not coincide with the selected demodulator phase angles used by receiver manufacturers. This generator, however, does simulate the standards set by the NTSC for compatible color TV broadcasting.

GENERATING THE RAINBOW SIGNAL

The rainbow, or displaced-carrier, generator develops a 3.563795-MHz signal that is exactly 15,750 Hz below the 3.579545 MHz reference oscillator in the receiver under test. Thus, every 1/15,750 of a second, or the time to scan one horizontal line, the phase of the incoming test signal applied to the color receiver shifts 360 deg from the reference oscillator. This condition, which repeats itself every scanning line interval, is sensed by the receiver demodulators as though a picture of continuously varying hues were being scanned at the studio. The net effect is a display of hues or a rainbow pattern in a full color spectrum across the screen. Since the action is repetitive, the process repeats itself and a continuous rainbow pattern appears.

As the demodulators sense phase changes from zero to 360 deg, the rainbow pattern should shift (starting from the left of the screen) from yellow-orange to red to magenta to blue to cyan to green. [Recall that this sequence takes place since 90-deg phase represents red, 180 deg (approximately) produces blue, 240 deg cyan, 300 deg green, and zero or reference is yellow.] The screen will not display yellow since horizontal retrace time accounts for about 10 percent of the total horizontal scan time, and thus one-tenth or 30 deg of phase-shift information is lost while the beam is returning from the right-hand side of the screen to the left.

Note how the demodulator axes, whether they be I/Q, (R - Y)/(B - Y), X/Z, or other combinations, are conveniently located when the rainbow pattern is changed from a continuously blending display to a series of sharply defined bars, each separated by 30-deg intervals. The display rainbow is thus converted to a gated or color bar generator with some rather immediate advantages to the technician.

THE GATED RAINBOW COLOR BAR GENERATOR

By applying switching circuits to trigger the 3.56-MHz rainbow generator on and off at brief periods corresponding to 30-deg intervals during the scan of each horizontal line, the receiver now responds to incoming signals that interact with the internal 3.58-MHz reference oscillator during very specific intervals of time. Now each scanning line consists of (1) a short time when no incoming signal enters and thus no color appears, (2) a signal shortly thereafter representing, say, 30-deg separation between the two and creating a yellow-orange area, (3) a brief period where again no incoming signal arrives, and finally (4) a signal where a 60-deg phase difference exists, and so on. Instead of a blend of hues on the screen, there now appears a series of color bars, each separated by a blank space (Fig. 7-4). Since these bars represent 30-deg intervals of phase shift, it is simple to be aware of where each should appear if the color set is functioning properly.

Now the generator provides a very specific pattern which will display the same known bar pattern on the screen of any color set in proper operating order. Receivers with demodulator phasing errors or chrominance troubles will display an abnormal bar pattern with sufficient clues to alert the technician to possible trouble areas. A gated-rainbow display is shown in Color Plate XIV.

In addition to the visual display on the kinescope screen, the gated-rainbow generator gives a specific output waveform (see Fig. 7-6) used to signal trace in conjunction with a wideband oscilloscope. Each short burst of 3.56-MHz signal in the generator output represents a specific color as indicated, and only ten bars are active because of the retrace time interval. Note the presence of a 3.58-MHz color burst signal (precisely generated within the gated-rainbow generator) to synchronize the 3.58-MHz subcarrier oscillator in the receiver. Although this 3.58-MHz burst signal is most important and is thus part of the total gated-generator output signal, its color (yellow, since it is reference or zero phase) is not seen since it exists during the end of horizontal retrace. Also note the horizontal sync pulse to lock the receiver sweep and generate the correct timing signals for the color sync section.

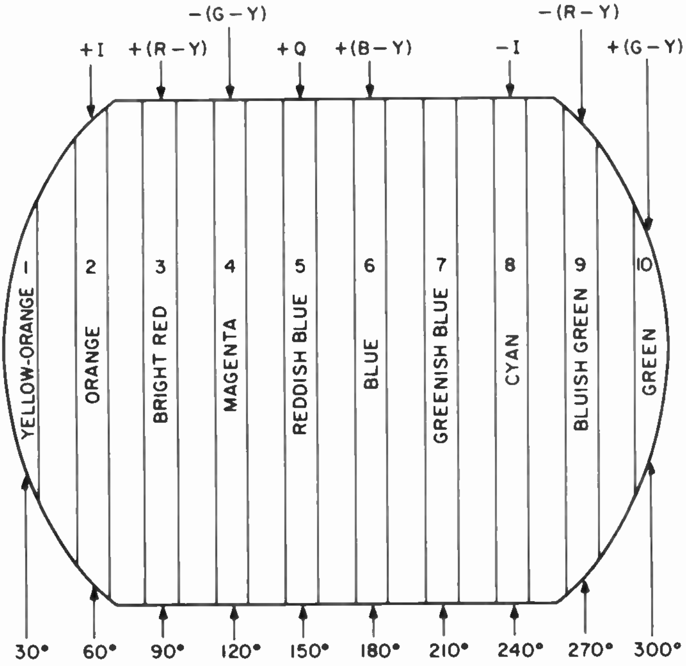


Fig. 7-4 A gated-rainbow color bar generator pattern as it would appear on a color receiver screen.

THE NTSC COLOR BAR GENERATOR

Consider a simple NTSC generator providing only a single bar on a receiver under test. The output of the generator would consist of a 3.579545-MHz color burst reference signal to synchronize the receiver's color sync section and a second 3.579545-MHz signal displaced from burst by a specific phase angle. If a different color is to be displaced, the only change that would take place in the generator would be the insertion of a different phase shift between burst and the new color signal.

A delay line, using coaxial cable or lumped circuit constants, is inserted between the 3.58-MHz reference oscillator in the NTSC generator and the color signal output (Fig. 7-5). By placing appropriate taps along the delay line assembly, specific time (and thus phase) delays can be chosen. If these taps are then routed to a selector switch, a specific time delay corresponding to a particular color can be fed from the NTSC generator.

Thus the NTSC generator deals with a 3.58-MHz reference signal and develops different colors by means of specific time delay intervals; the

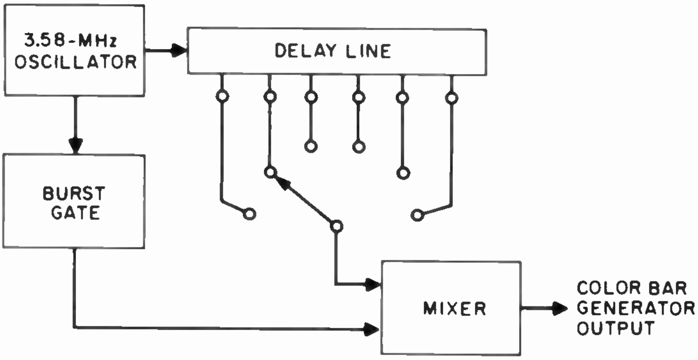


Fig. 7-5 A tapped delay line is used to insert specific fixed delays between the 3.58-MHz input and the NTSC generator output as a means to develop phase shifts to display colors.

rainbow generator uses a 3.56-MHz oscillator to produce a continuous phase shift as each horizontal line is scanned.

When the fixed-phase NTSC signal is applied to a receiver under test, the demodulators receive a 3.58-MHz signal with a particular phase shift and convert the signal to its appropriate color on the kinescope.

The NTSC generator produces the primary colors—red, blue, and green—and their complementary colors—cyan, yellow, and magenta—plus white. Refer to Color Plate XV for an NTSC display.

By incorporating electronic switching circuits into the generator design, the NTSC colors can be displayed in various arrangements on a color kinescope.

USING THE COLOR BAR GENERATOR FOR SIGNAL TRACING

With a known source of chrominance input, a color bar generator, the chrominance section of a color receiver may be rapidly signal traced. With the color bar generator fed to the receiver, the video detector waveform is first observed and should appear as in Fig. 7-6a. A wideband oscilloscope is necessary, together with a low-capacitance probe, to minimize circuit loading and waveform distortion. Next, the scope probe is moved successively to the bandpass amplifier input, its output (the demodulator input), and finally to the demodulator output (one grid of the color kinescope).

As the scope probe is moved from one stage to the next, peak-to-peak waveform amplitude can be compared with that in the manufacturer's service notes, and abnormal departures in waveform appearance or amplitude can quickly identify a defective stage.

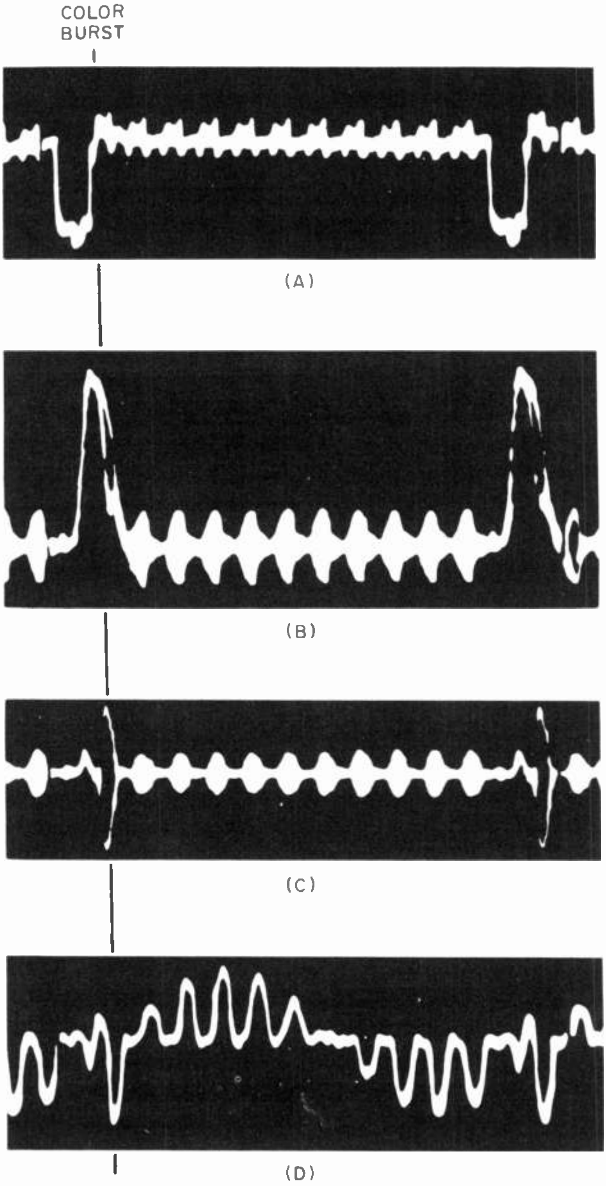


Fig. 7-6 Waveforms observed on a scope when a color bar generator is used to trace a color signal from the picture detector to the kinescope grid: (a) picture detector, (b) grid of bandpass amplifier, (c) grid of demodulator, and (d) grid of red kinescope.

Although signal tracing with a station program can be performed, it is rather difficult to measure stage gain or waveform appearance while the transmitted signal is changing. The use of the fixed color-bar generator signal is far more convenient.

USING THE COLOR BAR GENERATOR TO CHECK COLOR AND HUE

A properly operating color set, with a color bar generator connected to the antenna input, will produce a display of ten vertical bars varying in hue in this sequence; yellow-orange, orange, red, magenta, reddish-blue, blue, greenish-blue, cyan, bluish-green, and green.

The key bars to commit to memory are the third (red), fourth (magenta), sixth (blue), and tenth (green); these are the colors as viewed starting from the left side of the screen with the hue control in mid-position (refer to Fig. 7-3). The third, sixth, and tenth bars correspond to R - Y, B - Y, and G - Y signals respectively. The fourth bar (magenta) is used to check hue control range; as this control is rotated in one direction, the fourth bar becomes red, and as the hue control is turned in the opposite direction, the bar becomes reddish-blue, signifying a total phase swing of 60 deg.

Should the color bar pattern appear on the screen with the bars slightly off color when the hue control is at mid-position, a slight touchup of the color burst phasing transformer may be sufficient to restore the pattern to normal. Should the phase error be off considerably, as evidenced by, say, magenta in the second bar, a complete realignment of the color sync section may be necessary.

Most color bar generators include an output control to vary the input amplitude applied to the receiver. It is thus possible to use the generator on properly operating sets in order to determine the lowest level at which color and color sync are satisfactory. Then, when testing a defective receiver, it is simple to know when the set has been restored to its proper operating condition. As the output control is reduced, the color intensity on the receiver will drop, but the colors should remain locked in sync. As color begins to fade out, the color sync circuits may lose tight control, and stripes of several colors will appear on each bar. This loss of color sync at low levels of color bar generator input is normal.

USING THE COLOR BAR GENERATOR AND SCOPE TO ADJUST PHASE

With a color bar generator and wideband oscilloscope, exact phase settings for the two receiver demodulators can be rapidly performed.

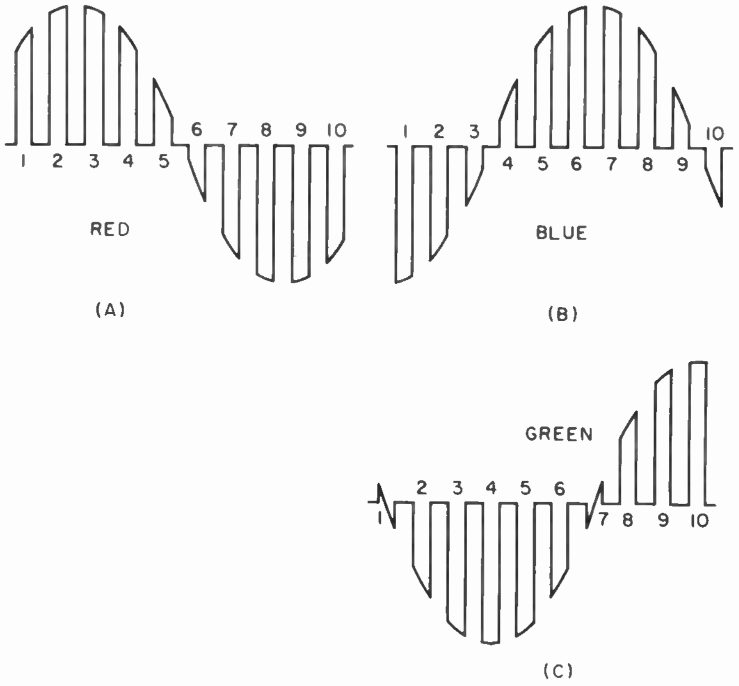


Fig. 7-7 When a color bar generator is used to check or adjust demodulator phase, the null or zero-crossing point on the scope connected to the demodulator output is carefully observed: (a) red waveform; (b) blue waveform; and (c) green waveform.

The technique involves applying the color bar generator to the receiver input and then closely examining the scope waveform of the color difference signals at the kinescope grids. The color bar generator and receiver are set to produce a stable bar pattern on the screen and the receiver hue control is set at mid-position.

From the schematic diagram on the service notes, determine which demodulator is driven directly from the internal 3.58-MHz oscillator. Let's assume the R – Y demodulator is fed from the oscillator directly and the B – Y demodulator is then fed a phase-shifted (90-deg) signal tapped from the 3.58-MHz oscillator.

To phase adjust this particular receiver, first connect the scope probe to the R – Y demodulator output or red grid of the kinescope. Adjust the scope for a 7,875-Hz time base so that two cycles will be displayed on the scope. The waveform in Fig. 7-7a will be seen with the third bar (red) appearing at maximum if the phase has been set properly; otherwise, one of the other bars will appear larger and adjustment will be indicated.

Rather than attempt adjustment for maximum amplitude of the third bar (or R - Y signal), it is more convenient to adjust for a null or zero crossing of the sixth bar (B - Y). Recall that the output of the R - Y demodulator should be zero for a 180-deg input; the sixth bar represents this phase signal. Thus, the burst transformer adjustment is rotated slowly until the center of the sixth bar passes through zero. At this time, the R - Y phase adjustment is correct.

Next, the scope probe is moved to the blue grid to observe the B - Y demodulator output (Fig. 7-7b). Now the sixth bar (B - Y) should be maximum while the third (B - Y) and ninth -(B - Y) bars pass through zero. If this condition is evident, the B - Y demodulator phasing is accurate. Otherwise, check to see whether there is a B - Y adjustment to touch up (most receivers have only one master phase adjustment or whether a component failure exists in the phase-shifting network.

Finally, move the scope probe to the green grid Fig. 7-7c and check to make sure that the G - Y output is proper. The tenth bar should be maximum while the first and seventh bars pass through zero.

USING THE COLOR BAR GENERATOR TO CHECK DEMODULATOR PHASING

With just a color bar generator, a grid shunt switch, and no oscilloscope, it is possible to check demodulator phase adjustments and matrix operation. It is necessary, of course, for the technician to know color bar signals and their sequence on the screen.

Assuming that the previously mentioned R - Y, B - Y receiver were to be quickly checked, the grid shunt switch would be used to bias off the green and blue guns first. With only the red gun working, a series of red bars would appear on the screen with spaces between the bars (Fig. 7-8). Now advance the brightness control until the spaces between bars are just visible. You will notice the spaces are lighter at the left of the screen and darker on the right (See Color Plate XVI.)

Recall that the R - Y demodulator is correctly phased when the sixth bar (B - Y) has zero output. Thus, the sixth bar should have the same brightness as the space on either side of it. To correctly identify the sixth bar, use the grid shunt switch to restore all guns to full operation. Then switch back to blue and green grids off.

If the phase adjustment is correct, the sixth bar will be of the same brightness as its adjacent spaces. As the hue control is varied back and forth, the sixth bar will appear brighter and darker than the adjacent spaces. If a slight touchup is necessary, adjust the burst transformer (with the hue control in mid-position) for the equal brightness condition.

Similarly, the B – Y phasing may be checked by biasing on the blue gun and cutting off the red and green guns. Now a series of blue bars will appear with spaces on the left appearing darker and those on the right lighter. The R – Y signals should pass through zero, and thus you would examine the third and ninth bar to check whether these bars are of the same brightness as their adjacent spaces.

Finally, to check the green grid, bias off the red and blue guns and check to see if the seventh bar [90 deg away from (G-Y)] passes through zero; the seventh bar brightness should match the level of the spaces on either side of it.

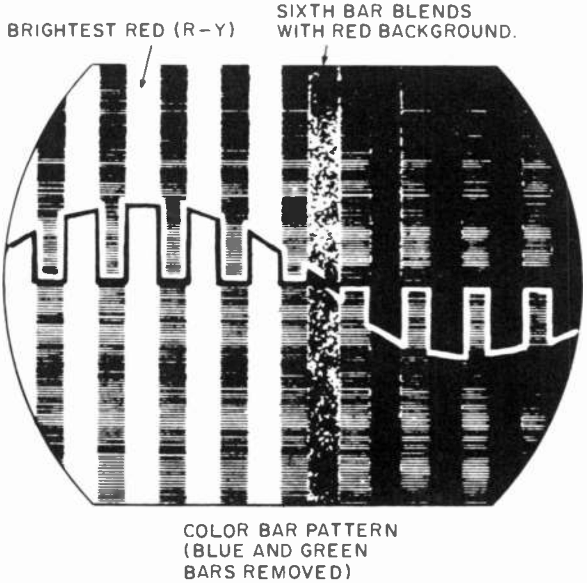


Fig. 7-8 A color bar generator can rapidly check for proper demodulator phasing.

THE VECTORSCOPE—A COLOR BAR GENERATOR AND SCOPE IN ONE

A relatively new instrument designed expressly for color TV troubleshooting and demodulator phase checking is the vectorscope. This instrument is basically an oscilloscope with a built-in color bar generator. The output of the color bar generator section is fed to the inputs of the receiver demodulator stages, and one demodulator output is fed to the vertical amplifier of the scope section while the second demodulator output is fed to the horizontal amplifier. The resultant display, as will be described shortly, offers an immediate visual display of the chrominance demodulator performance.

If an unkeyed rainbow display was fed to (R − Y), (B − Y) demodulator stages (Fig. 7-9a) with outputs connected to the vectorscope, the circular vectogram shown in Fig. 7-9b would appear with the "pie-cut" due to the blanking and color burst period during which time the color generator output is zero. The pattern appears as shown since full output would occur at 90 deg for the R − Y demodulator while the B − Y de-

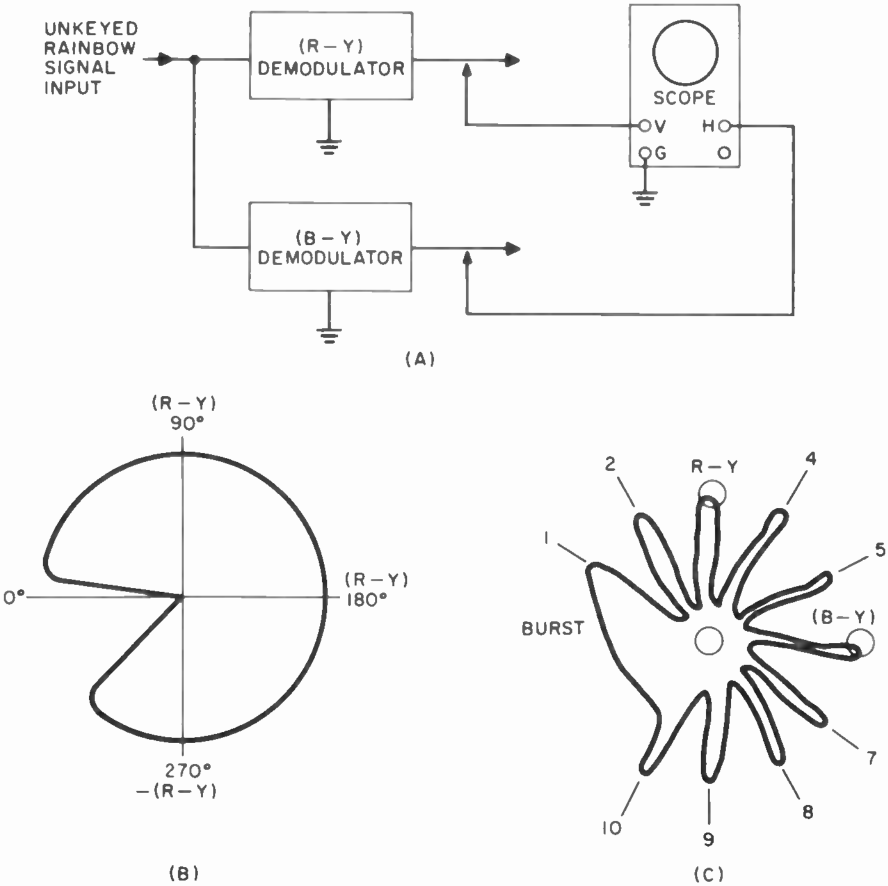


Fig. 7-9 A vectorscope combines a color bar generator and oscilloscope in one instrument.

modulator would have zero output; at 270 deg, the B - Y output would again be zero while the R - Y output would be maximum negative.

Now if a keyed rainbow-generator signal is used with the vectorscope, the circular pattern is replaced by spokes or "petals" (shown in Fig. 7-9c) since generator output does not appear continuously but rather occurs every 30 deg in phase. Only ten spokes (instead of twelve) are displayed, due to the blanking interval. With the keyed display, each spoke represents a particular chroma phase; for example, the third spoke (pointing straight up) represents R - Y, the sixth spoke represents B - Y, the second spoke represents I, etc. The display should appear as just stated if the set is properly phase adjusted, with the hue control in mid-position. As the hue control is rotated, the shape of the vectorgram remains the same, but the position of the spokes shifts along a circular path. If the receiver is performing properly, rotation of the hue control should cause each spoke to shift one position in either direction from its mid-position setting (or 60 deg total). A vectorscope is equipped with a calibrated scale or graticule so that the phase angle can be read directly.

By carefully observing the third and sixth bar, the R - Y, B - Y receiver can be quickly checked for phasing and quadrature displacement. For receivers using other demodulator axes, the correspondingly appropriate spokes would be examined.

THE COLOR TV TEST JIG

When trouble strikes a chassis in a console TV set, whether it be monochrome or color, the technician cannot become a furniture mover and cart the set to the shop. He must remove the chassis and have facilities in his shop to complete all necessary connections to put the receiver under proper test.

With black-and-white sets, the technician merely removes the yoke, the focus coil (if one is used), and the chassis. He can then use a test picture tube, slipping the yoke into place until service is completed. It is not too difficult a task to return the chassis, replace the yoke, and then adjust the yoke for proper scan and alignment to avoid tilt on the screen.

When a color chassis removal is necessary, however, the technician can create a major job for himself if he attempts more than just chassis removal. Should he decide to remove the deflection yoke, he must first remove the purity coil and convergence assembly. When he returns to the customer's home with the repaired chassis, he will face a challenging purity and convergence adjustment setup after he replaces the picture tube components. He may spend more time on this chore than on the chassis service job. But the chassis can't be serviced without these accessories plugged in!

The answer to this dilemma involves an investment in a color test jig—a cabinet, a color kinescope, deflection and convergence yokes, and an assortment of plugs and connectors to connect various manufacturers' chassis to the test jig. Suppliers of test jigs provide thorough cross-reference listings that permit the technician to quickly select the proper cables and extensions for the numerous models of domestic and foreign color receivers now in use.

PROBES FOR COLOR TV SERVICING

To extend the utility of VTVM's and oscilloscopes for color TV service work, RF (or demodulator) and low-capacitance probes are provided. Also, for accurate adjustment of the high-voltage supply when a receiver is installed or repaired, a high-voltage probe is most useful.

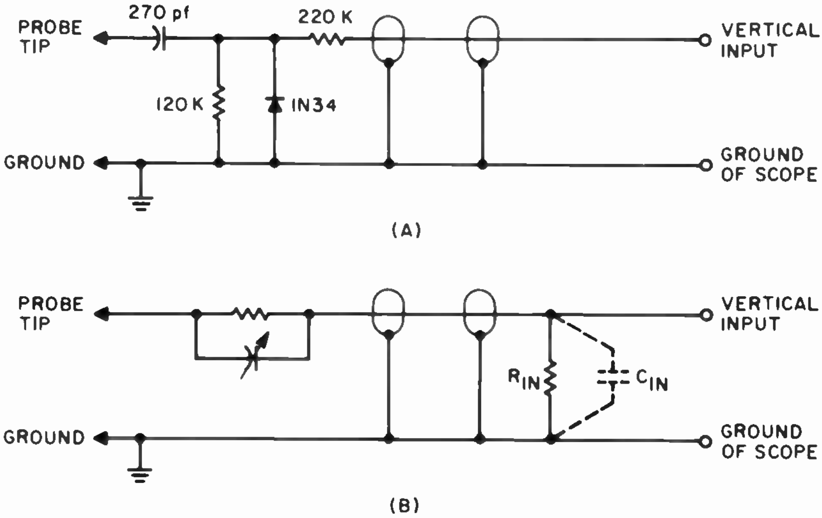


Fig. 7-10 An RF probe (a) and a low-capacitance probe (b) extend the utility of an oscilloscope and VTVM.

The RF or demodulator probe (Fig. 7-10a) allows the technician to trace incoming RF signals and IF signals as they proceed through their various amplifier stages. As soon as the probe output indicates a loss or severe attenuation, the defective stage has been isolated. From this point, a rapid check of voltages and resistance readings will generally pinpoint the specific component failure.

Circuit loading caused by the scope cable and input circuit capacitances can seriously affect circuit performance during testing and cause distortion of the observed waveform. To minimize this loading, which can exceed 80 pf in a typical test setup, a low-capacitance probe is used (Fig. 7-10b). The probe is adjusted by means of a built-in trimmer to match the time constant of the probe to that of the scope input circuit; with both time constants equal, high-frequency signals will not be degraded. The probe reduces the circuit loading to one-tenth of the actual value, or below 10 pf, but also attenuates the signal under test by a factor of ten. This attenuation is not serious, however, since most scopes offer more than adequate gain to provide a proper display.

The exact value of high voltage is not particularly critical in a black-and-white set; in a color set, the exact value is rather critical since the performance of the high-voltage regulator stage and the convergence and purity adjustments depend on a specific setting. Since the high voltage in color sets extends to 30,000 volts, a probe is used which allows reading up to 50 KV to be made. The probe consists of a voltage divider (using accurate, high-quality resistors) encased in a well-insulated grip with a grounded, arc-over protection arrangement to prevent accidental contact.

Review Questions

1. Why is it impractical for a service technician to use a color program to adjust for proper convergence?
2. What are two useful applications for the dot/crosshatch generator?
3. Name two useful applications for the color bar generator.
4. Briefly describe the difference between the (a) display rainbow, (b) gated-rainbow, and (c) NTSC color bar generators.
5. What is the color of the third bar on a gated-rainbow generator?
6. Briefly describe how the range of the "tint" control can be checked with a color bar generator.
7. What is a vectorscope and for what applications is it useful?
8. Why is a color TV test jig essential in a service shop?
9. Why is a high-voltage d-c probe necessary for color TV servicing?
10. Explain why a wideband scope is needed for color TV servicing.

8

Color TV Troubleshooting

DIAGNOSING TV TROUBLES

When the major electronic product owned by a consumer was a five-tube radio with a handful of resistors and capacitors, servicing by the "seat of the pants" was possible, though less profitable than a sound technical approach. When tube replacement didn't cure the radio defect, a tedious part-by-part soldering exercise could eventually restore operation.

With today's complex color TV receiver, the technician cannot profitably follow any amateurish approach. For example, sets use printed circuit boards, making unnecessary parts substitution a risk since board damage could result. The maze of components involved likewise could bewilder the technician who is not adequately trained to service a color set.

Just as a doctor must thoroughly understand anatomy and the auto mechanic know the operation of an internal combustion engine, so must the color TV technician become fully acquainted with the theory of colorimetry, the tricolor kinescope and its accessories, and the assortment of color circuits.

Color mixing, for example, hardly seems a subject to be studied by a radio-TV technician. Yet numerous color set faults have been incorrectly diagnosed, with hours of wasted labor, because of a lack of such knowledge. A color set with an overall cyan (bluish-green) tint could be restored to proper operation merely by increasing the output of the kinescope red gun. But the technician would first have to know that a cyan tint indicates a deficiency of red. Otherwise he could spend valuable time trying to locate troubles in the circuitry or, worse yet, disturb critical adjustments that have no bearing on the basic problem.

Diagnosing color TV troubles is an exercise in training, logic, patience, and the use of the senses. As thorough a training as possible is an obvious asset. Books, magazine articles, and manufacturers' service notes are available as a source of such knowledge; firm self-discipline is needed to take advantage of the information on a regular basis.

Snap judgements without ample opportunity to evaluate alternatives can send the color TV technician up a long, unsuccessful road filled with frustration and confusion. That's where the use of the senses and patience come into play. The experienced technician has learned, often the hard way, that he must look, listen, smell, and feel before he leaps to a conclusion.

Color TV is more complex to service than its black-and-white counterpart. But it also offers more clues to the service technician when faults develop. The experienced serviceman learns to check overall receiver performance first on the basis of the receiver as a black-and-white set. He may tune in a movie or rerun in black-and-white or observe a color program with the color control set to minimum.

He will then separate overall operation from color or chrominance performance. Is the black-and-white picture proper? Are sync, AGC, sound, height, width, and linearity correct? Any defects of this type call upon his previous servicing of familiar black-and-white sets.

If the black-and-white picture displays a tint over the entire screen, or if there are ghosts or fringes of color at the edges of objects or blotches of color in various areas over the screen, the technician then dips into his recently acquired color TV experience and decides on the need for degaussing or demagnetizing the kinescope or whether to touch up purity or convergence adjustments.

Only when the technician is satisfied that black-and-white performance is satisfactory will he view a color picture. He then notes whether colors are vivid and true and remain locked in sync. Failures in color are carefully analyzed using all senses. Is there a burning odor indicating an overheated resistor, a tiny visible crack in the printed circuit board causing intermittent color, a power resistor cool to the touch because of an open lead? A meter and scope can then eventually locate just about all defects.

SERVICING THE COLOR TV RECEIVER

Many of the circuits contained in a color receiver are identical to those found in modern black-and-white sets. The tuner and IF sections demand more stringent alignment, but the circuitry is fairly straightforward. Similarly, the vertical and horizontal deflection systems of color sets are more demanding in terms of output power and high voltage, but once again the circuitry is not markedly different from that in black-and-white receivers. The chrominance section—bandpass amplifiers, color killer, demodulators, color-difference amplifiers—and the color sync section—burst gate, 3.58-MHz oscillator, reactance tube, and phase detector—are new elements for the technician.

The color receiver is more complex than its black-and-white counterpart and therefore it is quite important to apply logical servicing techniques to avoid time-consuming tests on many circuits that have little or no bearing on the trouble presented. To isolate color receiver troubles, the most common practice involves checking the set for proper black-and-white reception. A careful observation will reveal any defects or imperfections in sweep size or linearity, sound, AGC, sync for the deflection circuits, AFC, contrast, etc. Any defects noted at this time should be corrected before taking the next step—observing a picture in color.

CHECKING THE BLACK-AND-WHITE PICTURE ON A COLOR SET (Fig. 8-1)

With the color or saturation control set at minimum, carefully fine-tune the receiver on a strong station transmitting color. Turn the fine-tuning control until sound bars just appear and the picture is on the verge of loosing sync; then back off until the sound bars just disappear. Adjust the contrast and brightness controls for a good picture.

Now carefully check the picture for sufficient detail, adequate sync, proper linearity both horizontally and vertically, sound level, absence of hum bars, or AGC overload buzz. Remedy any minor variations from acceptable performance with rear-panel controls wherever possible.

Next, turn to an unused channel and observe the raster as the brightness control is rotated from bright to dark. A variation in white to gray to black should occur with no trace of a dominant color over the screen. If a color tint appears over the screen during this test, first degauss the set before becoming involved with purity and gray-scale adjustments.

Another possibility of a dominant hue on the screen illustrates how a chrominance section defect can affect black-and-white reception. A weak or defective demodulator or color-difference amplifier tube will change its associated plate voltage. Since these stages are generally direct-coupled to the kinescope grids, the bias shift at the kinescope will change the gray-scale tracking and place a tint over the entire screen. Similarly, a defective 3.58-MHz oscillator may affect kinescope bias and gray-scale tracking.

If an untinted raster is obtained, switch back to a strong station and carefully observe the edges of outlines in the picture. If color fringing appears, it may be necessary to touch up the static and dynamic convergence settings.

CHECK LIST FOR
BLACK-AND-WHITE RECEPTION

1. CAREFULLY FINE TUNE FOR BEST PICTURE

2. CHECK:
   - ☐ CONTRAST
   - ☐ SOUND
   - ☐ SYNC
   - ☐ HORIZONTAL SIZE AND LINEARITY
   - ☐ VERTICAL SIZE AND LINEARITY
   - ☐ PROPER AGC SETTING
   - ☐ SCREEN FREE FROM COLOR TINT
   - ☐ "FRINGING" AT EDGES OF OBJECTS

3. CORRECT ANY DEFECT IN BLACK-AND-WHITE DISPLAY BEFORE VIEWING COLOR PICTURE

Fig. 8-1 Check list for establishing that the color receiver provides an acceptable black-and-white picture.

CHECKING COLOR RECEPTION ON A COLOR RECEIVER (Fig. 8-2)

When it is apparent that black-and-white performance is up to par, tune in a color station and turn up the color control; again carefully set the fine-tuning control as previously described. Observe the color picture for the following points:

1. Does the color or saturation control bring the colors to full vivid intensity?

CHECK LIST TO DETERMINE COLOR PERFORMANCE

1. CAREFULLY SET FINE TUNING FOR COLOR RECEPTION
2. CHECK:
   - ☐ COLOR CONTROL RANGE
   - ☐ TINT CONTROL RANGE
   - ☐ ACCEPTABLE FLESH TONES WITH TINT CONTROL IN MID-POSITION
   - ☐ ADEQUATE COLOR SYNC LOCK
3. EVALUATE PERFORMANCE ON BASIS OF ABOVE CHECKS

Fig. 8-2 Check list for establishing proper color reception.

2. With the tint or hue control at mid-position, are flesh tones normal?

3. Does the color sync remain steady as the tint control is varied through its entire range?

4. As various color stations are switched, does the tint control correct for the slight phase shift among stations and produce proper flesh tones?

These brief and simple checks are sufficient to offer an initial evaluation of color receiver performance. Insufficient color saturation could stem from chrominance section defects or RF/IF misalignment, covered on the following pages under "No Color" and "Weak Color." Loss of color sync or weak color sync, evidenced by horizontal or diagonal bands of color over the black-and-white picture, stem from troubles in the automatic frequency and phase control (AFPC) section or improper adjustment of the various transformers in this section.

NO COLOR, BLACK-AND-WHITE PICTURE NORMAL (Fig. 8-3)

An obvious, but often overlooked, check when a "no-color" complaint is encountered is whether the station or stations viewed are transmitting color programs. Today almost all evening programs are in color, but many daytime reruns are monochrome.

Next, carefully adjust the fine-tuning control until sound bars just appear and then back off slightly. The fine-tuning control is a critical adjustment in a color receiver, and new color set owners often ignore this control and immediately complain of "no color." With the fine-tuning control properly set, and with the color saturation control at minimum, a good black-and-white picture should be present; no color should be evident if purity and convergence adjustments are in order. Turn the fine-tuning control until the sound bars just appear, and then turn up the color saturation control. If color appears in the sound beat pattern or along the edges of outlines in the picture, the demodulators and amplifiers in the chrominance section are functioning. Absence of color with this simple check indicates failure of the chrominance section. Make sure, by the way, to set the AGC and color-killer threshold controls for maximum sensitivity.

If the chrominance section appears to be operative, check the antenna installation. In cases where a new color set is connected to an existing antenna, it is possible for adequate black-and-white reception to exist in conjunction with color reception that is poor or sufficiently bad to result in no color. In strong-signal areas, remove the existing antenna lead-in and connect an indoor antenna to the set to see whether reception can be improved. If improved reception is obtained, further inspection of the existing antenna installation may reveal broken or lost antenna elements and/or breaks in the lead-in cable.

Assuming that the antenna system (antenna, transmission line, and

CHECK LIST FOR
NO COLOR, BLACK-AND-WHITE
RECEPTION NORMAL

- ☐ FINE TUNING SETTING
- ☐ STATION TRANSMITTING COLOR
- ☐ ANTENNA/LEAD IN SYSTEM
- ☐ CHROMINANCE TUBES
    - BANDPASS AMPLIFIER
    - BURST AMPLIFIER
    - COLOR KILLER
    - 3.58-MHz OSCILLATOR
- ☐ AGC, COLOR KILLER ADJUSTMENTS

Fig. 8-3 Check list for no color, black-and-white reception normal.

any multi-set couplers involved) is satisfactory, a color bar generator is useful to isolate the cause of malfunctioning in the RF/IF section or the chrominance section. This is done by removing the antenna lead-in and then connecting the color-bar generator RF cable to the receiver. The color saturation control is turned up, the AGC and color-killer threshold controls are set to maximum sensitivity, and the fine-tuning control is carefully tuned until the interfering sound bars just disappear.

If the color bar pattern appears normal, the antenna system is at fault. If color bars do not appear, disconnect the RF cable of the color bar generator and apply the generator's video output cable to the receiver's first video amplifier input, using the appropriate video polarity signal. If colors appear on the screen, the chrominance section is working properly, and a check of the RF/IF response curve will probably show a dip at the color subcarrier frequency, indicating the need for proper alignment or possible RF/IF component failure.

If the color bar generator fails to produce a color pattern on the screen, a check of the chrominance section is in order.

Since the color-killer stage controls the conduction of the bandpass amplifier, make sure to check the killer threshold setting. Also, the color killer responds to color transmission by the presence of burst delivered from the burst amplifier. Check the color killer, bandpass amplifier, and burst amplifier tubes before undertaking chassis removal. Similarly, a defective 3.58-MHz oscillator stage will prevent color signal processing since the demodulator stages require reference signal sources for their operation. Therefore, the 3.58-MHz oscillator tube should also be checked or replaced before more detailed servicing is attempted.

The 3.58-MHz oscillator can be quickly checked by measuring the grid leak bias; readings of −10 volts and higher can be made without chassis removal by the use of adapter sockets when exposed printed-circuit sockets are not used.

A grid-to-cathode short in the color-killer tube will keep this stage conducting even with the presence of burst delivering a high negative d-c voltage to the bandpass amplifier grid. Tube substitution will quickly rule out this possibility.

Component defects in the bandpass amplifier, such as a leaky plate or screen bypass capacitor, can cause low operating voltages and little or no chrominance signal output for the demodulator stages.

Note that a failure in one of the demodulator or color-difference amplifier stages will not result in "no-color" symptoms since some color signals will be applied to the picture tube. Only faults affecting signals from reaching all three control grids of the picture tube can cause the "no-color" complaint.

"NO COLOR" SIGNAL TRACING

A color-bar generator and a wideband oscilloscope will hasten the isolation of a "no-color" symptom caused by a defect in the chrominance section.

The color bar video signal is applied to the first video amplifier grid and the waveform at the plate would appear as shown in Fig. 7-6a. After passing through the small coupling capacitor to the bandpass amplifier, the waveform appears as Fig. 7-6b. An amplified version of this waveform will appear at the bandpass amplifier output and grid of each demodulator. If a color bar generator is not available, the wideband scope can be used to signal trace the incoming color station signal in a similar manner.

Once the point of chrominance loss or severe attenuation is localized, voltage checks are made to isolate the specific component responsible for the fault. Exact value replacement with proper regard for maintaining original lead length and layout is recommended.

Another approach involves turning up the color saturation to maximum and checking for color "snow" (see Color Plate XVII). If necessary, turn the color-killer threshold control for maximum color sensitivity. If no color snow is observed, check the 3.58-MHz oscillator and bandpass amplifier stages.

COLOR ON SOME CHANNELS, NOT ALL

As previously described under "no-color" conditions, the antenna is a critical element of the color system. When the chrominance section produces color pictures on some channels but not all, substitute an indoor antenna for the existing antenna. Tune in one of the stations that is not receiving color, extend the indoor antenna rods, and rotate their position to determine whether color can be obtained.

In most cases, the substitution will cure any problem stemming from the following distortions in the resonant characteristics of the antenna: (1) A dip in the antenna response curve near the color subcarrier frequency of the affected channel (Fig. 8-4); (2) a mismatch between the antenna, transmission line, and receiver that can cause severe attenuation of the color subcarrier; and (3) reflected signals or "ghosts" that may result in partial cancellation and thus lowered response at the subcarrier frequency. It is also possible that an excessive signal level caused by the use of a high-gain antenna in a strong-signal area will produce overload at the RF stage and thus affect the overall RF response to the extent that the color subcarrier level will be low relative to the RF carrier.

If a substitute antenna does not restore color to all channels, it is then necessary to do a sweep-generator check of the RF response of the

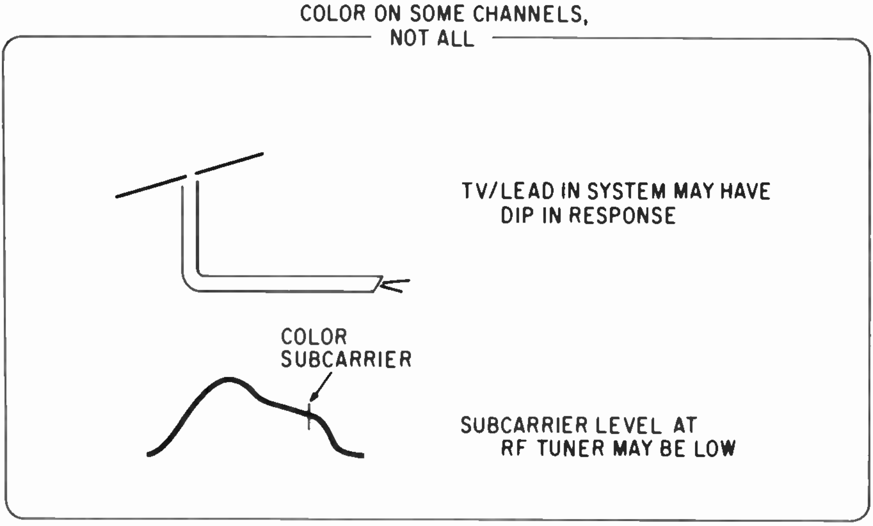


Fig. 8-4 A dip in the antenna/lead-in response curve may produce a "no-color in one channel" symptom.

channel under investigation. Tilt or attenuation departures from a flat response is tolerable in black-and-white tuners but must be avoided in color sets.

WEAK COLOR

When a color receiver is capable of producing a strong, clear black-and-white picture but cannot deliver a saturated color image, the troubleshooting technique to follow is similar to that in "no-color" situations. It is assumed, of course, that the set does provide weak or unsaturated colors of correct hue that are locked in color sync.

First check the bandpass amplifier, the 3.58-MHz oscillator, and the color-killer tubes. If a color-bar generator and wideband scope are available, follow the signal tracing procedure outlined for "no-color" situations, and check peak-to-peak amplitude waveforms against those tabulated in the manufacturer's service notes. Once the source of inadequate gain is localized, the component responsible can be found and replaced.

If the chrominance section waveforms agree with the manufacturer's values, the RF/IF section is suspect however excellent the quality shown for a black-and-white picture. A response check of the RF and IF sections will indicate a loss in gain somewhere in the vicinity of the color subcarrier. Proper realignment should restore full color saturation.

LOSS OF COLOR SYNC

The function of the color sync or AFPC section is to provide two reference signals for the color demodulators. A defect in this section results in a picture that contains color in the form of horizontal or diagonal bands across the screen (see Color Plate XVIII for this "barber pole" effect.) Another symptom of a defective color sync section is change of hue during program viewing. Inability to obtain correct hues despite full rotation of the hue control or narrow range of tint control are other indications of faults in this section.

The color sync section is in many ways similar to a horizontal AFC system. In horizontal AFC, the local 15,750-Hz sweep oscillator is compared with the incoming sync pulses representing the deflection sweep timing at the transmitter. Errors between the two are detected by comparison, and automatic corrective action is taken until the local horizontal oscillator operates at exactly the sync frequency and thus at the frequency of the station oscillator.

In a color sync section, incoming burst is separated from the chrominance signal by the burst gate and applied to a phase detector together with the locally generated 3.58-MHz signal from a crystal oscillator. Deviations in frequency and/or phase develop a correction d-c voltage which is applied to a reactance tube connected across the 3.58-MHz oscillator tuned circuit. Corrective action at the reactance tube restores perfect phase and frequency lock of the local 3.58-MHz oscillator with the transmitter reference.

Obviously, the tubes (or semiconductors) for these stages should be checked first if color sync is lost (Fig. 8-5). Once these checks or tube substitutions have been made, it is suggested that the entire automatic frequency and phase control (AFPC) adjustment procedure be performed.

CHECK LIST FOR
LOSS OF COLOR SYNC

☐ BURST AMPLIFIER
☐ PHASE DETECTOR
☐ 3.58-MHz CRYSTAL
☐ AFPC SETUP ADJUSTMENTS

Fig. 8-5 Check list for loss of color sync.

AFPC ALIGNMENT

The alignment procedure described applies to the majority of sets in use today that contain crystal-controlled oscillators corrected by reactance-tube action. First check the manufacturer's service notes for specific circuit details, location of test points, and voltage readings to be expected.

Basically the procedure involves (1) setting the 3.58-MHz crystal oscillator frequency, (2) tuning the 3.58-MHz burst transformer, (3) adjustment of the reactance coil, and (4) final checking to assure solid color sync lock and adequate range of the hue or tint control.

The steps to be followed appear below.

Step 1. Tune in a strong color station or use a color bar generator. Set the color or saturation control to maximum, the hue or tint control to mid-position, and the color-killer threshold to maximum sensitivity. Tune the 3.58-MHz oscillator. Short the grid of the burst amplifier to chassis, using a short clip lead, to remove burst from the phase detector. The phase detector voltage is now only a function of the 3.58-MHz input. Connect a VTVM probe to the cathode of the phase detector tied to one side of the burst transformer. Adjust the transformer in the 3.58-MHz oscillator plate circuit for maximum reading on the VTVM.

Failure to observe any reading on the VTVM at this time indicates either a defective oscillator stage, phase detector circuit, or the coupling arrangement between the two. To isolate the specific fault, first check the oscillator grid bias, which should be about −10 volts.

Check the tube and individual circuit components, and then replace the 3.58-MHz crystal if no grid bias is developed. If bias is obtained but no VTVM reading is observed, replace the phase detector tube (or check the semiconductor diodes). Also check the connections to the printed-circuit board for possible poor contact.

A wideband oscilloscope is particularly useful for rapid inspection of the appearance of the 3.58-MHz signal at the oscillator grid and phase-detector input.

Step 2. Adjust the burst transformer. Leave the VTVM at the same phase detector point as in Step 1, and remove the clip lead from the burst amplifier grid. Due to the presence of burst, the VTVM reading should increase. Tune the burst transformer coil for maximum VTVM deflection.

A lack of voltage increase at the VTVM indicates that burst is not reaching the phase detector. Since color is present (by its out-of-sync appearance on the screen at this time), the bandpass amplifier is working and the burst amplifier should be checked. First compare d-c voltage readings at various electrodes, and then use a scope to determine whether the gating pulse is reaching the burst amplifier. It is possible that the timing network delaying the arrival of the gating pulse from the flyback transformer is defective, causing complete or partial loss of burst.

Step 3. Adjust the reactance stage coil. Use a short clip lead to ground the phase detector output. Observe the transmitted color picture or color bar pattern, and tune the plate coil of the reactance tube. The colors will change from diagonal or horizontal bands until they appear fairly well locked in sync but drifting slowly in hue or tint. This is the "zero beat" condition where the free-running frequency of the 3.58-MHz oscillator is very close to the transmitted reference signal.

If the oscillator cannot be adjusted to this "zero beat" condition, check the oscillator voltages and components, the 3.58-MHz crystal, and the reactance tube and its associated components.

Step 4. Check the color sync lock. Remove the clip lead from the phase detector output, and note whether the color immediately locks in sync. If nothing happens, and the "zero-beat" hue drift continues, check the reactance tube and its components.

If the phase detector is not properly balanced (change in component values or mismatched diodes), the color will change from the slow drift condition to many diagonal or horizontal bands.

Finally, if the color locks in sync, try reception on all color channels. Observe any weak stations particularly. As signal level is reduced, the color saturation may become less pronounced but the color sync should be maintained.

Check the range of the hue or tint controls. A shift of at least ±30 deg from mid-position should be possible. To perform this test, connect the color bar generator to the color receiver, and tune for a proper color bar display. Observe any particular bar, for example, the eighth bar—cyan—with the tint control in mid-position. Rotate the tint control to one extreme, and the cyan bar should shift to the ninth bar during this test. Then rotate the tint control to the other extreme position; the cyan bar should move to the seventh bar position. If this range is not covered, or if the colors lose sync during tint control rotation, repeat the AFPC adjustment procedure.

COLOR IN A BLACK-AND-WHITE PICTURE

Poor purity, improper convergence adjustments, a shift in the gray-scale tracking, and certain other color section defects permit colors to appear on the color receiver screen during monochrome reception.

Poor purity can cause various areas of the screen to appear in color in the absence of any video signal even though most of the raster appears gray or white. Poor purity stems from a faulty or slipshod purity setup when the receiver is installed or after it has been moved from one location to another. If the steel supports holding the picture tube are magnetized by a strong field from a vacuum cleaner, for example, purity will be affected. To remedy this problem, degauss the screen area and, if necessary, repeat the purity adjustment.

Color fringing, or outlines of the primary colors along the edges of objects, results from faulty convergence. Static convergence refers to exact registration of the three electron beams at the center of the screen; dynamic convergence concerns the outer edges. Convergence touchup may be all that is required to correct such complaints. At times, however, defects within the dynamic convergence circuits may be responsible. Such circuit defects can be pinpointed when a particular step during the convergence setup procedure fails to perform what the service notes indicate. Also make sure that the convergence assembly is properly positioned on the neck of the picture tube.

COLOR PURITY

Viewers may tolerate slight misconvergence, with color fringes at the edges of objects, but will be quite upset over improper purity when one side of their favorite film star's face is flesh-tone on one side of the screen and cyan at the other side.

With proper purity, the screen will display only red when the red gun is biased on and the blue and green guns are biased off. Electrons leaving the red gun will strike only the phosphors producing red output over the entire screen. Similarly, when each of the other guns operates alone, only its particular color will appear over the entire screen. With these conditions satisfied, a white raster (or gray, depending on brightness setting) will appear when all three guns are operating with no video signal input.

If purity is not set properly, the red gun may produce a red raster over most of the screen with perhaps the upper left area slightly pink. When pure green and blue rasters are superimposed on this red raster as all three guns are turned on, the major portion of the screen will appear correctly as white but the upper left area will appear as cyan since there is insufficient red.

CHECKING COLOR PURITY ADJUSTMENT

First obtain a blank raster by removing an IF tube, or use a color bar/dot-bar generator containing provisions for a no-signal situation. Then follow this procedure:

1. Degauss the receiver. The receiver may be on or off. Plug in the degaussing coil, and bring it parallel to the screen faceplate. Move the coil slowly along the entire front of the tube and then along the sides of the set for a few minutes. Then move as far from the set as possible and turn off the power to the degaussing coil.
2. Connect a dot-bar generator to the receiver video input, and adjust the static convergence magnets until the center convergence is fairly good.
3. Switch the dot-bar generator off, and observe the raster with the blue and green screen controls turned down and the red screen up. Check the entire raster for evidence of less than perfect red.
4. If a uniform red raster is not present, loosen the deflection yoke mounting screws, and move the yoke back to the convergence coil assembly. Now the raster will be considerably impure with a rather broad red area somewhere near the center.
5. Carefully adjust the spacing of the purity ring tabs, and rotate the purity assembly until the red area is as close to the center of the raster as possible.
6. Now move the deflection yoke forward until the entire screen is red. The yoke will generally not be touching the bell of the kinescope for this proper setting.
7. Use a ten-power magnifier to check for proper red purity over the entire red area. If proper red purity is now achieved, turn off the red gun and repeat the inspection for green and blue. In most cases, once the red raster is pure, the other two will offer no difficulties. Should a problem arise, however, recheck the center convergence adjustments and repeat the purity procedure.

SERVICING THE HIGH-VOLTAGE SECTION

Color receivers include high-voltage supplies delivering 25 KV and up. Obviously such service factors as critical lead dress, component placement, and proper solder joints that apply to 18–20 KV black-and-white sets are even more important in color receivers.

In addition to more rugged horizontal output and damper and HV rectifier tubes, the color set requires a high-voltage regulator tube to maintain a fairly constant high voltage setting. Failure of this tube function will produce variations in picture size as the scene brightness changes.

Absence of high-voltage involves the same troubleshooting steps for color as for black-and-white sets. The deflection tubes, damper, HV rectifier, and HV regulator tubes are each checked (or substituted, if possible, by a new or known good tube). If the trouble is not caused by a tube, the horizontal oscillator output, horizontal amplifier output, and damper circuit must be checked until the stage is isolated and the defective component replaced, just as in black-and-white servicing.

In many color sets, failure of the focus rectifier to deliver the necessary 5 KV or so on the focus anode will prevent a raster on the screen despite the presence of adequate high voltage. To check this possibility, use a HV probe with a VTVM or multimeter to check the focus voltage.

PREDOMINANT HUE OVER ENTIRE SCREEN

If the screen of a color receiver suddenly displays a picture with a predominant hue, it is not unusual for the viewer (and some technicians) to immediately conclude that the picture tube is defective. Although this possibility is one of several, it is not the most likely cause of the trouble. And it would be quite embarrassing, time consuming, and considerably expensive to replace a color kinescope only to turn the set on and find the predominant hue still in existence.

A predominant hue over the screen signifies that a change has taken place in the bias (cathode/control grid) or screen voltages in one or more of the guns. The first step is to measure the various electrode potentials, and check these voltage readings against those in the manufacturer's service notes. Knowledge of basic color mixing is handy here. If the predominant hue is yellow, for example, it is possible that the red gun bias or screen voltage has changed and insufficient red beam current thus causes the yellow hue. Finally, make sure that each heater in the three-gun assembly is lit.

Receivers using high-level demodulators (which are directly coupled to the kinescope) can exhibit this symptom if there is a failure in the 3.58-MHz subcarrier oscillator. The loss of 3.58-MHz oscillator signal at the demodulators changes their plate voltages and thus upsets the bias voltages on the guns.

In sets using color-difference amplifiers (such as R - Y, B - Y), an open filament in the B - Y amplifier tube causes conduction to cease and plate voltage to rise. This increase of positive voltage at the grid of the blue gun causes excess blue beam current and the screen will display a predominant blue color.

Of course, another possible cause of this condition is misadjustment of gray-scale tracking (the procedure is described elsewhere). Readjust if necessary, and note whether the hue reappears after the set is on for a while. If it recurs, replace the demodulator and color-difference amplifier tubes.

NO RASTER, NO BRIGHTNESS

The initial checks for this condition include focus and high voltage, kinescope heater supply, and kinescope screen and bias voltages.

Although the high voltage can be sensed by the crackling or sizzling sound as the set warms up, it is best to use a high-voltage probe to measure the exact value of high voltage and focus voltage.

Assuming that high voltage is present, the next voltage checks take place at the screen grid of each gun. A loss in screen voltage at each of the guns would be necessary in order to preclude brightness; this situation is rather unlikely. Similarly, a loss in positive potential at each of the three control grids could cause this symptom; here again, the likelihood is rather remote since each control grid is fed from a separate amplifier (or demodulator).

Now consider a simple failure such as an open filament in the last video amplifier tube. The plate voltage rises to B+ since no plate current flows, and the kinescope cathodes suddenly increase to a level sufficient to cut off all three guns. An open screen resistor or shorted screen bypass in the video amplifier tube would cause the same rise in plate voltage and excess kinescope bias. The net result—no raster or brightness on the screen. Check all d-c voltages on the last video amplifier; any defect that causes a kinescope bias in excess of 200 volts will cut off the picture.

BRIGHT PICTURE WITH NO CONTROL OF BRIGHTNESS

Any factor responsible for insufficient kinescope bias will result in a picture with excessive brightness. Since all three guns must be involved, it is more likely that the trouble exists in the cathodes (common to all three guns) rather than the grids (each grid is supplied by its individual amplifier or demodulator).

If the last video amplifier stage is conducting very heavily—as the result of a grid-to-cathode short, for example—its plate voltage will drop to a low d-c level, thus lowering the cathode voltages and resulting in a brighter-than-normal raster with no control over brightness.

Many receivers use a brightness control in the grid circuit of the last video (or luminance) amplifier to set the bias of this stage and thus the kinescope cathode voltages. Thus brightness control is supplied a negative voltage from the grid leak bias developed from circuits such as those of the blanker or horizontal oscillator. Any defect in this supply or the associated filter networks will cause this negative voltage to drop or be lost completely, resulting in excessive conduction of the video amplifier stage and hence high brightness.

HIGH-VOLTAGE PROBLEMS–THE REGULATOR TUBE

When the high-voltage regulator tube becomes non-conducting as the result of an open filament or circuit component failure, the high voltage will rise sharply (in excess of 27 KV in many sets). This effect is brought about by the decrease in loading effect offered to the high-voltage supply. Arcing, corona, or component breakdown may become evident as the brightness control is varied to kinescope cutoff, at which time no load exists for the high-voltage supply. As the brightness control is varied to increase brightness, the picture size will change drastically, indicating lack of regulation. A cathode-to-grid short in the regulator tube will cause an excessive load to be placed on the high-voltage supply, thus lowering it and resulting in low brightness and poor focus. The same condition will occur if the grid-to-cathode bypass capacitor should short.

An unusual symptom to observe is a picture that appears to oscillate in size—both height and width—and in brightness level at a slow rate. This condition can be traced to a gassy regulator tube producing an action similar to that of a neon-relaxation oscillator. To pinpoint this trouble, turn up the brightness control until the picture blooms, indicating that the regulator tube is cutoff. At this time, the size fluctuations should stop.

X-RAY RADIATION IN COLOR RECEIVER

A great deal of publicity has been expended on the harmful effects of X-ray radiation caused by the 25-KV (and higher) voltages encountered. After a considerable amount of study and evaluation by leading X-ray specialists and TV design engineers, it has been fairly well determined that the radiation situation is now under control.

The three potential sources of harmful radiation were found to be the picture tube, the high-voltage rectifier, and the high-voltage regulator tubes. It was determined that no measurable X-ray radiation was emitted when the following precautions were taken:

1. The receiver high-voltage was set to the manufacturer's specified level. Excessive high-voltage could produce sufficient X-ray radiation to penetrate the high-voltage compartment and thus offer a potential hazard to the viewer. An accurate high-voltage meter to measure the rated value is a necessary service tool.
2. All metal shields associated with the high-voltage compartment were fastened securely; shields removed and not replaced by previous servicemen were to be restored and fastened.
3. Early-model receivers used a 6BK4 shunt regulator tube. Replacing this type with an updated design, type 6EL4, offered improved shielding properties.

TROUBLESHOOTING CHARTS

Tables 8-1 through 8-6 list the common color troubles that may be encountered in a color TV receiver. Tables 8-7 and 8-8 list troubles in the low-voltage and high-voltage power supplies, included because of their effect on color. Using these tables in conjunction with the check lists and test procedures given previously in this chapter should help to identify most TV color FC troubles quickly and efficiently.

Review Questions

1. Explain why it is useful to check the performance of a color TV set by first examining its reception of black-and-white transmission.
2. Name two possible troubles that could cause a raster (set not tuned to a station) to appear with an overall tint rather than white or gray.
3. How would you begin checking "no color; black-and-white picture normal"?
4. Can a faulty antenna/cable system cause problems in color reception on one channel while the remaining channels are OK? Explain.
5. How is loss of color sync displayed on a color receiver?
6. How would you check whether the 3.58-MHz crystal oscillator is functioning?
7. State three causes for color appearing on a black-and-white picture on a color receiver.
8. During the color purity adjustment procedure, what influence does yoke position have?
9. Can a defective focus rectifier cause a "no brightness" condition? Explain.
10. What could cause a bright picture and leave no means to control the brightness level?

TABLE 8-1 COLOR IN BLACK AND WHITE PROGRAMS

Trouble	Remedy
Improper purity (tint over entire screen or one area)	1. Degauss receiver 2. Check beam landing using low-power magnifier. Correct landing errors at center of screen with purity magnet. Landing errors off center require yoke setting. (See "Purity Adjustments") 3. Check static convergence using dot/bar generator. 4. Check adjustment of edge or rim magnets

TABLE 8-1 COLOR IN BLACK-AND-WHITE PROGRAMS (CONT'D)

Trouble	Remedy
Color fringing over entire screen	1. Degauss receiver 2. Check static convergence; touch-up may restore proper convergence over entire screen
Color fringing at center of screen	1. Degauss receiver 2. Check static convergence. Make sure convergence assembly is properly located on neck of kinescope over internal pole pieces. Beam movement should be at least one inch. Also check that magnets are not reversed in their sleeves.
Color fringing at areas off center	1. Check dynamic convergence. Locate area affected and controls relating to this area. If in doubt, slightly adjust each control noting area involved and then return control to original position. When pertinent controls are found, slowly adjust and note whether improvement is evident. If it is, continue. If control does not have sufficient effect, check location of assembly on kinescope neck. Next, check circuitry and components involved for defects. 2. Check waveforms at vertical and horizontal convergence circuit points
Poor gray-scale tracking (tint over screen as brightness is varied)	1. See "Gray-scale Tracking Procedure" 2. Adjust kinescope screen controls, observing high brightness areas; on older receivers, adjust background controls, observing low brightness areas 3. Check kinescope electrode voltages against manufacturer's service notes, noting particularly any bias variations 4. Check emission of each of the three guns; if necessary, use color kinescope booster
Dominant color over entire screen (black-and-white program)	1. Check bias on each gun of kinescope. If screen is cyan, for example, it is possible red gun is cutoff or low in emission. Check bias and associated color-difference amplifier or demodulator stage. Check emission of guns lacking sufficient output. 2. If blue is excessive, check for grid-cathode short on blue gun.

TABLE 8-1 COLOR IN BLACK-AND-WHITE PROGRAMS (CONT'D)

Trouble	Remedy
Color "snow" on screen	1. Check color killer. A defective stage or improper threshold setting will allow noise to pass through color section and appear on screen. To adjust color killer threshold control, tune to an unused channel. Rotate control until "snow" appears as black-and-white confetti. Adjust control until "snow" suddenly appears in color. Now back off to the point where the "snow" returns to black-and-white.

TABLE 8-2 NO COLOR, BLACK AND WHITE RECEPTION OK

Trouble	Remedy
No color on all channels	1. Check fine tuning settings 2. Check color-killer threshold setting 3. Perform this test: Rotate fine tuning control until sound beat pattern appears on screen. If color "snow" exists, the chrominance section is operating, and the trouble is in the RF, IF detector or video amplifier. Check alignment since a drop-off at the subcarrier frequency may be the cause. If color "snow" does not appear, the chrominance section is defective. Check the bandpass amplifier, burst amplifier, 3.58-MHz oscillator and color killer. 4. Check 3.58-MHz oscillator bias (− 8 volts or higher is expected) 5. Temporarily short the color-killer bias to check whether color can be restored 6. See "Signal Tracking with the Color Bar Generator" to locate defective stage
No color on one channel; all other channels OK	1. Check that station's transmitting color program 2. Check antenna and transmission line system. Disconnect lead-in to set and substitute a simple indoor antenna (rabbit ear). Rotate and note whether color appears. It is possible for the antenna system to have a dip in response for one channel so that black-and-white appears acceptable but color is weak or missing entirely. 3. Check RF alignment for the affected channel, using sweep generator

TABLE 8-3 WEAK COLOR

Trouble	Remedy
Weak color on all channels	1. See "No Color" chart and follow steps suggested 2. Check RF/IF alignment for insufficient amplitude near the color subcarrier frequency 3. Compare peak-to-peak signal levels at bandpass amplifier, demodulators, and color-difference amplifiers with manufacturer's service notes 4. Check agc and color-killer threshold adjustments
Weak color on one channel	1. Check antenna/transmission line system 2. Perform sweep alignment test for weak channel, observing position of color subcarrier on response curve

TABLE 8-4 LOSS OF COLOR SYNC

Trouble	Remedy
Color runs through picture (or color breaks into horizontal or diagonal bands)	1. Check for burst signal; use wideband scope to trace burst from video to bandpass amplifier and burst gate 2. Perform AFPC alignment (See "AFPC Alignment") 3. Check reactance tube and circuit components 4. Check phase-detector diodes 5. Use color bar generator and wideband scope to signal trace burst through color sync section (See "Using Color Bar Generator to Signal Trace") 6. Check burst transformer for open or short 7. Check for open horizontal output transformer winding supplying timing pulse to burst gate (or amplifier)
Intermittent color sync	1. Use color bar generator and check level where sync action fails. If color sync holds on weak input, check antenna/transmission line system. If color sync is poor using generator, check or replace 3.58-MHz oscillator, burst amplifier, AFPC detector, and reactance tube. 2. Perform AFPC adjustment 3. Check/replace 3.58-MHz crystal

TABLE 8-4 LOSS OF COLOR SYNC (CONT'D)

Trouble	Remedy
Loss of color sync as stations are switched	1. Touch up AFPC adjustment, starting with balance potentiometer 2. Check or replace 3.58-MHz oscillator, burst amplifier, AFPC detector and reactance tube

TABLE 8-5 INCORRECT COLORS ON SCREEN

Trouble	Remedy
Incorrect colors (all colors present)	1. Check hue control range. If necessary, perform AFPC alignment. 2. Check phase shift network between 3.58-MHz oscillator and demodulator
Incorrect colors; one primary color missing	1. Check demodulator and color difference tubes, then their plate, screen, and bias voltages. Determine which color is missing and investigate specific section. For example, if reds are missing, check R − Y (or X) demodulator and R − Y amplifier. A color bar pattern is especially helpful in quickly identifying defect. The color bar output waveform is then used to signal trace. 2. Check for open filament in one gun of color kinescope.
Color correct at only one setting of brightness control	1. Check kinescope electrode voltages, especially bias 2. Check "Gray-scale Tracking" adjustment
One color dominant in picture	1. If reds, for example, appear more dominant than greens or blues, check for excessive output at X or R − Y demodulator and/or R − Y amplifier 2. Check bias voltages on kinescope 3. Color difference amplifier tube may be gassy 4. Examine bandpass amplifier alignment
Flesh tone difficult to adjust with hue control	1. Check AFPC alignment 2. Defective component in color AFPC loop 3. Check purity and convergence set up 4. Check 3.58-MHz transformer and phase coil adjustments

TABLE 8-6 MISCELLANEOUS COLOR TROUBLES

Trouble	Remedy
Color smear	1. Check bandpass amplifier response curve and compare with manufacturer's notes 2. Check AFPC alignment 3. Check delay line
"Hum" bars in color (horizontal bars in color on screen)	1. Check or replace demodulator and color difference amplifier tubes. A cathode-to-heater short may be responsible. Bias each gun off; when hum bar disappears, defective gun is found.
Color appears only in large areas of picture	1. Check IF alignment for improper alignment in the color subcarrier region.
Color displaced to left or right of monochrome picture (poor registration of color)	1. A faulty delay line prevents the chroma signal from arriving at the screen at the proper time as the luminance signal. Check for open or short in delay line or an open ground connection from the delay line shield.
Beat interference pattern in picture	1. Check fine tuning adjustment 2. Check IF alignment 3. Look for loose tube shields or poor grounding of RF tuner cable to IF strip
Color shifted to right of monochrome picture	1. Check delay line 2. Examine RF/IF alignment
No black and white picture; color OK	1. Check video (luminance) amplifier 2. Check for open delay line
"Snow" on all channels	1. Check or replace tuner tubes 2. Check antenna and lead-in cable
Excessive contrast; AGC control has no effect	1. Check AGC tube 2. Measure flyback pulse to AGC keyer. Check for open winding on flyback transformer.

TABLE 8-7 LOW-VOLTAGE SECTION

Trouble	Remedy
Receiver dead; no raster, no sound, no picture (filaments not lit)	1. Check On/Off switch 2. Check line fuse or circuit breaker. Many sets use 1-in. length of No. 22 wire; older sets use thermal resistor in series with transformer primary winding. 3. If series filaments set, locate defective tube 4. Check a-c power outlet
Receiver dead; filament lit	1. Check low-voltage fuse 2. Check low-voltage rectifier tube or semiconductor 3. Low-voltage surge resistor may be open
Dark horizontal bar across screen	1. Open filter capacitor in low-voltage power supply 2. Check rectifier diodes 3. Check for tube short in video IF, tuner, or video section
Picture height and width insufficient	1. Check for low a-c line voltage 2. Check or replace rectifier tubes 3. Leak electrolytic filter capacitors

TABLE 8-8 HIGH-VOLTAGE SECTION

(BE CAREFUL SERVICING THIS SECTION. VOLTAGES IN EXCESS OF 25 KV ARE INVOLVED)

Trouble	Remedy
No brightness on screen; sound OK	1. Listen for high-voltage "crackling" sound a minute or two after set is turned on. If "crackling" is heard, high voltage is present. Measure screen, focus, and bias voltages on color kinescope. Check plate voltage on luminance amplifier which sets cathode level on kinescope. 2. If no "crackling" sound is heard, check HV rectifier, HV regulator, horizontal oscillator and amplifier, focus rectifier, and damper tubes; also check HV transformer 3. Check HV fuse 4. Use scope to check for presence of horizontal drive waveform to horizontal amplifier tube

TABLE 8-8 HIGH-VOLTAGE SECTION (CONT'D)

Trouble	Remedy
Excessive high voltage; picture size varies as brightness changes	1. Check HV regulator tube 2. Check bias on HV regulator stage. A cathode-to-heater short (or short in cathode-to-grid bypass capacitors) can develop zero bias and disrupt regulator action. 3. Use HV probe and voltmeter to check for proper HV regulator setting.
Picture blooms as brightness is varied	1. Check or replace HV regulator tubes 2. Use HV probe and voltmeter to check HV setting with recommended level in manufacturer's service notes
Picture changes size, focus, and brightness at a slow, steady rate	1. A gassy regulator tube may cause the high-voltage regulator stage to oscillate. Replace the HV regulator tube.
Arcing or corona discharge (blue glow and/or ozone odor)	1. Check wires from flyback transformer and high-voltage section for close proximity to metal chassis. Try to isolate breakdown by observing section in dark room to spot arcing. 2. Check HV filter capacitor 3. Check HV anode connection to kinescope 4. If any HV solder joints are sharp or pointy, arcing may occur. Use soldering iron to round all HV terminations. 5. Check for internal breakdown within kinescope
Poor focus	1. Check focus rectifier 2. Check focus control for open or intermittent contact.
Keystone-sharped raster	1. Check for shorted yoke. 2. Check for defective resistor or capacitor in yoke assembly.

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