Basic Television, Bernard Grob

Chapter 24, Color Television

Color Plates

PLATE I. Normal color television picture reproduced on screen of tricolor kinescope. (*RCA*.)

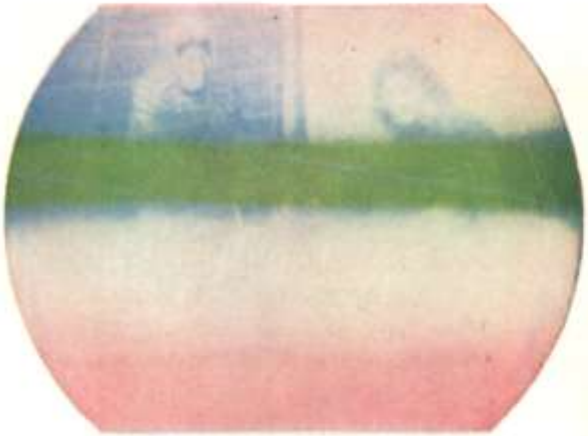

PLATE II. 60-cps hum voltage in the *Q* signal. (*RCA*.)

PLATE III. Color television picture reproduced with *I* signal but no *Q* signal. (*RCA*.)

PLATE IV. Color television picture reproduced with *Q* signal but no *I* signal. (*RCA*.)

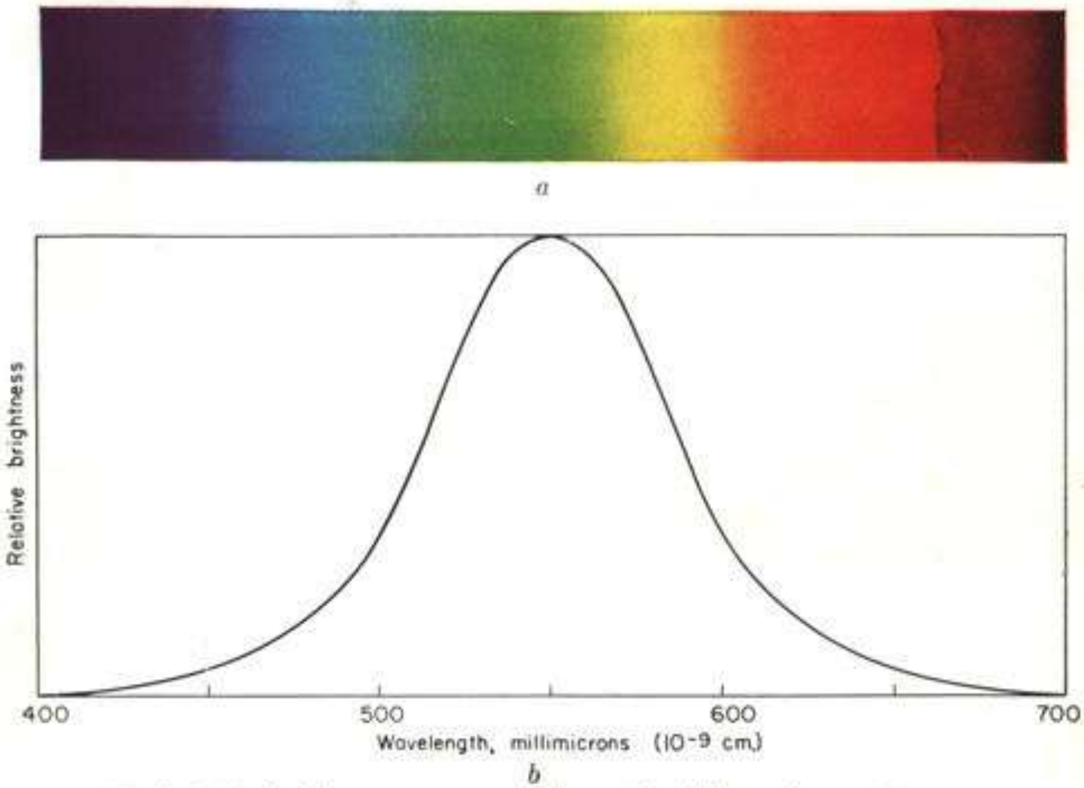

PLATE VI. Relative brightness response of the eye for different hues, with corresponding camera signal voltage. (*a*) Colors of different wavelengths; (*From Weber, White & Manning, College Physics, McGraw-Hill Book Company, Inc.*, 1952.) (*b*) Brightness, or signal voltage response.

Plate VII. NTSC Flag illustrating color resolution in color television. Largest areas in full color as mixtures of red, green, and blue; smaller areas in cyan and orange; smallest details in black-and-white. (*From Proceedings of the IRE, Second Color Television Issue, Jan. 1954*.)

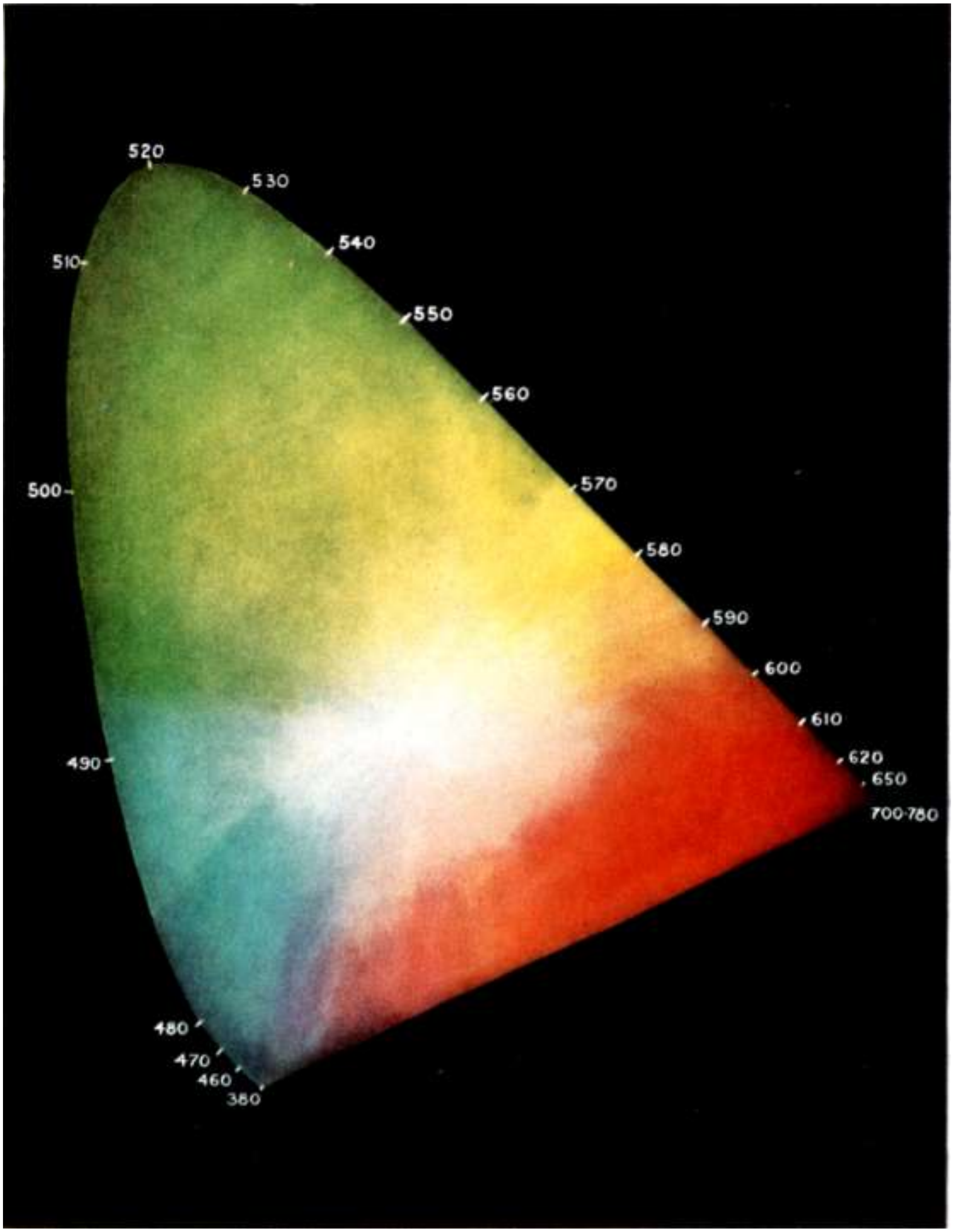

Plate VIII. Hue and saturation values for red, green, and blue, and their color mixtures. In terms of the rectangular coordinates in the chromaticity diagram in Figure 24-38, the lowest point on the horseshoe curve at darkest blue has the approximate coordinates $x = 1.7$, $y = 0.1$; the highest point of green is $x = 0.8$, $y = 8.4$; the darkest red at the right is $x = 7.3$, $y = 2.7$. (RCA.)

24-21 . Typical Color Television Receiver.

Essentially, the color television receiver consists of the same circuits as a monochrome receiver for the picture and sound, with the addition of the

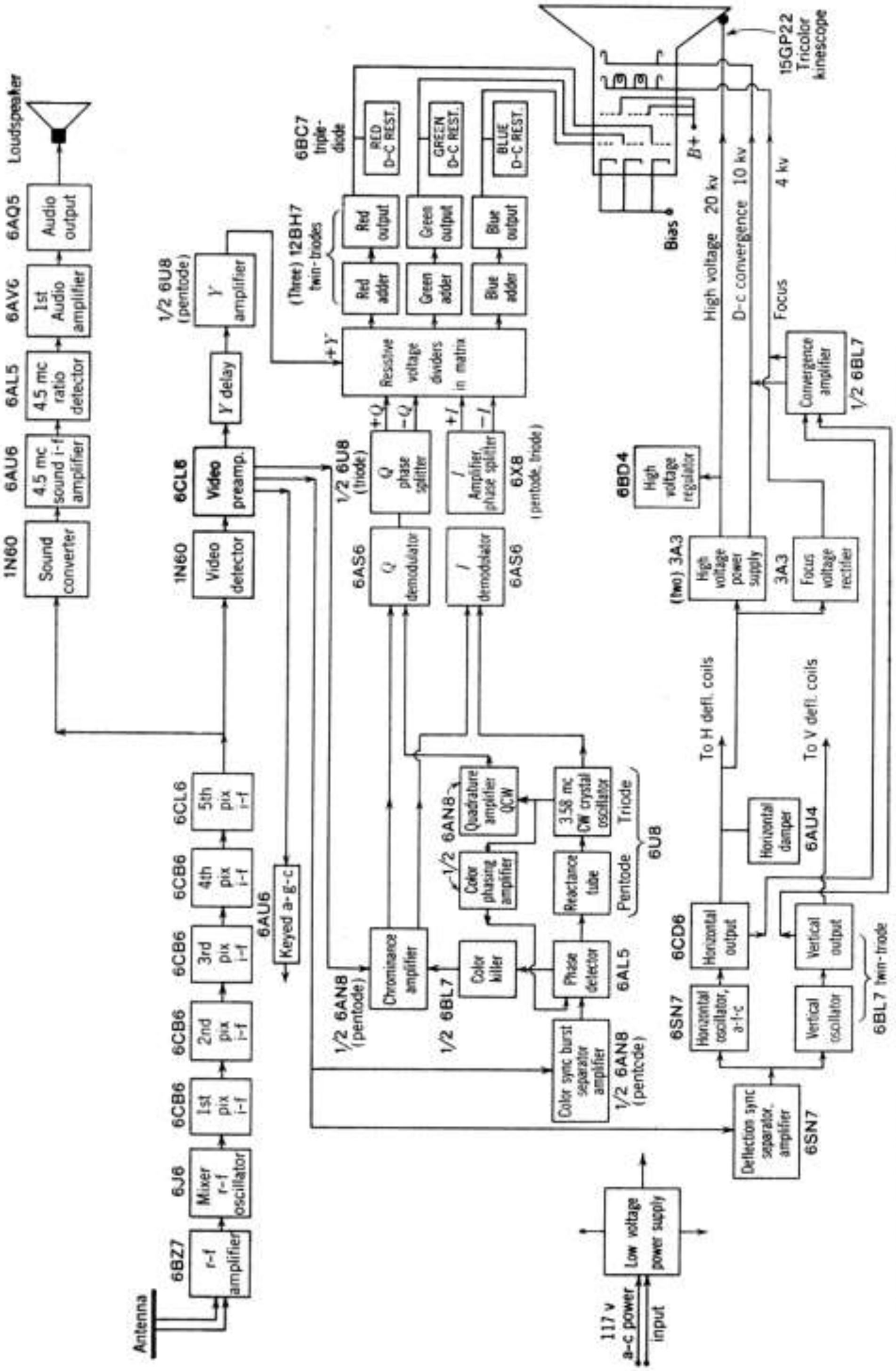

FIG. 24-33. Block diagram of typical color television receiver for *I* and *Q* signals, with three-gun tricolor kinescope.

chrominance video section for the color information and auxiliary circuits for the color kinescope. For best results on u-h-f as well as v-h-f channels, the receiver generally uses 45.75 and 41.25 Mc for the i-f picture and sound carrier frequencies, respectively, and the 4.5 Mc intercarrier sound. To illustrate how the circuits fit together, Fig. 24-33 shows in block-diagram form the stages in a typical color receiver utilizing the *I* and *Q* chrominance signals with a three-gun tricolor kinescope.

R-F and I-F Sections. Starting at the left in the figure, the r-f tuner selects the antenna signal for any u-h-f or v-h-f channel, converting the r-f signal frequencies of the picture and sound signals to the i-f signal frequencies of the receiver. The r-f signal circuits, including the antenna and transmission line, are the same as in monochrome receivers—except that here uniform response for each selected channel is more important to prevent attenuating the 3.58-Mc color subcarrier modulation on the r-f picture carrier signal. The station selector and fine tuning are provided as front-panel controls, as in monochrome receivers. However, adjustment of the fine tuning control is more important because a slight mistuning of the r-f local oscillator results in no i-f signal for the 3.58-Mc chrominance subcarrier, which has a corresponding intermediate frequency of 42.17 Mc at the edge of the i-f pass band near the i-f sound carrier frequency. This is illustrated by the i-f response curve in Fig. 24-34*a*. A crystal-diode detector produces the desired video signal output corresponding to the envelope of the amplitude-modulated i-f picture carrier signal input.

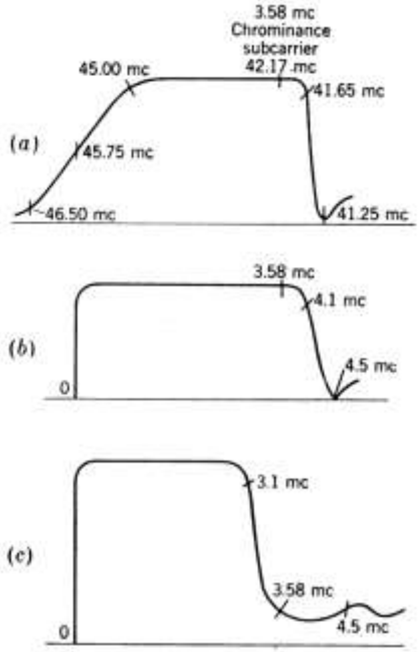

FIG. 24-34. Response curves for receiver illustrated in Fig. 24-33: (*a*) i-f amplifier, (*b*) video preamplifier, and (*c*) *Y* video amplifier.

Sound Section. Notice that a crystal-diode detector is also used in a separate sound-converter stage to produce the 4.5-Mc intercarrier-sound signal. Both the picture and sound i-f carrier signals are coupled into the sound converter to produce the 4.5-Mc intercarrier beat. Then the 4.5-Mc signal for the associated FM sound signal is detected by a ratio detector to produce the required audio output for the loudspeaker. A separate sound converter is used, instead of taking the 4.5-Mc beat from the video detector, in order to minimize the amplitude of the 0.9-Mc beat between the 3.6-Mc chrominance subcarrier frequency and the 4.5-Mc sound carrier frequency in the video circuits.

Video Preamplifier. The video detector output amplified in the video preamplifier, or first video amplifier stage, is the total composite video signal containing the luminance signal variations, the blanking and deflection sync pulses for horizontal and vertical scanning, and the 3.58-Mc chrominance information including the burst for color sync. The frequency response required in the video preamplifier to include the 3.58-Mc chrominance signal is shown in Fig. 24-34*b*. Since the composite video signal from the video preamplifier includes all the required information, it is coupled to the following circuits:

1. Keyed a-g-c amplifier, which produces a-g-c bias for the r-f and i-f amplifiers as in monochrome receivers.
2. Sync separator and amplifier section which provide horizontal and vertical synchronizing signals for the horizontal and vertical deflection circuits, as in monochrome receivers, with automatic frequency control for the horizontal deflection oscillator. The horizontal and vertical output circuits supply sawtooth scanning current for the deflection yoke on the neck of the color kinescope to produce the scanning raster.
3. Luminance video amplifier which supplies the *Y* signal required for addition with the color-difference voltages to produce the red, green, and blue video signals.
4. Chrominance amplifier, which supplies the 3.58-Mc color subcarrier signal for the chrominance section of the receiver.
5. Burst separator and amplifier, which supplies the 3.58-Mc reference burst for the color synchronizing circuits.

Chrominance Section. The input to the chrominance section includes the two-phase modulated 3.58-Mc color subcarrier from the video preamplifier; the output consists of the desired red, green, and blue video signals for the tricolor kinescope. First the input signal is amplified in the chrominance band-pass amplifier. A typical chrominance amplifier circuit can be seen by referring back to Fig. 24-18. The 3.58-Mc modulated chrominance signal from the band-pass amplifier is then coupled to the two synchronous detectors for the *I* and *Q* signals. Each synchronous detector has two input voltages: chrominance signal from the band-pass amplifier and c-w output from the local 3.58-Mc carrier oscillator. The c-w oscillator output for the *Q* demodulator is shifted 90° in phase by the quadrature amplifier. As a result, the *Q* demodulator's output is the *Q* color-difference voltage, while the *I* demodulator supplies *I* color-difference voltage.

Figure 24-35 shows the demodulator and amplifier circuits used in this receiver for the *I* and *Q* video signals. Compensation for the vestigial side-band transmission of the *I* signal is accomplished in the *I* amplifier circuits by increasing the gain for the 0.5- to 1.5-Mc *I* video frequencies transmitted with single side bands, compared to the 0- to 0.5-Mc *I* video frequencies transmitted with double side bands. After sufficient amplification and phase inversion, both plus and minus polarities of the *I* and *Q* voltages are coupled into the matrix circuit, to be combined with the *Y* signal from the luminance amplifier. The *Y* video amplifier's frequency response is usually limited to approximately 3 Mc, as shown in Fig. 24-34*c*. This minimizes the 3.58-Mc dot pattern in the picture and avoids cross- talk between the luminance and chrominance signals produced by non- linear operation in the video output stage, which would cause incorrect color values in the matrixing.

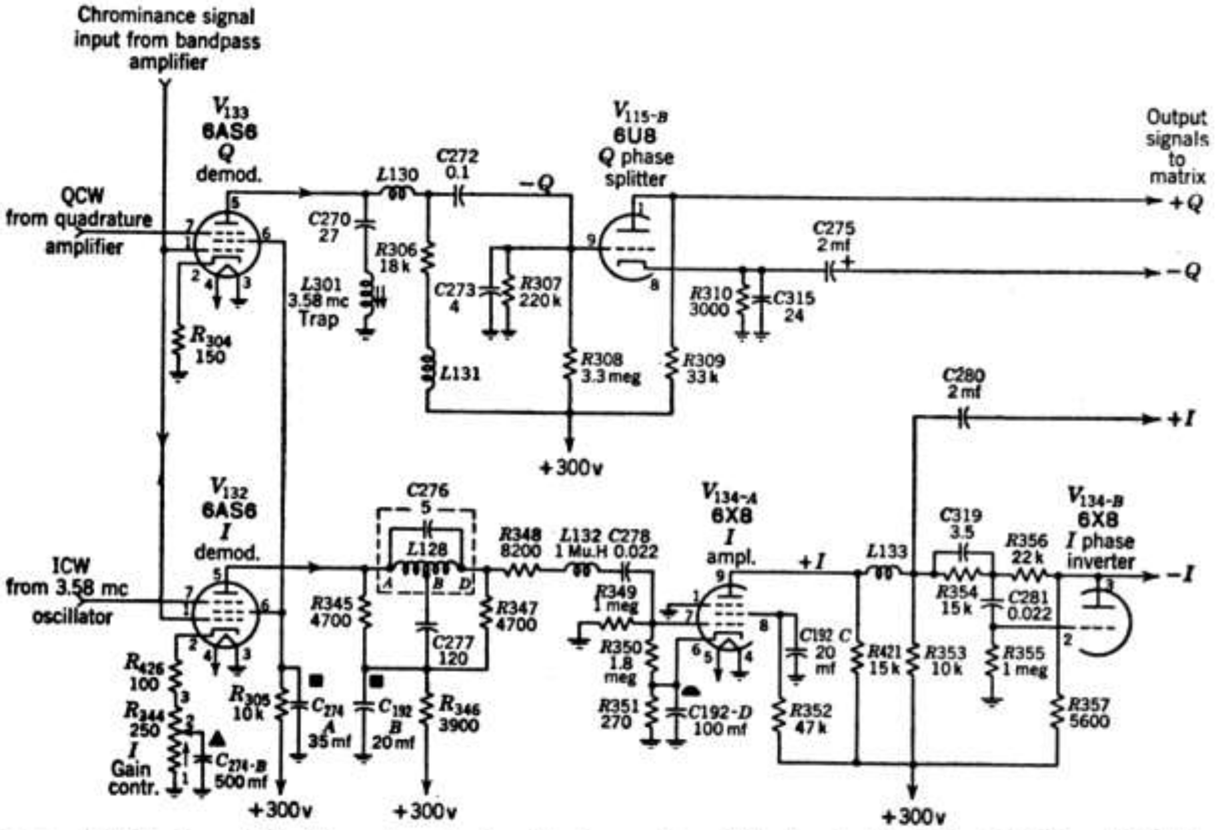

FIG. 24-35. *I* and *Q* video signal circuits in receiver illustrated in Fig. 24-33. (*RCA*.)

Matrix Circuit. Figure 24-36 shows the resistive voltage-divider circuits for the passive matrix network in the input to the color adder stages. Notice that the *I* and *Q* signals have the polarities corresponding to the colors needed to form each primary. For instance, the green adder stage has -*Q* input, which is yellow-green, and -*I* signal, which is the blue-green cyan. With proper proportions of *I*, *Q*, and *Y* voltage, each adder stage produces in the output circuit its respective primary color video voltage. The three color output stages then amplify the primary video signals enough to drive the control grids of the three-gun tricolor kinescope. The

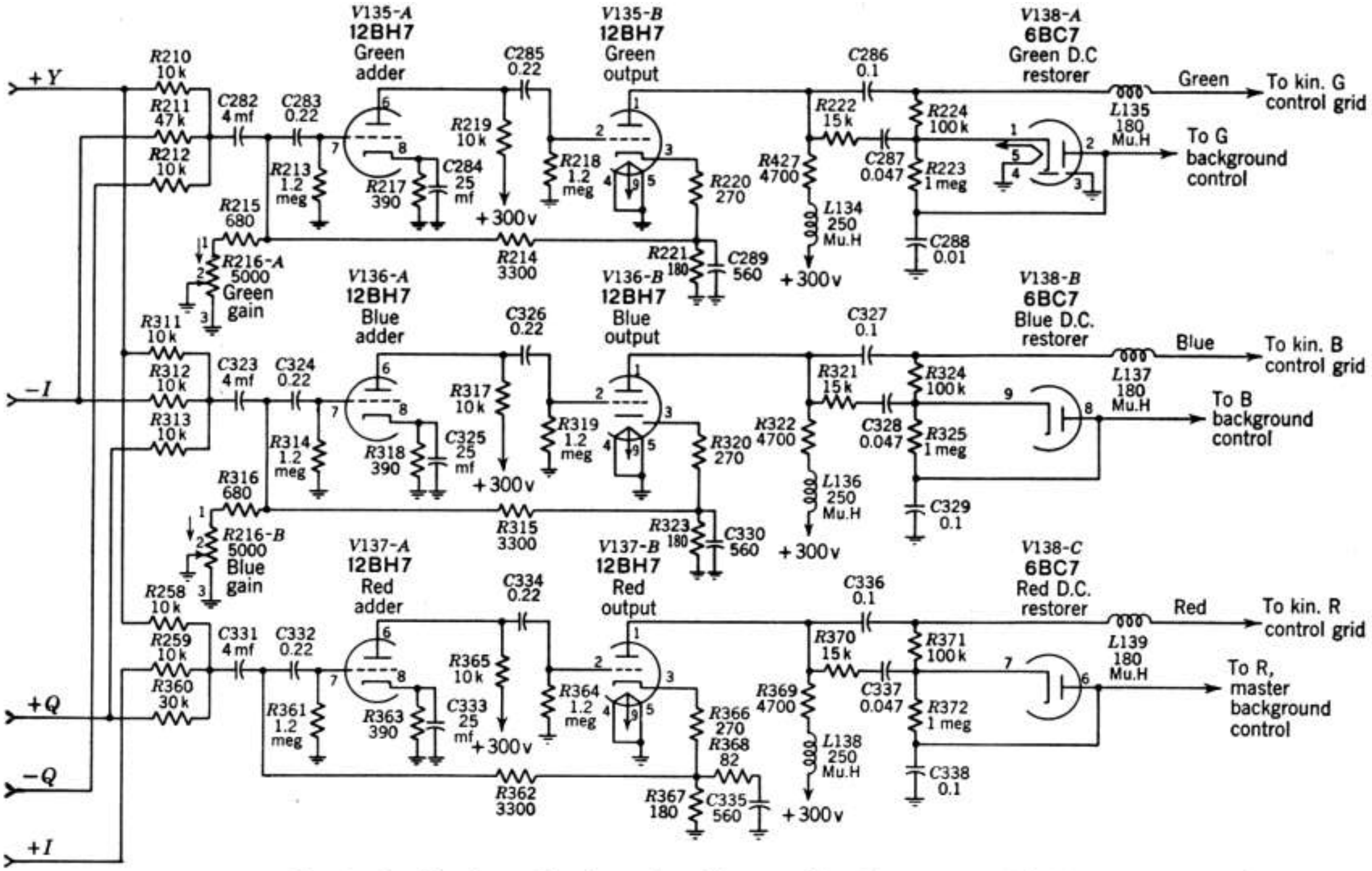

FIG. 24-36. Matrix section in receiver illustrated in Fig. 24-33. (*RCA.*)

three d-c restorers provide automatic background control for each of the primary colors. The primary color adder and output stages have a 3-Mc bandwidth so that the *Y* video signal can reproduce the fine detail of the picture in black and white.

Color Sync Section. For color synchronization, video signal input containing the 3.58-Mc color burst is taken from the video preamplifier and coupled to the burst amplifier. As shown by the typical circuit in Fig. 24-23, the burst amplifier is tuned to 3.58 Mc and gated by horizontal deflection voltage to produce output only for the 3.58-Mc color sync burst following each horizontal sync pulse. The color sync burst has the reference phase required for synchronizing the 3.58-Mc local subcarrier oscillator. With the 3.58-Mc color sync burst voltage and carrier volt- age from the 3.58-Mc local oscillator coupled into the phase detector, it controls the phase of the c-w oscillator, through the reactance tube, to establish the correct hues in the picture. The schematic diagram of this a-p-c (automatic phase control) circuit is in Fig. 24-24. The phase detector is also used to supply negative d-c bias voltage to cut off the color killer stage when there is no color sync burst and, therefore, no color transmission.

Kinescope Convergence, Focus, and Anode Voltage. The color receiver uses reaction scanning for horizontal deflection, with the horizontal output circuit supplying flyback high voltage for the kinescope anode. However, the tricolor kinescope has additional high-voltage requirements. A voltage doubler supplies 20 kv for the anode of the tricolor kinescope, with a load current of about 750 µ for the highlights in the picture, equal to the total beam current for the three guns. A voltage regulator is necessary to stabilize the anode voltage for different brightness levels, as the amount of high voltage affects convergence. In addition, the voltage divider in the high voltage supply also provides about 10 kv for the convergence electrode in the kinescope. Proper convergence also requires an a-c correction voltage provided by the convergence amplifier stage, which varies the instantaneous value of convergence voltage to converge the three beams for any deflection angle. For this *dynamic convergence*, the amplifier combines 60-cps voltage from the cathode of the vertical output stage with 15,750-cps voltage from the horizontal deflection amplifier's cathode circuit. A separate focus voltage rectifier obtains high voltage a-c input from the horizontal output transformer to produce about 4 kv d-c voltage output for electrostatic focusing of the kinescope.

Low-voltage Supply. In the low-voltage power supply, two selenium rectifiers are used in a voltage doubler circuit to produce about 400 volts *B*+, with a load current of about 400 ma. The low-voltage supply provides direct current through the horizontal and vertical scanning coils in the yoke, which can be adjusted by the horizontal and vertical centering controls for exact positioning of the scanning raster. Direct current is also supplied for the color purity coil and field neutralizing coil. The accelerating grid of each electron gun in the tricolor kinescope uses +400 volts, approximately, from the low voltage, which can be adjusted for each electron gun. The amount of 60 cps a-c input power to the receiver is about 500 watts.

Color Receiver Schematic Diagram. Figure 24-37 shows the complete schematic diagram of a color television receiver, for reference purposes. This is essentially the same circuit as the receiver illustrated in block-diagram form in Fig. 24-33, both using a wide-band matrix for *I* and *Q* signals, with a three-gun tricolor kinescope. Note, though, that in Fig. 24-37 the hue control varies the phase of the burst signal obtained from the video preamplifier, instead of varying the 3.58-Mc oscillator phase.

24-22. Color Controls. Table 24-2 lists the additional controls for color in a television receiver, in order to summarize their functions in producing a good color picture. Although the usual controls for a monochrome receiver, such as station selector, fine tuning, volume, contrast, and deflection adjustments are omitted in this table, it should be noted that correct setting of all the controls is important. This is especially true of the fine tuning control, which must be set exactly to provide the chrominance signal for the picture i-f amplifier. Otherwise, there is no color. The fine tuning control should be set for color in the picture, with the saturation control turned up and minimum 0.9 Mc beat, which is evident as a coarse herringbone pattern in the picture. Of the color controls, usually the hue or phasing control and the saturation control are on the front panel of the receiver as operating controls. When switching between stations broadcasting in color, readjustment of the fine tuning, hue, and saturation controls will usually be necessary. The remainder of the color controls are on the chassis, either at the rear or available from the front through a hinged cover, or at the side of the cabinet.

Correct adjustment of the color controls is also necessary for a good black-and-white picture when a monochrome broadcast is received. As indicated in Table 24-2, the following adjustments are set with a monochrome picture for good black-and-white reproduction without color: screen-grid and d-c bias voltages for the red, green, and blue guns in the kinescope; green and blue gain controls. Convergence is checked with a dot generator, which is similar to a bar generator or crosshatch generator used for checking scanning linearity. Its purpose is to supply video signal that produces black and white rectangular dots on the kinescope screen. About ten rows of horizontal and vertical dots are produced, so that each dot is much larger than the phosphor-dot trios. For checking colors in the reproduced picture, a color-bar generator can be used. A typical generator produces video signal for ten vertical color bars differing in hue from orange to green by 30° spacing in phase angles, corresponding approximately to the *R* - *Y*, *B* - *Y*, *I* , and *Q* axes and intermediate colors.

Table 24-2. Color Controls

Control	Circuit	Function	Adjustment
Saturation or chroma	Chrominance band-pass amplifier	Vary level of 3.58-Mc chrominance signal	Vividness of colors; no color at zero setting
Hue or phasing	3.58-Mc oscillator a-p-c or sync burst circuit	Vary phase between 3.58-Mc c-w oscillator and sync burst	Correct hues, as determined by flesh tones or hue of known object
A-F-C balance	Color phase detector in a-p-c circuit	Balance diode circuits of phase detector	Zero d-c output at balance
Deflection yoke on kinescope neck	Horizontal and vertical deflection circuits	Produce scanning raster	Rotation tilts raster; movement along tube neck affects purity
Purity coil on kinescope neck	Low-voltage power supply	Align three electron beams	Pure red at center area of raster
Purity adjustment	Low-voltage power supply	Vary direct current in purity coil	Pure red at center of raster
Field-neutralizing coil around kinescope faceplate	Low-voltage power supply	Corrects beam misalignment caused by external fields	Pure red at edge area of raster
Convergence magnet(s)	Permanent magnets	Align each electron beam with respect to the other two for proper convergence	Vary d-c convergence voltage and position magnets to make dot trios produce white, in center area of raster
D-C convergence	High-voltage supply	Adjust d-c voltage applied to convergence electrode in kinescope	Vary d-c convergence voltage and position magnets to make dot trios produce white, in center area of raster
Horizontal dynamic convergence	Horizontal output circuit	Vary d-c convergence and focus voltages at horizontal line rate	Convergence at left and right sides of raster
Vertical dynamic convergence	Vertical output circuit	Vary d-c convergence and focus voltages at vertical field rate	Convergence at top and bottom of raster
Focus	Focus voltage rectifier in high-voltage supply	Vary focusing grid voltage for kinescope	Sharp focus in raster and picture. Affects convergence also

Table 24-2. Color Controls (*continued*)

High-voltage	Shunt regulator in high-voltage supply	Stabilize kinescope anode voltage	Constant high voltage for all brightness levels. Affects convergence also
Red-screen, green-screen, and blue-screen	Low-voltage power supply	Vary kinescope screen-grid voltage for red, green, and blue electron guns	Low-level white raster, without picture
Green-gain and blue-gain	Green adder and blue adder stages	Provide enough green and blue video signal, compared to red	High-contrast black-and-white picture without color
Red (master), green, and blue background	Kinescope grid-cathode circuit	Vary d-c bias voltage for red, green, and blue electron guns	Black-and-white picture without color tracking from low brightness to high brightness
I Gain	*I* signal amplifier and phase splitter	Provide enough *I* signal compared to *Q* signal	Correct hues in color bars, primarily red and yellow

24-23. Color Troubles. Considering only symptoms that affect the color, while the sound, raster, and monochrome picture are normal, color troubles can be considered in the following categories: no color, no color hold, incorrect colors, or undesired color interference. These color troubles can usually be localized to either the chrominance section of the receiver or the color kinescope.

No Color. This trouble symptom can be established definitely by checking on different channels to see that a normal monochrome picture is obtained on all stations but there is no color for a program known to be televised in color. Before assuming the trouble is in the color circuits, the setting of the fine tuning control should be checked, as maladjustment can result in no chrominance signal for the picture i-f amplifier. The fine tuning should be adjusted by varying the control until sound bars are visible and then adjusting for minimum 920-kc beat interference. Also, the adjustment of the saturation control should be checked, as the zero setting results in no color. In the chrominance section of the receiver, no color can be caused by the following conditions : (*a*) Inoperative chrominance band-pass amplifier, resulting in no signal for the synchronous detectors. Excessive bias from the color killer stage can cut off the chrominance amplifier. (*b*) Inoperative 3.58-Mc subcarrier oscillator, resulting in no detection of the chrominance signal, or insufficient oscillator output. Notice that these troubles cut off all the color signal voltages, resulting in no color. A trouble in only one color causes incorrect hues.

No Color Hold. No color sync results in changing colors or in horizontal color bands that drift vertically. Since the lack of color sync means that the 3.58-Mc subcarrier oscillator's phase is continuously changing, this causes variations of hue corresponding to the color bands. The further the crystal-controlled 3.58-Mc subcarrier oscillator is from the correct phase, the greater the number of color bands. The loss of color hold can be caused by an inoperative burst amplifier, resulting in no color sync voltage, or a defect in the automatic-phase-control circuit. If the crystal allows the oscillator to lock in at a frequency differing from the subcarrier by multiples of 15,750 cps, stationary vertical color bars appear. This trouble of incorrect oscillator frequency is caused by a defective crystal.

Incorrect Colors. Troubles causing incorrect color values can be localized to either the tricolor kinescope or the chrominance circuits by noting the appearance of the raster alone and a monochrome picture. When there is color in the raster, with the contrast control at minimum, the trouble is either in the color purity or the red, green, and blue screen-grid adjustments, assuming the use of a three-gun tricolor kinescope. Non-uniform coloring in the raster results from incorrect purity. Uniform red, green, or blue in the raster indicates too much screen-grid voltage for that color. When the raster is white but a monochrome picture has color with the contrast control turned up, then the trouble is either in the convergence and focus adjustments or the chrominance and video signal circuits. Color fringing at the edges of objects in the picture indicates incorrect convergence or focus. Color throughout the entire monochrome picture is caused by lack of balance in the a-c signal drive for the three electron guns.

When the monochrome picture is reproduced correctly in black and white but color pictures have the wrong hues—assuming the hue control is set properly for the correct reference phase—this indicates (*a*) no quadrature phase between the ICW and QCW oscillator voltages for the demodulators or (*b*) incorrect relative gain for the color signal voltages. The quadrature amplifier for the QCW signal must be aligned exactly at 3.58 Mc to produce the required 90° phase. Incorrect relative gain for the color-difference voltages in the synchronous detectors or in the color adder stages can be caused by a circuit defect or misadjustment of the color gain controls. If there is no *I* signal at all because of an inoperative *I* demodulator, the picture is reproduced without orange and cyan color values. This effect can be seen in Plate IV. Without the *Q* signal, as shown in Plate III, purple and yellow-green are missing from the picture.

Color Hum Bars. Hum voltage in the chrominance video circuits produces horizontal pairs of hum bars in the picture, as in monochrome receivers, but the bars have the colors associated with the stage where the hum is injected. For instance, 60-cycle hum voltage caused by cathode-heater leakage in the *Q* demodulator will produce one pair of hum bars with the *Q* colors. As shown in Plate II, one-half cycle of the hum voltage produces magenta-to-purple colors and the opposite polarity in the next half-cycle produces yellow-green.

Color Snow. When the chrominance band-pass amplifier is not cut off for a monochrome picture, the stage amplifies luminance signal-voltage variations of approximately 2 to 4 Mc, which are detected in the color demodulators, resulting in random speckles of color in the picture. Because of the relatively coarse grain, the color snow is also called *confetti*.

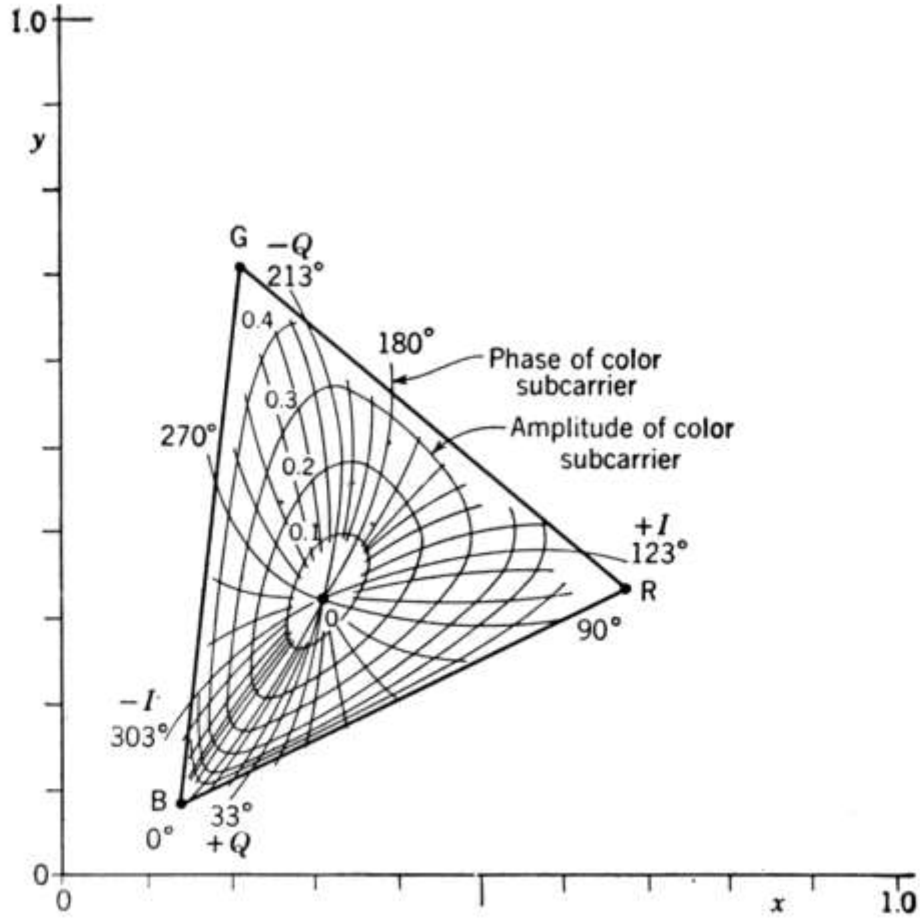

Fig. 24-38. Chromaticity diagram showing color subcarrier phase and amplitude as a function of hue and saturation. Refer to color plate VIII for actual hue and saturation values. (*From "Colorimetry in Color Television," Part III, by F.J. Bingley, Proceedings of the IRE , Second Color Television Issue, January, 1954* .)

24-24. ClE[1] Chromaticity Diagram. Although different systems of colorimetry can be used to specify color values numerically, the internationally

---

[1] Abbreviation for the Commission Internationale de L'Eclairage (CIE), also called the International Commission on Illumination (ICI).

standardized chromaticity diagram illustrated in Fig. 24-38 is used to indicate the color specifications in color television. To read the chromaticity diagram, consider the horizontal x axis and vertical y axis as the rectangular coordinates of a graph. The points marked R, G, and B on the triangle indicate the primaries specified for color television. For red, $x = 0.67$, $y = 0.33$; for green, $x = 0.21$, $y = 0.71$; for blue, $x = 0.14$, $y = 0.8$. The white at the center is the reference white illuminant C, with coordinates $x = 0.31$, $y = 0.32$.

Actual chrominance values are reproduced in color Plate VIII. This horseshoe-shaped curve is called the spectrum locus because it represents all hues produced by splitting white light into its component spectral colors. The hue is indicated by the numerical values on the curve, which give the dominant wavelength in millimicron units (10^{-9} cm) . These points are saturated values of the hues represented by a straight line through the white point at the center to intersect the horseshoe curve. Opposite ends of the straight line intersect the curve at points that are complementary hues. Along any one line of constant hue, values closer to white at the center have less saturation. It should be noted that the straight line closing the bottom end of the horseshoe curve corresponds to the range of *non-spectral* purple colors. These colors do not occur in the spectrum of natural white light but can be produced by additive mixtures of red and blue. Referring to Fig. 24-38, the color values in the I signal correspond to the line joining the orange point $x = 0.55$, $y = 0.42$ and the cyan point $x = 0.16$, $y = 0.26$, through illuminant C. Colors on the I axis, then, are orange hues of varying saturation up to white, or the complementary cyan hues of varying saturation. The axis for the Q signal joins the yellow-green point $x = 0.4$, $y = 0.55$, through white, to the purple point at $x = 0.24$, $y = 0.12$. By suitable combinations of I and Q, all the chrominance values in the RGB triangle can be reproduced in the color television system. This is illustrated in Fig. 24-38, which shows how the phase and amplitude of the 3.58-Mc modulated chrominance signal correspond to chromaticity values. The concentric rings around the white point at C correspond to varying saturations for different amplitudes of the modulated color subcarrier signal, while the curved lines from point C indicate the phase angle and corresponding hue.