COLOR TELEVISION

Simplified Theory and Service Techniques

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Foreword

It is with pride and a great measure of satisfaction that Philco Corporation presents "Color Television—Simplified Theory and Service Techniques" to the men whose interests or careers lie in the field of electronic service work. The publication of this study-reference book ends two years of research and careful preparation and makes available the most informative and understandable approach to a subject of such extraordinary complexity.

Its purposes are purely practical—to introduce and simplify the basic theory of color television, and to quickly train the reader (one who now enjoys a working knowledge of monochrome television) to master the techniques of trouble-shooting and servicing color television circuits, regardless of their manufacture. Thus, this book will be recognized as Philco's finest effort to increase the knowledge and skills of service technicians everywhere . . . a policy to which Philco has adhered for over a quarter-century.

Color television, an outstanding electronic miracle of our time, came into being through the efforts of an entire industry. No one manufacturer pioneered it nor developed it. The creation of the Compatible Color Television System is officially credited to the research scientists and engineers of over forty U. S. manufacturers. But creation, manufacture and distribution are not enough to assure the continued growth of color television as a practicable medium of education and entertainment for all America.

Service, rendered efficiently, is the determining factor . . . and it is to the men of the service profession who provide color television maintenance that this book is especially dedicated.

HENRY T. PAISTE JR.
Vice-President—Product
Performance & Service
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PHILCO CORPORATION

1. REVIEW OF BLACK AND WHITE TELEVISION

A COLOR TELEVISION SYSTEM essentially comprises a monochrome television system with additional features. The color television signal is the same as the monochrome television signal with the color information added. Therefore, it is advisable to review the black and white (monochrome) television system before studying the additional features required in the color television system.

SECTION 1.
THE COMPOSITE TELEVISION SIGNAL

The Federal Communications Commission specified that the monochrome television signal occupy a bandwidth of six megacycles within its assigned channel in the television broadcasting spectrum. It further specified that each channel be divided, as illustrated in figure 1-1, into two main portions, one for the audio signal and the other for the composite video signal.

The audio signal occupies a bandwidth of fifty kilocycles which is centered on a carrier frequency of 5.75 megacycles above the low frequency limit of its assigned channel. The r-f carrier of the audio signal is frequency modulated and 25 kilocycles deviation represents 100% modulation.

The composite video signal is amplitude modulated and is transmitted within a bandwidth of four megacycles. The video carrier frequency is 1.25 megacycles above the low frequency limit of its assigned channel. To limit the television channel to a six-megacycle bandwidth and still allow a four-megacycle bandwidth for the video signal, vestigal sideband transmission must be employed. In this system a considerable amount of the lower sideband is filtered out at the transmitter. For practical reasons, 1.25 megacycles of the lower sideband must be transmitted; consequently the video carrier frequency is 1.25 megacycles above the low frequency limit.

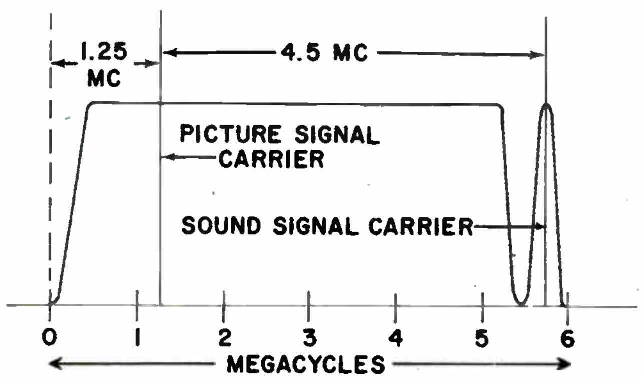


Figure 1-1. Composite television signal

SECTION 2.
THE COMPOSITE VIDEO SIGNAL

The composite video signal contains all of the information required for the reproduction of a scene on a television picture tube. This signal contains the video signal, blanking pulses and synchronizing (sync) pulses. Figure 1-2 identifies the signals and pulses and illustrates the sequence in which these signals and pulses are transmitted.

Video Signal

The video signal is an amplitude-modulated wave whose varying amplitude produces corresponding light changes on a television picture tube. The amplitude variations are such that maximum video amplitude produces black and minimum video amplitude produces white on the television picture tube. The maximum and minimum video amplitude values, as shown in figure 1-2, represent 75% and 15% respectively of the maximum carrier voltage.

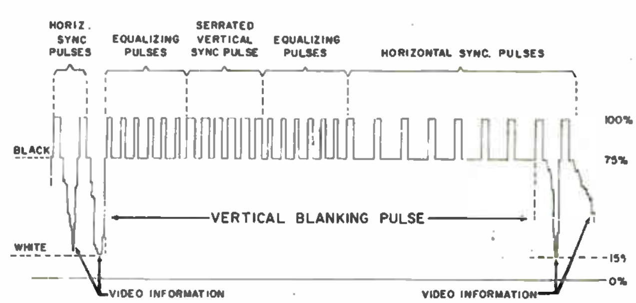


Figure 1-2 Composite video signal

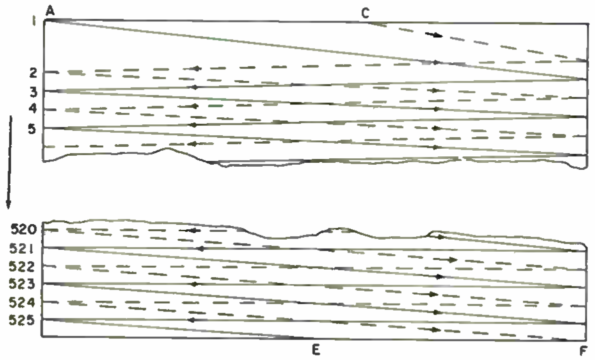


Figure 1-3. Beam pattern for interlace scanning

Sync Pulses

Before proceeding with the sync pulses, a brief refresher on the use of these pulses may prove helpful. As is well known to the television service technician, the television receiver uses a horizontal oscillator and a vertical oscillator to assemble the video information in a form suitable for viewing. These oscillators must be controlled so that the various elements of the picture are positioned correctly on the television picture tube otherwise the picture elements would be scattered and the picture tube would not convey any intelligence to the viewer. This, of course, is evidenced in television receivers when the sync circuits are not functioning properly. Therefore, a means of synchronizing these oscillators with their counterparts at the television studio is mandatory. Synchronization is accomplished with the horizontal sync pulses, the vertical sync pulses, and the equalizing pulses. These pulses control the vertical and horizontal oscillators so that the picture elements are positioned on the television picture tube in the same relative position that they occupy in the scene that is being televised.

The vertical sync pulses trigger the vertical oscillator of the receiver, keeping it in synchronism with the vertical oscillator at the television studio. This pulse, as shown in figure 1-2, consists of a series of short pulses or serrations. The serrations also are used to trigger the horizontal oscillator but do not themselves trigger the vertical oscillator. The vertical sync pulse can be considered one pulse having a duration of 190.5 microseconds. These pulses are transmitted at the rate of 60 pulses per second corresponding to the 60 fields per second.

The horizontal sync pulses trigger the horizontal oscillator of the receiver, keeping it in synchronizism with the horizontal oscillator at the television studio. During the time that the vertical sync and equalizing pulses are being transmitted, the horizontal oscillator is triggered by the serrations of the vertical sync pulse and the equalizing pulses. The horizontal sync pulse is five microseconds wide and is transmitted at a rate of 15,750 pulses per second corresponding to the 525 horizontal lines per frame. The serrations of the vertical sync pulse and the equalizing pulse are transmitted at twice this frequency to provide for half line scanning necessary for the proper interlacing of two succeeding fields.

Six equalizing pulses precede and six equalizing pulses follow the vertical sync pulse. The time between the last horizontal sync pulse and the first equalizing pulse changes from a full horizontal line interval to a ½ horizontal line interval every other field due to the ratio between 15,750 cps and 60 cps, which produces the necessary difference between fields to provide interlaced scanning. Since the horizontal oscillator is adjusted to the frequency of the horizontal sync pulses, it is triggered only by every other equalizing pulse or serration of the vertical sync pulse.

Blanking Pulses

The blanking pulses function to disable or blank the television picture tube during periods when video information is not being received. As a result of this blanking action, the vertical and horizontal retraces are not observed by the television viewer. The sync pulses, as shown in figure 1-2, are superimposed on the blanking pulses, hence, they are not observed.

A ten microsecond blanking pulse is provided to blank the horizontal retrace between succeeding horizontal lines. A blanking pulse, approximately 1016 microseconds, is provided to blank the vertical retrace between succeeding fields.

SECTION 3. THE TELEVISION PICTURE

Components of the composite video signal operate their respective circuits in the television receiver to produce a picture suitable for viewing. All components are received in a definite sequence and each performs a definite function.

The position of the electron beam is controlled by the horizontal and vertical oscillators. This beam scans the picture area in a predetermined fashion illustrated in figure 1-3. Complete scanning of the picture is accomplished in two fields, one indicated by the solid lines and the other indicated by the dashed lines. The electron beam, as it follows its predetermined pattern, is varied in brilliance or intensity by the video signal. The following is the sequence of events that takes place in scanning a television picture:

Referring to figure 1-2, assume that the vertical sync pulse has returned the beam to the top of the picture and that the last horizontal sync pulse on the vertical blanking pulse has returned the beam to the left-hand side of the picture. As the beam sweeps from left to right, the vertical blanking pulse is removed. This point is indicated by point A of figure 1-3. After the vertical blanking pulse is removed, video information varies the intensity of the beam in accordance with the picture content of the line being scanned. When the beam reaches point B of figure 1-3, a horizontal blanking pulse is received which blanks the electron beam for 10 microseconds. 1.3 microseconds after the start of the horizontal blanking signal, the horizontal sync pulse is received and returns the beam to point 3 of figure 1-3. The beam then starts its next horizontal sweep. At the end of the 10 microsecond blanking period, video information is again presented to the picture tube as described previously. The above sequence is repeated for 1/60 of a second while the beam is moved in a downward direction at a uniform rate by the vertical oscillator.

When the electron beam reaches point E of figure 1-3, a vertical blanki'.g pulse is received which blanks the electron beam. The vertical sync pulse, mounted on the vertical blanking pulse, is then received and returns the electron beam to the top of the picture tube. During the vertical blanking period, the horizontal sweep is still active, its oscillator being triggered by the equalizing pulses and the serrations of the vertical sync pulse. During the sweep following the last horizontal sync pulse, the vertical blanking pulse terminates, thereby the electron beam scans one half line, points C to D of figure 1-3. At point D, a horizontal sync pulse mounted on a horizontal blanking pulse is received. The sequence of events is repeated as described above; however, this time the beam scans the dashed lines of figure 1.3. When the beam reaches the bottom of the picture, at point F, a vertical blanking pulse is received. During the blanked period, the beam is returned to the top of the picture at point A and the first sequence of events is repeated. The time interval between the last horizontal sync pulse for each field and the first equalizing pulse alternates between the time required from the start of one horizontal line to the start of the next horizontal line and one half the time required from the start of one horizontal line to the start of the next horizontal line. This time difference for succeeding fields provides the half lines necessary for interlaced scanning.

SECTION 4. THE TELEVISION RECEIVER

The purpose of the television receiver is to receive the composite television signal and transform this signal into a presentation suitable for viewing and listening.

Thus far, the components of the television signal have been discussed. This section contains a resume of the transformation of these signal components into the desired end result.

Simplified Block Diagram

Figure 1-4 illustrates the stages that the television signal transverses before being acceptable for presentation to the picture tube and speaker. Selection of the desired signal is accomplished in the tuner section which comprises the r-f, mixer and oscillator stages. These stages not only select the desired channel (television channel) but change its carrier frequency to a lower frequency, the intermediate frequency. The tuner operates to change any r-f carrier frequency, within the frequency range of the tuner, to an intermediate frequency.

The composite television signal from the tuner is amplified in the i-f stages and applied to the video detector. The signal is rectified in the detector and then distributed to the first video amplifier and the sync amplifier.

The audio intelligence appears at the detector output on a 4.5 megacycle carrier as provided by the intercarrier sound system and is amplified in the first video amplifier. This signal is applied to the sound i-f stage where it is further amplified and then applied to the ratio detector. The detector separates the audio intelligence from the r-f carrier and applies the audio signal, through the audio amplifier, to the speaker for the reproduction of the sound portion of the television signal.

The video intelligence, after detection, is passed through the first and second video amplifiers where the signal is amplified before it is applied to the

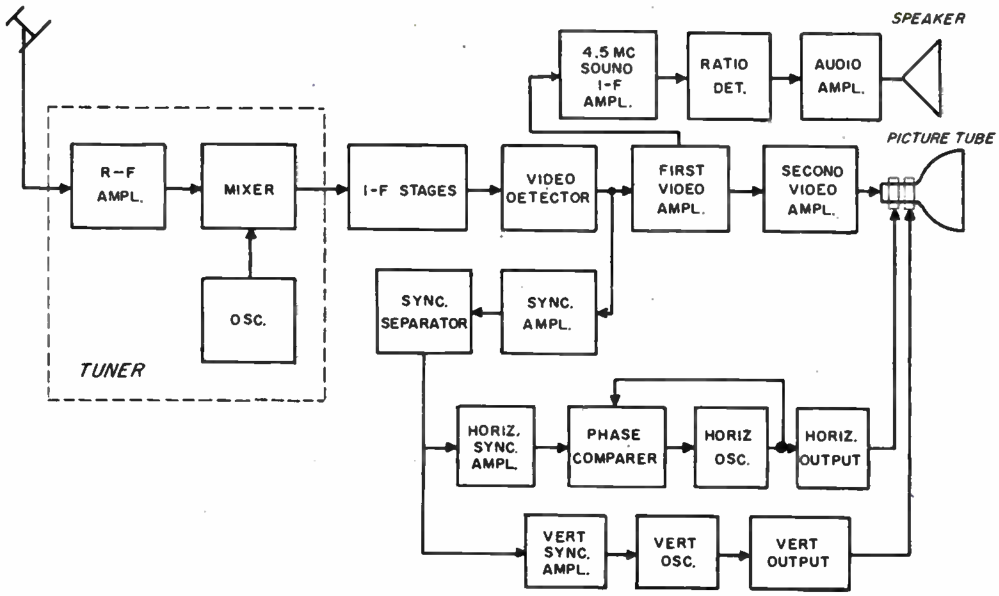


Figure 1-4. Intercarrier television receiver, typical block diagram

picture tube. The amplitude variations of this signal, which control the beam current of the picture tube, provide the light variations between black and white required to reproduce the scene being televised.

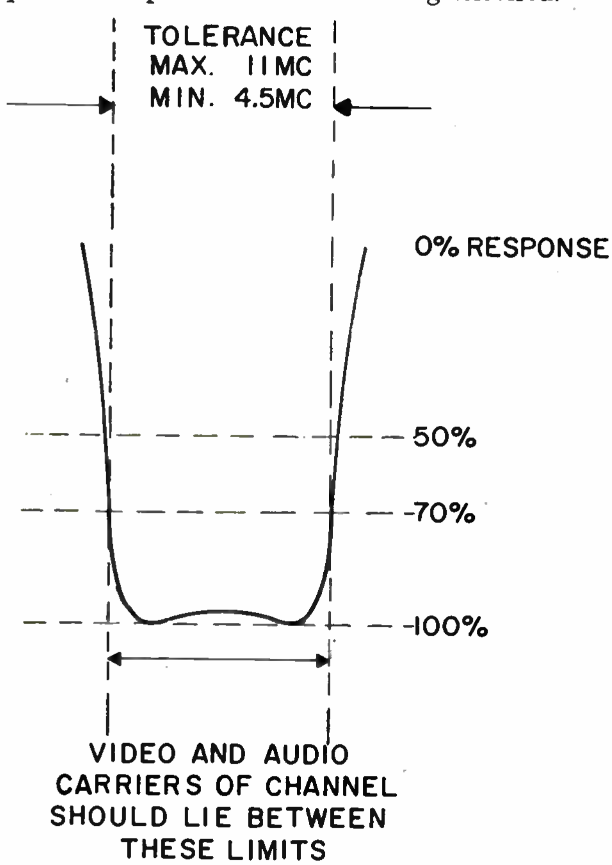


Figure 1-5. R-F response curve with bandpass limits

The sync information is amplified in the sync amplifier and applied to the sync separator which extracts the vertical and horizontal sync pulses from the composite television signal. The sync pulses then are separated from each other by the input circuits to the horizontal and vertical sync amplifiers. These signals then trigger their respective oscillators. The sweep voltages, from the horizontal and vertical oscillators, are fed through amplifiers to their respective deflection coils. The waveshapes and timing of these voltages are arranged to provide a linear and synchronized sweep for the picture tube as discussed in the previous section.

R-F Stage

The r-f amplifier in the tuner selects the desired signal. It must be capable of passing the entire band of frequencies of the television channel; otherwise the full intelligence contained in the signal will not be reproduced by the television receiver. At the same time there must be a degree of selectivity, which is one of the purposes of the r-f stage. Therefore, the bandwidth should not be much wider than that required to pass the television signal. Figure 1-5 illustrates a typical r-f response curve with the minimum and maximum frequency tolerances indicated.

Oscillator and Mixer

The oscillator and mixer stages, shown in figure 1-6, function to change the carrier frequency of any television channel, within the range of the receiver, to an intermediate frequency. This is accomplished by mixing the incoming signal (television signal) with a signal from the local oscillator. The local oscillator is adjustable and is mechanically coupled to the tuning system of the r-f and the mixer stages. Consequently, these stages are tuned simultaneously. The frequency of the local oscillator is adjusted in such a manner that the difference frequency between the desired frequency (television channel) and the local oscillator frequency is always the same. The amplifying section (i-f section) can thereby be designed to operate much more efficiently and to provide a more linear output.

I-F Section

In early models of television receivers, the sound and video signals were separated after the mixer stage and each were fed to their respective i-f sections. In present day models, separation of the audio signal is accomplished by the inter-carrier sound system. In this method, the sound signal and the composite television signal are simultaneously amplified in one common i-f section (video i-f section). Since these two signals are always separated by 4.5 megacycles (F.C.C. Standard), a beat signal of 4.5 megacycles appears when the audio and video signals are applied to the video detector. By design, the i-f stages subdue the sound i-f signal to less that 1/10 of the amplitude of the video i-f signal. Figure 1-7 is a typical i-f response curve and indicates relative amplitudes of the sound and video i-f carriers. When the two signals are mixed, the resultant difference frequency retains the characteristics of the weaker signal. Therefore, the 4.5-megacycle difference frequency predominately exhibits the frequency-modulation characteristic of the sound i-f signal and only a slight amount of video amplitude modulation is present. The slight amount of amplitude modulation is removed by the limiting action of the sound detector. The 4.5-megacycle sound i-f signal can be fed to the sound i-f section from any point after the video detector.

A bias voltage, commonly known as automatic gain control (agc) voltage, is applied to the tuner and i-f stages to prevent strong signals from overloading the television receiver. This negative voltage becomes more negative as the signal amplitude becomes greater, thereby reducing the gain of these stages to compensate for the strong signal.

A small positive voltage, the agc delay voltage, also is applied so that the signal voltage must reach a specified level before the agc voltage becomes effective. The development of the agc voltage is discussed later in this section.

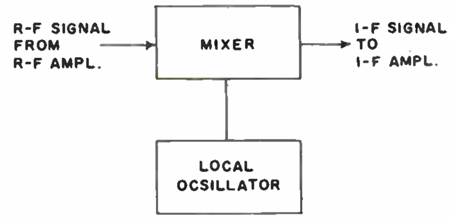


Figure 1-6. Oscillator and mixer

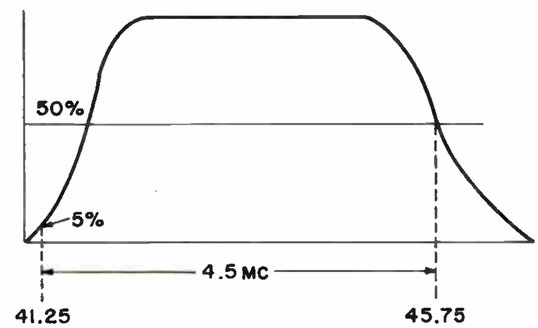


Figure 1-7. I-F Response curve

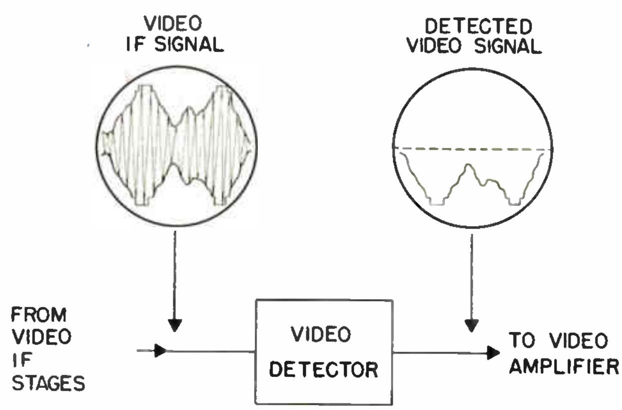


Figure 1-8. Input and output waveforms of video detector

Video Detector

The video detector recovers or separates the intelligence from the composite television signal by first rectifying the i-f signal. The rectified signal then is fed through an r-f filter, thereby removing the r-f components. Waveforms of the i-f signal and the resultant composite video signal are shown in figure 1-8. The various components of the output composite video signal are separated after detection and applied to their respective circuits. The audio and video signals are applied to the first video amplifier. The horizontal and the vertical sync signals are applied, through the sync amplifier, to the sync separator.

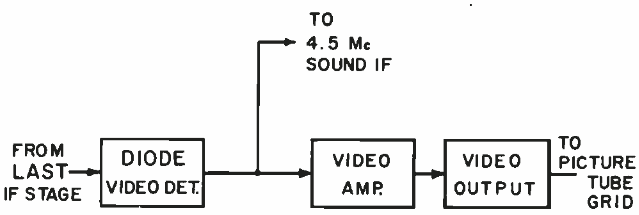


Figure 1-9. Video circuits, block diagram

Video Amplifiers

As previously stated, the F.C.C. television standards specify that maximum signal amplitude produces black on the picture tube while minimum signal amplitude produces white. It is the accepted industry practice that the signal from the detector shall be a negative-going wave. Therefore, the more negative the signal from the detector, the darker the picture.

The picture tube requires that it be operated at or near cut off to produce black and at or near saturation to produce white. The various shades of grey between black and white are produced by intermediate values of beam current.

To satisfy the picture tube requirements and at the same time observe the F.C.C. standards as stated above, a negative-going signal may be applied to the picture tube grid or alternatively, a positive-going signal may be applied to the picture tube cathode. In other words, the phase of the composite video signal between the detector and the picture tube is of paramount importance. From basic radio study, it is known that there is a 180° phase reversal as a signal is amplified through each stage. Therefore, the number of video amplifiers required between the detector and the picture tube depends on whether the video signal is applied to the picture tube grid or cathode. As illustrated in the block diagram of figure 1-9, when the signal is applied to the picture tube grid, an even number of video amplifiers, usually two, is employed to obtain the required phase. When the signal is applied to the picture tube cathode, an odd number of video amplifiers, usually one, is employed.

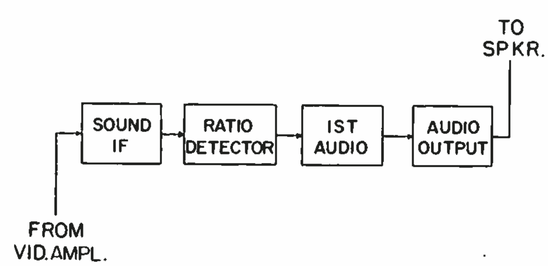


Figure 1-10. Audio circuits, block diagram

Audio Circuits

As explained earlier, audio information is contained in the 4.5-megacycle signal. This signal, as illustrated in figure 1-10, is applied from the first video amplifier to the 4.5-megacycle sound i-f stage. The signal is amplified in the sound i-f stage and applied to the ratio detector where the audio intelligence is separated from the r-f signal. Two stages of amplification, the first audio amplifier and the audio output stage, provide sufficient gain for the audio signal to drive the speaker.

Sync Amplifier and Separator

The composite video signal from the video detector is amplified in the sync amplifier. The output of the sync amplifier, a positive-going wave, is fed to the sync separator. The sync separator is biased to conduct only above the blanking level of the input signal. Thus, as seen in the waveforms of figure 1-11, only the horizontal and vertical sync pulses appear at the output of the sync separator.

The composite video signal also can be taken from the first video amplifier since the signal there is a positive-going wave. In such cases, a cathode follower (no phase reversal) is used for isolation to reduce the loading effect upon the output of the video amplifier.

Noise Rejection

To prevent noise from disrupting the horizontal and vertical sweep circuits, a noise inverter can be included in the circuit. As shown in figure 1-12, a positive-going composite video signal, together with any noise on this signal, is applied to the noise inverter. The noise inverter is biased so that it will amplify and invert the phase of noise pulses that are of a greater amplitude than the sync tip level. The inverted noise pulses are then mixed with the composite video signal at the sync separator. Since the noise pulses in the composite video signal are the same as the inverted noise pulses, but 180° out of phase, the noise pulses are cancelled in the sync separator.

If the sync amplifier is used in the television receiver rather than a cathode follower, the noise inverter will operate in the same manner as described above, except in this case, the positive-going signal is received from the sync amplifier.

Noise rejection also is accomplished by a noise clipper, figure 1-13. In this circuit a pentagrid tube is employed as the sync separator. The positive-going composite video signal is applied to the number three grid which, with the plate and cathode, operates in the conventional manner to separate the sync pulses from the composite video signal. A negative-going composite video signal is applied to the number one grid which is biased to cut-off plate current when noise pulses are of a greater amplitude than the sync tip level. Therefore, noise pulses, greater than sync tip level, will not appear at the plate of the sync separator.

AGC Voltages

Of the various methods used to develope agc voltage the most common method, illustrated in figure 1-14, employs the current drawn by the sync separator grid when the tips of the positive-going sync pulses drive the grid positive with respect to its cathode. Since this grid current is proportional to the amplitude of the sync pulses, it reflects the signal strength. Thus, this current can be fed through filters to develop a negative bias voltage which is proportional to the signal strength. The use of this agc voltage was explained earlier in this section.

A gated agc system is used in some circuits. This system would not be affected by pulses, usually noise, greater in amplitude than sync tip level occuring between horizontal sync pulses. In the gated agc system, figure 1-15, the positive-going composite video signal is applied to the gate tube grid. Its plate voltage, a positive pulse, is received from a winding on the horizontal output transformer. The tube is biased to conduct on the sync pulses but the tube can conduct only when plate voltage is applied, during horizontal sync time. Therefore, even if a pulse greater in amplitude than the sync pulse is applied to the grid between horizontal pulses, it does not develop an agc voltage. In this system, agc voltage is developed only during the horizontal sync time. The amplitude of the sync pulses determines the amount of conduction and is proportional to the signal strength. The current flow through the output circuit develops the agc voltage.

Separation of Sync Pulses

After the sync pulses are separated from the composite video signal, the vertical sync pulses must be separated from the horizontal sync pulses. The

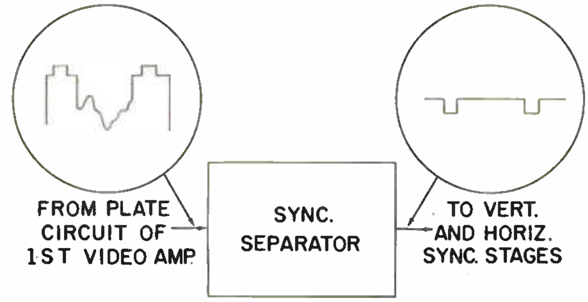


Figure 1-11. Sync separator, input and output waveforms

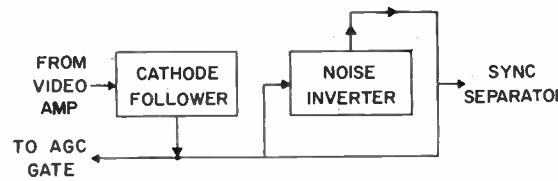


Figure 1-12. Noise inverter, block diagram

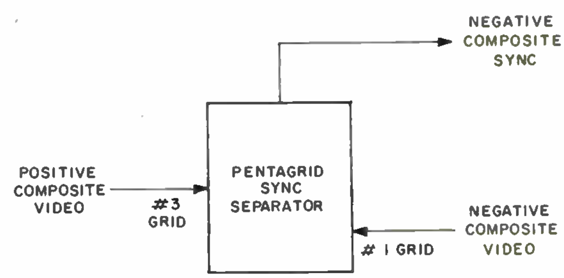


Figure 1-13. Sync separator and noise clipper

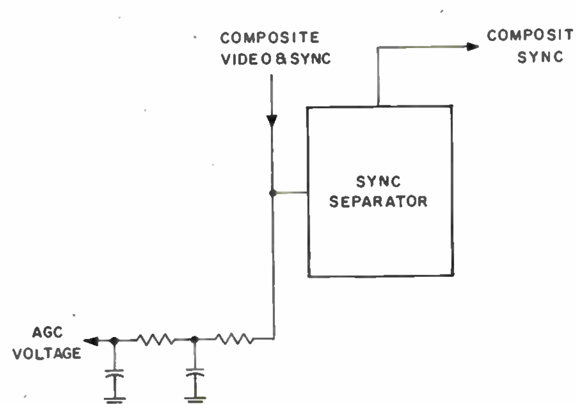


Figure 1-14. Development of agc voltage

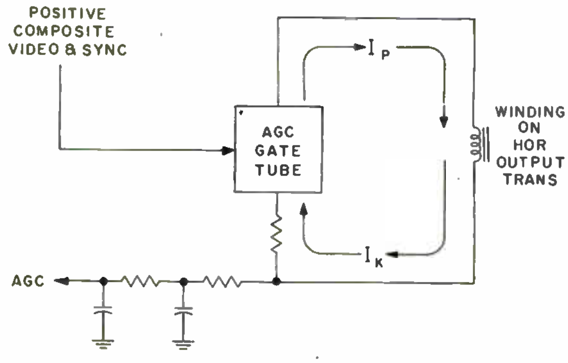


Figure 1-15. Development of gated agc voltage

vertical pulses are separated by an integrator. The horizontal sync pulses are separated by a differentiator.

An integrator circuit, figure 1-16, consists of resistors and capacitors usually in cascade with relatively long time constants. As the composite sync signal is applied to the integrator circuit, a series of small sawtooth pulses and a large serrated sawtooth pulse is obtained. The vertical oscillator is adjusted to respond only to the large sawtooth pulse and ignore the small sawtooth pulses and the serrations. This pulse triggers the vertical oscillator keeping it in synchronism with the oscillator at the transmitter.

The differentiator circuit, figure 1-17, is a resistor-capacitor combination that provides a very short time constant as compared to the vertical integrator circuit. The circuit components are such that when the composite sync signal is applied to this circuit, large pulses are obtained.

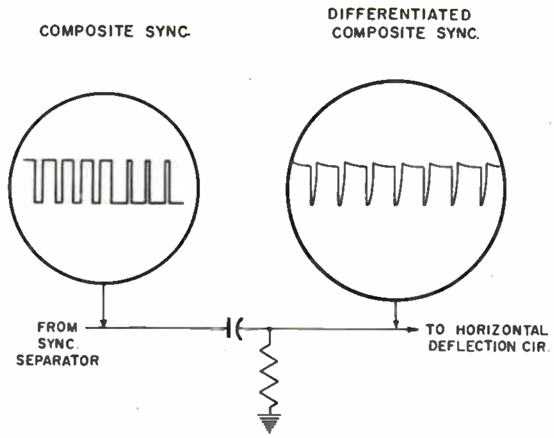


Figure 1-17. Differentiator circuit

Vertical Deflection Circuits

The vertical oscillator provides an output of a square or rectangular shaped wave for every vertical sync pulse. Shaping circuits, consisting of a capacitor or a series resistor and capacitor or both, result in a waveform as shown in figure 1-18. The shaping circuits compensate for the non-linear response of the deflection coil. After shaping, the signal is amplified in the vertical output stage and, when applied to the vertical deflection coils, provides a linear vertical sweep of the electron beam.

Horizontal Deflection Circuits

The horizontal sync pulses are applied to the horizontal deflection circuit in a different manner from that of the vertical deflection circuit. Usually some type of automatic frequency control for the horizontal oscillator is employed such as the Philco Phase Comparer. Instead of applying the horizontal sync pulse

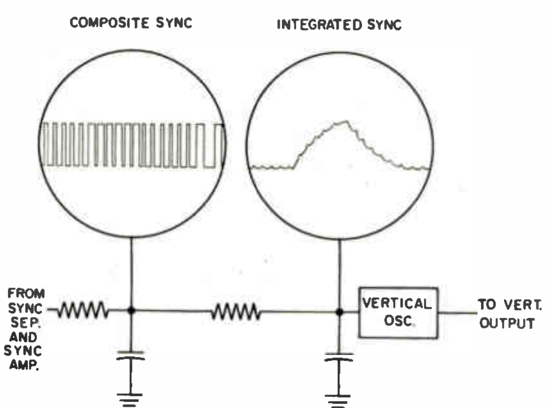


Figure 1-16. Integrator circuit

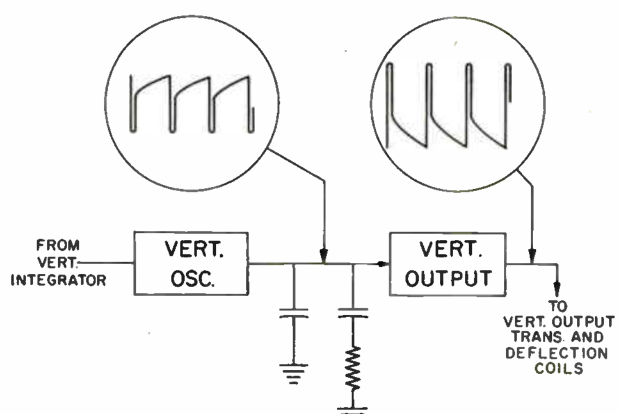


Figure 1-18. Vertical deflection circuits

to the oscillator, it is fed to a phase comparer stage. Here it is compared, in phase, to a portion of the output signal from the horizontal oscillator. Any difference in phase between the two signals produces a positive or negative voltage which controls the horizontal oscillator frequency. Thus, the receiver horizontal oscillator is synchronized with the transmitter horizontal oscillator.

The output of the horizontal oscillator is a rectangular shaped wave similar to the vertical oscillator waveform, but, of course, of different frequency. Here again wave shaping is required to compensate for non-linear response of the deflection coils. The shaped wave, shown in figure 1-19, is amplified in the horizontal output stage and, when applied to the horizontal deflection coils, provides a linear horizontal sweep of the electron beam.

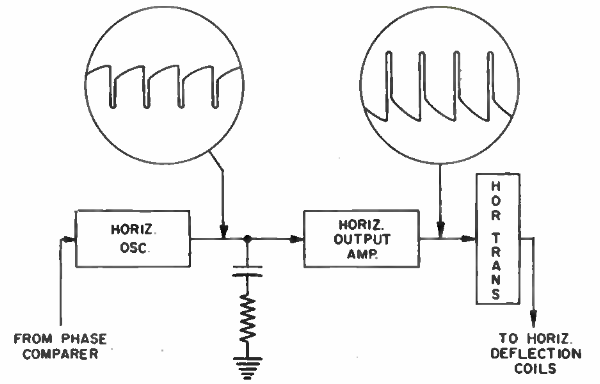


Figure 1-19. Horizontal deflection circuits

Horizontal Output Transformer

The horizontal output transformer not only transfers the horizontal sweep voltage from the horizontal output stage to the horizontal deflection coils but also provides high voltage for the picture tube anode.

The primary of the horizontal output transformer is wound as an auto transformer. The horizontal sweep pulse is applied to a portion of the primary winding. The retrace portion of the signal, or "fly-back" pulse as it is often called, goes through its minimum and maximum current limits very rapidly. Since self-induced voltage in an inductance is proportional to the rate of current change in units of time, a very high voltage is induced in a portion of the primary winding. This voltage pulse, due to transformer step-up action, appears across the entire primary winding as many thousands of volts. This voltage is applied to the high voltage rectifier and the d-c voltage from the rectifier is applied to the picture tube anode.

This rapid fly-back pulse also has an undesirable characteristic in that it causes ringing in the horizontal output circuit. This, of course, would interfere with the horizontal sweep voltage in the deflection coil. A damper tube connected across the deflection coil, conducts on the negative portion of this ringing voltage, thereby suppressing the ringing voltage very rapidly. The voltage developed by the damper tube during conduction is added to the receiver B-plus voltage. The total voltage, commonly referred to as B-plus boost voltage, is applied to portions of the sweep circuits.

2. COLORIMETRY

COLORIMETRY is the measurement or analysis of color. In this study of colorimetry some of the fundamental principals of light are discussed first to form a foundation for the understanding of color. However, prior to the study of colorimetry, it is well to remember that mixing paints or pigments is not the same as mixing colors of light. Therefore, it is recommended that the technician who previously has acquired knowledge of mixing pigments approach this subject with an open mind.

SECTION 1. FUNDAMENTALS OF LIGHT

Light is a form of radiant energy consisting of electromagnetic waves of extremely high frequency. Light waves, like radio waves, are transmitted from a source. They are reflected, focused and polarized in much the same manner as radio waves.

As shown in the frequency spectrum chart of figure 2-1, light waves have wavelengths between 0.00004 and 0.00007 centimeters. Since these figures are so small, it is more convenient to express the wavelength of light waves in terms of a smaller unit—the millimicron. One millimicron equals 10^{-9} meters or one thousandth of a millionth of a meter. Therefore, light waves have wavelengths between 400 and 700 millimicrons.

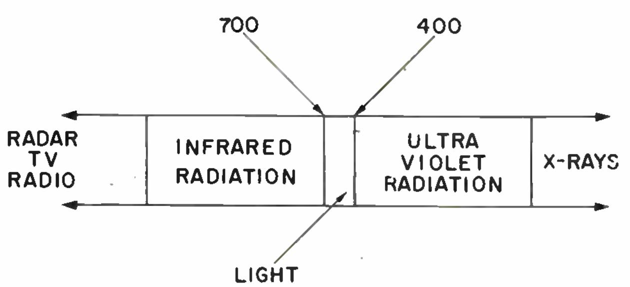


Figure 2-1. Frequency spectrum

Reflection and Absorption

Light, however, to the average person takes on a more practical meaning, that of illuminating an object so that it can be seen. If an object were placed in a room of absolute darkness, an observer in this same room could not see the object. If, however, a source of light illuminated the object, it would be visible to the observer. It is the reflection of light rays from the surface of the object which enables the observer to see it. All objects reflect light to varying degrees. If an object were absolutely transparent, its surface would not reflect light rays, therefore, it would be invisible. Of course, this condition is impossible since there are no known materials that do not reflect light. If an object is made of a translucent material, most of the light rays pass through the object while a small percentage of the light rays is reflected. If the object is not translucent, the light rays are either reflected or absorbed by the object. The amount of light reflected by the object is determined by its finish. If the object has a bright shiny surface, such as a mirror, as much as 90% of the light rays are reflected. Conversely, if the object has a dull black surface, such as a blackboard, only about 10% of the light rays are reflected.

Therefore, it can be stated that in order to see an object, light must be reflected from the object. The amount of light is not of particular importance since the eye has the ability to adjust itself to a large range of light levels.

Components of Light

When a beam of white light is directed through a refracting prism, as shown in figure 2-2, the prism disperses the light beam into a spectrum revealing all the colors contained in white light. Due to practical limitations, all the intermediate colors cannot be shown in figure 2-2. Detailed examination of a spectrum, produced with a refracting prism, reveals that the change from one color to another is gradual

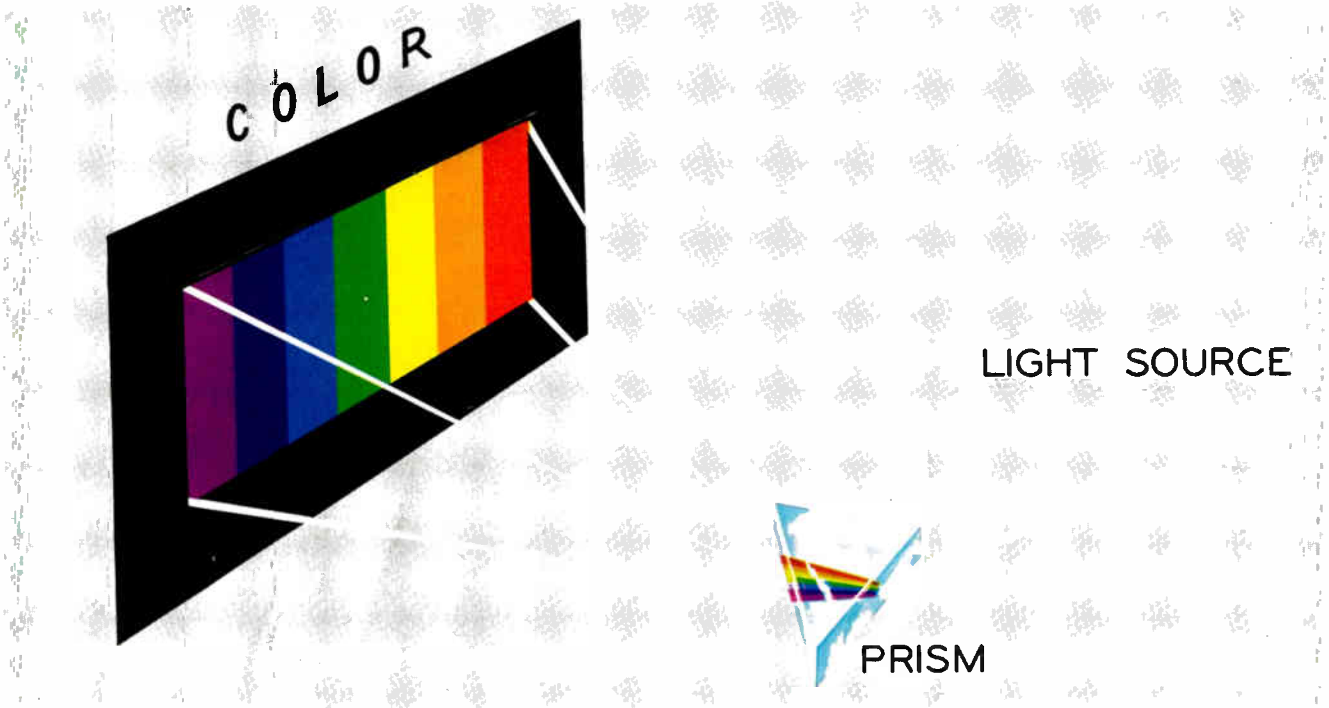


Figure 2-2. Refraction of white light

and many combinations of colors are traversed in going from the lower to the upper end of the color spectrum.

SECTION 2.
FUNDAMENTALS OF COLOR

Color is that aspect of light that produces the sensations of brightness, hue and saturation. Brightness is the amount of luminance or the brilliance of a color. Hue indicates the wavelength of a color, that is, its position in the spectrum. Saturation is that property that denotes the absence of white light; thus a color that does not have any white light is a saturated color, sometimes called a pure color. When white light is mixed with a color it becomes desaturated. Pastel colors are desaturated.

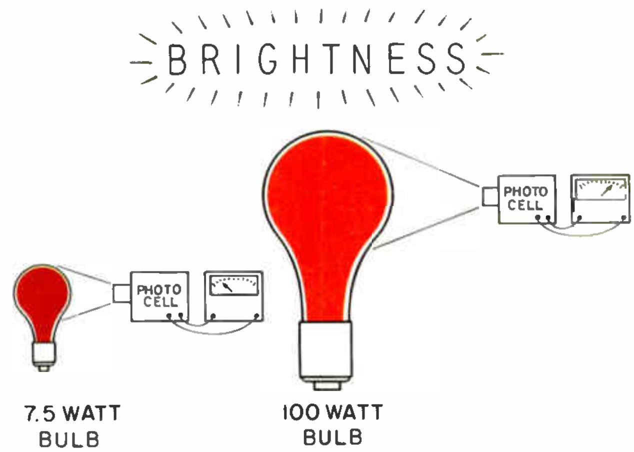


Figure 2-3. Brilliance measurement

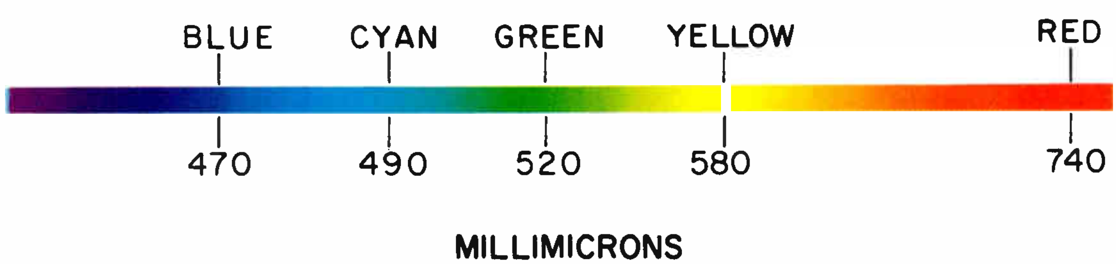


Figure 2-4. Visible light spectrum

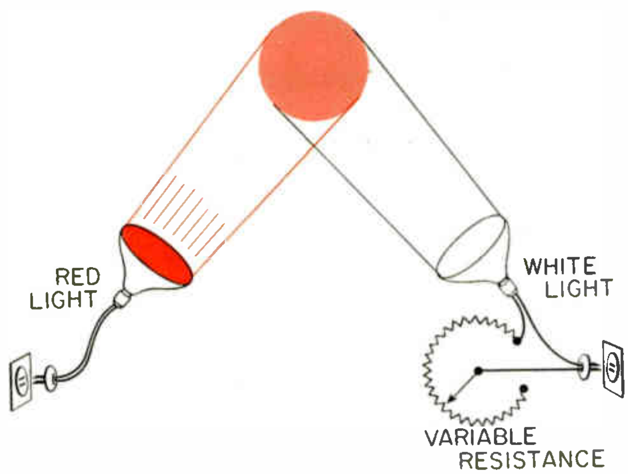


Figure 2-5. Desaturating a saturated red hue

Brightness

Brightness, as stated before, represents the brilliance of a color, saturated or desaturated. Brightness is measured in terms of lumens which is similar to watts (power) except it has been modified in accordance with the characteristics of the human eye. The amount of brightness of a colored light can be demonstrated as shown in figure 2-3. The light output from a 7.5 watt bulb is measured with a photocell connected to a meter calibrated in lumens (exposure meter). The meter indicates a specific number of lumens. A similar arrangement measures the light output from a 100 watt bulb. This meter indicates proportionately more lumens, thus establishing that the light output from the larger bulb is many times greater than that of the smaller bulb.

Hue

As one scans the visible light spectrum, as shown in figure 2-4, the sensation in the normal eye is changed from red at the lowest frequency (longest wavelength) through orange, yellow, green and blue to violet at the highest frequency. These sensations are called hues and, in the spectrum, they are fully saturated. Therefore, it can be seen that any hue has a specific frequency or wavelength. To the average individual a hue is not specific. Sky blue, baby blue, light blue, dark blue and navy blue seem to be specific colors, but actually they include a wide range of hues, desaturated to different degrees. Consequently, it is necessary to use exact color nomenclature in the manufacturing business and equally important in color television.

An important fact is that the hue of a color does not change with brightness. That is, no matter how dimly or brightly a colored object is illuminated, its hue remains the same.

Saturation

A saturated color is one that does not contain any white light. All colors in the visible spectrum are saturated or pure. To more clearly understand the saturation and desaturation of a hue, two sources of light are projected upon a screen as shown in figure 2-5. One light is pure red and has a fixed brightness. The other light is white and has an adjustment to control its brightness. Assume the white light is not illuminated, the red light on the screen is a saturated hue. As the brilliance of the white light is increased from zero to a value that is many times that of the red light, the resultant hue becomes less saturated (or more desaturated) until the red content is almost invisible. The percentage of saturation is the number of lumens (brightness) of the red light divided by the sum of the number of lumens of the red light plus the lumens of white light times one hundred. From this it can be seen that a color can have any percentage of saturation from 0 to 100%.

Desaturation of three saturated hues is illustrated in figure 2-6. As the eye travels towards the right-hand side, it is noted that the percentage of saturation increases until each of the three colors is almost completely saturated. At the left side, however, the color contains only a vestige of the saturated color.

SECTION 3.
COLOR STANDARDS

Chromaticity Diagram

The chromaticity diagram, illustrated in figure 2-7, is a graphical representation of hue and saturation with the brightness fixed. The chromaticity diagram is a standard means of designating the hue and the degree of saturation in terms of x and y co-ordinates.

The Federal Communications Commission has specified a color television system based on the following three primary colors:

COLOR	CO-ORDINATES	
	x	y
RED	0.67	0.33
GREEN	0.21	0.71
BLUE	0.14	0.08

These primary colors, when mixed in proportions of 30 % red, 59% green and 11% blue, produce the reference white.

Color Triangle

A color triangle is formed on the chromaticity diagram of figure 2-7 by joining the three primary colors specified by the F.C.C. This triangle, shown in figure 2-8, contains all the hues and saturations that can be produced in color television.

The F.C.C. specifications establish definite limits on color reproduction since only colors on or within the color triangle can be reproduced. However, these limits are greater than those possible in color printing and photography.

Saturated hues, on the periphery of the color triangle, are produced by mixing two of the primary colors while desaturated hues, within the confines of the color triangle, are produced by mixing all three primary colors.

Color Pyramid

A projection of the color triangle to include the brightness is illustrated in figure 2-9. Black or the absence of light, is at the apex of the pyramid. Color does not exist at this point since there can be no color without light. The projection from the apex through the center of the pyramid is the brightness axis. Saturated colors are on the surfaces of the pyramid while the desaturated colors are within the confines of the pyramid. The colors became progressively brighter from the apex to the base of the pyramid. The percentage of saturation becomes progressively greater from the central axis to the surface of the pyramid. Close examination reveals the brightness axis starts in the black region and progresses through various shades of gray and into the white region. From this it is seen that the only difference between black, all portions of the gray scale, and white is the amount of brightness. Therefore, when producing gray, as when producing the reference white, 30% red, 59% green and 11% blue are required, the only difference being the brightness.

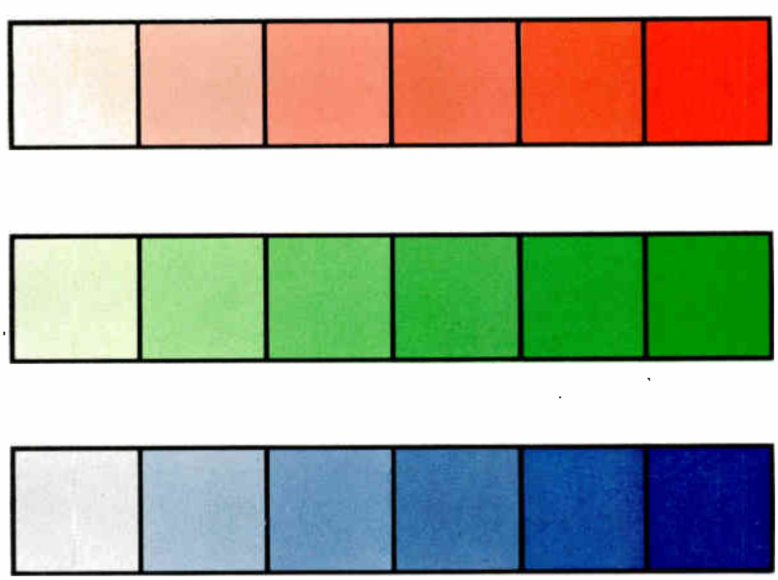


Figure 2-6. Desaturation of hues

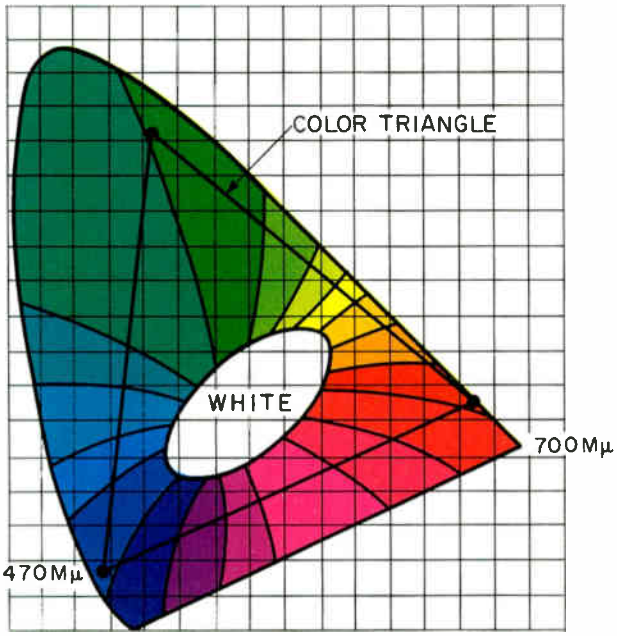


Figure 2-7. Chromaticity diagram

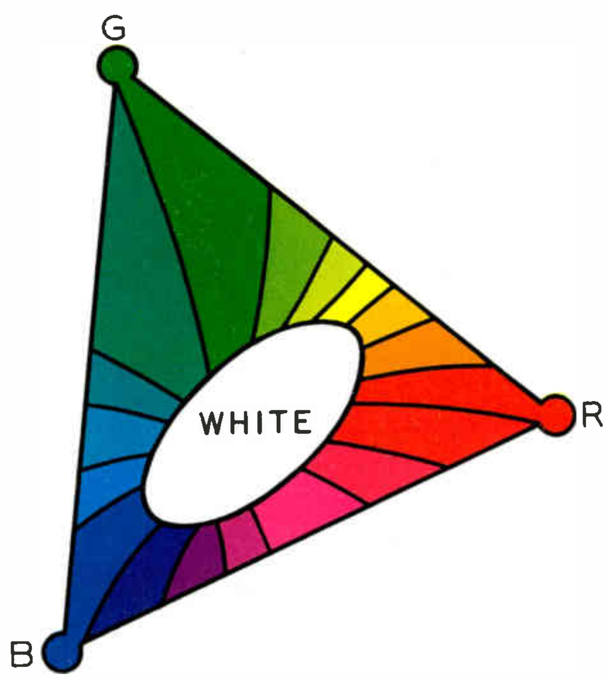


Figure 2-8. Color triangle

SECTION 4.
CHARACTERISTICS OF COLOR

Absorption and Reflection

As previously stated, when light falls upon an object, some of the light rays are absorbed by the object while others are reflected. It is the reflected light rays that enable an observer to see the object. Now, consider the object illustrated in figure 2-10 to be illuminated by a white light. The pyramid is made of a red material, the sphere of a green material and the cube of a blue material. As the white light illuminates the object, each colored portion of the object absorbs all wavelengths of the white light except the wavelength corresponding to its respective color. Therefore, the red pyramid reflects red, the green sphere reflects green and the blue cube reflects blue. It is this reflection of specific wavelengths that enables the observer to distinguish color.

If the illuminating source were red (the same wavelength as the red of the pyramid), as shown in figure 2-11, the only visible portion of the object to the observer would be the red pyramid. The green sphere or the blue cube would not be visible since wavelengths of green or blue are not available in the light source and consequently could not be reflected by the sphere or cube. The red light striking the sphere and cube is absorbed. Using the same principles of absorption and reflection, any one portion of a multicolored object can be made more visible to the observer by directing to it a light source whose wavelength matches the color of that portion.

Separation of Colors

Colors can be separated or extracted from a combination of colors by use of optical passive filters. The characteristics of these filters are similar to the characteristics of an r-f amplifier in that they pass a narrow band of frequencies and reject all others. Thus, the frequency (color) that passes through a passive filter is the one to which the filter is "tuned" (filter color).

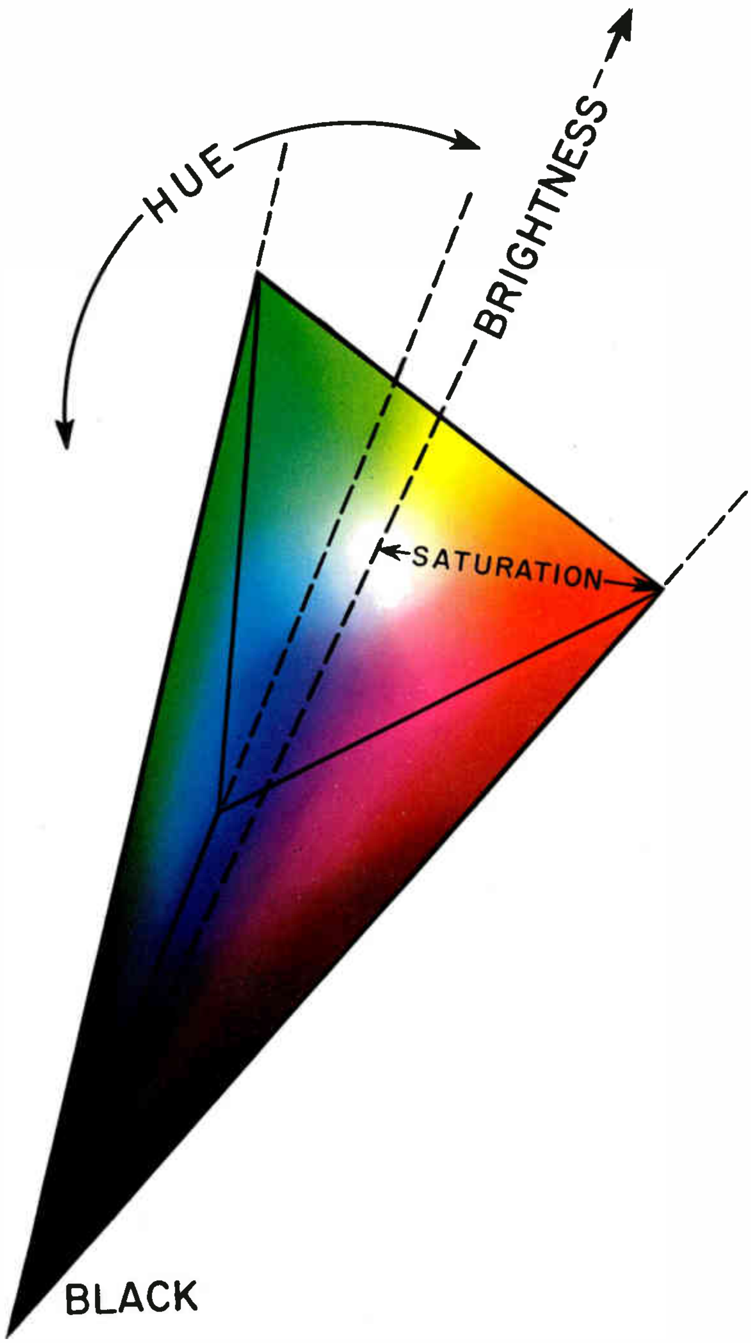


Figure 2-9. Color pyramid

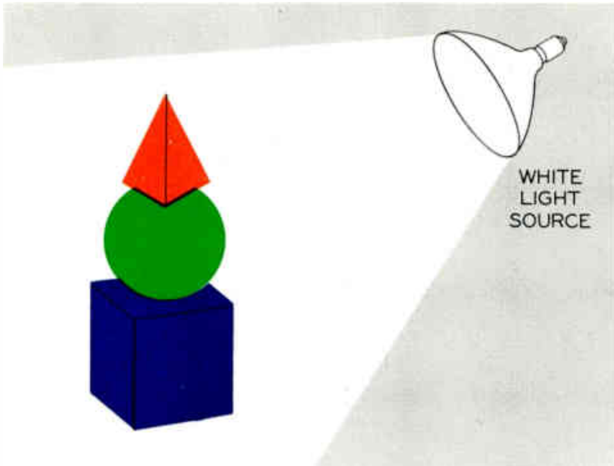


Figure 2-10. Object illuminated by white light

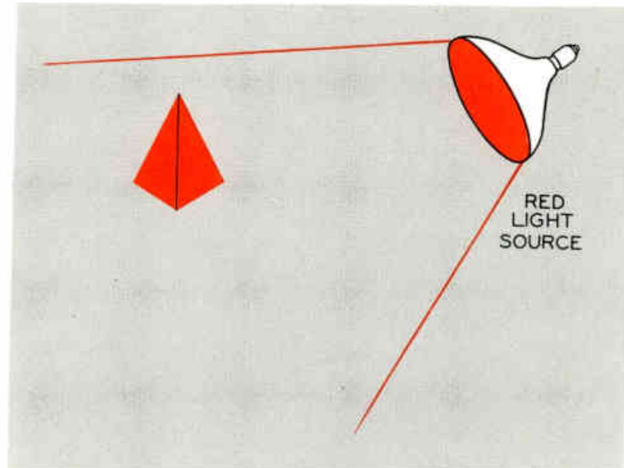


Figure 2-11. Object illuminated by red light

Three sources of white light are illustrated in figure 2-12. Each source is directed at a passive filter, one red, one green and the other blue. It can be seen that only the wavelengths of light corresponding to each filter color are visible at the right-hand side of the illustration. All wavelengths of the white light, except those to which the passive filter corresponds, are rejected and consequently do not pass through the filter.

As seen in figure 2-13, a passive filter also can be placed between an object and an observer. As shown in the illustration, a white light is focused on the object and each portion of the object reflects its respective color. As the three colors strike the blue filter, only the light reflected from the blue cube penetrates the filter, the other two being rejected. The observer can see only the blue cube even though the object is illuminated with white light.

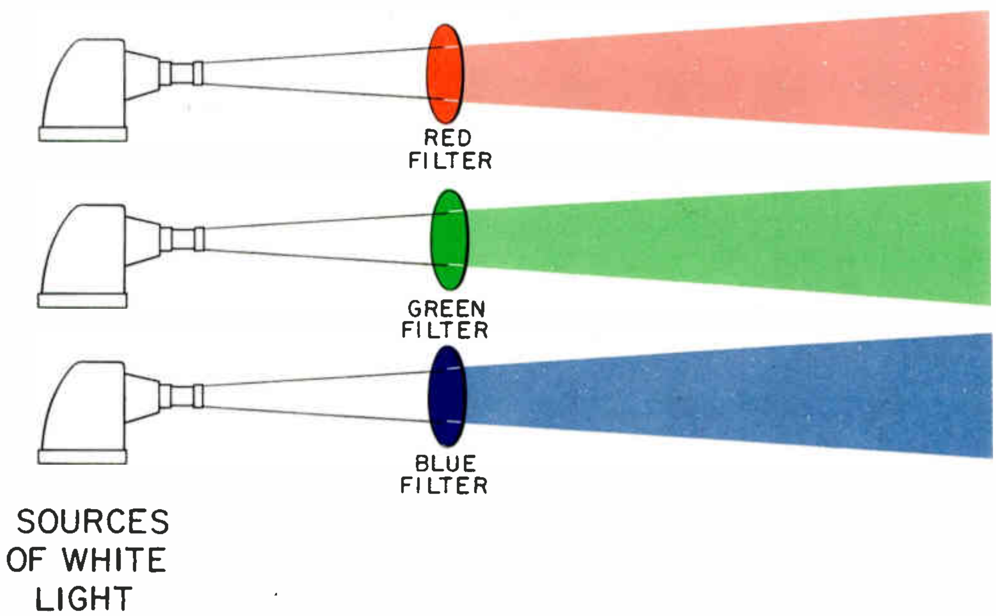


Figure 2-12. Separation of colors from white light

SECTION 5.
MIXING COLORS

As previously discussed in the color standards section, the three standard primary colors, red, green and blue, are mixed in different proportions to produce other colors. It also was stated that proportions of 30% red, 59% green and 11% blue combine to produce standard white. For simplicity in the following text and to eliminate confusing formulas, the following generalization will be made.

1 red unit represents 30% red
1 green unit represents 59% green
1 blue unit represents 11% blue

Thus it can be said that one red unit, one green unit and one blue unit combine to produce standard white.

Mixing Two Colors

In the illustration of figure 2-14 there are two lights, one blue and one green; each has a brightness of one unit. If these lights are so projected upon a screen that one light falls on the other, the observer sees a blue-green color called cyan. If the blue light is replaced with one unit of red light, the resultant color on the screen is yellow. Now, if the green light is removed and the blue light replaced, a third color, magenta, appears. Thus, equal units of blue and green produce cyan; equal units of green and red produce yellow; and equal units of red and blue produce magenta. If the units of light from each source are not equal, a different color results. The combined color then exhibits mostly the characteristics of the predominant color. When one unit of green light is mixed with three units of red light,

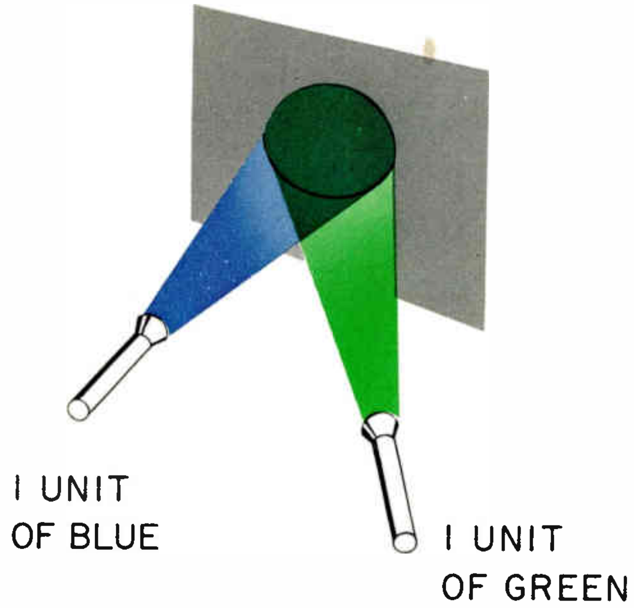


Figure 2-14. Mixing blue and green light

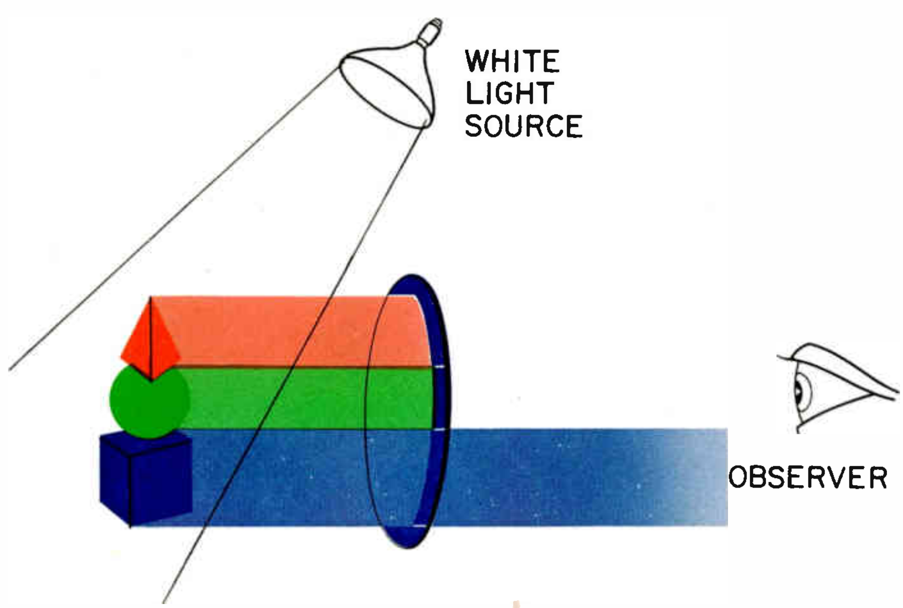


Figure 2-13. Separating reflected light

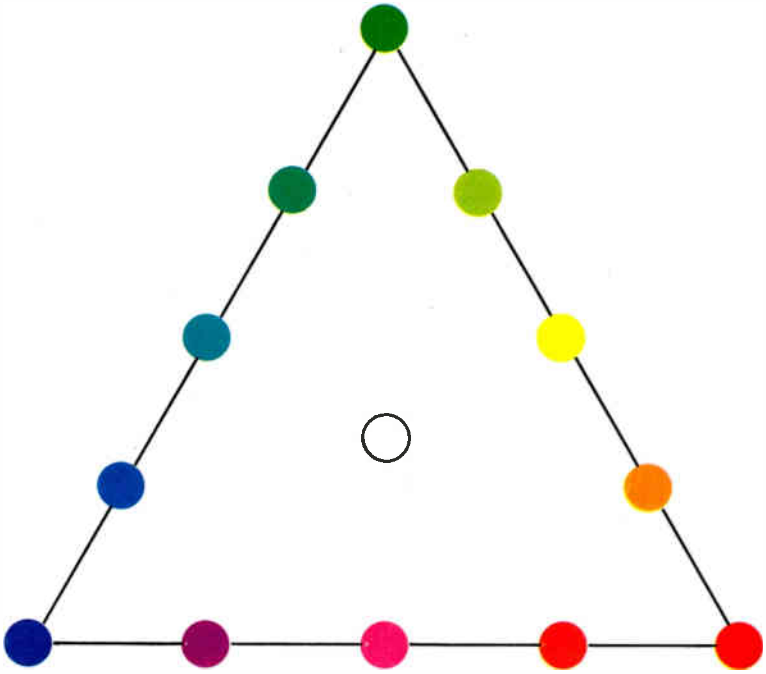


Figure 2-15. Color triangle

the result is orange. By varying the proportions of red and green a variety of colors ranging from red to green can be produced. A range of colors between green and blue similarly can be produced by varying the proportions of green and blue. A third range of colors between blue and red can be produced by varying the proportions of blue and red.

The ranges of colors produced by mixing the primary colors can be arranged in the form of an equilateral triangle, figure 2-15. The primary colors occupy the points of the triangle and the resultant colors are on the periphery. The proportions for any resultant color are inversely proportional to the distance between the resultant color and the two primary colors which are mixed to produce the resultant color. Examination of the equilateral triangle reveals orange is ¼ the distance from red and ¾ the distance from green. Stated in other words, three units of red and one unit of green produce four units of orange.

Mixing Three Colors

Equal units of red, green and blue produce standard white. Therefore, when mixing unequal units of the three primary colors, there always is some white content. To determine the resultant color, first determine the amount of white content by subtracting the lowest number of units in the combination from the combination. The two remaining colors are combined as explained previously. The resultant color is that which was produced by the two remaining colors and desaturated by the white content. As an example, determine the resultant color from five units of red, three units of green and two units of blue. The lowest number of units is two. Subtract two units from each quantity leaving three units of red, one unit of green and no blue. The two units of each color produced the white (six units of white). The two remaining colors, three units of red and one unit of green, produce four units of orange. The six units of white will desaturate the four units of orange 60%. Therefore, the resultant color is an orange that is desaturated 60%. It should be noted that when three primary colors are combined, there is always some white content, hence the resultant color always is desaturated and is represented within the periphery of the color triangle as illustrated in figure 2-8.

3. TRANSMISSION AND RECEPTION METHODS AND STANDARDS

SECTION 1. THE COMPOSITE COLOR SIGNAL

THE THREE properties of color are brightness, hue and saturation. Therefore, signals proportional to these properties of the televised color must be transmitted. Each color contains specific proportions of the three primary colors red, green and blue. Hence, if signals proportional to the brightness of the red, green and blue components of a color were transmitted, they could be received and applied to a color picture tube and reproduce the televised color. This is the basic principle of televising a color; however, it is not quite this simple. Voltages proportional to the brightness of the primary components of the color are first obtained. From these three primary signals, a brightness signal and two color-difference signals are then derived. The brightness signal contains the brightness information (one of the three properties of color) of the televised color. The brightness signal is identical to the monochrome video signal, hence it carries the information for monochrome television receivers. The two color-difference signals are combined in a color subcarrier; they contain the hue and saturation information of the televised color. These two signals, the brightness signal and the color subcarrier, contain the three properties of the televised color. These signals are transmitted and separated into their components at the receiver. The three primary signals derived from the transmitted signals, are applied to the color picture tube where they reproduce the televised color.

Extracting Primary Color Components

The first prerequisite in developing the brightness and color-subcarrier signals is to obtain three voltages which are proportional to the brightness of the primary color components of the color to be televised.

When a colored object is photographed on black and white photographic film, the reproduction reveals only the brightness components, since photographic film is sensitive only to the brightness of the light. Therefore, the object is reproduced on a gray-scale basis in proportion to the reflected light from the various portions of the object. The monochrome television camera operates in a similar manner. The mosaic of a television camera tube, like black and white film, is sensitive only to brightness. Therefore, the mosaic surface provides voltages proportional only to the intensity of the reflected color brightness information, and the reproduction is on a gray-scale basis, even though there is color on the mosaic surface.

In color television, three television camera tubes are arranged as illustrated in figure 3-1. Each tube is associated with an optical filter, one red, the second green and the third blue. The image of the object is split optically and directed through the filters to the associated camera tubes. Since the filter permits only its color to be presented to its camera tube, a substantially independent brightness voltage is obtained from each of the three camera tubes. The amplitude of each signal is proportional to the amount of reflected light of each primary color which strikes the mosaic surface of its respective camera tube.

Reproduction of the object could be accomplished by feeding these three independent primary brightness signals to three picture tubes arranged in a manner similar to the camera tubes of figure 3-1. The red signal would feed a picture tube with phosphors that emit saturated red light; the green signal would feed a picture tube with phosphors that emit saturated green light; and the blue signal would feed a picture tube with phosphors that emit saturated blue light. The red, green and blue portions of the object, in their original colors would then appear on their respective picture tubes. These individual images could then be assembled optically and presented to the viewer. It is possible but not practical to use this reception method. A 4.2-megacycle bandwidth is required for each signal to produce a color picture of the quality offered by the black and white standards. Therefore the color information could not be transmitted within the present F.C.C. frequency allocations for monochrome television. Also, this system would not be compatible with the existing system of monochrome television. A practical method for receiving and assembling these signals is described later in this section.

The Brightness Signal

The brightness signal is formed by combining specific proportions of the red, green and blue signal voltages. As shown in figure 3-2, the red, green and blue camera tubes are combined in one unit, the color television camera. The three signal outputs are fed to an adder unit where the proper portions of the red, green and blue signals are combined. The brightness signal is identical to the monochrome video signal.

White light contains 30% red, 59% green and 11% blue. The brightness signal contains these proportions so as to maintain the proper luminance of the colors for reproduction.

The Subcarrier and Color-difference Signals

Signals representative of the hue and saturation of the colors also are required. To see how these signals are related to hue and saturation, consider the color triangle shown in figure 3-3. The fully saturated colors are located on the periphery of this triangle, the white point approximately at its center. If a straight line is drawn from the white point, as shown, to a particular hue on the periphery, the points on this line represent colors which have the same predominant hue (in the case shown, all magenta), but with different degrees of saturation from zero at the white point increasing smoothly to a maximum at the side of triangle.

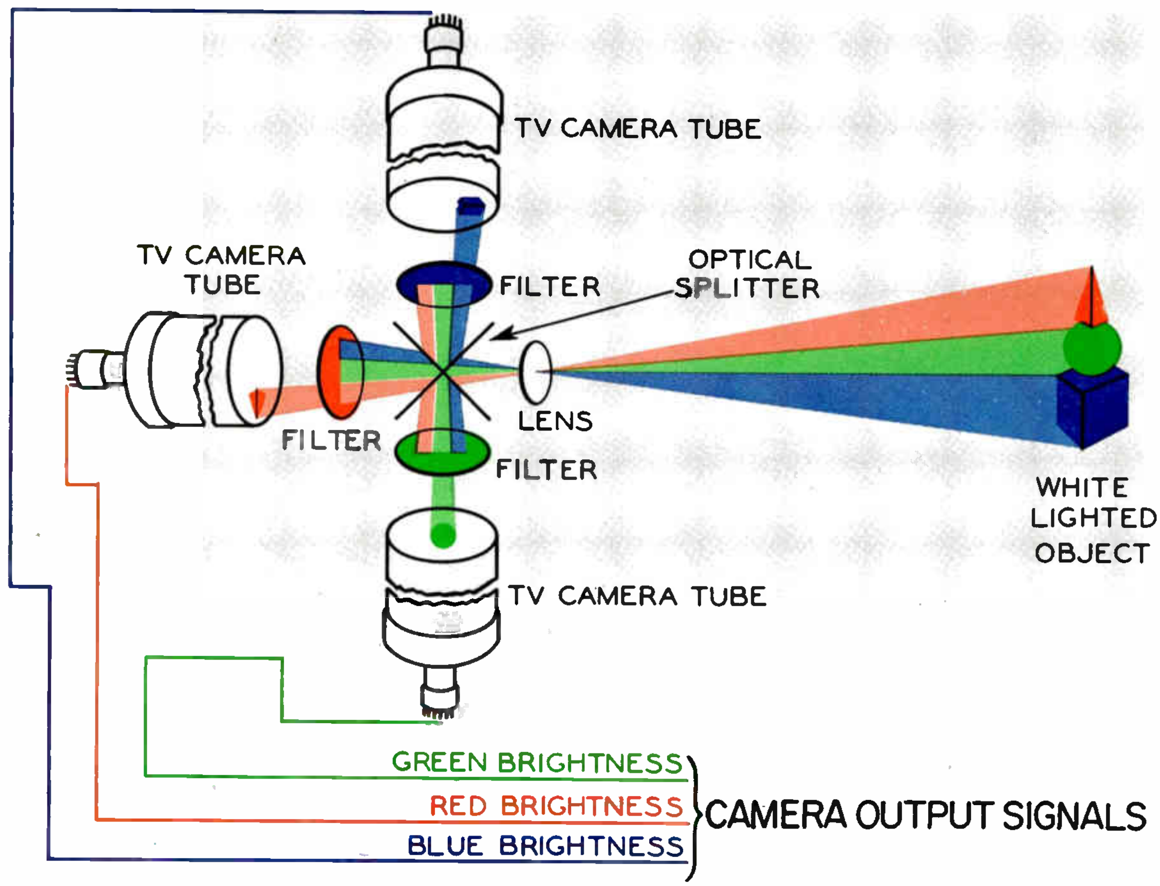


Figure 3-1. Fundamental arrangement for color pick-up.

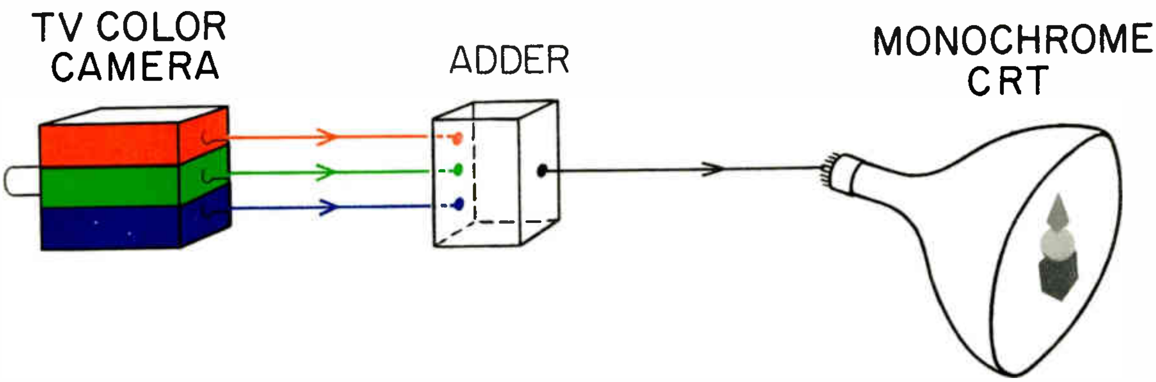


Figure 3-2. Forming the brightness signal.

Similarly any number of such lines may be drawn from the white point to the different saturated hues on the periphery, and if a sufficient number of such lines are drawn, all the points within the triangle are covered; that is, all the hues and all the possible degrees of saturation that are required to be reproduced by the color television system are covered.

Now, consider the transmission of one particular hue and saturation, as an example, point A on the diagram, figure 3-3. This point may be measured by the x and y co-ordinates, shown in the diagram as $x = 0.6$, $y = 0.4$; this is the method of specifying the color used in the science of colorimetry, by specialists in color printing and color photography. But the hue and saturation point also may be specified in another way, a way which illustrates the manner in which the hue and saturation information is actually carried by the color-subcarrier signal in the compatible color system. In this method, the

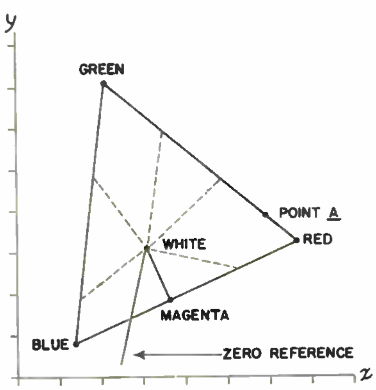


Figure 3-3. Plotting hue and saturation on x and y coordinates.

color point is located by the method of polar co-ordinates, that is by measuring its *distance* from the white point along the radial line shown, and by the *angle* of the radial line measured against the zero reference line shown. As is described more fully later in this chapter, the electrical phase angle of the color subcarrier measures the angle, which is proportional to the hue of the color point, and the amplitude of the subcarrier measures the radial distance, which is proportional to the saturation.

As stated earlier, the color subcarrier is made up of two color-difference signals which are selected and combined in such a manner that the subcarrier phase represents hue and its amplitude represents saturation. The color-difference signals themselves are produced by subtracting the brightness signal, described above, from each of the primary brightness signals associated with each of the camera tubes. The brightness signal is represented by the letter Y, the primary color signals by R for red, G for green and B for blue. Hence the color-difference signals are R-Y, B-Y and G-Y. The method by which they are formed is described later in this chapter.

It should be noted that there are two other color-difference signals which appear in the color transmission process. These are represented by the letters I and Q. The I and Q signals are formed by combining the R-Y and B-Y signals in particular amplitudes and polarities. Since the I and Q signals are not used to any extent in color television receiver operation, discussion of them is deferred to the end of the chapter.

The Composite Color Signal

The closed-circuit basic system illustrated in figure 3-4 shows the primary signal outputs from a color

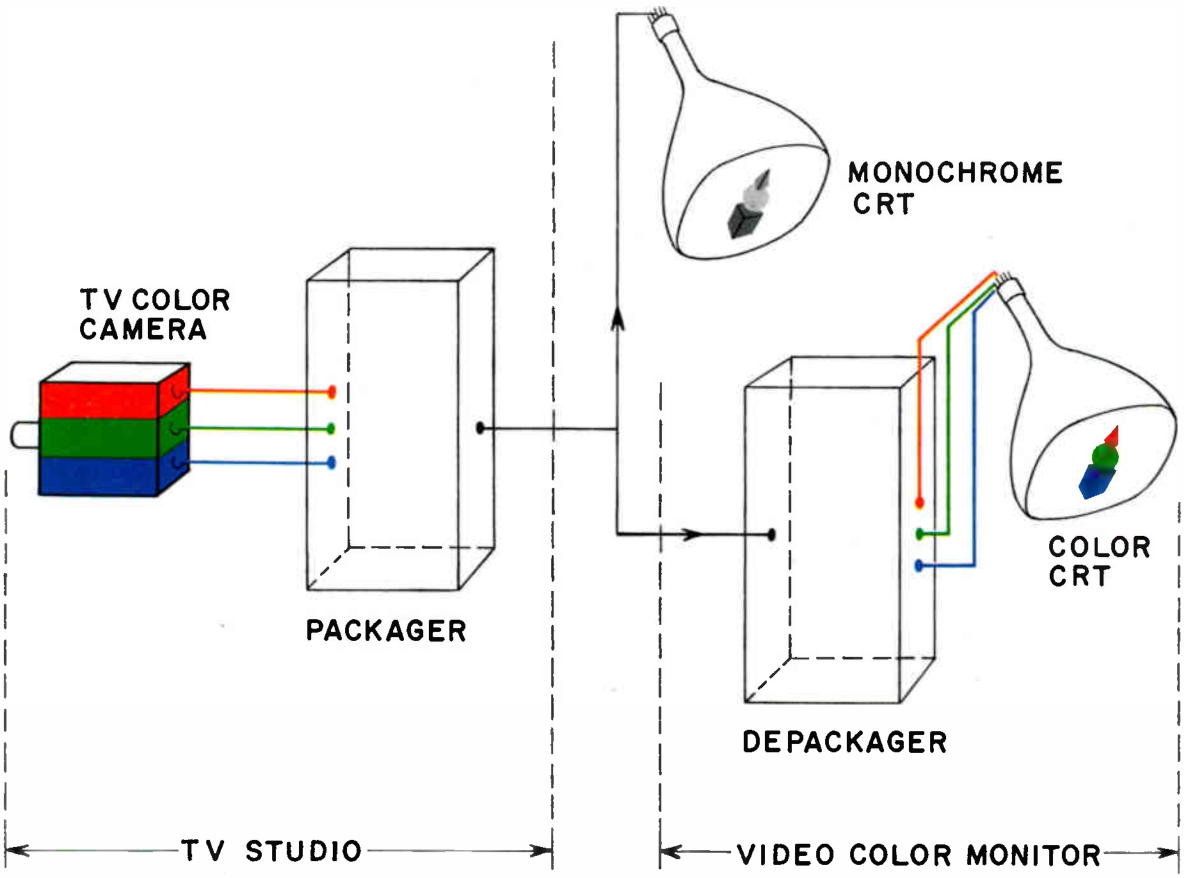


Figure 3-4. Composite color signal and compatible monochrome signal are developed from the primary color signals.

television camera entering a unit known as a "packager." Within this unit the three signals are intermixed in specified proportions to obtain the brightness signal, which, as stated, is basically the same as the present monochrome video signal. Simultaneously the unit produces two color-difference signals, which together with the brightness signal, comprise the composite color signal. In a manner to be described later, the color-difference signals are "interleaved" with the brightness signal for transmission over a single circuit. Interleaving the three signals does not affect the monochrome picture. After being "depackaged," the composite color signal can supply the color picture tube with the required red, green and blue primary signals to reproduce the colored image.

Transmission and Reception of the Composite Color Signal

Figure 3-5 illustrates the basic arrangement of components to produce the two color-difference signals and the brightness signal from the red, green and blue color signals which originate at the color television camera. These three signals combine to form the composite color signal which is transmitted to the color receiver. Figure 3-6 illustrates the basic arrangement of the components to change the composite color signal back to its original red, green and blue color signals. These color signals control their respective guns in the color picture tube, thereby reproducing the colored scene that is being televised. The r-f sections of the transmitter and the receiver are by-passed in this discussion since they are similar to their counterparts in a monochrome television system.

As illustrated by the positions of the potentiometer arms in figure 3-5, specific portions of each color signal are combined in adder A to produce the brightness signal, also referred to as the "Y" or luminance signal. This signal contains all frequency components from the camera outputs. Adder C receives the full output of red signal and adder B receives the full output of blue signal. Both of these adders

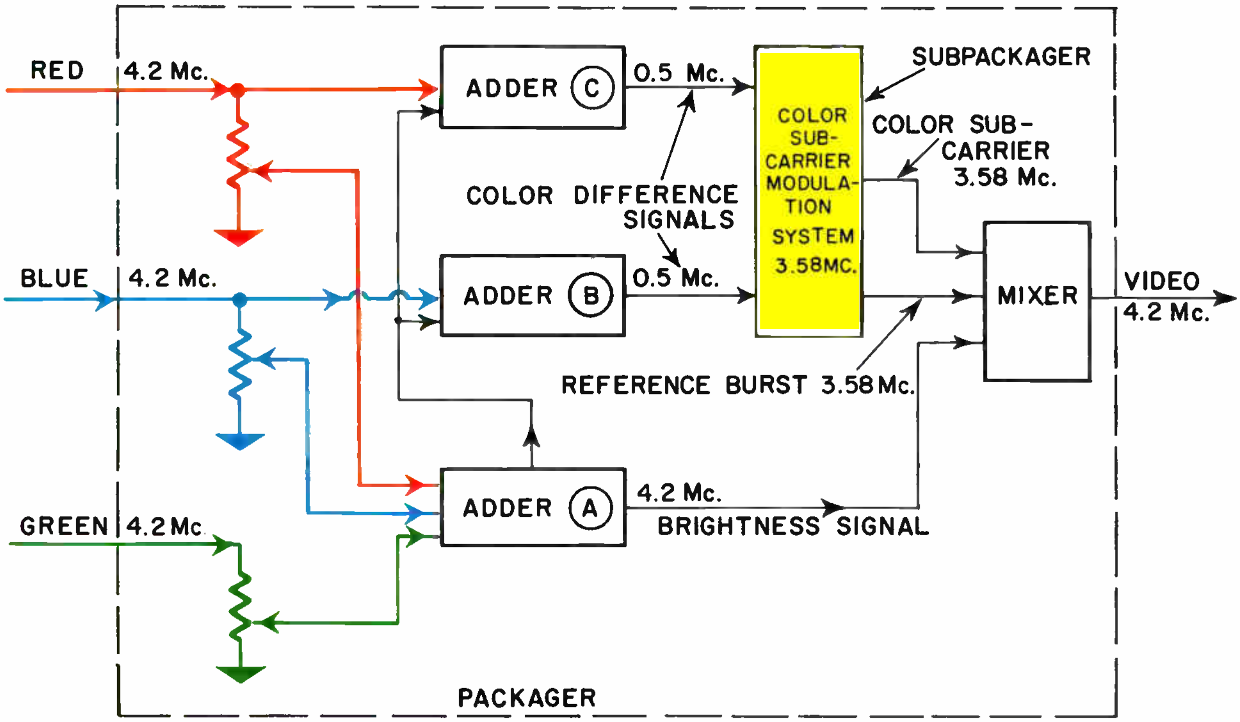


Figure 3-5. Transmission of the composite color signal.

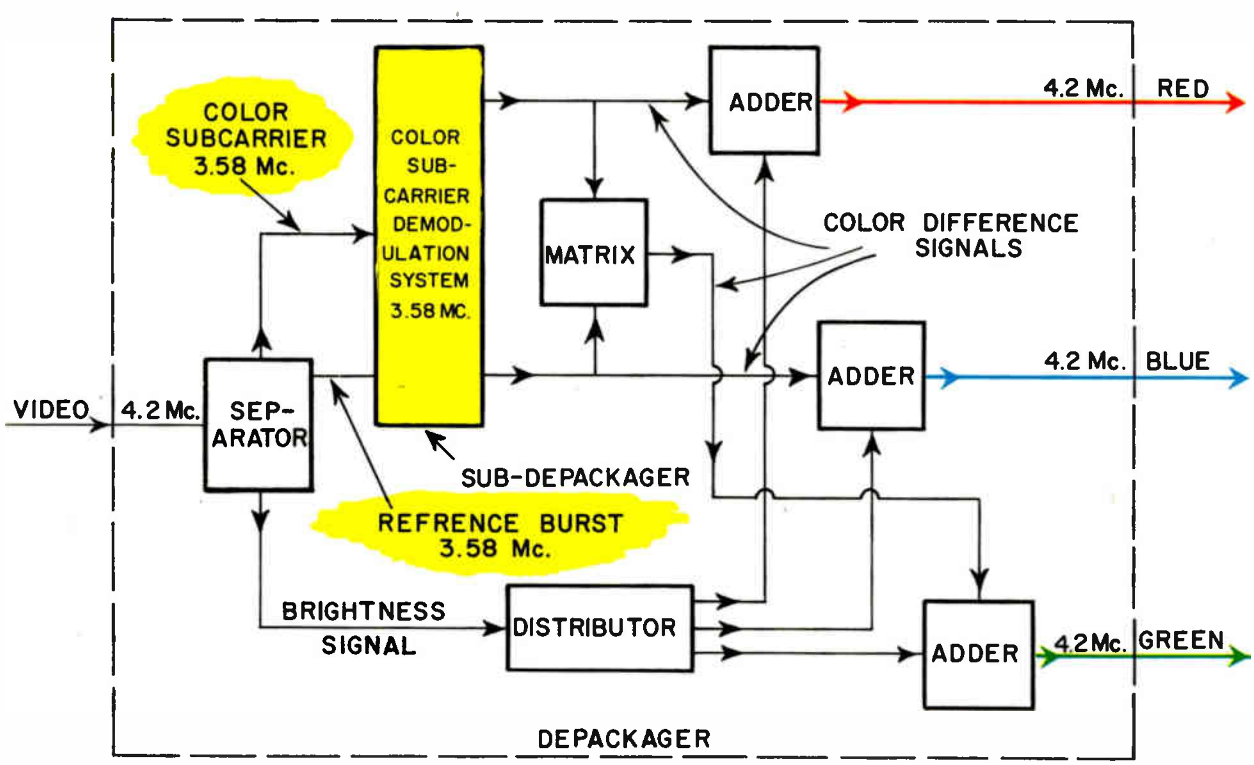


Figure 3-6. Reception of the composite color signal.

also receive a *negative* brightness voltage, –Y, from adder A. The signals within adder C are added together and form a color-difference signal, the R-Y signal. The signals within adder B also are added together and form another color-difference signal, the B-Y signal. The color-difference signals are applied to the color subcarrier modulation system where they modulate a 3.58-megacycle color subcarrier. This color subcarrier, containing the hue and saturation information, is interleaved with the brightness signal in the mixer. The output of the mixer, the composite color signal, is transmitted to the color receiver. A 3.58-megacycle reference burst, from the color subcarrier, also is applied to the mixer and transmitted to the color receiver. This, as will be explained later, is a phasing reference signal used in separating the color-difference signals in the receiver.

The composite color signal is received and after detection is applied to the separator shown in figure 3-6. The separator separates the brightness signal, the color-subcarrier signal, and the reference-burst signal. The brightness signal is fed to the distributor which applies the signal equally to the red, green and blue adders. The color-subcarrier signal is applied to the color-subcarrier demodulation system where the R-Y and B-Y color-difference signals are separated. A third color-difference signal, G-Y, carrying the green information is produced from R-Y and B-Y color-difference signals by combining them in the matrix unit.

Each of the three color-difference signals then is applied to an adder. In the adders, each color-difference signal is added to or subtracted from the brightness signal, depending on its polarity. The output of each adder is a color signal which is proportional to its corresponding signal from the color television camera. The color signals are applied to their respective guns of the color picture tube and control the tube in such a way as to reproduce the scene in color.

Adjusting for White Balance

One of the standards established for the color television system is the specific voltages that produce standard white. Therefore, the color television camera is adjusted to comply to this standard. The procedure is called "adjusting for white balance".

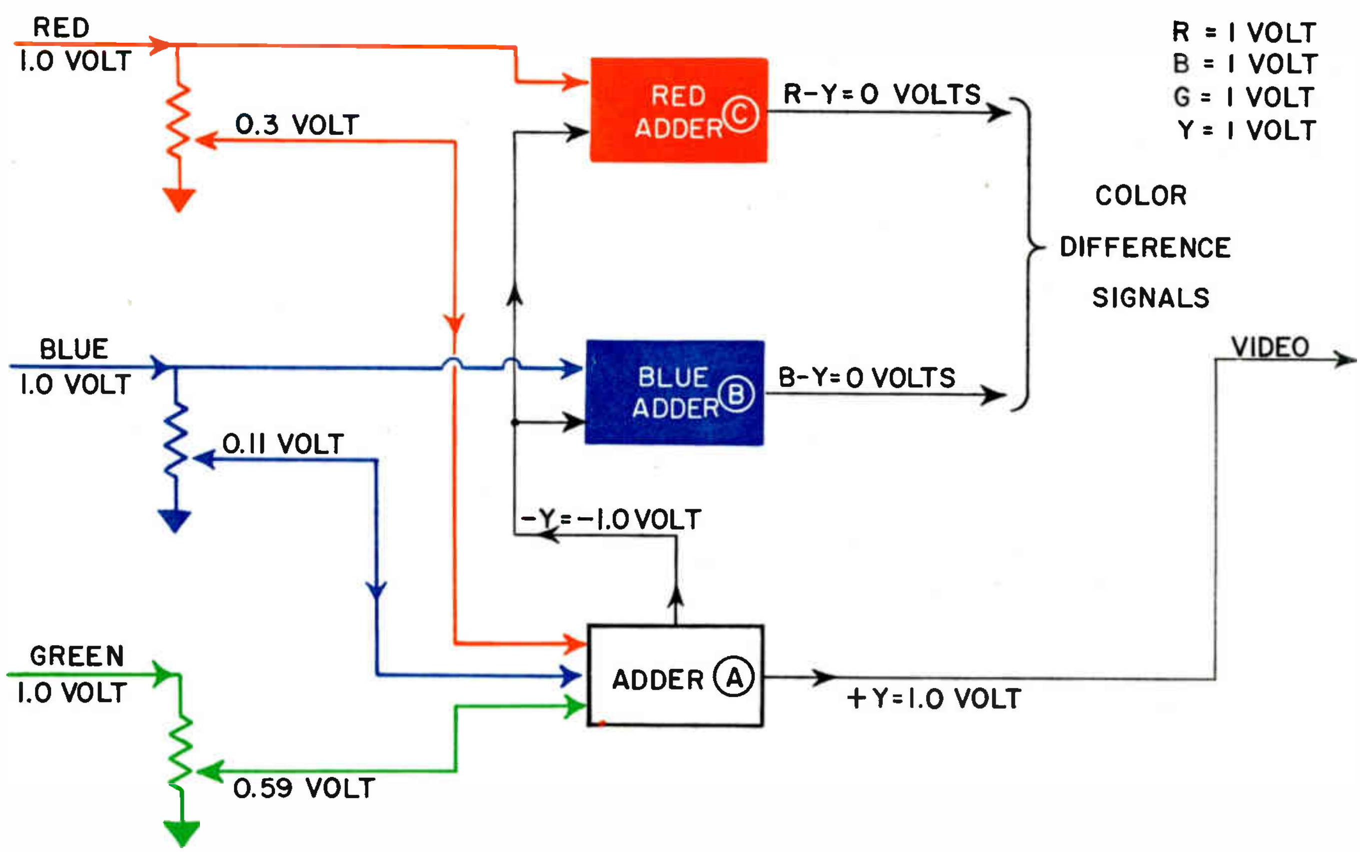


Figure 3-7. Televising a white object.

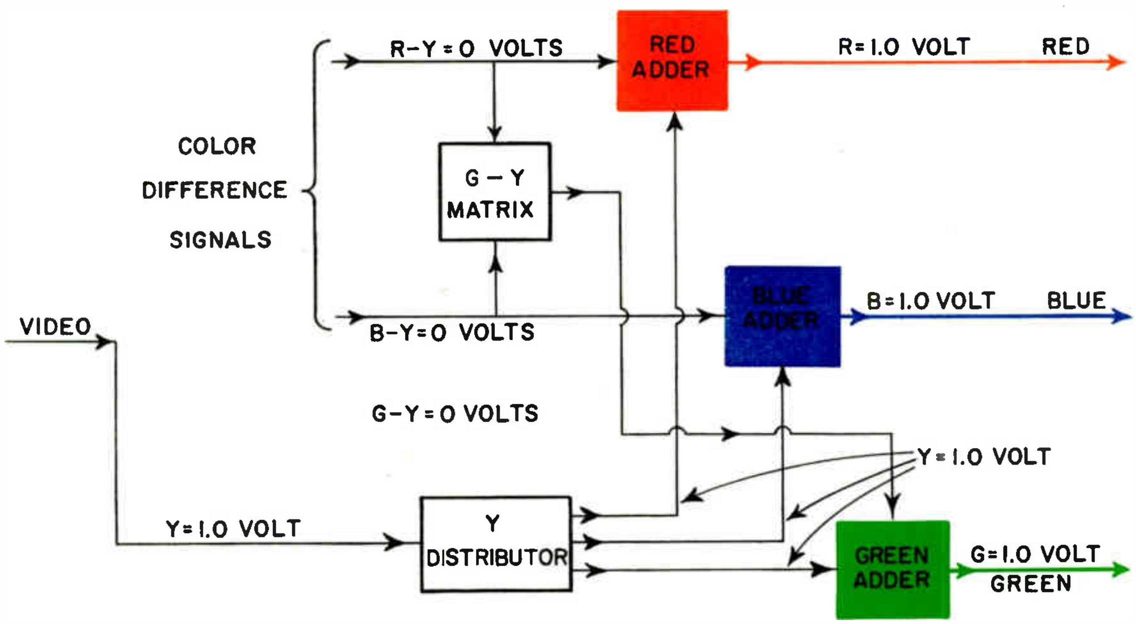


Figure 3-8. Reproduction of a white object.

In this procedure the camera first is adjusted for an output of one volt red signal, one volt green signal and one volt blue signal while the camera is viewing "standard white". The signal output circuits then are adjusted to provide 30% of the total red voltage, 59% of the total green voltage and 11% of the total blue voltage. To do this, as illustrated in figure 3-7, the arms of the potentiometers are adjusted to provide the proportionate amounts of signal voltage from the red, green and blue camera outputs. With the adjusting for white balance completed, the camera is ready to televise not only white, but any color used in the television system.

Televising and Reproducing a White Object

When a color television camera is televising a standard white object, the red, green and blue signals from the camera are each one volt. Since the arm of each potentiometer of figure 3-7 is adjusted to provide its proportionate amount of color signal voltage, 0.3 volt red, 0.11 volt blue and 0.59 volt green are applied to adder A. These three voltages add together and form the one volt of the brightness (Y) signal. A negative Y signal, developed in adder A, is applied to the blue and red adders respectively. The red adder adds the red signal and the negative Y signal and its output is the R-Y signal. The blue adder similarly adds the blue signal and the negative Y signal and its output is the B-Y signal. Since the negative Y signal is equal and of opposite polarity to the red and blue signals, there is a cancellation in both adders. Hence the R-Y and B-Y color-difference signals are both zero. Thus, white light does not produce a signal in either color-difference channel, since the negative Y voltage always cancels the red and blue camera signals.

When the camera televises a gray object, the color signals are equal to each other but of a lower value than the one volt indicated above. Lower voltages also appear at the arms of the potentiometers, but the relationship between the voltage on any arm and the total voltage across its potentiometer remains the same. So again there is no R-Y or B-Y output since the reduced negative Y signal is equal and of opposite polarity to the reduced red and blue camera signals.

As shown in figure 3-8, the one volt Y signal generated by the white televised object is received and applied to the Y distributor which furnishes a one volt Y signal to the red, green and blue adders. Since there were no R-Y or B-Y signals generated at the transmitter, there are no signals for the color-difference channels. Therefore, the G-Y signal is not developed within the matrix nor does the red or blue adder receive an R-Y or B-Y signal. Consequently, the one volt Y signal furnishes one volt red signal, one volt blue signal and one volt green signal. These signal voltages, being identical to those at the camera output for standard white, reproduce the white object on the picture tube.

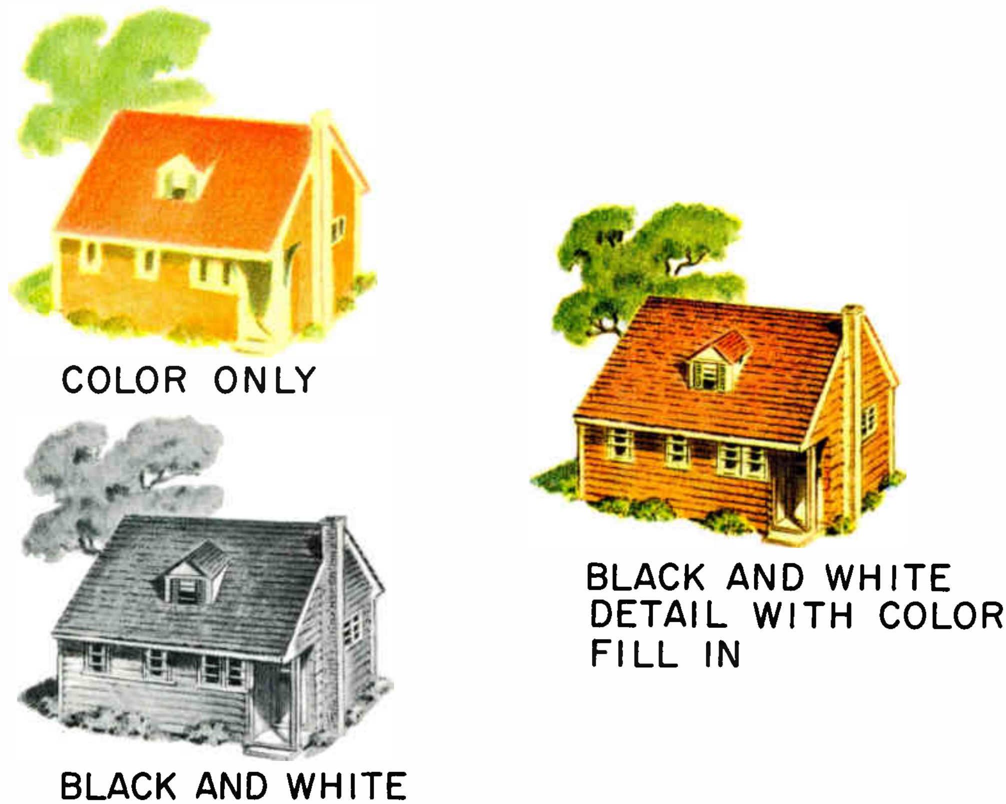


Figure 3-9. Construction of a high-detail color picture.

Televising and Reproducing a Saturated Color

In describing the transmission and reception of the signals corresponding to saturated colors, the derivation of the signal voltages for saturated blue is given. The formulas are applicable, however, to any televised color. The only difference is the signal values from the color television camera and the numerical values resulting from them.

Assuming that a saturated blue object is being televised, the color camera voltages are the following:

Red = 0 volts
Green = 0 volts
Blue = 1 volt

To produce the Y signal, 30% red, 59% green and 11% blue are combined in adder A. Hence,

$$Y = 0.3R + 0.59G + 0.11B$$

Substituting:

$$Y = (0.3)(0) + (0.59)(0) + (0.11)(1) = 0.11 \text{ volt}$$

The polarity of the Y signal is inverted and applied to the red and blue adders as a -0.11 volt signal. Since there is no red signal, the output of the red adder is

$$R\text{-}Y = 0 - 0.11 = -0.11 \text{ volt}$$

Since one volt is applied to the blue adder,

$$B\text{-}Y = 1 - 0.11 = 0.89 \text{ volt}$$

The three signal voltages to be transmitted are thus established, namely

Y signal = 0.11 volt
R-Y signal = -0.11 volt
B-Y signal = 0.89 volt

These three signal voltages are received and distributed in the color television receiver. The Y signal is applied to the Y distributor and from there is applied to the red, green and blue adders. The R-Y signal is applied to the red adder and the B-Y signal is applied to the blue adder. The R-Y and B-Y signals also are applied to the G-Y matrix.

The G-Y signal is developed in the G-Y matrix from the R-Y and B-Y signals and then fed to the green adder. The G-Y signal is

$$G\text{-}Y = -0.51\,(R\text{-}Y) - 0.19\,(B\text{-}Y).$$

This is derived as follows:

$$\begin{aligned} \text{Since } Y &= 0.3R + 0.59G + 0.11B, \\ -Y &= -0.3R - 0.59G - 0.11B \\ R\text{-}Y &= R - 0.3R - 0.59G - 0.11B \\ \text{or } R\text{-}Y &= 0.7R - 0.59G - 0.11B \\ B\text{-}Y &= B - 0.3R - 0.59G - 0.11B \\ \text{or } B\text{-}Y &= -0.3R - 0.59G + 0.89B \end{aligned}$$

Adding B-Y and R-Y,

$$\begin{aligned} R\text{-}Y &= 0.7R - 0.59G - 0.11B \\ B\text{-}Y &= -0.3R - 0.59G + 0.89B \\ \hline R+B-2Y &= 0.4R - 1.18G + 0.78B \end{aligned}$$

Finding G, by rearranging this last equation,

$$\begin{aligned} 1.18G &= 0.4R + 0.78B - R - B + 2Y \\ 1.18G &= -0.6R - 0.22B + 2Y \end{aligned}$$

Developing G-Y

$$1.18G - 1.18Y = -0.6R - 0.22B + 2Y - 1.18Y$$

Simplifying

$$\begin{aligned} 1.18(G\text{-}Y) &= -0.6R - 0.22B + 0.82Y \\ 1.18(G\text{-}Y) &= -0.6R - 0.22B + 0.6Y + 0.22Y \\ 1.18(G\text{-}Y) &= -0.6R + 0.6Y - 0.22B + 0.22Y \\ 1.18(G\text{-}Y) &= -0.6(R\text{-}Y) - 0.22(B\text{-}Y) \end{aligned}$$

Dividing

$$\frac{1.18(G\text{-}Y)}{1.18} = \frac{-0.6(R\text{-}Y) - 0.22(B\text{-}Y)}{1.18}$$

Then, finally

$G\text{-}Y = -0.51(R\text{-}Y) - 0.19(B\text{-}Y)$, as stated above. Substituting the R-Y and B-Y values for saturated blue, $G\text{-}Y = -(0.51)\,(-0.11) - (0.19)\,(0.89)$

$$\begin{aligned} G\text{-}Y &= 0.06 - 0.17 \\ G\text{-}Y &= -0.11 \text{ volt} \end{aligned}$$

In the red, green and blue adders, the red, green and blue signals respectively are derived as follows:

$$\begin{aligned} R &= R\text{-}Y + Y = -0.11 + 0.11 = 0 \text{ volts} \\ G &= G\text{-}Y + Y = -0.11 + 0.11 = 0 \text{ volts} \\ B &= B\text{-}Y + Y = 0.89 + 0.11 = 1 \text{ volt} \end{aligned}$$

These three signal voltages, when applied to their respective guns in the color picture tube, reproduce the saturated blue object being televised.

Bandwidths of the Color-Subcarrier and Brightness Signals

The brightness signal is transmitted within a bandwidth of approximately four megacycles while the color subcarrier as used in color receivers is transmitted within a bandwidth of approximately 0.5 megacycle. The bandwidth of the subcarrier is restricted to prevent interference with the sound and to improve reception of color signals on black and white sets. By combining the high-detail brightness signal with the low-detail color signal, a high detail color reproduction is obtained. Observe the black and white sketch of the house in figure 3-9. Notice the detail, the abrupt contrast changes from white to black, gray to black and gray to white. These abrupt changes produce the detail observed. The more abrupt the transition, the higher the frequency resulting. The same house, in color only, is shown in the same illustration. Some contrast exists between the orange sidewalls and red roof, but it does not provide much detail. By combining the low-detail color information and the high-detail brightness information, a high-detail color picture is produced as shown in figure 3-9. It is evident that additional color information is not necessary. In fact, if the color signal were transmitted with a bandwidth of four megacycles, more information than the eye could perceive would be reproduced on the picture tube. Thus, it is not necessary to reproduce color in fine detail since the human eye can not detect this detail, and it is necessary only to transmit enough color detail to satisfy the eye.

Summation of the Composite Color Signal

The brightness signal or Y signal varies from zero volts when scanning a black object to a maximum positive value when scanning a white object. The Y signal is generated by mixing 30% red, 59% green and 11% blue of the color camera output signals. Both the R-Y and B-Y signals are non-existent during the transmission of white, gray or black. The R-Y and B-Y signal voltages vary from a negative value through zero volts to a positive value dependent on the transmitted color. The numerical values of the R-Y and B-Y signals are identical for complementary colors, but their polarities are opposite. Complementary colors are the colors opposite each other on the color triangle; green and magenta are complementary to each other. The following table lists the voltages and polarities of the R-Y and B-Y color-difference signals when scanning a portion of a televised scene containing the tabulated hues and their complements.

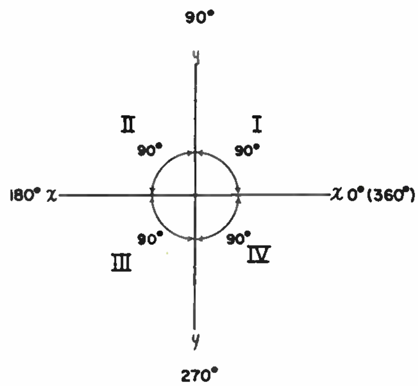


Figure 3-10. Vector co-ordinates.

HUE	COMPLEMENT	COLOR-DIFFERENCE SIGNALS	
		(R-Y)	(B-Y)
RED		+0.7	-0.3
	CYAN	-0.7	+0.3
BLUE		-0.11	+0.89
	YELLOW	+0.11	-0.89
GREEN		-0.59	-0.59
	MAGENTA	+0.59	+0.59

The G-Y signal is derived in the receiver from the R-Y and B-Y signals by satisfying the formula G-Y = -0.51 (R-Y) -0.19 (B-Y). One method of obtaining the G-Y signal is first, to change the polarity of the R-Y and B-Y signals, by feeding each signal through an inverter. Then, by voltage divider networks, obtain 51% of the minus (R-Y) signal and 19% of the minus (B-Y) signal. These two signals are added together to produce the desired G-Y color-difference signal. The latter operation, that of getting the proper percentages of the R-Y and B-Y signals and then combining them, is called matrixing.

SECTION 2.
REVIEW OF VECTORS

The Vector and Its Co-ordinates

A vector is a straight line with an arrowhead on one end. Its length and angle, relative to a reference line, represent respectively the amplitude and the relative phase of an alternating voltage at any instant.

Vectors are plotted on a set of co-ordinates as shown in figure 3-10. The x axis is the horizontal co-ordinate and the y axis is the vertical co-ordinate. The co-ordinates are perpendicular and form four 90° angles at their intersection. Each section is called a quadrant. The set of co-ordinates is completed by assigning angle references (degrees) as shown in the illustration. The quadrants are identified by Roman Numerals, thus, I quadrant is between 0° and 90°, II quadrant is between 90° and 180°, III quadrant is between 180° and 270° and IV quadrant is between 270° and 360° (0°).

Vectorial Presentation of a Sinewave

"Relative phase angle" describes a point on a sinewave, relative to the zero-degree reference point. The zero-degree reference point is that point where the sinewave passes through zero voltage on its positive-going portion of a cycle. Figure 3-11A is a sinewave plotted on a zero-voltage reference line. The degrees along this line indicate the relative phase

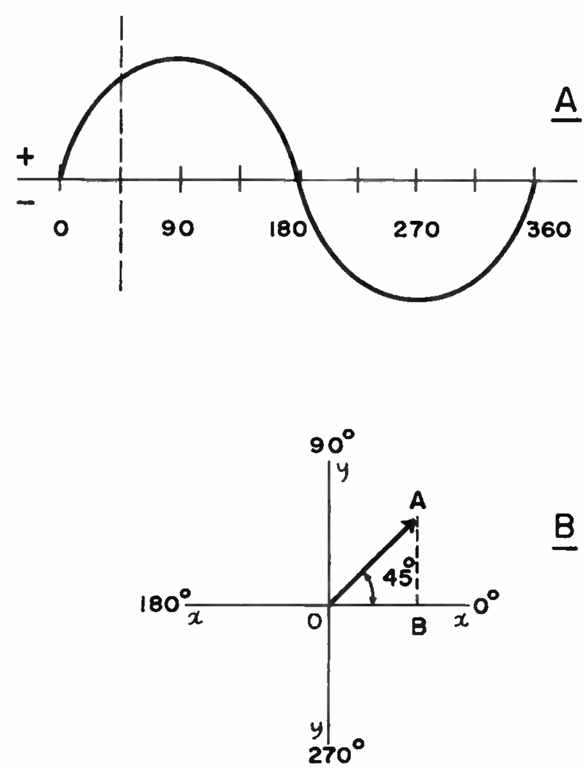


Figure 3-11. Vectorial and graphical illustration indicating a 45° relative phase angle.

angles of the sinewave. Thus, any point of a sinewave can be identified by a relative phase angle between 0° and 360°. The 360 degrees of the co-ordinates discussed previously correspond to the 360 degrees of a sinewave. Hence, the relative phase angle of a sinewave is represented by an angle formed between the 0° reference line of the x co-ordinate and a vector. Thus, the 45° relative phase angle of the sinewave of figure 3-11A (dashed line) is represented by the 45° angle in the vectorial diagram of the same illustration. The length of vector OA in figure 3-11B, to some convenient scale, represents the maximum voltage of the sinewave. The instantaneous voltage of a sinewave is the maximum voltage multiplied by the sine (trigonometric function) of its relative phase angle. Also, the opposite side of a right triangle is the hypotenuse (representing maximum voltage) multiplied by the sine of the angle corresponding to the relative phase angle. Therefore, the side opposite the relative phase angle represents the instantaneous voltage. Hence, a line (dashed line AB) drawn perpendicular to the x axis, from the arrowhead of vector OA to the x axis, represents the instantaneous voltage of the sinewave at the time that the relative phase angle is 45°.

It should be noted that the positive half of the sinewave has relative phase angles between 0° and 180° and the negative half of the sinewave has relative phase angles between 180° and 360°.

The illustrations of figure 3-10 and 3-11 show a complete set of co-ordinates with degree markings. However, the complete set of co-ordinates is not necessary and usually not shown. The only necessary portion of the co-ordinates is the reference line; the rest can be visualized.

Comparison of Two Sinewaves

Two sinewaves are illustrated in figure 3-12. Sinewave A has started and completed 45° of its cycle before sinewave B starts. Therefore, there is a phase difference between A and B of 45°. Since sinewave A started before sinewave B, sinewave A leads sinewave B or conversely, sinewave B lags sinewave A. Such waves are said to be "out-of-phase".

Time C of the two sinewaves is plotted vectorially in figure 3-12. The relative phase angle of sinewave A is 90°, hence it is plotted 90° from the 0° reference line or on the 90° axis. The relative phase angle of sinewave B is 45°, its vector is plotted 45° from the 0° reference line. The length of each vector, to some convenient scale, represents the maximum voltage of its associated sinewave. Since the sinewaves have

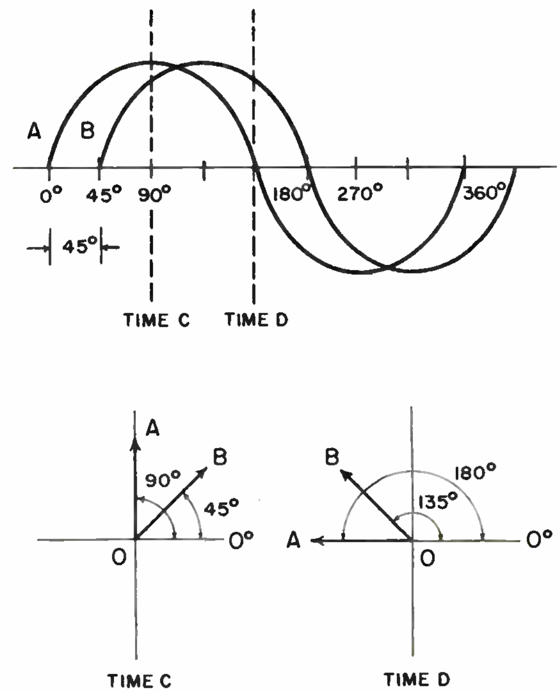


Figure 3-12. Comparison of two sinewaves of same frequency.

equal maximum amplitudes, the vectors are the same length. At time D, the relative phase angle for sinewave A is 180° and is plotted accordingly. The relative phase angle for sinewave B is 135° and plotted 135° from the 0° reference line. The angular phase difference between the two vectors remains at 45°, and sinewave A still leads sinewave B. In passing, it should be noted that the phase difference between two sinewaves of the same frequency (as in figure 3-12) remains constant while the phase difference between two sinewaves of different frequencies is constantly changing.

When two or more sinewaves go through their minimum and maximum peaks at the same time, the voltages are said to be "in-phase". Plotting vectors of in-phase voltages is the same as for out-of-phase voltages. The vectors simply occupy the same line on the vectorial diagram. If the amplitudes of the voltages are identical, the arrowheads are superimposed on one another, and a suitable notation indicating that two or more voltages are being represented should be included. If the voltages are of different amplitudes, the arrowheads indicate the number of voltages as well as their respective amplitudes.

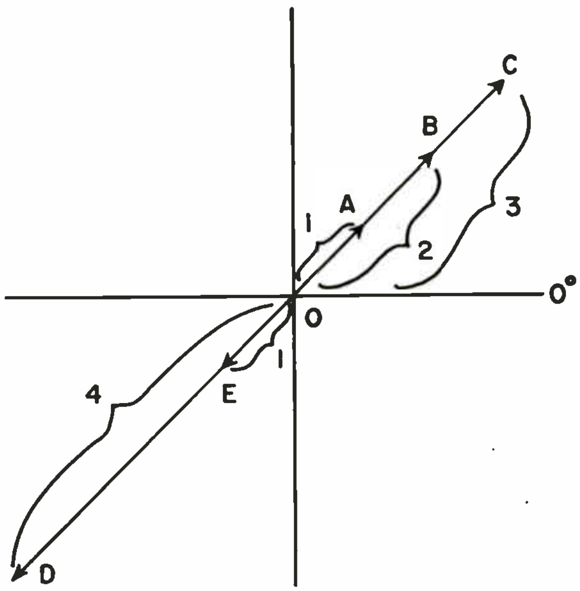


Figure 3-13. Addition of in-phase and 180° out-of-phase vectors.

Addition of Vectors

Vectors are added to determine a resultant voltage from two or more alternating voltages. For example, in radio or television transmission a radio-frequency carrier voltage is added with two sideband voltages to obtain the resultant modulation envelope. Many other resultant voltages are derived in the same manner.

Vectors that have phase angles of 0° or 180° are added arithmetically while all other vectors are added either by the parallelogram method, the resolution method, or the tail-to-arrowhead method, as described below. The resultant vector for two or more in-phase (0° phase angle) vectors is obtained by drawing a vector, at the same angle of the vectors being added, equal to the combined lengths of the vectors to be added. Thus, as shown in figure 3-13, the sum of vector OA, representing one volt, and vector OB, representing two volts, is vector OC, representing three volts.

If the vectors are 180° out-of-phase (180° phase angle), subtract the length of the shorter vector from the length of the longer vector. The result of this subtraction is the length of the resultant vector which is plotted at the same angle as the larger vector. Thus, as shown in figure 3-13, the difference between vector OC, representing three volts, and vector OD, representing four volts, is vector OE, representing one volt.

The parallelogram method of addition consists of constructing a parallelogram whose two adjacent sides are the vectors to be added. As a brief reminder, a parallelogram is a four-sided figure whose opposite sides are equal and parallel. Thus, a square and rectangle are two forms of parallelograms. The resultant vector is the line drawn from the intersection of the two vectors to the opposite corner of the parallelogram. In figure 3-14, vector OA is added to vector OB. The resultant vector is obtained by first forming the parallelogram. Construct line AC equal and parallel to vector OB. Construct line BC equal and parallel to vector OA, thus forming the parallelogram. The resultant vector then is constructed from O to C. If more than two vectors are added, add the resultant vector of the first two vectors to the third vector and then add that resultant vector to the fourth vector and so on until all vectors are added. The last resultant vector is the resultant of all the vectors.

The resolution method of vector addition first extracts the vertical and horizontal components of each vector. The vertical components and the horizontal components are individually added in the same manner as in-phase and out-of-phase vectors. The resultant horizontal component and the resultant vertical component are then added by the parallelogram method. As shown in figure 3-15, vectors OA and OB are being added by the resolution method. Two lines are drawn from the arrow-

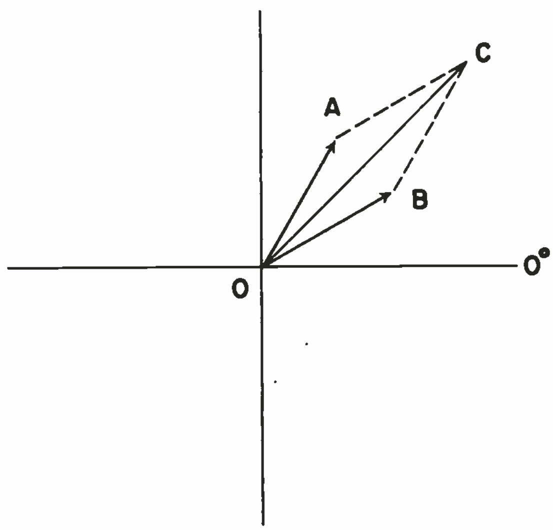


Figure 3-14. Addition by the parallelogram method.

head of vector OA, one perpendicular to the horizontal axis and the other perpendicular to the vertical axis. Thus OA_1 and OA_2 are respectively the vertical and horizontal components of vector OA. Similar lines are constructed from vector OB, thus establishing its components as OB_1 and OB_2. The vertical components, OB_1 and OA_1 are added. The resultant vertical component is OC_1. The horizontal components OA_2 and OB_2 are added. The resultant horizontal component is OC_2. By the parallelogram method, add the resultant horizontal and vertical components, OC_2 and OC_1 respectively, and obtain the resultant vector OC.

Before describing the tail-to-arrowhead method of addition, it is well to emphasize that a vector does not necessarily have to originate at the intersection of the co-ordinates. Further, a vector does not change in any respect if its length and direction relative to the other vectors remains unchanged. In the tail-to-arrowhead method, the vectors are repositioned so the tail of one touches the arrowhead of the other. The resultant vector is a line constructed from the tail of the first vector, at the intersection of the co-ordinates, to the arrowhead of the last vector. Figure 3-16A is two vectors arranged in the manner in which all vectors have been presented thus far. To add these vectors by the tail-to-arrowhead method, it is first necessary to rearrange them. As seen in figure 3-16B, retaining its same length and direction, vector OB is positioned so that its tail meets the arrowhead of vector OA. Therefore, vector OB of figure 3-16A is

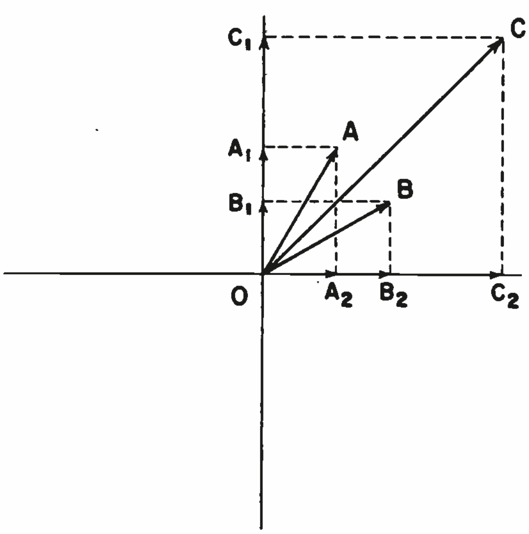


Figure 3-15. Addition by the resolution method.

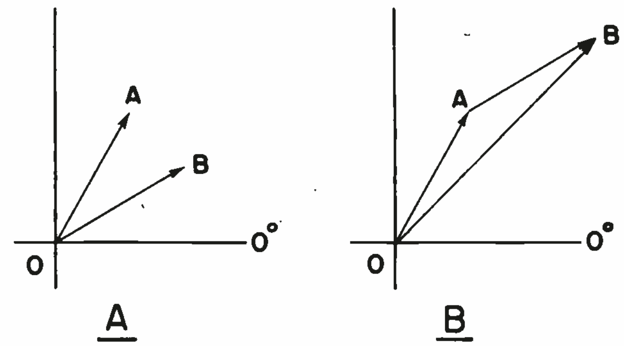


Figure 3-16. Addition by the tail-to-arrowhead method.

the same as vector AB of figure 3-16B. The result is obtained by constructing vector OB from the tail of vector OA to the arrowhead of vector AB.

It is well to understand that even though the vectors in the preceding discussion represent voltage, vectors are not restricted to the representation of voltages. Vectors also can represent current and everything stated about voltage with respect to vectors also could be applied to current. In other words, current could be substituted for voltage in the preceding text. Further, only two vectors were involved in each of the above examples of the addition of vectors. However, the number of vectors that can be added is not limited.

SECTION 3.
COLOR SUBCARRIER MODULATION SYSTEM

During the study of the transmission of the composite color signal, it was stated that the R-Y and B-Y color-difference signals modulated a 3.58-mc color subcarrier. This method of simultaneously transmitting two independent color-difference signals is explained in the following paragraphs. However, before proceeding with this modulation system, a brief review of conventional amplitude modulation is presented to provide easier understanding of the color subcarrier.

Review of Amplitude Modulation

Amplitude modulation produces three voltages in the output circuit of a transmitter. These voltages

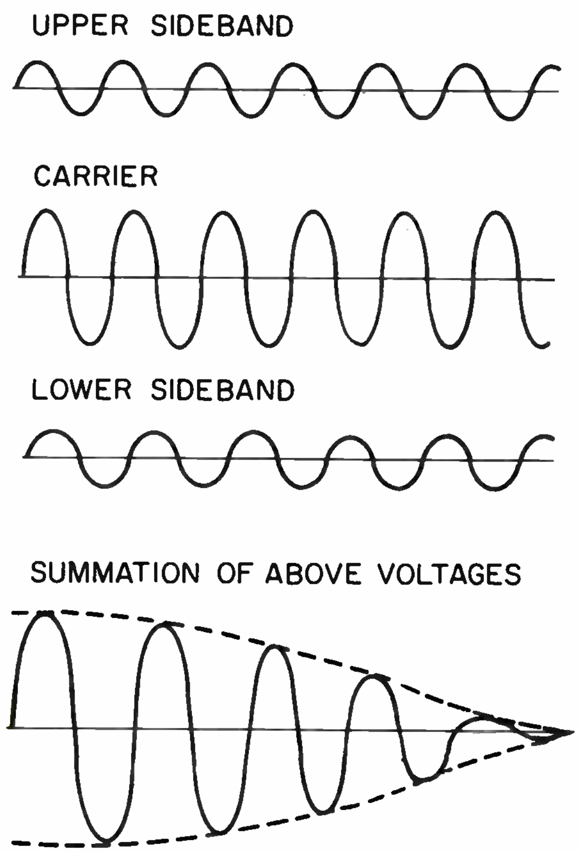


Figure 3-17. The amplitude modulated signal.

are the carrier, the upper sideband and the lower sideband. They are transmitted as three distinct voltages even though, when observed or measured by some measuring device, the device reacts to the summation of the three voltages, since the voltages simultaneously actuate the measuring device. If this same a-m signal were presented to an oscilloscope, the effect of the three simultaneous voltages causes the electron beam of the cathode-ray tube to react to the instantaneous sum of the three voltages. The carrier, upper sideband and lower sideband voltages could be observed if a receiver, with extremely high Q tuning circuits, were tuned in turn to the frequency of each voltage, and an oscilloscope, connected before the detector, were used as the viewing instrument. The oscilloscope would present a constant-amplitude, r-f voltage for each signal. If three such arrangements were provided, one receiver tuned to each signal and an oscilloscope, to present the voltage of each received signal, the waveform of the carrier, upper sideband and lower sideband would be displayed on its respective oscilloscope.

Assuming the a-m signal is a 100-kc carrier and is being modulated 100% by a 10-kc audio note, the three waveforms would be as shown in figure 3-17. The amplitude of each sideband is one-half that of the carrier. This indicates the carrier is modulated 100%. The frequency of the upper sideband is the carrier frequency (100-kc) plus the modulating frequency (10-kc) or 110-kc. The frequency of the lower sideband is the carrier frequency (100-kc) minus the modulating frequency (10-kc) or 90-kc. Therefore, the frequency difference between the carrier, and the upper sideband is the same as the frequency difference between the carrier and the lower sideband and this frequency difference is equal to the modulating frequency. If these three signals are viewed either at the transmitter or prior to detection in an appropriate receiver (one that has sufficient bandwidth to accept the carrier and its sidebands), the waveform presented is the summation of the three signals as shown in figure 3-17. The summation waveform is the conventional manner in which an a-m signal usually is presented. The dotted line across the peaks of the summation waveform represents the modulating signal. It is called the "modulation envelope".

Figure 3-18 illustrates the same three voltages being received by a receiver. The voltages independently pass through the r-f system of the receiver at the frequencies indicated by the vertical lines drawn through the receiver r-f response curve. As illustrated, just prior to detection, the modulated signal still is three independent sinewave signals. These three voltages, when applied to the detector, add vectorially. The resultant voltage from the detection is the original 10-kc audio signal.

The three voltages again are illustrated in figure 3-19. They are drawn to scale over a period of one-half cycle of the modulating frequency. The positive carrier peaks are selected for the vector addition since the phase angles between the carrier and each of its sidebands, when the carrier is at a relative phase angle of 90°, are of interest. The detector rectifies the three signals, thereby eliminating the lower (negative) half of each signal and it simultaneously adds vectorially the positive (upper) portions of the r-f signals. The output capacitor and load resistor of the detector provide a relatively long time constant. The output capacitor charges to the peak value of each positive portion of the resultant voltage, but, due to the time constant, discharges very little voltage before the next positive portion recharges it. Thus, the output voltage from the detector is a d-c voltage varying in amplitude in accordance with the original modulating signal.

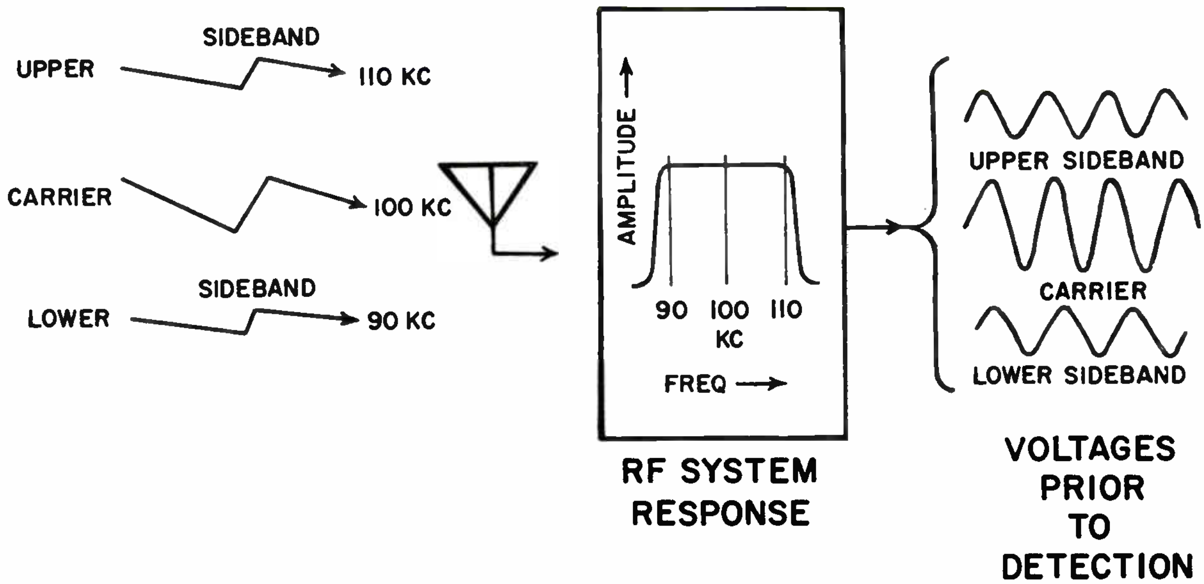


Figure 3-18. Reception of an amplitude modulated signal.

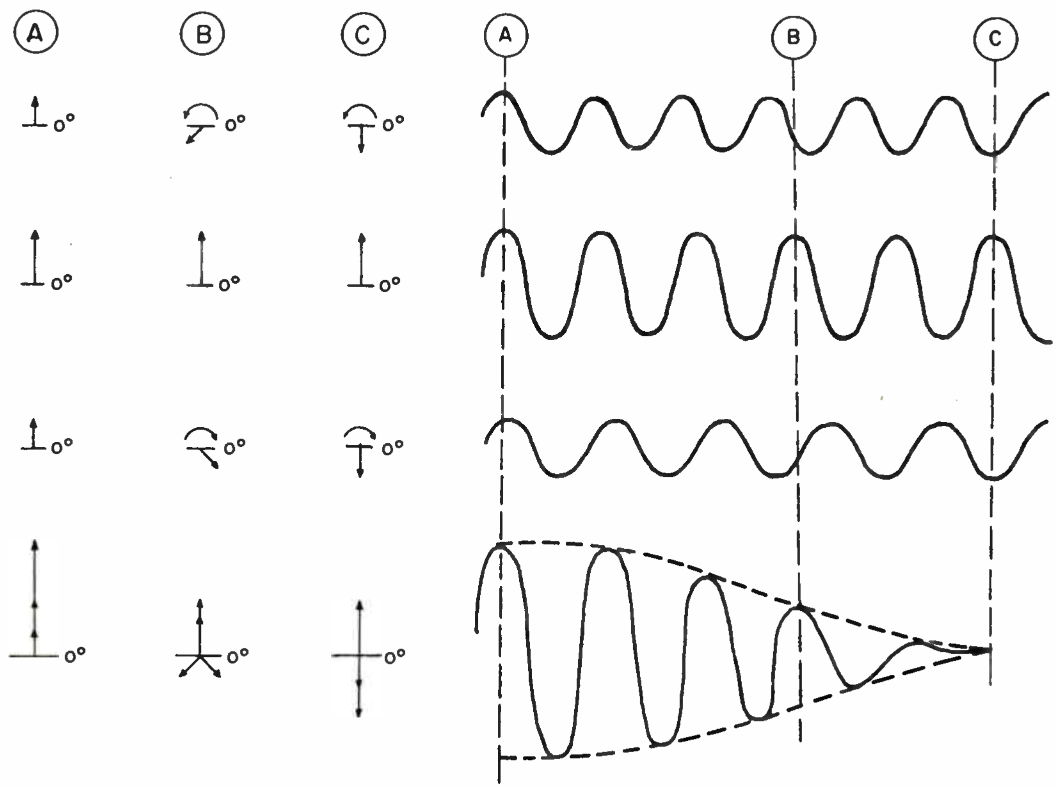


Figure 3-19. Forming the modulation envelope from the carrier, the upper sideband and the lower sideband.

The vectorial addition of the carrier and both sidebands is represented in figure 3-19. Each set of vectors on the left-hand side of figure 3-19 represents the voltages and phase relationships of the carrier and its sidebands at the indicated time. Hence, vectors under A, B and C respectively represent times A, B and C in the illustration. The vectors are illustrated as shown rather than in the conventional form for two reasons: The vectors are plotted adjacent to their respective waveforms to enable the reader to associate each vector with its waveform more rapidly, and also to avoid possible confusion since the upper sideband vector would be superimposed on the lower sideband vector at times A and C.

Since the sideband voltages are being compared with the positive peak of the carrier voltage, time A is selected to occur at a relative phase angle of 90° on the carrier voltage. Observing time A, it is noted that the upper sideband is at a relative phase angle of 90° and the lower sideband also is at a relative phase angle of 90°. The sideband vectors therefore are plotted accordingly. The vectorial diagram at the bottom of the A column represents the addition of the carrier and both sidebands at time A. This instantaneous resultant voltage for time A determines the amplitude of the first positive portion of the modulation envelope in the lower right-hand section of figure 3-19.

Times B and C similarly are selected to occur at a relative phase angle of 90° on the carrier voltage. A vector, representing the relative phase angle and the peak amplitude of each voltage at each indicated time, is plotted for times B and C in the same manner as the vectors at time A. The addition of the voltage at times B and C is respectively represented by the vectorial diagrams at the bottom of the B and C columns. These instantaneous resultant voltages, one for time B and one for time C, determine the amplitude of the positive portions of the modulation envelope at times B and C respectively. If a point, representing the instantaneous resultant voltages, were plotted for each time the carrier voltage is at a relative phase angle of 90°, the amplitude of each positive portion of the modulation envelope could be determined. A smooth line drawn through these plotted points represents the output voltage of the detector. In other words, it is the addition of the carrier and its two sidebands at the time the carrier is at a relative phase angle of 90° that reproduces the modulating frequency.

Since the output of the detector is obtained by vectorially adding the carrier and both sidebands each time the carrier is at a relative phase angle of 90°, when plotting the output voltage of a detector from the carrier and its sidebands it is necessary only to plot the instantaneous voltages each time the carrier is at a relative phase angle of 90° and then draw a smooth line through these points. The output voltage of the carrier and its sidebands in figure 3-19 is represented by the dashed line across the positive peaks of the modulation envelope.

Examination of the vectorial diagrams used during the addition of the three voltages reveals that the phase angles between the carrier and each of its sidebands are always equal, but one sideband leads the carrier while the other sideband lags the carrier. These phase angles are equal as stated above, because the frequency differences between the carrier and each of its sidebands are equal. The phase angles between the carrier and each of its sidebands, although equal to each other, are constantly changing with time. Their rate of change is proportional to the frequency difference which is caused by, and equal to, the modulating frequency. Since the phase angles are of interest only when the carrier is a relative phase angle of 90°, the carrier frequency can be considered a reference and is represented on the vectorial diagrams as a fixed amplitude at 90°. However, the vectors representing the sidebands can be visualized as rotating in opposite directions around the carrier vector at a rate, in revolutions per second, equal to the modulating frequency. Therefore, it is the rate of change of the phase angles between the carrier and its sidebands that produces the detected audio frequency. It then can be concluded that the sidebands are the conveyors of the transmitted intelligence and the carrier voltage is merely a fixed-amplitude reference voltage, of secondary importance. Since the carrier only is a reference signal, a suppressed-carrier modulation system can be used successfully. In a suppressed-carrier modulation system, detection is accomplished by generating a carrier in the receiver and mixing the locally-generated carrier with the received sidebands prior to detection. The same result then is obtained as if the incoming signal included the carrier voltage.

Suppressed-Carrier Modulation System

A suppressed-carrier modulation system transmits only the two sidebands; the carrier is suppressed prior to transmission. Generating the sidebands of a suppressed-carrier modulation system can be accomplished in numerous ways. The simplified circuit of figure 3-20 is suitable for explanation.

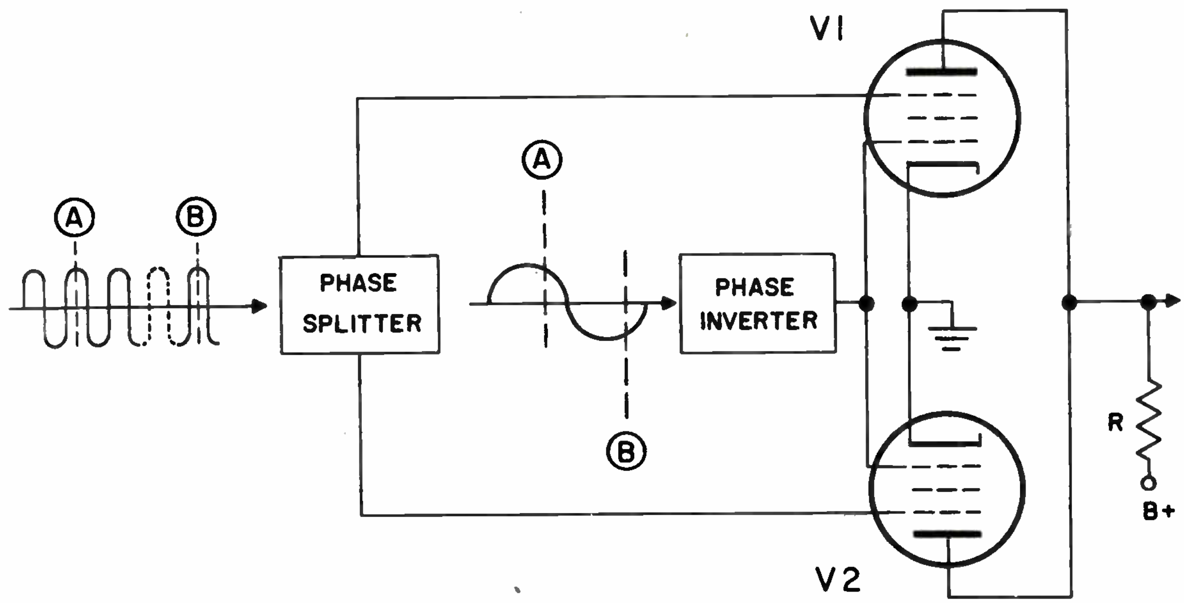


Figure 3-20. Suppressed-carrier modulation system.

The carrier voltage is applied through a phase splitter which simultaneously provides two signals of opposite polarity. One signal is applied to the suppressor grid of V1 while the other signal is applied to the suppressor grid of V2. Since these voltages are equal but of opposite polarity, the signals on the modulator plates also are equal but of opposite polarity. Considering the modulators one at a time, assume a negative voltage is applied on the suppressor grid of V1. This causes V1 to conduct less current. With less current passing through the tube, and hence through the common plate load resistor R, there is less voltage drop across resistor R. At the same time, a positive voltage is applied to the suppressor grid of V2. This signal causes greater conduction in V2 and a larger voltage drop across resistor R. Since the currents of both tubes flow through resistor R and one tube conducts more to the same degree that the other tube conducts less, the net result is no change in the voltage drop across resistor R, hence no signal output.

The circuit now will be analyzed with a modulating voltage applied. The voltage relations in the circuit are compared at two times. The first time occurs when the modulating voltage, in a positive polarity, is applied to the phase inverter and the carrier voltage is applied to the phase splitter at a relative phase angle of 90°. This time is indicated as time A in figure 3-20. The modulating voltage is inverted by the phase inverter to compensate for the 180° phase reversal of tubes V1 and V2. Thus, the positive portion of the modulating voltage is applied to the control grid of tube V1 in a negative polarity. Assuming a gain of unity, the amplitude of the carrier voltage at the plate of tube V1 is equal to the original carrier voltage. Two sideband frequencies also appear at the plate of tube V1. These are the sum and difference frequencies of the modulating and carrier frequencies. These sideband frequencies have the same characteristics as their counterparts in the conventional a-m signal explained previously. The amplitude of each sideband is then one-half the amplitude of the carrier at 100% modulation and one sideband leads the carrier while the other sideband lags the carrier.

The peak amplitudes of the sidebands and carrier on the plate of tube V1 are represented vectorially in the upper portion of diagram A of figure 3-21. Vector OA represents the carrier and vectors AB and AC represent the sidebands. The vectors are plotted from the arrowhead of the carrier vector since it is the relative phase angles of the sidebands which are of interest at the time when the carrier is at its positive peak (relative phase angle of 90°). Further, this type of presentation presents a more realistic

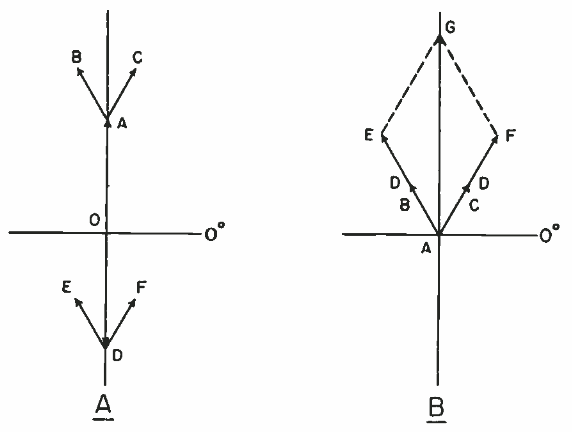


Figure 3-21. Voltage relationship of the suppressed-carrier modulation system at time A.

view of the sidebands rotating at identical rates and in opposite directions from the carrier with time. As explained in the review of vectors, if a vector retains its relative angle and length, it can be repositioned to portray the desired effect without changing the value of the vector. The carrier frequency on the plate of tube V2 is 180° out-of-phase with the carrier frequency on the plate of tube V1. Thus, the carrier vector is plotted at a relative phase angle of 270° as indicated vectorially in diagram A of figure 3-21. The carrier voltage at the plate of tube V2 is equal in amplitude but opposite in polarity to the carrier voltage at the plate of tube V1. Therefore, the carrier voltages cancel. The amplitude and phase of the sidebands on the plate of tube V2 are equal to the amplitude and phase of the sidebands on the plate of tube V1 since both sets of sidebands are generated from the same sources. Hence, vectors AC and DF are in-phase and vectors AB and DE are in-phase. The sideband vectors are rearranged in diagram B of figure 3-21. The only difference between diagrams A and B is that the carrier vectors are eliminated since they are equal in amplitude and of opposite polarity and the sideband vectors are repositioned to facilitate their addition. The resultant of these sideband voltages is vector AG which represents the voltage across resistor R. This resultant voltage across resistor R is the instantaneous voltage developed at time A.

After time A, the modulating voltage, as shown in figure 3-20, goes through its zero voltage and its negative peak and finally reaches a point 180° from the previous point. This point, at time B, is now analyzed. During the same time interval, from time A to time B, the carrier voltage, which is assumed as being ten times greater in frequency than the modulating voltage, has completed five cycles. Hence, time B on the carrier frequency is at the fifth positive peak after time A. To conserve space the dotted portion of the carrier waveform represents several complete cycles.

Vectorial diagram C of figure 3-22 represents the plate voltages at time B. The carrier vectors OA and OD are drawn the same as in the previous diagrams since the carrier at time B is at a positive peak or at a relative phase angle of 90°, as it was at time A. However, the direction of the upper and lower side-band vectors have changed 180°. The amplitudes of the sideband vectors and carrier vectors are identical to those of the corresponding vectors in the previous diagram since the amplitudes of the carrier and modulating voltages remained the same. Vectorial diagram D of figure 3-22 is the same as diagram C, except, as before, the carrier vectors are eliminated and the sideband vectors are repositioned to facilitate the addition. The resultant voltage, vector AG, is the instantaneous voltage that is developed across resistor R at time B.

Suppressed-Carrier Modulation System with Delayed Carrier

The delayed carrier system is similar to the suppressed-carrier modulation system just described, except that the carrier frequency is delayed 90 carrier degrees before it is applied to the phase splitter. The two systems are combined to fulfill the requirements for the color-subcarrier modulation system.

The circuit (figure 3-23) used for the analysis is the same as figure 3-20 except it includes a 90° delay circuit. The phase angles between the carrier and its sidebands, when the carrier is at a relative phase angle of 90°, determine the instantaneous voltages of the modulation envelope. Hence, time A is the time when the maximum positive voltage, indicated by A in figure 3-23, is applied to the 90° delay circuit. The delay circuit artificially detours the signal so that the signal reaches the output of the delay circuit a definite number of microseconds after it was applied to the input of the delay circuit. In the 90° delay circuit, the time delay is equal to the time required for the carrier voltage to complete ¼ of its cycle. At the time the positive peak of the carrier is applied to the delay circuit, its value at a relative phase angle of 0° is leaving the delay circuit since it was this point that was applied 90° earlier. Therefore, the carrier is at a relative phase angle of 0° at the output of the 90° delay circuit at time A.

The delayed carrier voltage is applied to the phase splitter which simultaneously provides two signals 180° out-of-phase with each other. One signal is applied to the suppressor grid of tube VI while the other signal is applied to the suppressor grid of tube V2. The modulating voltage, in the positive portion of its cycle, is applied to the phase inverter. The output of the phase inverter is applied to the parallel-connected control grids of tubes V1 and V2. Again, as before, the final point of interest in the system is the resultant voltage that appears across resistor R. Vector diagram A of figure 3-24 illustrates the relationship of the carrier and its sideband voltages on the plates of tubes V1 and V2 at time A. Note, the carrier vectors have rotated 90° but are still 180° out-of-phase; hence, they cancel. Sideband vectors AB and DE are in-phase. Sideband vectors AC and DF also are in-phase. The sideband vectors are rearranged in diagram B of figure 3-24. The resultant vector, vector AG, represents the instantaneous voltage that appears across resistor R of figure 3-23 at time A.

At time B in figure 3-23, the modulation voltage is in the negative portion of its cycle and the carrier again is at a positive peak. Diagram C of figure 3-25 represents the relationship of the sidebands and their carriers at the plates of tubes V1 and V2. As noted, the carrier vectors are 180° out-of-phase and the sideband vectors are opposite to the conditions found during the positive portion of the modulating voltage (shifted 180° in-phase). Since the carrier vectors

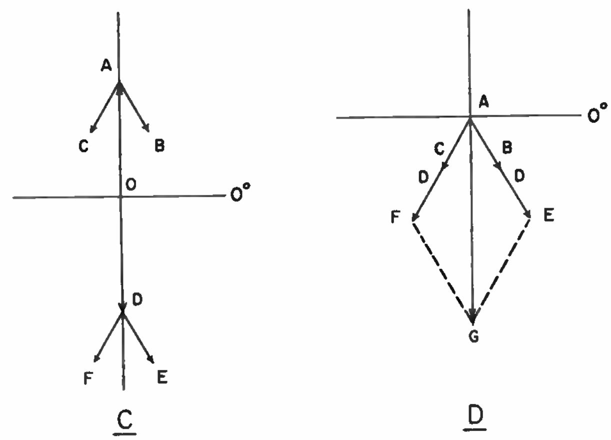


Figure 3-22. Voltage relationship of the suppressed-carrier modulation system at time B.

are of opposite phase, they cancel leaving only the sidebands as shown in diagram D of figure 3-25. The vectorial sum of the sidebands is found in the same manner previously explained. The resultant vector, vector AG, represents the instantaneous voltage that appears across resistor R of figure 3-23 at time B.

It should be noted that the resultant vector falls in a negative direction when the modulating voltage is negative and falls in a positive direction when the modulation voltage is positive. Even though the carrier has been delayed 90°, the statement still holds true that positive modulation results in a positive modulation envelope and negative modulation produces a negative modulation envelope.

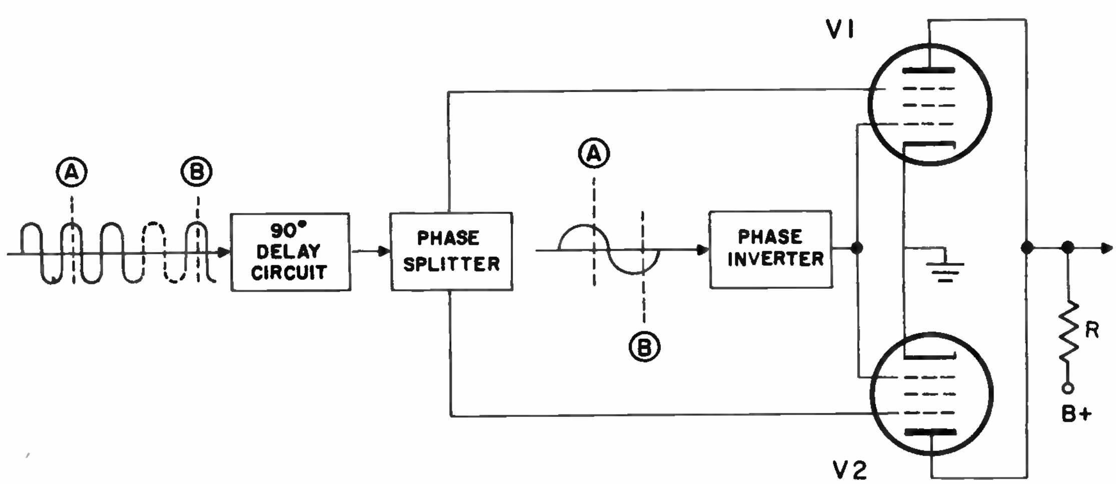


Figure 3-23. Suppressed-carrier modulation system with delayed carrier.

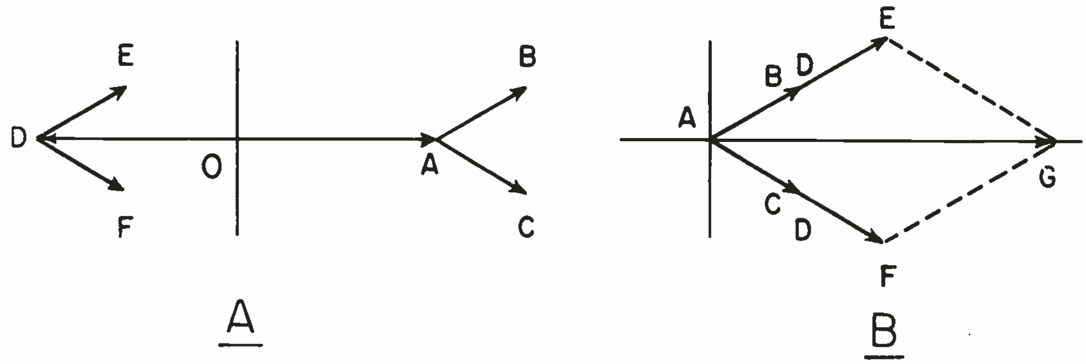


Figure 3-24. Voltage relationship of the suppressed-carrier modulation system with delayed carrier at time A.

In summation, in the suppressed-carrier modulation systems, the vectorial sum of the sidebands when the carrier is at its positive peak produces the resultant voltage of the modulation envelope. Unlike amplitude modulation, the modulation envelope is an a-c voltage varying from a positive value, through zero to a negative value. Its instantaneous value is dependent on the phase angles between each sideband and the carrier's positive peak voltage.

Combining the Two Modulating Systems

Thus far, two modulating systems have been discussed. When these two systems are combined, two signals are transmitted simultaneously by the same carrier frequency. By paralleling the outputs of the two modulating systems, the resultant voltage from each modulating system combines vectorially and forms a new resultant voltage that is related to both the phase and amplitude of the resultant voltage from each modulating system. Hence, the resultant voltage from the combined systems is both phase and amplitude modulated.

Figure 3-26 illustrates the two systems combined. Signals A and B are such to produce output voltages represented by vectors A and B respectively. Therefore, the resultant voltage from the combined systems represents the phase and amplitude of the subcarrier. As was illustrated with the individual modulating systems, it is possible for either the A or B vectors to be positive or negative. Thus, many combinations of amplitude and polarity of the A and B vectors produce a multitude of resultant vectors for the subcarrier.

As an example, assume vector A to be positive and vector B to be negative, the resultant vector then would be in the second quadrant. If vector A were negative and vector B positive, the resultant vector would be in the fourth quadrant. Thus, by changing polarity of the A and B vectors, the resultant vector can be positioned to any of the four quadrants.

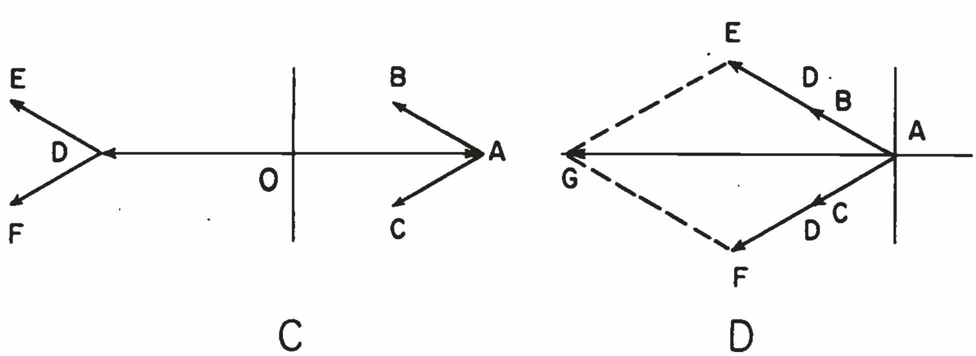


Figure 3-25. Voltage relationship of the suppressed-carrier modulation system with delayed carrier at time B.

In the illustration the lengths of vectors A and B are equal; only their polarities are changed. In the vectorial diagrams of figure 3-27, the lengths of vectors A and B are unequal. Note how the resultant vector shifts from an almost vertical position in diagram 1, through intermediate positions in diagrams 2 and 3, to an almost horizontal position in diagram 4. Thus, changing the lengths of the A and B vectors while both are positive, moves the resultant vector through the full 90° of the first quadrant. Therefore, by changing lengths and polarities of the A and B vectors, the resultant vector can be positioned to any angle and amplitude. Conversely, for each relative phase angle and length of the resultant vector there is only one combination of polarities and lengths of the A and B vectors.

Recall that the three primary-color signals from the color television camera are transformed into the R-Y and B-Y color-difference signals. Each of these color-difference signals varies from a positive value, through zero, to a negative value. Their values are dependent on the hue and saturation of the color being televised. It has been explained that the R-Y and B-Y signals can be plotted on a set of co-ordinates within the color triangle and, when these signals were added vectorially, the resultant vector determined the hue and saturation of a color. The direction of the vector determines the hue and the vector length determines the saturation. The vector within the color triangle is positioned by varying the values of the R-Y and B-Y color-difference signals.

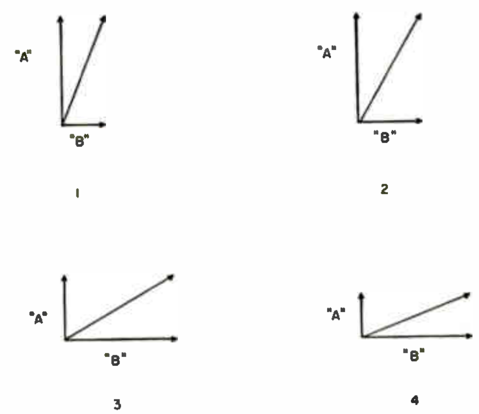


Figure 3-27. Positioning resultant vector in first quadrant.

It is identical to the resultant voltage vector of the color-subcarrier modulation system since the same signals comprise the resultant vector in both cases.

In summation, it has been shown how two individual modulating voltages each modulates a suppressed carrier. The suppressed carrier of one modulating signal is delayed or shifted in phase 90 carrier degrees from the suppressed carrier of the other modulating signal. When the modulating envelopes from the individual modulating systems are combined, a new subcarrier modulation envelope results which has a direct relation to the phase and amplitude of the individual modulation envelopes. As the phase and amplitude of the individual modula-

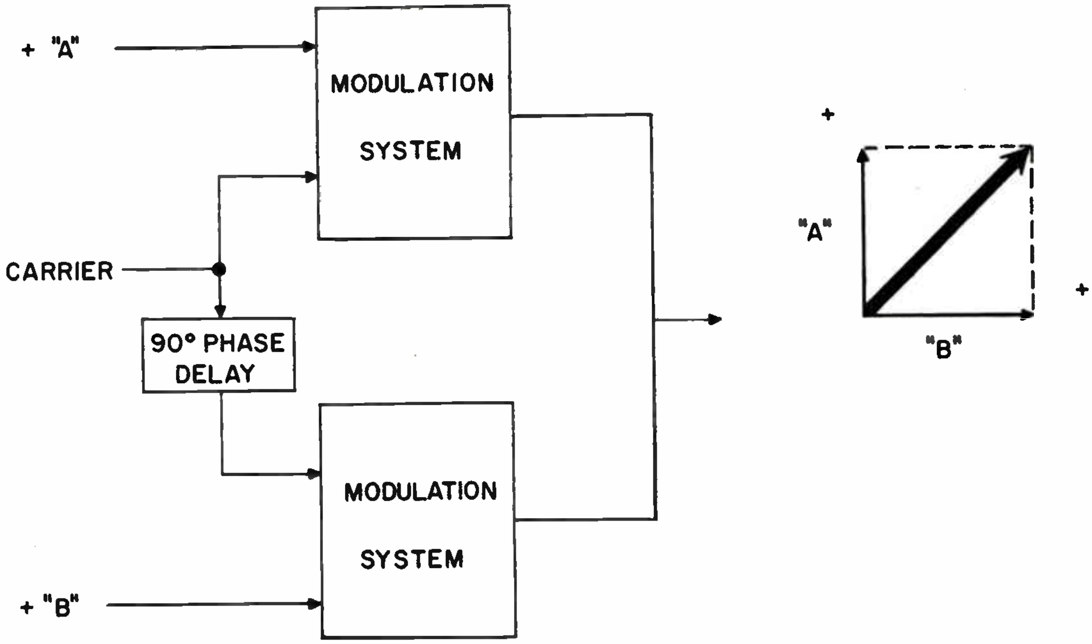


Figure 3-26. Combining two systems.

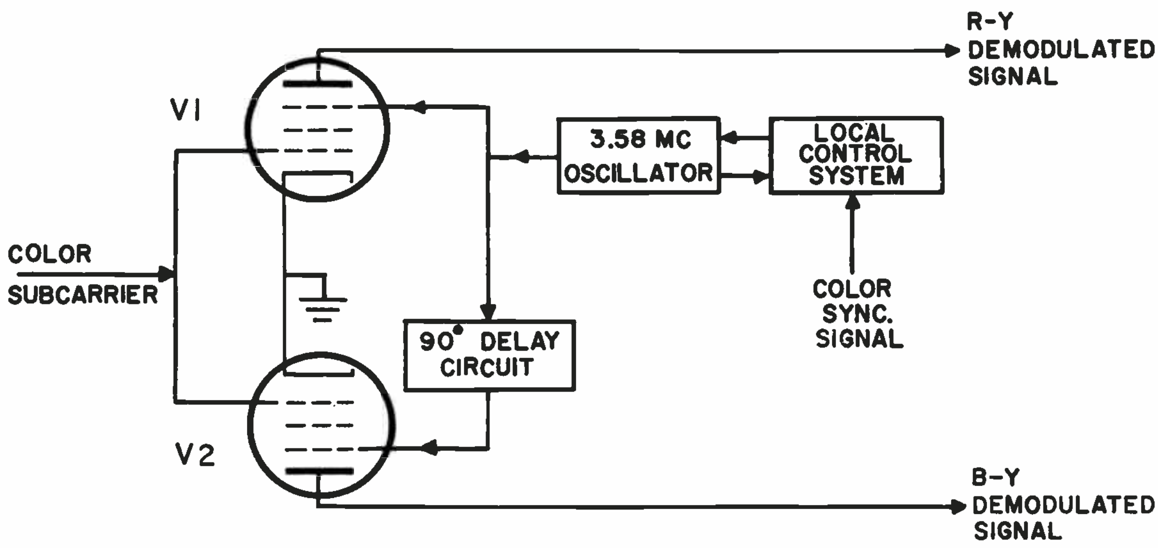


Figure 3-28. Color-subcarrier demodulator.

tion envelopes change, the subcarrier modulation envelope changes its amplitude from zero to maximum and shifts its phase with respect to a reference frequency between zero and 360 carrier degrees. Thus, the two color-difference signals are transmitted, and when received and processed, produce a resultant color on the receiver picture tube identical to the color being viewed by the color television camera.

Demodulation of the Color Subcarrier

The red, green and blue signals from the color television camera are combined to form R-Y and B-Y color-difference signals at the transmitter. These signals modulate two suppressed carriers of 3.58-mc. This system provided a color subcarrier containing two sets of sideband frequencies. Each set has an upper sideband and a lower sideband. One set conveys the R-Y information while the other set conveys the B-Y information. These sideband frequencies are received by the receiver. During the demodulation of these signals, a locally-generated carrier signal is inserted with each set of sidebands. The demodulator circuit then provides a reproduction of the R-Y and B-Y color-difference signals that were applied to the color-subcarrier modulation system at the transmitter.

Figure 3-28 is a simplified diagram of a demodulator. This figure illustrates that the color subcarrier is applied simultaneously to both demodulator tubes; a common oscillator supplies the carrier frequency for both demodulators; the carrier frequency applied to the B-Y demodulator is delayed by 90 carrier degrees, and a means is established to synchronize the 3.58-megacycle oscillator with its counterpart at the transmitter.

The color subcarrier is fed to the control grid of each demodulator. It is important to remember that the color subcarrier in reality is four individual r-f voltages, the upper and lower sidebands of the R-Y and B-Y color-difference signals. It was explained previously that a suppressed-carrier type of transmitted signal requires that a signal of the same frequency and phase of the suppressed-carrier be reinserted with the sidebands to recover the modulating signal. Therefore, a 3.58-megacycle signal, precisely controlled in frequency and phase, is locally generated and applied directly to the R-Y demodulator and a portion of the same signal is applied through a 90° delay circuit to the B-Y demodulator. In this manner, a carrier signal whose frequency and phase are identical to the frequency and phase of the R-Y carrier in the modulator, is applied to the R-Y demodulator. Similarly, a carrier signal whose frequency and phase are identical to the frequency and phase of the B-Y carrier in the modulator, is applied to the B-Y demodulator.

By design, the amplitude of the 3.58-megacycle oscillator is many times that of the sideband signals. One reason for the large ratio of amplitudes is to reduce the effect of the unwanted sidebands in each demodulator. As explained, the R-Y and B-Y sidebands are applied to each demodulator but only the

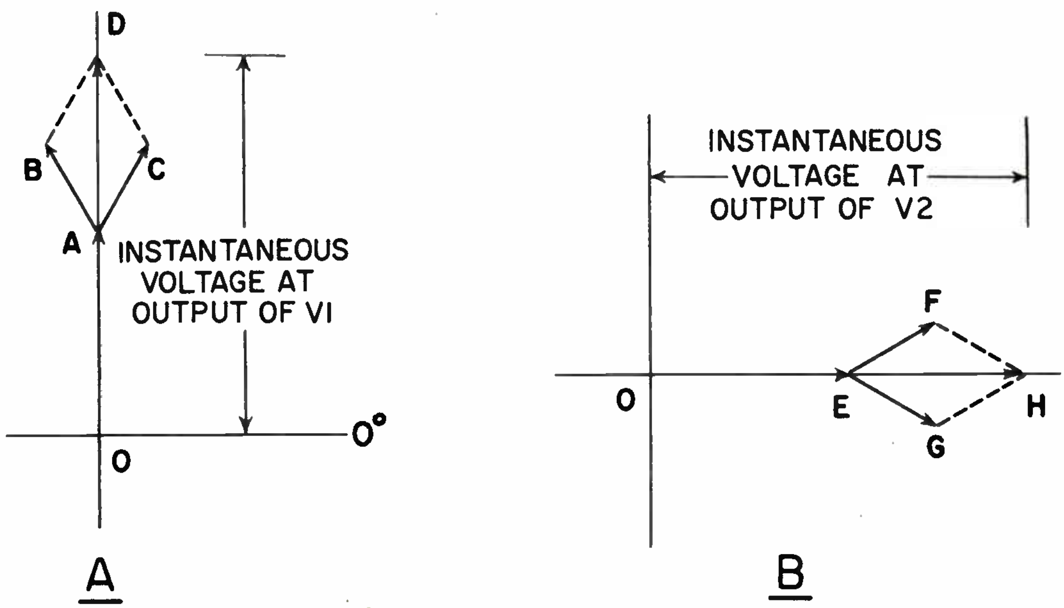


Figure 3-29. Voltage relationship of the color-subcarrier demodulator.

upper and lower sidebands corresponding to one of these are desired in that demodulator. The resultant voltage of the unwanted sidebands always is displaced 90° from the carrier frequency in each demodulator. Therefore, the higher the ratio of amplitude between the sidebands and the carrier, the less the unwanted sidebands will displace the carrier voltage from its reference axis, hence the less phase distortion of the output signal. Therefore, for all practical purposes, it can be assumed that the B-Y sidebands are applied only to the B-Y demodulator tube and the R-Y sidebands are applied only to the R-Y demodulator tube.

Thus far, the demodulator circuit has been discussed as an integral unit to provide the reader with an overall understanding of the demodulating system. In the following paragraphs, each portion is discussed individually.

Vector diagram A of figure 3-29 illustrates the voltages at the output of tube V1 in figure 3-28. Vector OA represents the carrier voltage. Notice that it is of the same relative phase angle as the carrier at the output of the R-Y modulator. Since one sideband vector always leads the carrier by the same number of degrees that the other sideband lags the carrier, the resultant sideband voltage always is either in-phase or 180° out-of-phase with its associated carrier. Therefore, the resultant sideband voltages (vectors AB and AC) at this time will add to the carrier voltage. The resultant vector OD, is the instantaneous voltage at the output of the R-Y demodulator. As the sideband vectors rotate, the demodulator instantaneously adds the three voltages and thereby reproduces an instantaneous voltage which, when the r-f component is removed, varies in accordance with the modulating voltage. Since it is the sidebands that produce the variations in the output signal, the carrier voltage can be of any amplitude as long as it is at least twice the amplitude of the sidebands and of constant amplitude.

Vectorial diagram B of figure 3-29 illustrates the voltages at the output of tube V2 in figure 3-28. Vector OE represents the carrier voltage. The carrier voltage for the B-Y demodulator is applied through a 90° delay circuit, hence it lags the carrier applied to the R-Y demodulator by 90°. This delay is required to have the carrier in-phase or 180° out-of-phase with the resultant of the received B-Y sidebands, since they were transmitted at this same phase relationship. The resultant sideband voltages (vectors EF and EG) either add or subtract from the carrier vector. In the case illustrated, the resultant sideband voltage adds to the carrier. Vector OH is the instantaneous voltage at the output of the B-Y demodulator. Again, as in tube V1, as the sideband vectors rotate, the demodulator instantaneously adds the three voltages and thereby reproduces an instantaneous voltage, which, when the r-f component is removed, varies in accordance with the modulating voltage.

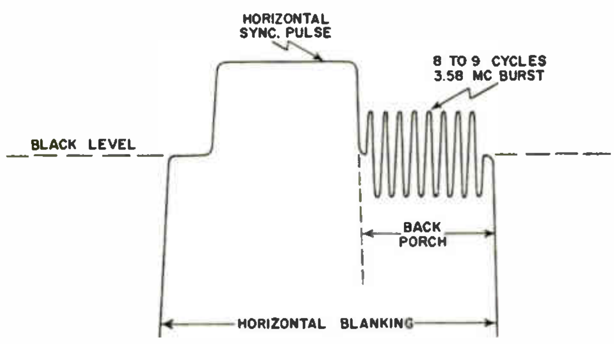


Figure 3-30. The burst signal.

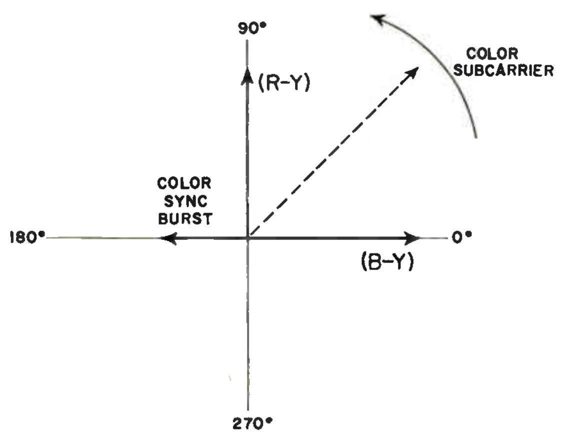


Figure 3-31. Phase relationships of the R-Y, B-Y and burst signals.

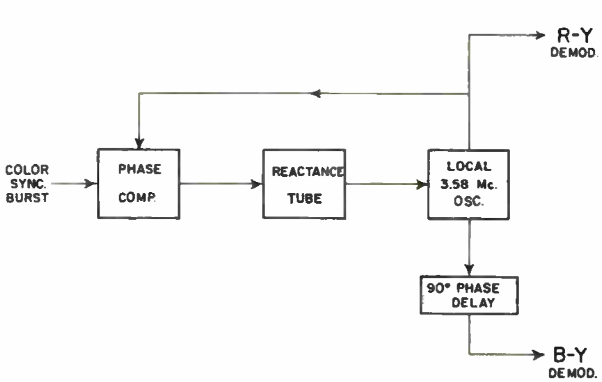


Figure 3-32. Synchronizing the carrier signals.

Color Sync Signal

It has been established that, for the demodulation of a suppressed-carrier signal, a carrier must be inserted at the receiver and further, this inserted carrier must be in-phase with the suppressed carrier. To control the carrier at the receiver, the color-sync signal is provided. This signal consists of eight or nine cycles of a 3.58-megacycle sinewave signal which is keyed into the back porch of the horizontal sync pulse, as illustrated in figure 3-30. This color-sync, "burst" as it is called, occurs during the horizontal blanking time; it is not transmitted during the vertical blanking and retrace times. The phase of the burst sinewave leads the R-Y carrier by 90° as established in the F.C.C. Standards. Figure 3-31 illustrates the phase relationship of the B-Y color-difference signal, R-Y color-difference signal and the burst. At any instant in time, the phase difference among the signals always is as represented in the vectorial diagram of figure 3-31.

Controlling the Local 3.58-Megacycle Oscillator

As shown in the simplified block diagram of figure 3-32, the burst is fed to a phase comparer. A sample of the color-reference oscillator also is fed to the phase comparer. The phase comparer provides a d-c voltage that is positive or negative as the color oscillator drifts above or below the assigned frequency. This d-c voltage is applied to a reactance tube. This tube, connected into the frequency-determining portion of the color oscillator, returns the oscillator to its proper frequency and phase. By virtue of the phase comparer action, the output of the color oscillator lags the burst by 90°. Therefore, the output of the color oscillator is in-phase (90° relative phase angle on the vector diagram of figure 3-31) with the R-Y suppressed carrier.

Summary of Transmission and Reception of the Color-Difference Signals

Figure 3-33 is a simplified block diagram of the transmitter and receiver. The R-Y and B-Y color-difference signals are assumed to be positive. The R-Y signal is applied to the R-Y modulator, and a 3.58-megacycle carrier, at a relative phase angle of 270°, also is applied to the R-Y modulator. The output of the R-Y modulator is two sidebands whose resultant voltage has a relative phase angle of 90°. At the same time, the B-Y signal is applied to the B-Y modulator. The carrier, applied through a 90° phase delay circuit, is applied to the B-Y modulator at a relative phase angle of 180°. The output of the B-Y modulator is two sidebands whose resultant

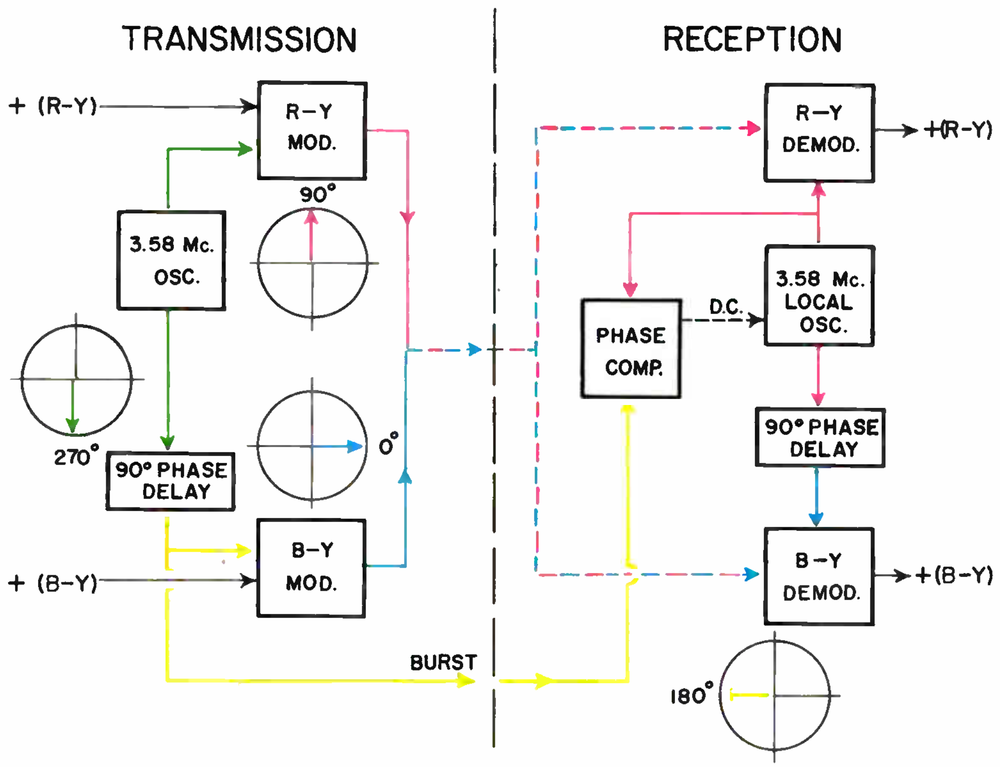


Figure 3-33. Modulation and demodulation of the color subcarrier.

voltage has a relative phase angle of 0°. The two resultant voltages (R-Y and B-Y) are combined and transmitted as the color subcarrier. A portion of the carrier from the 90° delay circuit (relative phase angle of 180°) also is transmitted as the burst signal.

In the receiver, the color subcarrier is applied to the R-Y and B-Y demodulators. The burst signal is applied to the phase comparer. Due to the inherent 90° phase shift of the phase comparer, the local oscillator signal is applied directly to the R-Y demodulator and a portion of the same signal from the local oscillator is applied through a 90° delay

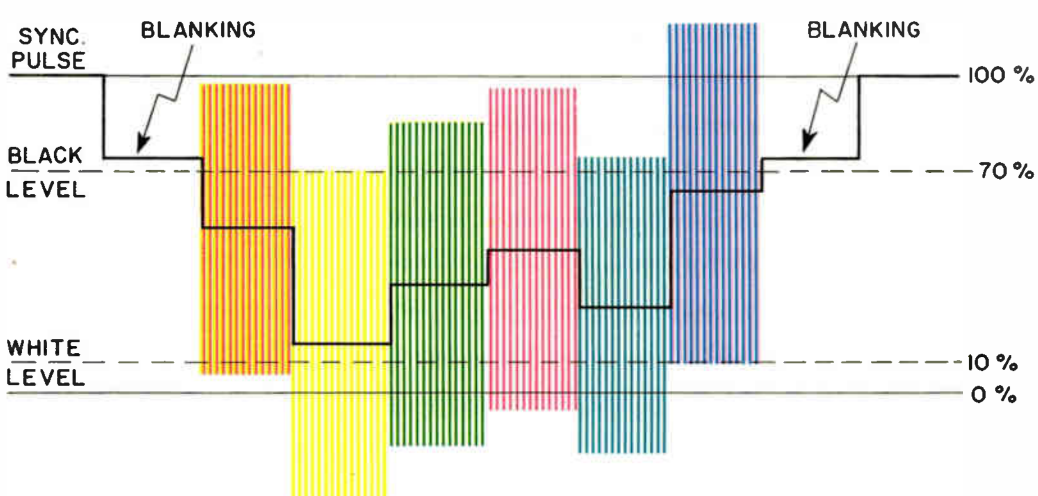


Figure 3-34. Waveform of the color-video signal with R-Y and B-Y signals containing saturated colors.

circuit to the B-Y demodulator. In this manner carrier signals are applied to each demodulator which are in-phase with the resultant voltage of the desired sidebands. Thus the R-Y demodulator detects the R-Y signals and the B-Y demodulator detects the B-Y signals.

The R-Y and B-Y modulation information is combined, placed on a single carrier frequency, transmitted, received and detected to provide a reproduction of the original R-Y and B-Y signals.

The Color-Video Signal

The color-video signal contains the color subcarrier and the Y signal. The color subcarrier is an r-f wave whose amplitude corresponds to the saturation of a color and whose phase, relative to the burst, corresponds to the hue of the color. The amplitude of the Y signal corresponds to the brightness of the color. Therefore, the three characteristics of a color, hue, saturation and brightness, are contained in the color-video signal. The Y signal also is the signal used to activate the video circuits of a black and white television receiver during color transmissions. Earlier in this chapter it was stated that the Y signal always is proportional to the red, green and blue voltage outputs from the color television camera. The proportions are such that 59% green, 30% red and 11% blue comprise the Y signal.

Up to this point the discussion has been confined to saturated colors and maximum amplitudes of the R-Y and B-Y color-difference signals. Figure 3-34 (see page 43) illustrates the color-video signal for saturated red, yellow, green, magenta, cyan and blue along with their respective brightness levels. They have been plotted to scale depicting one horizontal scanning line of a color-bar chart made up of these colors. The purpose of this illustration is to point out the fact that the color subcarrier may extend into the white or black levels and in some instances extend into the modulation region below zero carrier level. This signal can not be transmitted in full amplitude. It is apparent from this that some alteration or modification to the color-difference signals must take place prior to transmission if they are to meet transmission requirements. To fulfill transmission requirements the amplitudes of the R-Y and B-Y color-difference signals are reduced at the transmitter. The R-Y color-difference signal is reduced to 87.7% of its original value and the B-Y color-difference signal is reduced to 49.3% of its original value. The same composite video signal for the one horizontal line shown before is reproduced again in figure 3-35, but this time with R-Y and B-Y reduced by the specified amounts. The reduction of R-Y and B-Y amplitude does not in any way alter the "Y" or luminance signal. Notice that all of the color-subcarrier signals, except yellow and cyan, now fall within the zero to 100% modulation limits of the carrier. As mentioned previously, all of these colors are saturated colors and saturated colors almost never occur in nature. Consequently, color signals never reach the amplitudes illustrated. In the receiver the respective amplitudes are returned to normal.

In summation, three signals are necessary to convey the color information to the television receiver: the "Y" or brightness signal, which is the high-definition signal and contains frequency components up to 4.2-mc; the color subcarrier which conveys the hue and saturation information and contains frequency components up to 0.5-mc; and the color sync burst at a frequency of 3.58-mc.

SECTION 4.

I AND Q COLOR-DIFFERENCE SIGNALS

In the preceding discussion, the color transmission process has been described in terms of the R-Y and B-Y color-difference signals. Actually the R-Y and B-Y signals are not transmitted. The transmitted color subcarrier contains R-Y and B-Y color-difference information, but it is developed by modulating the two 3.58-mc suppressed carriers with I and Q signals. The essential differences between the I and Q color-difference signals and the R-Y and B-Y color-difference signals are: (1) the phase of the I and Q signals is shifted 33° in advance of R-Y and B-Y respectively and (2) the frequency limits of the I and Q signals are 1.3-mc, and 0.5-mc, respectively. The reason for shifting the phase of the color-difference signals is the fact that above 0.5-mc only one color-difference signal is being transmitted. Consequently, the picture elements created between 0.5 and 1.3-mc are colored by only the colors which this one color-difference signal, the I signal, will create. To understand more clearly the need of the different phase angle for the higher definition color-difference signal it is well to observe the various colors which each color-difference signal creates when transmitted. As an example, observe the I axis shown in figure 3-36. This axis is plotted on a diagram denoting the various colors developed by the instantaneous resultant voltage of the color-subcarrier modulation. When I is at its maximum positive amplitude, the color reproduced is reddish-orange. As the amplitude of the signal reduces, this color becomes desaturated until at zero amplitude it is white. As the I signal increases negatively it reaches a value that produces a saturated color resembling cyan, just slightly toward blue. Generally speaking, the I axis is said to pass from orange, through white to cyan and is often referred to as the orange-cyan axis. Now observe that each axis illustrated in figure 3-36 passes through only two specific colors. These are the primary colors of the axis. Don't lose sight of the fact that reference is being made to the transmission of *only one* color-difference signal. The I axis was chosen for the high-definition color signal since the colors along this axis fulfill the requirements of the human eye for satisfactory color reproduction, as established by subjective viewing tests. Incidentally, the same two primary colors of the I axis, orange and cyan, were used as the primary colors in early color movies.

It is important to realize that there is no great difference between the I-Q system and the (R-Y)-(B-Y) system. To appreciate this fact more clearly, assume for the moment that the I signal is limited in bandpass to 0.5 megacycles as is the Q signal. This makes the I-Q and (R-Y)-(B-Y) systems similar except for phase angle. To explain the similarity further, consider the two vector diagrams of figure 3-37. These diagrams illustrate the phase and amplitude of the color subcarrier for both systems of transmission when a red scene is being televised. The relative phase angle of the color subcarrier in both instances is exactly the same, 103 degrees. It should be noted that the amplitude of the color subcarrier also is identical in both diagrams. Hence, the phase relative to burst and amplitude of the resulting color subcarrier are the same. The only things that change are the phases and amplitudes of the vectors (color-difference signals) which create the color subcarrier. Therefore, regardless of the hue or saturation of a color being transmitted, the color-subcarrier modulation envelope is the same whether transmitted by the I and Q color-difference signals or R-Y and B-Y color-difference signals up to 0.5-mc of picture detail. At higher frequencies, the color subcarrier changes since only one color-difference signal, the I signal, is transmitted. The Y or brightness signal and burst are received and processed as explained earlier and are not affected by demodulating the R-Y and B-Y signals instead of I and Q signals. Therefore, for picture information below 0.5 megacycle, the output from the transmitter is identical regardless of which of the two sets of color-difference signals is used.

Basically, there is no major change in the reception and demodulation of the color subcarrier. By transmitting the higher-frequency color components on one color-difference signal, the receiver manufacturer has a choice of demodulating the color subcarrier on R-Y and B-Y co-ordinates or I and Q co-ordinates. The majority of receiver manufacturers demodulate the color subcarrier to provide R-Y and B-Y because the circuits are less complex. This is true because the signals which must be derived after detection of the color subcarrier are R-Y, B-Y and G-Y. Most receiver manufacturers demodulate the color subcarrier so as to obtain directly R-Y and B-Y, and G-Y then is derived from R-Y and B-Y. This eliminates the necessity of transforming I and Q into R-Y and B-Y in the receiver, after demodulation.

Since the color subcarrier below 0.5 megacycle created by I and Q color-difference signals is identical to that created by R-Y and B-Y color-difference signals, the color subcarrier when demodulated at the R-Y and B-Y axis results in the same information that would be derived if the demodulation were to take place at the I and Q axis and transposed to R-Y and B-Y afterwards. To produce R-Y and B-Y color-difference signals in the demodulator outputs, the demodulators work at the relative phase angles of zero degrees and 90 degrees. The voltage outputs from the demodulators are in direct proportion to the co-ordinate quantities of R-Y and B-Y for the phase and amplitude of the color subcarrier at any instant. The output of each demodulator is filtered to remove the r-f voltage and leave a varying d-c voltage proportionate to the modulation. The resulting R-Y and B-Y voltages then are applied to the circuits previously discussed to produce the red, green and blue signals.

SECTION 5.
FREQUENCY INTERLEAVING

Stated at the beginning of this study was the fact that all of the brightness and chroma information must be transmitted within the frequency limits of the standard black-and-white television channel. It was shown that the brightness signal required the full 4.2 megacycles allocated for video information. It was mentioned that the chroma information is interleaved with the brightness signal, thereby sharing a portion of the 4.2-megacycle band required for brightness information.

Frequency interleaving, or "band sharing" as it is sometimes called, is relatively new to television and its basic principles should be understood. The monochrome (black and white) television system uses the frequency spectrum rather inefficiently, in that many gaps exist in which no information is transmitted. The reason for this lies in the scanning process used

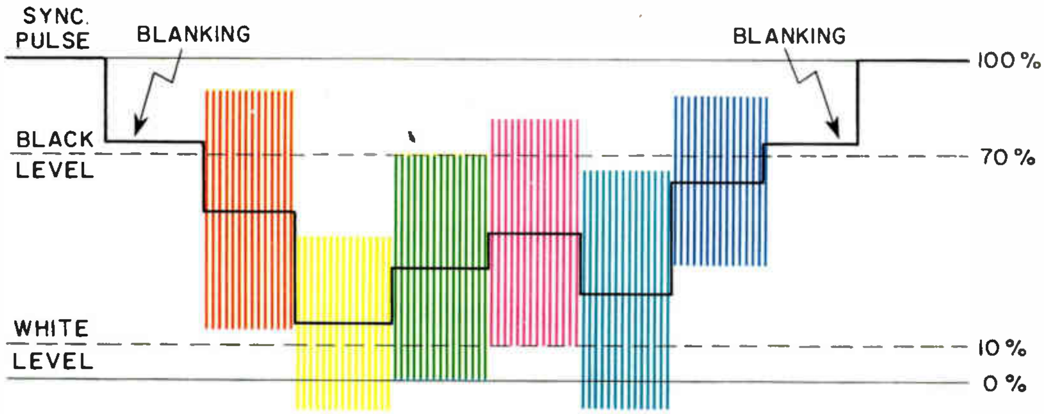


Figure 3-35. Waveform of color-video signal with R-Y and B-Y signals proportionately reduced.

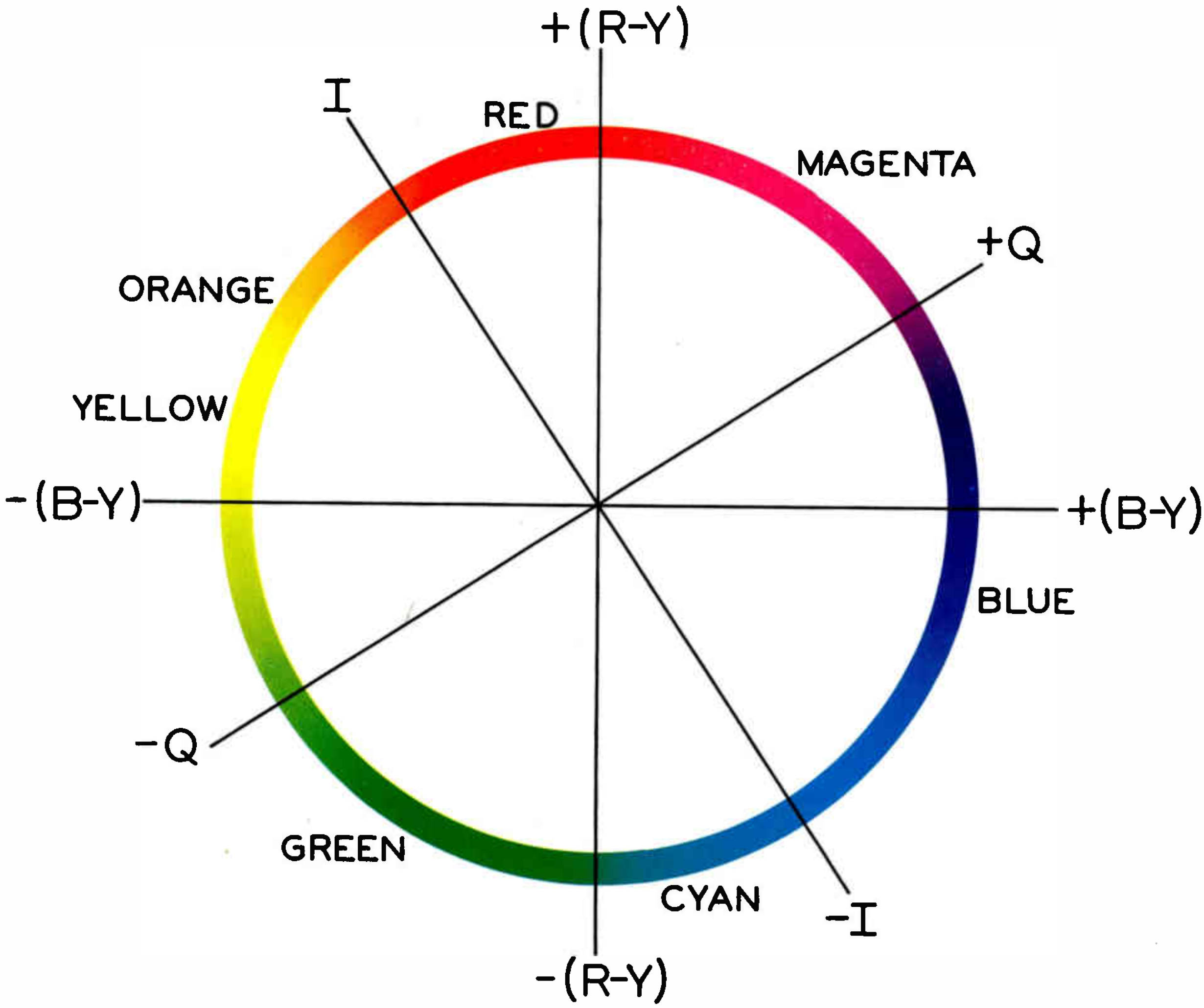


Figure 3-36. Relationship of I-Q co-ordinates and (R-Y)–(B-Y) co-ordinates indicating the colors associated with each color-difference signal.

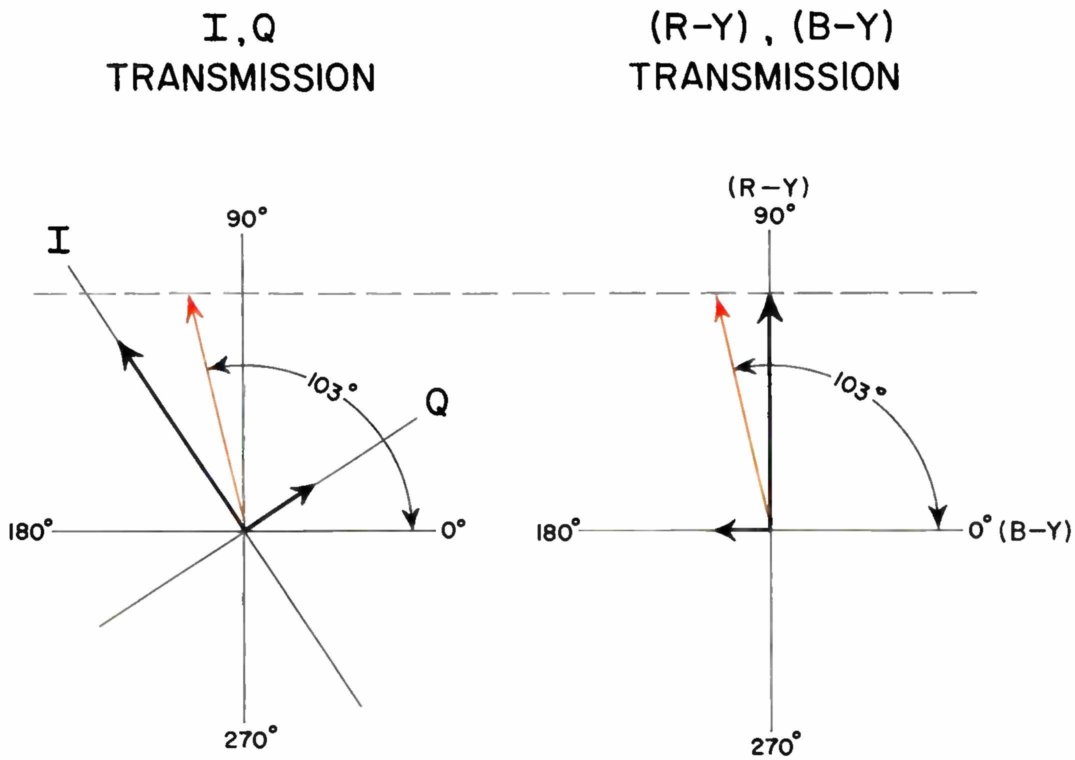


Figure 3-37. Vectorial analysis of identical signals transmitted by I-Q and (R-Y)-(B-Y) color-difference signals.

in television. The scanning method causes the video signal components to group about the harmonics of the vertical and horizontal scanning frequencies. From the standpoint of frequency interleaving, the grouping of the video signal about the harmonics of the horizontal frequency is of particular importance. Figure 3-38 illustrates the second through the fifth harmonics with their associate side frequencies above and below. It is important to note the space or unoccupied region between the groupings of energy. This space is utilized for the transmission of the chrominance signal by frequency interleaving. In order to make efficient use of this space, the F.C.C. revised the Television Signal Standards for color and monochrome transmission to provide horizontal and vertical sweep frequencies of 15,734 cps and 59.94 cps. This slight change does not affect the operation of monochrome receivers.

For explanatory purposes and easier understanding, it is best to express the signal components in terms of half the horizontal line frequency as the reference or starting point. Hence it is observed in figure 3-39 that the monochrome video signal falls in groups at even multiples of half the horizontal line frequency, 450th, 452nd, 454th, 456th, 458th etc. Therefore, the unoccupied spaces fall at the odd multiples of half the horizontal line frequency, 451st, 453rd, 455th, 457th etc. Consequently, the chrominance carrier is of a specific frequency (3.579545 mc) such that the color information consists of an odd multiple of half the line frequency and is therefore interleaved between the monochrome information.

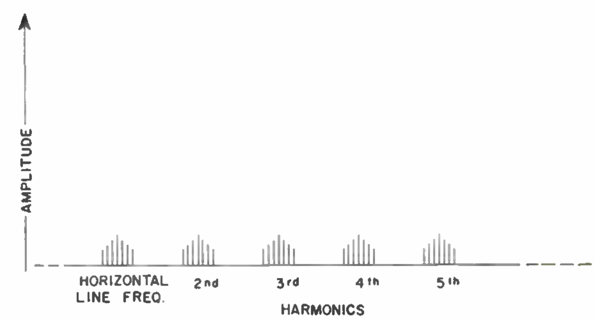


Figure 3-38. Grouping of video signal about horizontal line frequency and harmonics.

To understand more clearly why the video signal information groups about the harmonic frequencies of these new vertical and horizontal scanning frequencies, it is necessary to review the derivations of a rectangular wave and a sawtooth wave.

Derivation of Rectangular and Sawtooth Waves

Resolving a wave is a mathematical process known as Fourier analysis. The following is a simplified explanation. A rectangular wave contains a multitude of sinusoidal waves. The lowest frequency component (fundamental frequency) included in a rectangular wave is determined by the repetition rate of the rectangular wave. Each succeeding higher frequency component of the rectangular wave is a harmonic of the fundamental frequency. A perfect rectangular wave theoretically contains all harmonics of the fundamental frequency. The fundamental frequency and the result of five of its harmonics are illustrated in figure 3-40. Examination of this illustration reveals the fact that if more harmonics were added to the last resultant wave, its sides would become steeper and its top flatter. Therefore, it should be conclusive that a rectangular wave contains all the harmonics of the rectangular wave fundamental frequency or its repetition rate.

A sawtooth wave similarly is illustrated in figure 3-41. As with the rectangular wave, the fundamental frequency of the sawtooth wave is its repetition rate. Examination of this illustration shows that a sawtooth wave contains all harmonics of the fundamental frequency.

Frequency Components of the Video Signal

The color television system requires that the picture be scanned horizontally at a rate of 15,734 times per second and vertically at a rate of 59.94 times per second. Of primary interest at this time is the horizontal scanning rate. Assume that the scene being scanned is a vertical black bar centered on a white field as illustrated in figure 3-42A. The video voltage

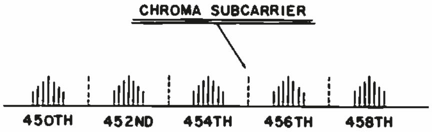


Figure 3-39. Grouping of video signal about harmonics of one-half horizontal line frequency.

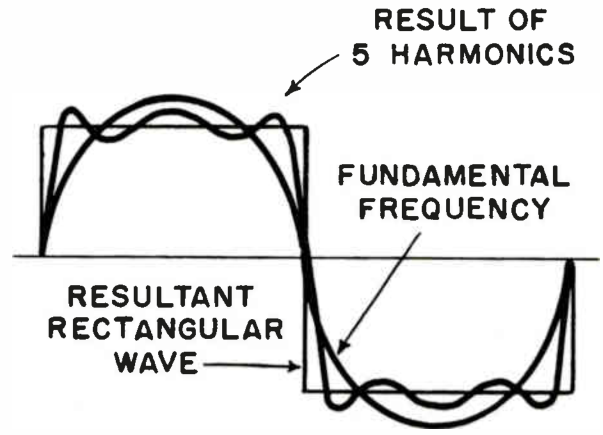


Figure 3-40. Derivation of a rectangular wave.

developed when scanning one line of this scene is plotted in figure 3-42B. Note that the video voltage is a rectangular wave. Since the same shaped video voltage is developed for each horizontal scanning line and the scanning lines have a repetition rate of 15,734 cps, the output signal contains a series of rectangular waves which have a repetition rate of the scanning frequency, or 15,734 cps. As was stated previously the repetition rate of a rectangular wave is the fundamental frequency of the rectangular wave. Therefore, the video information frequency components for this scene recur at 15,734 cps and its harmonics.

Next, assume that the scene being scanned is a gradual shading from white through gray to black as illustrated in figure 3-43A. Plotted directly below is the video voltage developed during one horizontal scanning line (figure 3-43B). In this instance, the video voltage is a sawtooth wave. The video voltage for each scanning line will be a similar sawtooth wave. Thus, the video information consists of a series of sawtooth waves with a repetition rate or fundamental frequency of 15,734 cps. Since the frequency components of a sawtooth wave are the fundamental frequency and all its harmonics, the video voltage of this scene contains frequencies of 15,734 cps and all harmonics of 15,734 cps.

The rectangular wave and the sawtooth wave are basic wave shapes which form more complex wave shapes occurring in the video modulation when scanning an average scene. Therefore, it can be stated that all video modulation has a fundamental frequency of 15,734 cps due to the method of line scanning used in television. Now it is evident why the video signal is illustrated as appearing at 15,734 cps intervals in figure 3-38.

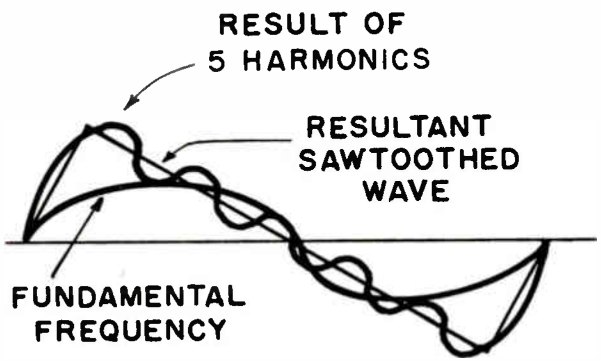


Figure 3-41. Derivation of a sawtooth wave.

The side frequencies, above and below the harmonics of the horizontal scanning frequency, are spaced 59.94 cycles apart. They are the result of the changes in video information from one field to the next. These field changes occur at the vertical scanning rate, thus resulting in frequencies that are harmonics of the vertical scanning frequency. Some energy is produced at the vertical frame rate, but is normally so small that it is disregarded.

For the explanation of frequency interleaving, ideal conditions were cited. In an average telecast, portions of the picture are moving, thereby developing any frequency within the video spectrum. Therefore, the fundamental frequency of the video information may vary from 15,734 cps. The variation is proportional to the rapidity of the motion. This causes some interference between the interleaved monochrome and chroma signals as evidenced by slight discontinuity along the edges of the moving portion of the scene. However, this effect is negligible.

Low Visibility of the Subcarrier

The chroma signal which varies about the brightness signal and modulates each horizontal scanning line, is inverted 180° each frame. This prevents the chroma subcarrier from producing an objectionable black and white interference pattern throughout the picture. This inversion of the chroma signal occurs because it passes through a whole number plus one-half cycles each frame. A portion of one modulated horizontal scanning line is illustrated in figure 3-44A. 525 horizontal lines later (the corresponding line in the next frame), the modulation is inverted 180° as indicated in figure 3-44B. Since these two signals are equal and opposite, they essentially cancel each other (figure 3-44C). This apparent cancellation is due to the persistence of human vision, by which the eye retains the brightness sensation of the horizontal scanning line from one frame to the next.

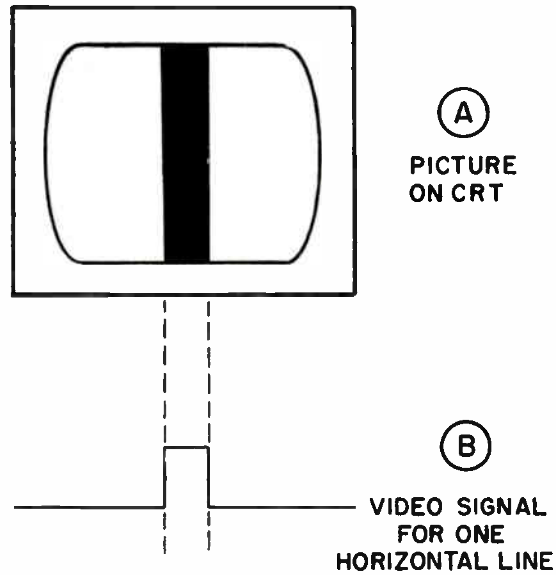


Figure 3-42. Rectangular wave video signal.

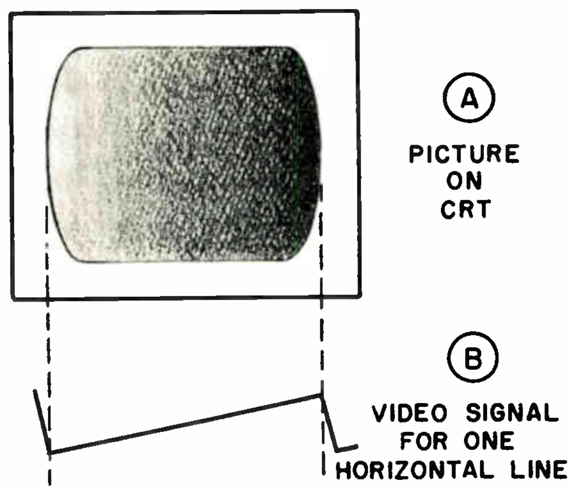


Figure 3-43. Sawtooth wave video signal.

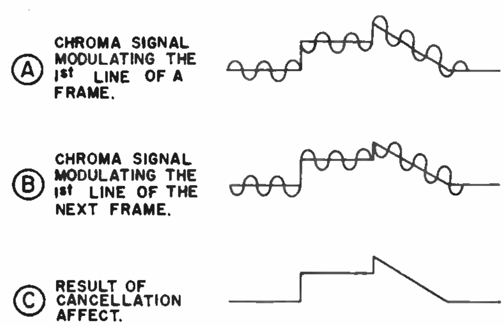


Figure 3-44. Interference cancellation in frequency interleaving.

4. CIRCUIT DESCRIPTION

THIS CHAPTER describes the theory of operation of all the circuits in a typical color television receiver, with the exception of the tri-gun picture tube and its directly associated circuitry. Due to the complexity and newness of the crt and its associated circuits, chapter 5, in its entirety, is devoted to their explanation. The theory of the chroma circuits is emphasized since many service technicians are not acquainted with these circuits. The first section of this chapter contains a block diagram analysis. In the latter sections, each circuit is analyzed individually.

SECTION 1. BLOCK DIAGRAM

The block diagram of figure 4-1 illustrates a typical color television receiver. The individual circuits of the color receiver are grouped, according to function, in eight sections. The title of each section relates to the predominant function of its section. This material is intended to permit the service technician to acquire an understanding of how the individual circuits are integrated in the complete television receiver.

Tuner Unit

The tuner unit of a color television receiver is very similar to its counterpart in the monochrome receiver. The selected video and sound signals are amplified in the r-f amplifier and then coupled to the mixer. The video signal includes video, sync pulses, equalizing pulses, blanking pulses and color subcarrier. In the mixer stage, these signals are combined with an r-f signal from the local oscillator, thereby converting the video and sound r-f signals to i-f signals. The relationship between the incoming signals and the local oscillator signal is such that the frequency differences are always the same; that is, the corresponding intermediate frequencies are the same for all channels. In the typical receiver under discussion, as produced by most manufacturers, the video i-f carrier frequency is 45.75 mc and the sound i-f carrier frequency is 41.25 mc. The mixer output is designed to cover all signals within this frequency range as well as 1.25 mc above the video carrier and slightly below the sound carrier. These signals are applied to the video i-f section.

Video I-F Section

This section contains five i-f stages which are stagger-tuned to provide the bandwidth required to amplify the full range of frequencies received. The output signal from the third i-f stage (video, sync pulses, equalizing pulses, blanking pulses, color subcarrier and sound) is applied to both the fourth and fifth i-f stages. The output of the fourth video i-f stage is applied to the video section. The output of the fifth video i-f stage is applied to the chroma and sound i-f section. The overall frequency response of this section is such to amplify the video signals much more than the sound signals. The difference in amplitude levels between the video and sound signals is utilized in the sound and chroma detector to obtain a 4.5-mc signal which contains the characteristics of the f-m sound signal. Adjacent channel rejection traps are used extensively throughout this section.

Video Section

The video section detects and amplifies the video signal, and applies it to the cathode of the picture tube. The sync separator, noise inverter and agc amplifier also are incorporated in this section.

The signals from the video i-f section are applied to the video detector. The detected signals are amplified in the first video amplifier. A 3.58-mc trap in the plate circuit of the detector prevents the color subcarrier from entering the video amplifiers. From the first video amplifier, the sync, blanking and video signals are applied to a delay line. Physically, the delay line resembles a length of coaxial cable. However, it is designed specially to delay the blanking and video signals by the same amount of time that the chroma signals are delayed in the chroma section. In this manner all signals that are coincident at the transmitter also appear coincident at the picture tube. The output of the delay line is amplified in the second and third video amplifiers and applied, in a positive-going polarity, to the cathode of the picture tube. Pulses from the deflection section are applied to the second and third video amplifiers for suppression of the vertical and horizontal retrace lines on the picture tube.

Portions of the signal from the first video amplifier are applied to the sync separator, noise inverter and agc amplifier. The sync separator extracts the positive-going horizontal and vertical sync pulses from the output of the first video amplifier. These sync pulses then are applied to the phase splitter in the deflection section. The noise inverter inverts all signals (noise) above sync tip level. When these inverted signals combine with the original signal at the input of the sync separator, they cancel and thereby eliminate noise pulses greater than sync tip level from the sync separator.

The agc circuit automatically adjusts the gain of the r-f and i-f sections to compensate for differences in signal strength at the receiver site. The amplitude of the sync pulses normally is constant from any particular television transmitter. Their amplitude is therefore proportional to signal strength, and they may be used as the criterion from which the necessary receiver gain is determined.

The agc amplifier, which receives the video and sync signals from the first video amplifier, is designed to develop a negative d-c voltage proportional to the maximum positive voltage of the input signal (sync tip level). This negative voltage is applied as the agc voltage to the tuner and i-f sections. The agc voltage reduces the gain of these sections as the signal strength increases. Additional compensation, to adjust for different requirements of the tuner and i-f sections, is incorporated in individual circuits to the tuner and i-f sections. A positive pulse from the horizontal output transformer also is applied to the agc amplifier. This pulse acts as a gate and permits the circuit to operate only during horizontal sync pulse time. This reduces the tendency of undesired signals, during line time, to determine the amount of agc voltage.

Chroma and Sound I-F Section

The fifth video i-f circuit amplifies the composite color signal and applies it to the sound and chroma detector. The fifth video i-f amplifier is tuned very broadly with very steep sides on the response curve, particularly on the sound side. The video i-f carrier frequency and the sound i-f signals heterodyne in this detector and produce the 4.5-mc sound i-f signal. The chroma signal also is detected. The 4.5-mc sound signal and the chroma signal are then amplified in the first and second chroma sound i-f amplifiers.

Portions of the output signals from the second chroma and sound i-f amplifier are applied to the audio section, the chroma amplifier and the burst amplifier. The portions of the signal applied to the chroma amplifier and burst amplifier are fed through a 4.5-mc trap to prevent the 4.5-mc intercarrier-sound signal from entering the chroma channels. Only the 3.58-mc chroma signal enters the chroma amplifier in the color separation section. The frequency response of the sound i-f amplifier rejects the chroma signal. Therefore, only the 4.5-mc intercarrier-sound signal is applied to the sound i-f amplifier. A voltage from the phase comparer in the chroma section is applied to the second chroma and sound i-f amplifier for automatic chroma control (acc). This signal controls the gain of the second chroma and sound i-f amplifier in much the same manner as the agc voltage controls the gain of the r-f and i-f sections.

Audio Section

This section receives and amplifies the 4.5-mc intercarrier-sound signal, and applies it to the ratio detector. The ratio detector converts the frequency variations of this signal into an a-f voltage. The a-f voltage is amplified in the first audio and audio output stages and activates the speaker in accordance with the transmitted sound.

Color-Separation Section

The 3.58-mc chroma signal from the second chroma and sound i-f amplifier is amplified in the chroma amplifier and then applied to the R-Y and B-Y demodulators. The output of the R-Y demodulator is the R-Y signal. The output of the B-Y demodulator is the B-Y signal. The output from the common-cathode circuit of the demodulators is the G-Y signal. The three color-difference signals are applied to their respective grids in the tri-gun picture tube.

A positive-going luminance signal (+Y) is received from the video detector in the luminance channel. This signal is inverted three times as it is amplified by the three video amplifiers between the video detector and the picture tube. Thus, the luminance signal is applied to the cathodes of the picture tube in a negative-going direction. Since the color-difference signals (R-Y, B-Y and G-Y) are applied in a negative-going direction to the control grids of the picture tube, the luminance signals cancel. Therefore, the red, green and blue signals control the intensity of their respective electron beams.

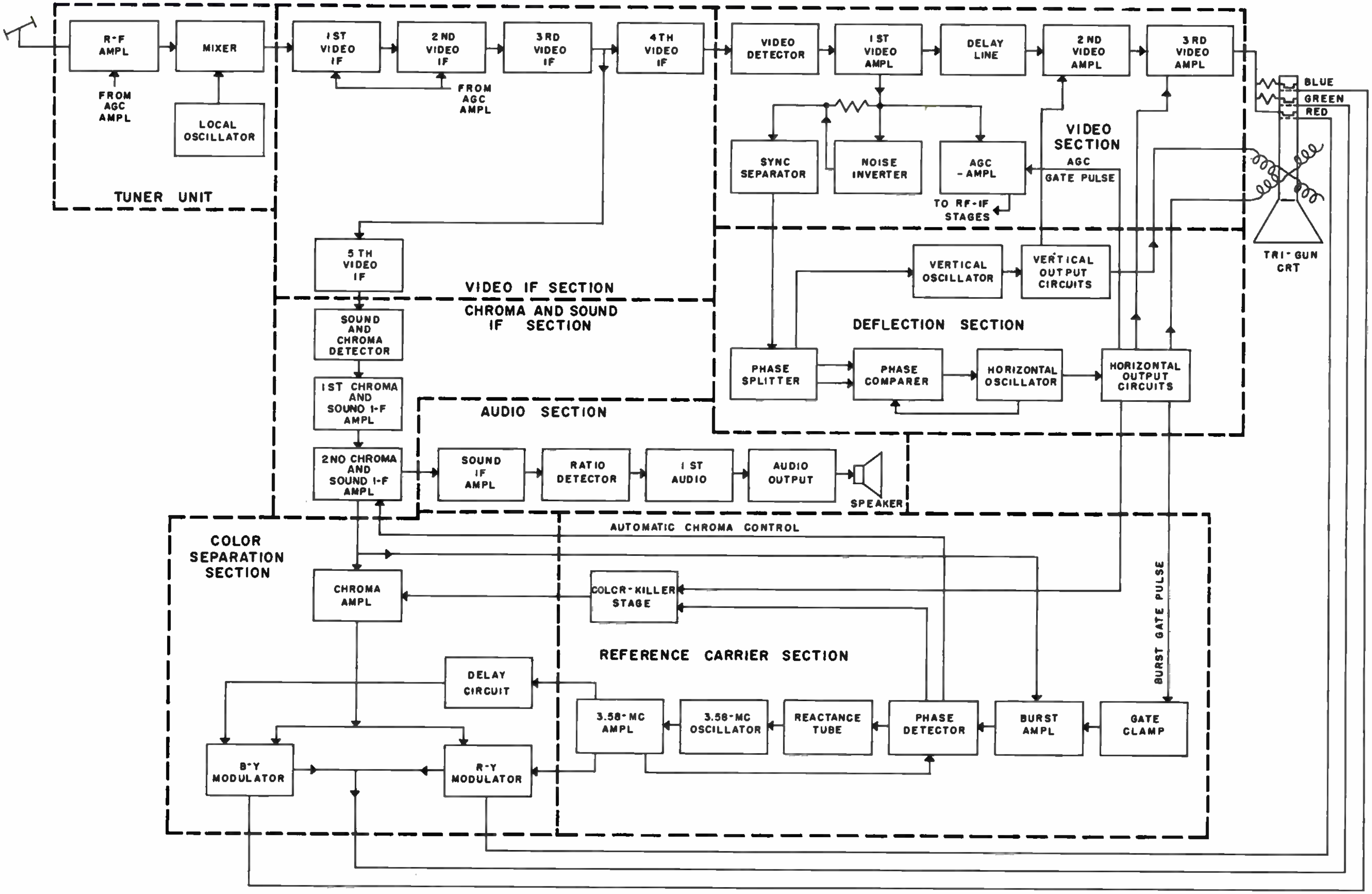


Figure 4-1. Typical Philco Color Television Receiver.

Reference Carrier Section

A signal is generated in the 3.58-mc color-reference oscillator and amplified in the 3.58-mc amplifier. The amplifier has two outputs, one to the R-Y demodulator and the other to a delay circuit. The output of the delay circuit is fed to the B-Y demodulator. Therefore, two carriers are applied to the demodulators and the delay circuit determines the phase difference between them.

A negative pulse from the horizontal output circuit is amplified and shaped in the gate clamp and applied to the burst amplifier. Also applied to the burst amplifier is a signal containing color information and burst from the second chroma and sound i-f amplifier. Since the burst is positioned on the back porch of the horizontal sync pulse at the transmitter, the gate pulse from the gate clamp and the burst arrive at the burst amplifier at the same time. Hence, the burst positions itself on top of the gate pulse while the color information remains at the same level. The burst amplifier is biased such that only the burst appears in its plate circuit. The 3.58-mc burst signal, which is the phase reference standard, is applied to the phase detector. A portion of the signal from the 3.58-mc amplifier also is applied to the phase detector.

If the phase of the 3.58-mc signal from the amplifier is not correct, a d-c voltage appears at the reactance tube grid. This tube is a part of the frequency-determining portion of the 3.58-mc oscillator. When a d-c voltage is applied to the reactance tube, the tube appears either more or less capacitive to the oscillator, thereby changing its frequency. As soon as the output signal from the 3.58-mc oscillator is of the correct phase, there is no output from the phase detector. By this means the output signal of the reference oscillator maintains correct phase.

A portion of the voltage developed in one half of the phase detector is applied to the second chroma and sound i-f amplifier for automatic chroma control. A portion of this same voltage is applied to the color-killer stage. The color-killer stage is so connected to the chroma amplifier that the chroma amplifier is cut off when the color-killer stage conducts. A positive pulse from the horizontal output transformer causes the color-killer stage to conduct except when burst signals are being received. When a burst is received, a negative voltage from the phase detector causes the color-killer to be cut off, thereby permitting the chroma amplifier to function. In this manner the color-killer stage deactivates the chroma channel when the color television receiver is receiving black and white programs.

Deflection Section

Sync signals from the sync separator, in the video section, are applied to the phase splitter from which positive vertical sync pulses and both positive and negative horizontal sync pulses are obtained. The horizontal sync pulses are fed to a balanced phase comparer. A portion of the signal from the horizontal oscillator also is applied to the phase comparer. If the horizontal oscillator is not of the correct frequency, a control voltage is applied from the phase comparer to the horizontal oscillator, which adjusts the oscillator frequency, thereby maintaining frequency stability.

The output of the oscillator is amplified in the horizontal output tube, and applied through the horizontal output transformer to the horizontal deflection coils. These provide the magnetic field for the horizontal deflection of the electron beams. The horizontal output transformer also provides pulses for the agc gate, the color-killer gate, the burst gate and horizontal retrace suppression.

The vertical sync pulses are applied from the phase, splitter, through an integrator network, to the vertical oscillator where they synchronize the vertical sweep with the transmitted signal. The vertical output tube amplifies the oscillator output and applies the signal to the vertical deflection coils, which provide the magnetic field for the vertical deflection of the electron beams.

SECTION 2.
THE TUNER UNIT

The tuner, shown schematically in figure 4-2, is similar to that employed in the monochrome receiver. The tuner is designed for a balanced 300-ohm input impedance. It is a high gain, incremental type, employing an X-155 tube as an r-f amplifier and a 6X8 tube as the oscillator-mixer. The tuner has 12 positions for channel selection of VHF, channels 2-13 and one position for UHF. A vernier control is provided for fine-tuning adjustment of the local oscillator. Component and circuit design specifications are such to reduce oscillator drift to a minimum.

The output of the tuner is the composite color television signal but its frequencies are reduced to the i-f range which is passed by the video i-f section. An agc voltage is applied to the r-f amplifier to compensate for variations in signal levels in different localities and between television stations. A trap is incorporated in the input impedance matching circuit to prevent any interference at the receiver's intermediate frequencies from entering the r-f circuits.

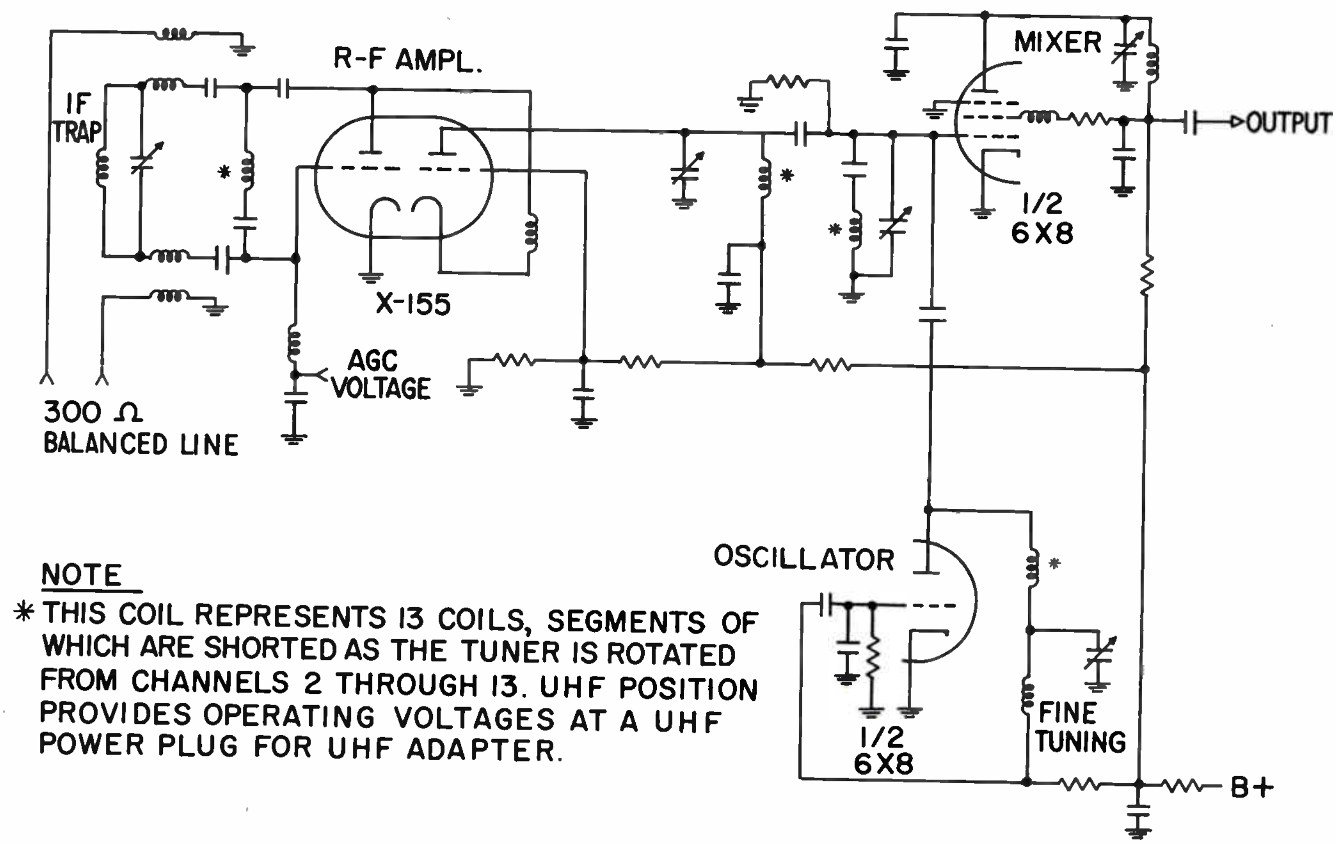


Figure 4-2. Simplified schematic diagram of a tuner.

SECTION 3. THE VIDEO I-F SECTION

The video i-f section, shown schematically in figure 4-3, contains five stagger-tuned stages. The first four stages amplify the signal for application to the video detector. The additional stage, which receives its signal from the third video i-f stage, amplifies the signal for application to the sound and chroma detector.

First Video I-F Stage

The composite color signal is applied to the control grid of a 6BZ6 tube. Two traps are incorporated in the grid circuit of this stage. The 47.25-mc trap attenuates the sound carrier of the lower adjacent channel while the 41.25-mc trap reduces the amplitude of the desired sound carrier. The latter reduction is necessary to obtain the proper ratio between the sound carrier and the video carrier and also to reduce the possibility of an objectional beat signal of approximately 900 kilocycles between the intercarrier sound (4.5 mc) and the chroma subcarrier (3.58 mc). AGC voltage is applied to the control grid. The plate circuit is tuned by the variable capacitor in conjunction with the fixed inductances. The portion of the output signal that appears across the 220-ohm resistor is applied, through the capacitor and inductance, to the grid of the second video i-f stage.

Second Video I-F Stage

The composite color signal from the first video i-f stage is applied to the control grid of a 6BZ6 tube. A 39.5-mc trap and a 41.25-mc trap are in the grid circuit. The 39.5-mc trap attenuates the picture carrier of the upper adjacent channel. The 41.25-mc trap reduces the sound carrier for the reasons explained above. AGC voltage is applied to the control grid. The stage is tuned in the plate circuit by the variable capacitor in conjunction with the fixed inductance. The portion of the output signal that appears across the 220-ohm resistor is applied through the capacitor and inductance to the grid of the third video i-f stage.

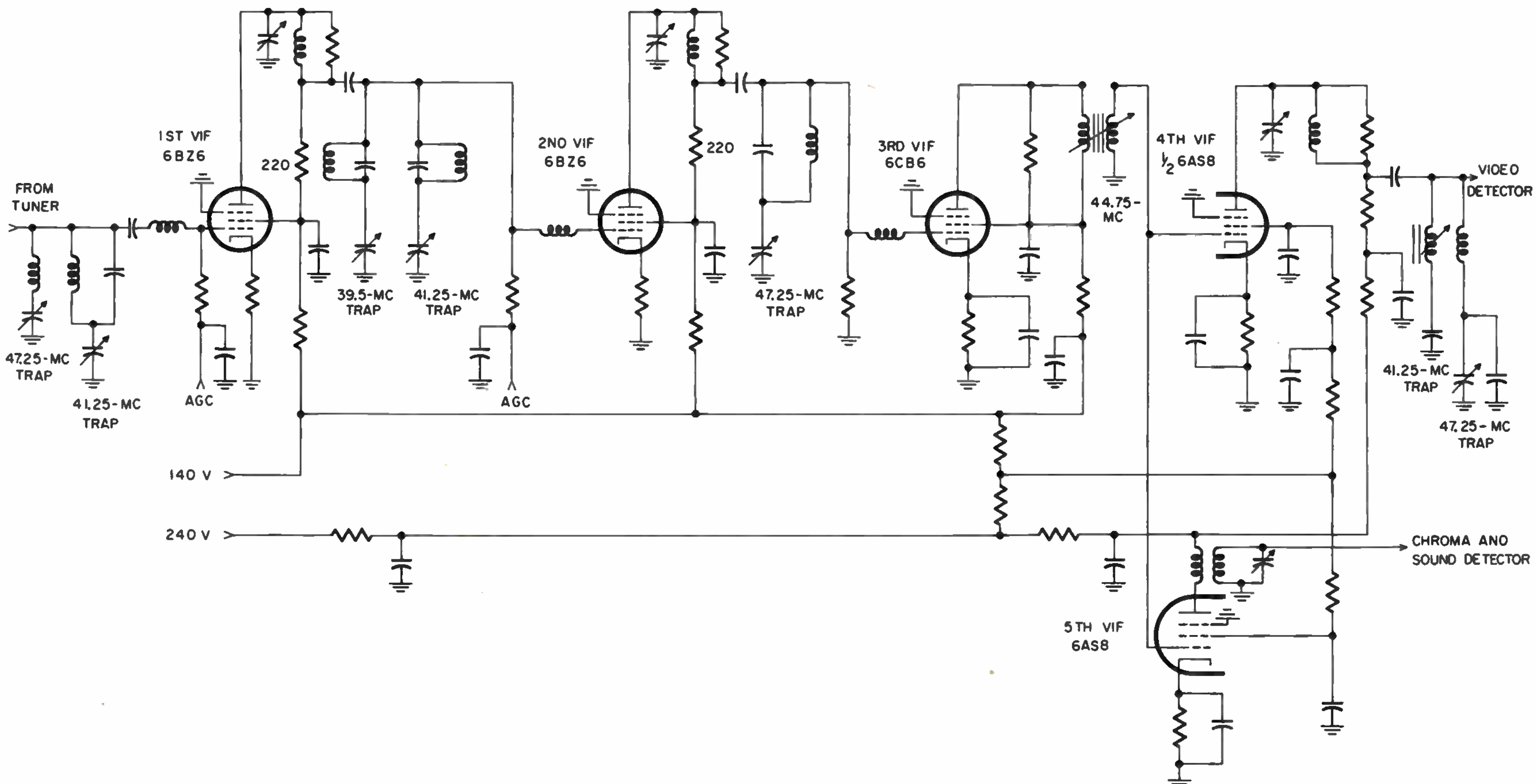


Figure 4-3. The video i-f section.

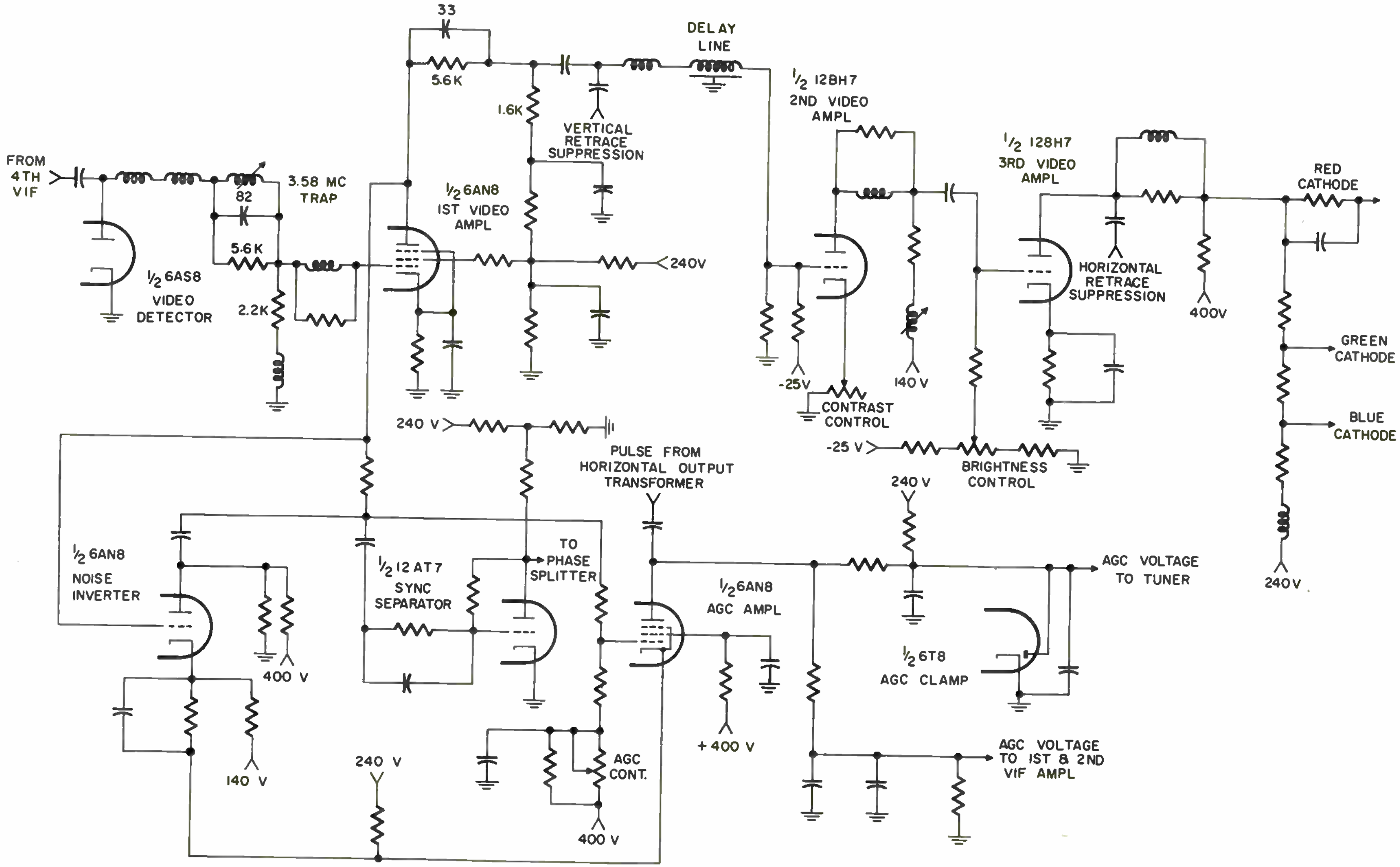


Figure 4-4. The video section.

Third Video I-F Stage

The signal from the second video i-f stage is applied to the control grid of a 6CB6 tube. A 47.25-mc trap is incorporated in the grid circuit to attenuate the sound carrier of the lower adjacent channel. The signal appears across the primary of the tuned i-f transformer, which is inductively coupled to the fourth and fifth video i-f stages.

Fourth Video I-F Stage

From the secondary of the third i-f transformer, the signal is applied to the control grid of the pentode section of a 6AS8 tube. This stage is tuned in the plate circuit by a variable capacitor in conjunction with the fixed inductance. The output signal appears across the 220-ohm resistor and is coupled to the video detector through a capacitor. Another 47.25-mc trap is incorporated in the output circuit to attenuate the sound carrier of the lower adjacent channel.

Fifth Video I-F Stage

The signal from the secondary of the third i-f transformer is applied to the control grid of the pentode section of another 6AS8 tube. This stage amplifies the composite color signal and it appears across the primary of the transformer in the plate circuit. The signal is transformer-coupled to the chroma and sound detector.

SECTION 4. THE VIDEO SECTION

The video section, figure 4-4, contains a video detector, a delay line, three video amplifiers, a sync separator, a noise inverter and an agc amplifier. These circuits detect and amplify the video and sync pulses for application to the picture tube and other associated circuits.

Video Detector

As the positive portions of the composite-video i-f signal are applied to the plate of the detector, the diode section of a 6AS8 tube, the tube conducts and by-passes these portions to ground. The negative portions of the composite-video i-f signal appear across the 2.2K plate load resistor and inductance, and the r-f component is filtered out. The 3.58-mc chroma signal appears across the tuned circuit (consisting of the variable inductance, the 82-mmfd capacitor and the 5.6K resistor) in series with the input to the first video amplifier. This circuit prevents the chroma signal from reaching this stage.

First Video Amplifier

The positive-going video signal across the 2.2K resistor and inductance is amplified in the pentode section of a 6AN8 tube. Due to the reactance relationship between the parallel combination of the 5.6K resistor and the 33 mmfd capacitor and the 1.6K resistor in the plate circuit, the sync pulses appear across the parallel combination while the higher frequency video appears across the 1.6K resistor. The signals (sync and video) across the complete plate load of the first video amplifier are applied to the noise inverter, sync separator and agc amplifier while the signal (video) across the 1.6K resistor is applied to the delay line.

Delay Line

The delay line, figure 4-5, is a coil of fine wire wound around a flexible powered iron core. This is covered with a thin layer of polyethylene. A layer of copper wire, with its strands parallel to the iron core, is placed around the polyethylene. The delay line has an overall protective covering of vinyl. The length of the line is approximately 15 inches and it delays the video signal (brightness signal) approximately 1.1 microseconds. The delay line compensates for the signal delay peculiar to the narrow-band amplifier in the chroma channel. By delaying the brightness signals in the wide-band amplifier, the corresponding chroma and brightness signals arrive at the picture tube at the same time.

A portion of the signal from the vertical output transformer also is applied to the input to the delay line for vertical retrace suppression.

Second Video Amplifier

The signals from the delay line, the negative-going brightness signal and positive-going pulse for vertical retrace suppression, are applied to the control grid in ½ of a 12BH7 tube. The signals appear across the plate load resistor and are applied to the third video amplifier. A potentiometer, which controls the bias in the second video amplifier is the contrast control. The control grid has a fixed bias.

Third Video Amplifier

The signals from the second video amplifier are applied to the control grid of the third video amplifier, one-half of a 12BH7 tube. The plate load of this tube is a resistor network such that the full signal voltage is applied to the cathode of the red gun, 80% of the full signal voltage is applied to the cathode of the green gun and 66⅔% of the full signal voltage is applied to the cathode of the blue gun. This compensates for the difference in illumination from the red, green and blue phosphor dots in the picture tube. Bias for this stage is obtained from the brightness potentiometer which is part of a series circuit from -25V to ground.

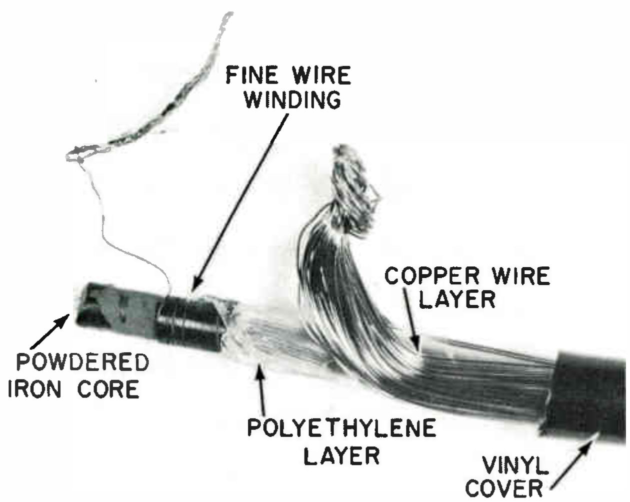


Figure 4-5. The delay line.

Sync Separator

The video signals, with positive-going sync, from the plate circuit of the first video amplifier, are applied to the control grid of the sync separator, the triode section of a 12AT7 tube. This stage conducts only on sync pulses and provides negative-going sync pulses at its plate.

Noise Inverter

The video signals, with positive-going sync, from the plate circuit of the first video amplifier also are applied to the control grid of the noise inverter, the triode section of a 6AN8 tube. The tube is biased to conduct only on signals whose amplitude is above sync tip level. If a noise pulse appears in the plate circuit of the first video amplifier, the noise inverter conducts and a negative-going pulse appears at the control grid of the sync separator. At the same time, the positive-going noise pulse in the plate circuit of the first video amplifier is applied to the control grid of the sync separator. The two noise pulses, being of opposite polarity, cancel in the sync separator.

AGC Amplifier

The video signals, with positive-going sync, from the plate circuit of the first video amplifier also are applied to the control grid of the agc amplifier. The agc amplifier is the pentode section of a 6AN8 tube. The plate voltage is obtained from a winding on the horizontal output transformer; therefore, the tube can conduct only during the time the horizontal pulse is on the plate. Thus, it is a gated agc system. The agc amplifier is so biased that conduction is proportional to the amplitude of the sync pulses. Therefore, the higher the amplitude of the sync pulses the more negative the agc voltage which, in turn, reduces the gain of the first r-f amplifier and first and second i-f video amplifiers.

The bias of the agc amplifier is controlled partially by the agc potentiometer. Separate agc voltages for the r-f stage and i-f stages are developed in the output circuit. A small positive delay voltage is applied to the first r-f stage to limit agc action when weak signals are being received. To prevent the agc voltage from going positive, the delay voltage is clamped by the diode section of the ratio detector and first audio stage, a 6T8 tube.

SECTION 5.

THE CHROMA AND SOUND I-F AMPLIFIER SECTION

The chroma and sound i-f section, figure 4-6, contains the chroma and sound detector and the first and second chroma and sound i-f amplifiers. This section detects and amplifies the chroma and sound signals. The sound is separated and applied to the audio section while the chroma is applied to the color separator section.

Chroma and Sound Detector

The signal from the secondary of the transformer in the plate circuit of the fifth video i-f amplifier is applied to the detector, a diode section of a 6AS8 tube. The input circuit of the detector is tuned to maintain linear frequency response. The positive portions of the signals are by-passed to ground through the diode while the negative portions of the signals appear across the 4.7K diode load resistor.

First Chroma and Sound I-F Amplifier

The signals from the diode load resistor are applied to the first chroma and sound i-f amplifier, the triode section of a 6AW8 tube. Tuned circuits are provided in the grid circuit to improve the linearity characteristics of the amplifier. The signals are amplified and applied through a coupling capacitor to the control grid of the second chroma and sound i-f amplifier.

Second Chroma and Sound I-F Amplifier

The second chroma and sound i-f amplifier is the pentode section of a 6AW8 tube. Its grid resistor is returned to the automatic chroma control circuit. This circuit is discussed in the local carrier section. The plate circuit contains two tuned circuits. The one nearest the plate is tuned to the intercarrier sound frequency (4.5 mc) while the other is tuned to the color-subcarrier frequency (3.58 mc). When the signals are applied to the control grid, they are amplified and appear across their respective tuned cir-

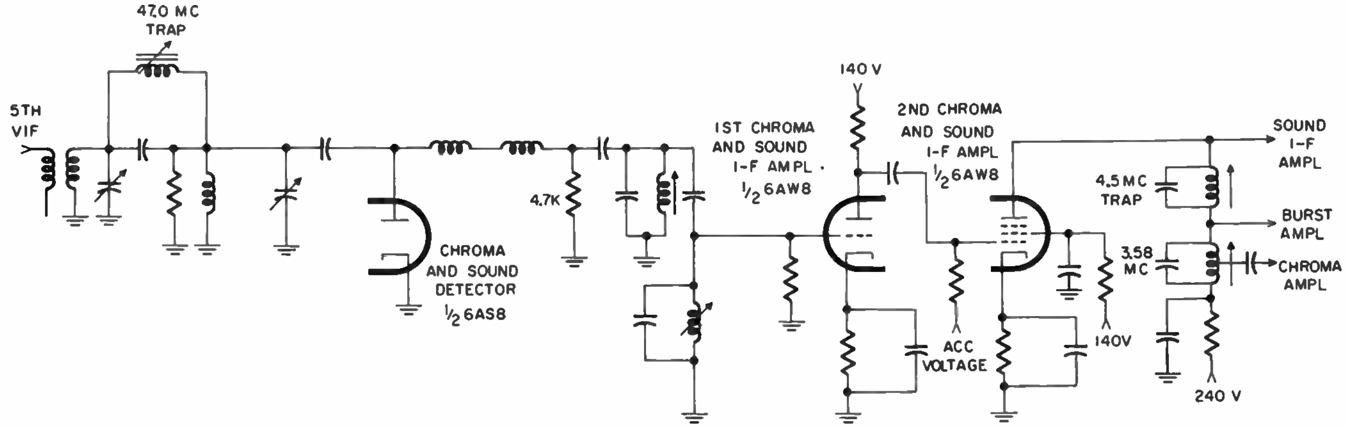


Figure 4-6. Chroma and sound i-f section.

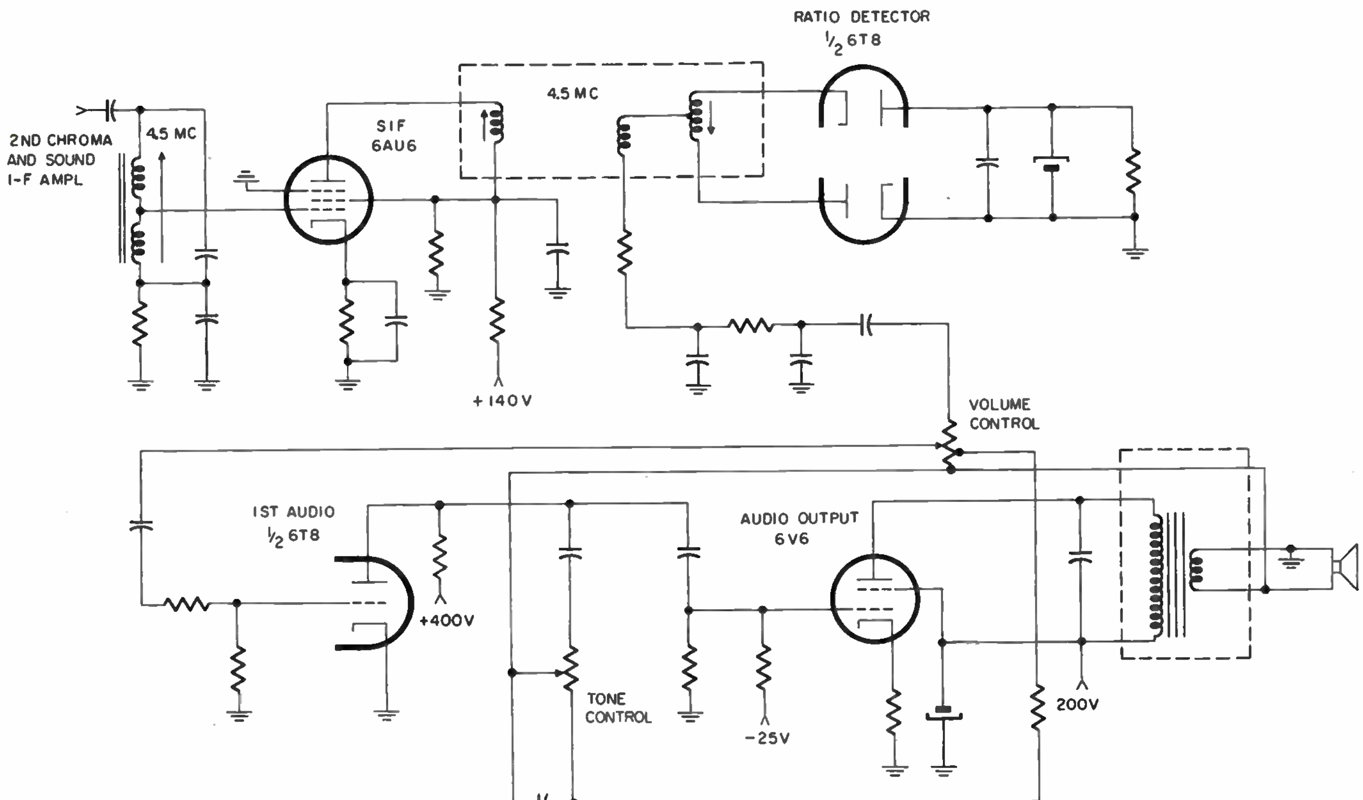


Figure 4-7. The audio section.

cuits in the plate circuit. Three output signals are taken from this plate load: the lead from the plate carries chroma, burst and sound signals while the other two leads carry only the chroma and burst signals. The lead from the plate is connected to the audio section where the audio signals are extracted; the lead from the top of the 3.58-mc tank circuit is connected to the local carrier section where the burst signal is extracted; and the lead from the center of the 3.58-mc tank circuit is connected to the color separation section where the chroma signal is utilized.

SECTION 6. THE AUDIO SECTION

The audio section, shown schematically in figure 4-7, contains one sound i-f stage, a ratio detector, first audio amplifier and an audio output tube. These stages receive the 4.5-mc intercarrier-sound signal. This signal is amplified and detected. The audio signal from the ratio detector is amplified in the first audio amplifier and then further amplified in the audio output tube for application to the speaker.

Sound I-F Stage

The signal from the plate of the second chroma and sound i-f stage contains chroma, burst and 4.5-mc intercarrier-sound signals. Since the input circuit of the sound i-f stage is tuned to 4.5 mc, only the sound signal is applied to the grid. The sound signal is amplified within this stage which contains a 6AU6 pentode tube. The amplified i-f signal is developed across the primary of the ratio-detector transformer.

Ratio Detector

The ratio detector contains both diodes of a 6T8 tube. A simplified schematic diagram is illustrated in figure 4-8. The function of the ratio detector is to convert the frequency variations of the sound i-f signal into an audio signal.

The 4.5-mc sound signal across the primary of the transformer is coupled to both the secondary and tertiary windings. However, the secondary and tertiary windings have negligible effect upon each other. The primary and secondary windings are tuned to 4.5 mc. The distributed capacity of the windings and the stray capacity of the circuit supply the capacitive reactance across each winding; hence a capacitor is not required to tune either winding.

As the frequency of the incoming i-f signal varies above and below the center frequency of 4.5 mc at an audio rate, the phase angle between the voltage across the secondary and the voltage across the tertiary also changes. This effectively changes the instantaneous voltage across each diode. The current pulses through the diodes (diodes conduct only during one-half cycle) charge or discharge capacitor C2, depending on the previous instantaneous voltage. Capacitor C2, permitting only slight changes between current pulses, provides an a-f signal proportional to the rate of change of the f-m signal.

Capacitor C3 and resistor R1 serve only to stabilize the output voltage of the diodes. These values are very high, hence they develop a voltage proportional to the average amplitude of the input signal. In this manner, amplitude variations in the input signal are not detected. Capacitor C1 completes the r-f path for diode V1.

First Audio and Output Stage

The audio signal from the ratio detector is applied to the triode section of a 6T8 tube. The audio signal is amplified in this stage and then applied to the audio output, a 6V6 tube, where the signal is further amplified before application to the speaker.

SECTION 7. THE COLOR SEPARATION SECTION

The color separation section, figure 4-9, contains the chroma amplifier, the demodulator and the delay circuit. The primary function of the color separation section is to extract the R-Y, B-Y and G-Y color-difference signals from the chroma subcarrier. The local (color-reference) carrier, required for demodulation, is discussed later in this chapter.

Chroma Amplifier

The chroma signal is developed across the grid resistor of the chroma amplifier. The burst also is developed across this resistor, but since it occurs during horizontal blanking period, it does not affect the picture tube. The chroma signal is applied to the control grid of the chroma amplifier, a 6CL6 tube. The signal is amplified and then transformer-coupled into the plate circuits of the B-Y and R-Y demodulators. The potentiometer in the cathode circuit of the chroma amplifier is the chroma control.

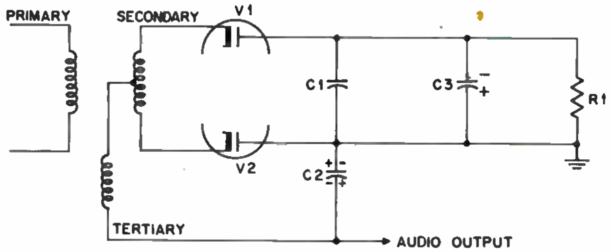


Figure 4-8. Simplified schematic of a ratio detector.

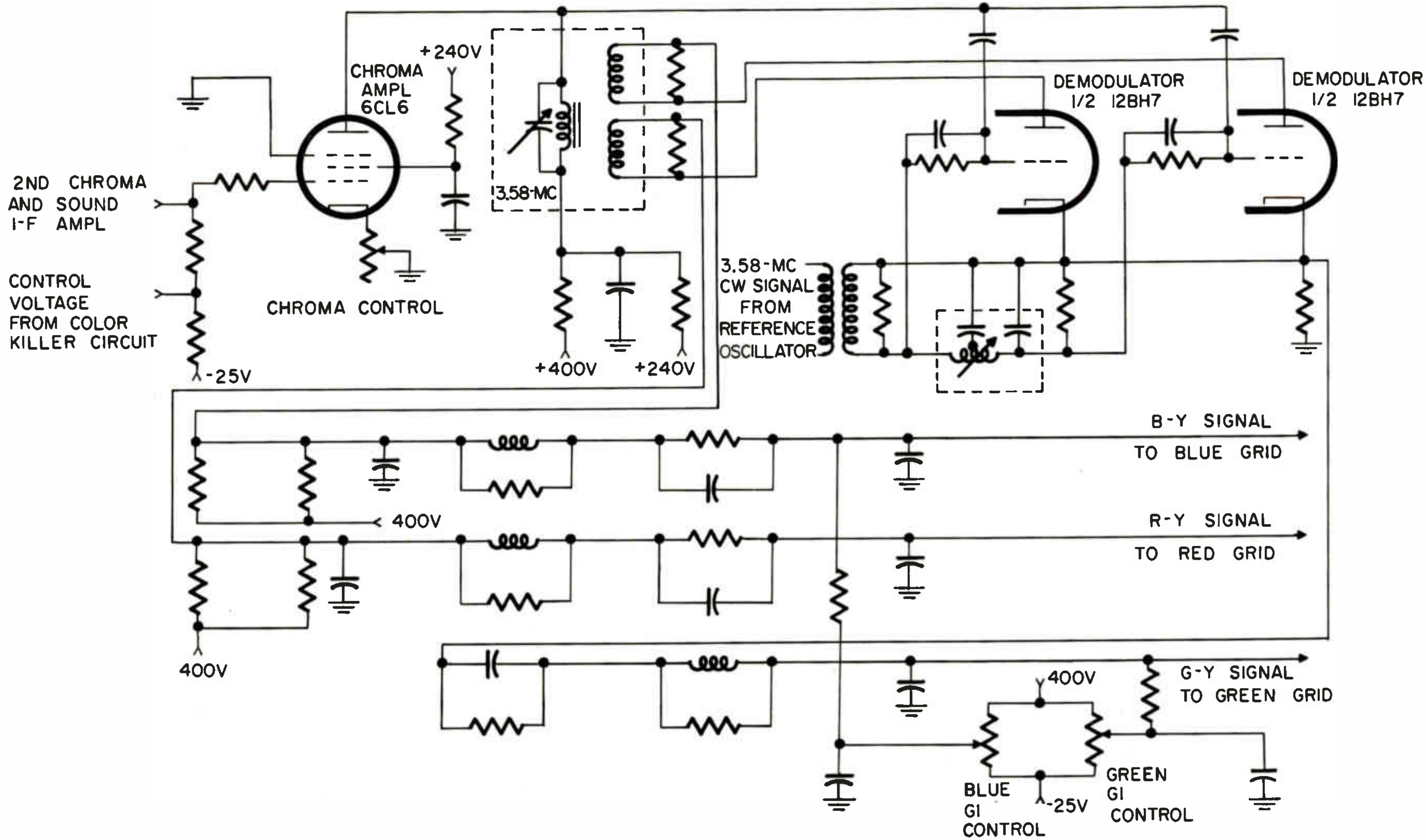


Figure 4-9. The color separation section.

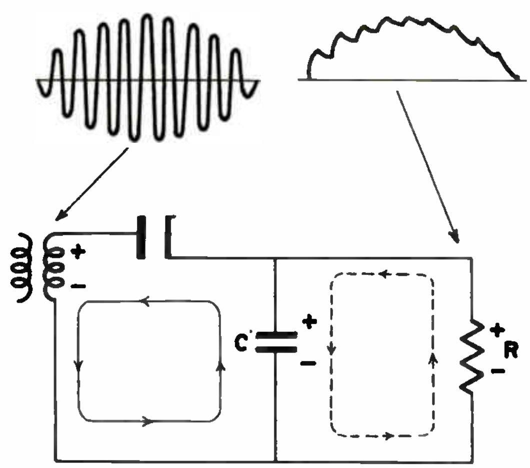


Figure 4-10. Basic series detector.

Demodulator

The output of the chroma amplifier is transformer-coupled to the demodulator stage. The demodulator detects the color-subcarrier and extracts the three color-difference signals. A reference signal, at the color-subcarrier frequency of 3.58 mc, is supplied from the reference oscillator section directly to the R-Y demodulator and through the delay circuit to the B-Y demodulator. By properly phasing the reference frequency, R-Y color-difference signal is obtained from one portion of the demodulator and B-Y color-difference signal is obtained from the other portion of the demodulator. G-Y color-difference signal is obtained across a common cathode resistor. The three signals thus obtained are applied to their respective grids of the red, blue and green guns of the picture tube.

Since most service technicians are not familiar with this type of circuitry, the following section is devoted to its explanation.

SECTION 8.
THE DEMODULATORS

The function of the high-level demodulator is identical to that of the basic demodulator discussed in Chapter 2 in that the ultimate purpose of the demodulator is to detect and separate the three color-difference signals from the color-subcarrier. The operation of the demodulator is developed in the following paragraphs from the basic series detector. As the explanation progresses, parts are added and rearranged until, in the final schematic, the demodulator is completely developed. This step-by-step procedure should enable the service technician to acquire a complete understanding of the demodulator circuit. This understanding is essential if the service technician is to analyze and service the demodulator circuits in the minimum amount of time.

Basic Detectors

The schematic diagram of figure 4-10 is a basic series detector. As a positive peak of the r-f signal appears across the secondary of the transformer (polarity indicated in figure 4-10), the diode plate is positive with respect to its cathode. Therefore, the diode conducts momentarily. The current pulse charges capacitor C practically to the peak value of the r-f cycle (instantaneous diode plate voltage). The polarity of the charged capacitor is indicated in figure 4-10. Capacitor C charges almost instantaneously due to the low impedance of its charging circuit. The charging circuit, indicated by a continuous line in figure 4-10 is from the source of voltage (secondary of the transformer), through capacitor C, the diode and then back to the source of voltage.

As soon as the r-f voltage becomes less positive than its peak value the diode can not conduct since its cathode is still at the positive value determined by the positive peak of the r-f cycle. The moment current stops flowing, capacitor C starts to discharge through resistor R. The discharge path is indicated by the dashed line in figure 4-10. However, resistor R presents a much higher impedance than the charging circuit; hence, capacitor C discharges much slower than it charged. Consequently, the voltage across capacitor C and resistor R cannot follow the rapid decrease of the r-f voltage. The r-f voltage decreases through zero to its negative peak and then increases again. As soon as it reaches a value that is positive with respect to the slowly decreasing cathode voltage, the diode again conducts and recharges capacitor C practically to the positive peak of the next r-f cycle. Again the diode cuts off as the r-f signal becomes negative with respect to the output voltage. Hence, the cathode voltage (output voltage) varies in accordance with the positive peaks of the r-f signal. The r-f signal and the detected signal are illustrated in figure 4-10. As noted, the output variation is not a smooth curve. However, the abrupt variations usually are removed in a filter system following the detector. Therefore, the output voltage varies between zero and some positive value and its shape (frequency) approximates a smooth curve drawn across the positive peaks of the r-f signal.

The next step in developing the demodulator is to alter the schematic diagram of figure 4-10. In figure 4-11, the circuit is arranged with the diode in series with the lower portion of the input transformer rather than the upper portion as in figure 4-10. As before, the circuit is observed with an a-m, r-f signal applied to its input. As a negative peak of the r-f signal appears across the secondary of the transformer (polarity indicated in figure 4-11), the diode plate is positive with respect to its cathode. As the polarity indicates, a negative r-f signal makes the diode plate positive with respect to its cathode. Therefore, the diode conducts momentarily. The current pulse charges capacitor C practically to the negative peak value of the r-f cycle (polarity indicated in figure 4-11). Capacitor C charges almost instantaneously due to the low impedance of its charging circuit. However, as noted in figure 4-11, the charging current flows in a clockwise direction from source of voltage through capacitor C, the diode and then back to the source of voltage; consequently, capacitor C is charged negatively. The voltage across capacitor C holds the diode plate negative with respect to its cathode until the next negative peak of the r-f signal raises the diode plate voltage from its negative value to a positive one.

As the diode plate becomes positive, capacitor C again charges practically to the negative peak value of the r-f cycle. During the time between negative peaks, current does not flow and capacitor C slowly discharges through resistor R. Again, as in the previous circuit, the time constant of resistor R and capacitor C is such that capacitor C loses only a portion of its charge in the time required for one complete cycle of the r-f signal. Therefore, in this circuit, the output voltage, for the same input voltage as in the previous circuit, varies between zero and some negative value and its shape (frequency) approximates a smooth curve drawn across the negative peaks of the r-f signal.

As shown in the preceding paragraphs the detected output signal in one circuit is dependent only on the amplitude of the positive peaks of the r-f signal and in the other case is dependent only on the amplitude of the negative peaks of the r-f signal.

To recover information from the color subcarrier, the detector may be required to detect not only the peaks of the r-f signal but any portion of each r-f cycle. The first circuit variation to accomplish the above is to add a source of d-c voltage between the lower end of load resistor R and ground as shown in figure 4-12.

Assume for a moment that there is no r-f signal applied to the input circuit. A portion of the B-plus voltage appears on the diode plate; consequently, the diode conducts and causes a voltage drop across resistor R. Assume this current develops a 90-volt

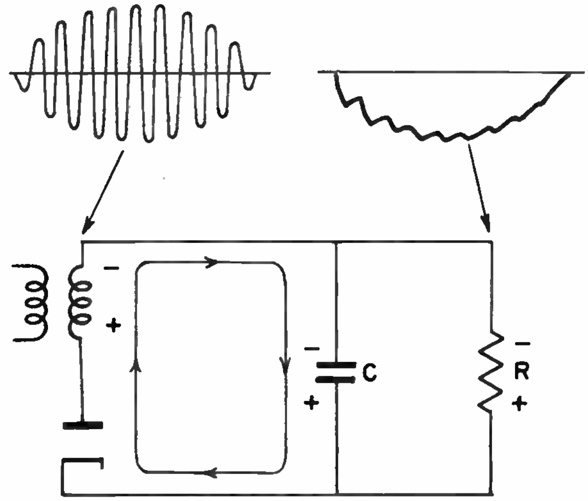


Figure 4-11. Series detector.

drop across resistor R. Hence there is 10 volts across the output as indicated in figure 4-12.

As a positive peak of the r-f signal appears across the secondary of the transformer (polarity indicated in figure 4-12), the diode plate is less positive and the plate current decreases. The decreased current flow decreases the voltage drop across resistor R and the output voltage increases. Concurrent with the changing conditions, capacitor C charges as rapidly as the output voltage increases. As the r-f signal decreases from its positive peak to its maximum negative value, the diode plate voltage progressively increases. The increasing plate voltage progressively increases the current flow and voltage drop across resistor R. Consequently, the output voltage progressively decreases from its maximum value to its minimum value. Again capacitor C follows the r-f variation since it is dis-

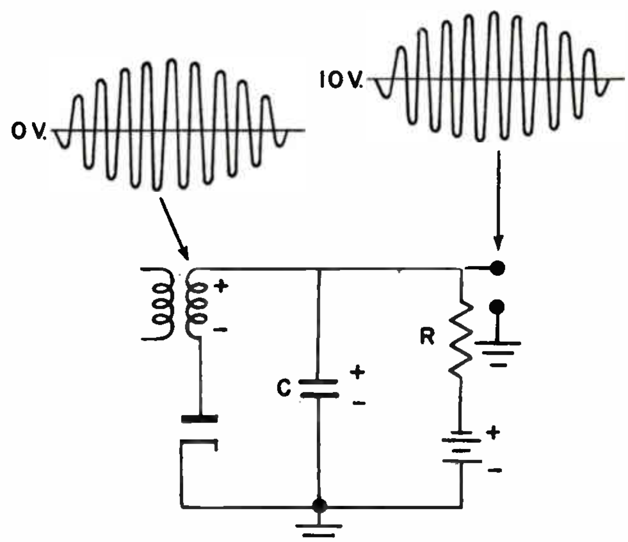


Figure 4-12. Detector circuit with voltage applied.

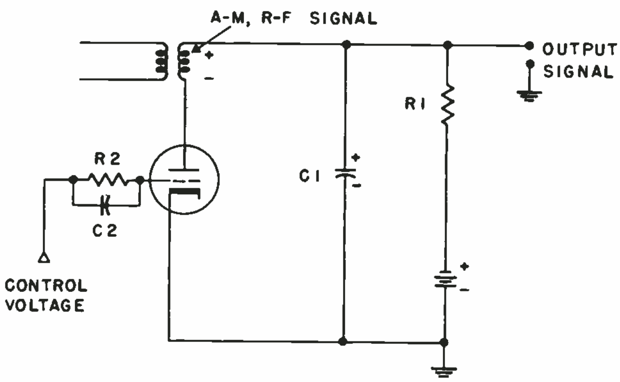


Figure 4-13. Controlled detection.

charging through the low impedance path of the diode and secondary of the transformer.

As the r-f signal increases from its maximum negative value to its positive peak, the diode plate voltage progressively decreases. The decreasing plate voltage progressively decreases the current flow and voltage drop across resistor R. Consequently, the output voltage progressively increases from its minimum value to its maximum value. Capacitor C again charges through the tube and transformer to the maximum positive value of the output signal.

From the foregoing, it is evident that the output voltage is a duplication of the input signal except that the r-f signal varies about a zero-voltage reference and the output voltage varies about a 10-volt reference. It is apparent that the circuit in figure 4-12 is not detecting the r-f signal. However, every portion of the r-f signal causes a proportionate amount of plate current to flow. In the circuits of figures 4-10 and 4-11, a pulse of current flows through the circuit each time the positive or negative peak of the r-f signal is in the plate circuit. Hence, either the positive or negative peaks of the r-f signal are detected in these circuits.

We now recall that in detecting the color subcarrier, the detector may be required to detect any one portion of each cycle of the r-f signal. Therefore, by controlling the diode of figure 4-12 such that plate current is permitted to flow only at the time when the desired portion of each cycle of the r-f signal is in the plate circuit, the desired portions of the r-f signal are detected.

Controlled Detection

If the diode of figure 4-12 is replaced with a triode and a control voltage is applied to the grid of this triode, such that it allows the triode to conduct only during the time when a portion of the signal is to be detected, the circuit detects the desired portions of the r-f signal. The circuit can thereby detect the positive peaks, detect the negative peaks, or detect any relative phase angle of each cycle. This circuit is illustrated in figure 4-13. The control voltage is a signal whose frequency is the same as the a-m signal applied to the plate circuit. The amplitude of the control voltage is such that its positive peaks cause the triode to draw grid current. This grid current, flowing through resistor R2, biases the tube to operate as a class C amplifier. Hence, plate current flows only during the short period of time that the positive peaks of the control voltage are applied to the grid circuit.

By controlling the phase angle between the control voltage and the a-m, r-f signal, any relative phase angle of the r-f signal can be detected. If both signals are in phase, the circuit detects the positive peaks of the signal since at all other times the triode is cut off. If the control voltage is phased such that its positive peaks are coincident with the negative peaks of the signal, the circuit detects the negative peaks of the r-f signal. Similarly, if the control voltage is phased such that its positive peaks are coincident with any relative phase angle of the r-f signal, the circuit detects that relative phase angle on every cycle of the r-f signal.

As each positive peak of the control voltage is applied to the grid in figure 4-13, there is a pulse of plate current. Assume this pulse of plate current causes a 90-volt drop across resistor R1. Capacitor C1 discharges to ten volts through the transformer and triode during conduction time. During the time between positive peaks of the control voltage, the triode is cut off and capacitor C1 charges through resistor R1. The capacitor tries to charge to the value of the

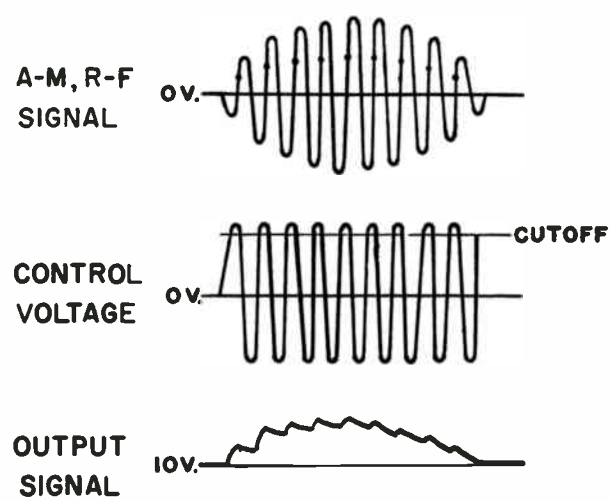


Figure 4-14. Detecting an a-m, r-f signal at a relative phase angle of 30°.

B-plus voltage; however, the time constant of resistor R-1 and capacitor C1 is relatively long compared to the time between positive peaks of the control voltage. Therefore, capacitor C1 recovers only a small increase in voltage before the next positive peak of the control voltage is applied to the circuit and discharges the capacitor to its original ten volts. The steady state output voltage, when only the control signal is applied, is sawtoothed; however, the variation in steady state output voltage is so slight compared to signal variations that will be obtained across the output circuit, the steady state output voltage is considered to have a constant value of ten volts.

If the a-m, r-f signal in figure 4-14 is applied to the plate circuit of figure 4-13 and the control voltage, phased as illustrated in figure 4-14, is applied to the grid of figure 4-13 the r-f signal is detected at a relative phase angle of 30°. Examination of figure 4-14 reveals that the positive peaks of the control voltage are coincident with the 30° relative phase angle portion of each cycle of the r-f signal. The phase angle between the two signals remains constant since the frequency of both signals is identical. As each cycle of the r-f signal, at a relative phase angle of 30° appears in the secondary of the transformer, a positive peak of the control voltage appears at the grid. The positive peak of the control voltage permits plate current to flow. The plate voltage is reduced by the instantaneous voltage of each r-f cycle at a relative phase angle of 30°.

Assume the r-f cycle being applied to the plate circuit has a positive peak value of ten volts; the instantaneous voltage, at a relative phase angle of 30°, is five volts. As the five volts appear in the plate circuit (polarity indicated in figure 4-13) it opposes the B-plus voltage which reduces plate current, and increases the output voltage from its steady state of ten volts to 15 volts. Simultaneously, capacitor C1 rapidly charges to 15 volts. As the control voltage decreases from its positive peak, the triode is cut off and remains cut off until the next positive peak of the control voltage. During cut-off time, capacitor C1 retains the 15-volt charge. (Capacitor C1 tries to charge from 15 volts to B-plus voltage; however, due to the relatively long time constant of capacitor C1 and resistor R1, the charge is not increased appreciably before the next positive peak of the control voltage is applied to the grid and for all practical purposes the charge is considered to remain constant for the duration of cut-off time.)

As the next positive peak of the control voltage is applied to the grid, the next r-f cycle at a relative phase angle of 30° appears in the plate circuit. The

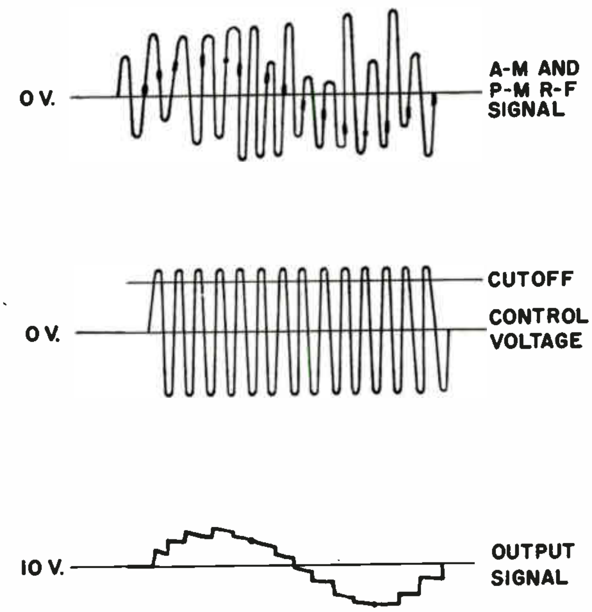


Figure 4-15. Detecting an amplitude-and phase-modulated signal.

instantaneous voltage of this r-f cycle is either greater or less than the previous instantaneous voltage. If it is greater, the circuit operates in the manner just described except capacitor C1 rapidly charges from 15 volts to a value of 15 volts plus the difference between the first and second instantaneous voltages. If it is less, the circuit operates in the manner described except capacitor C1 rapidly discharges from 15 volts to a value of 15 volts minus the difference between the first and second instantaneous voltages.

Since current flows only when a positive peak of the control voltage appears on the grid, and since each positive peak of the control voltage is coincident with the 30° relative phase angle of each cycle of the r-f signal, the output voltage varies concurrently with the instantaneous voltage of each r-f cycle at a relative phase angle of 30°. Therefore, as illustrated in figure 4-14, the output signal contains the variations of the detected portions of the r-f signal.

Detecting an A-M, P-M, R-F Signal

In the circuits just described the r-f signal was amplitude modulated and the control voltage was of the same frequency as the r-f signal. Therefore, the relative phase angle for detection, once selected, was the same for every cycle of the r-f signal. However, in actual practice the color subcarrier to be demodulated is both amplitude and phase modulated. An amplitude- and phase-modulated signal is illustrated in figure 4-15. Just below this signal is shown a control voltage.

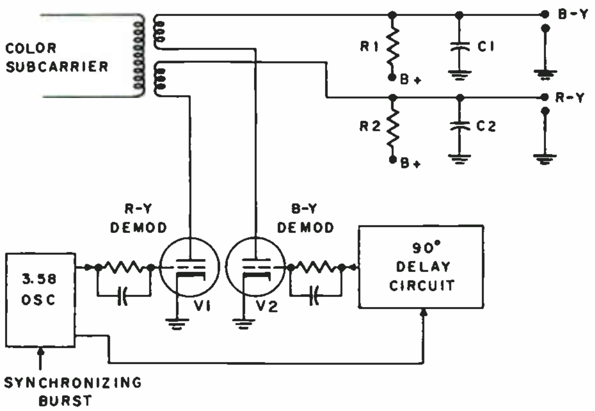


Figure 4-16. Basic demodulator.

The only difference between these signals and those discussed in the previous paragraphs is that phase modulation (P-M) has been added so the r-f signal is varied both in amplitude and frequency. Assume the r-f signal and the control voltage, phased as illustrated in figure 4-15, are applied to the circuit of figure 4-13. The r-f signal appears in the plate circuit and the control voltage appears in the grid circuit. As before, the triode conducts only during the time when each positive peak of the control voltage is applied to the control grid. The time that the tube conducts is the time that each positive peak of the control voltage is above the cut off line as illustrated in figure 4-15. The portion of the r-f signal that appears in the plate circuit when the tube is conducting is indicated by the heavy portion of the r-f signal. Therefore, it is these portions of the r-f signal that are detected. The waveforms of figure 4-15 are exaggerated for explanatory purposes; however, in actual circuitry where additional filtering is required, the output voltage is represented by a smooth line drawn through the detected portions of the r-f signal.

Detecting the R-Y and B-Y Color-Difference Signals

The R-Y and B-Y color-difference signals modulate 3.58-mc carriers. These carriers are 90° out-of-phase. When the carriers are removed and all sidebands combined, the color-subcarrier is formed. This color subcarrier is both phase and amplitude modulated, that is, it has the same characteristics as the r-f signal discussed in the preceding paragraph. A reference burst (3.58 mc) is transmitted. This burst synchronizes a locally generated carrier which, in turn, provides two carriers which are of the same phase and frequency as the suppressed carriers. The method of synchronism is discussed in the next section. These locally generated carriers have a frequency of 3.58 mc and have the same characteristics as the control voltage discussed in the preceding paragraph.

The portions of the color subcarrier that contain the information of one specific color-difference signal are coincident with the positive peaks of the suppressed carrier originally modulated by the color-difference signal. Therefore, by introducing a locally-generated carrier whose positive peaks are coincident with the positive peaks of one of the suppressed carriers, the color-difference signal that originally modulated that suppressed carrier appears in the output circuit of the detector.

The basic demodulator, illustrated in figure 4-16, is formed by combining two circuits, each identical to that of figure 4-13. The reference control voltage is applied directly to one tube and through a 90° delay circuit to the other tube. As noted in the illustration, one portion of the circuit is labeled B-Y demodulator and the other portion is labeled R-Y demodulator. The control voltage from the 3.58-mc oscillator is controlled such that it is in phase with the suppressed carrier of the R-Y modulator. The color subcarrier is applied, through the transformer, to the plate circuits of both the R-Y and B-Y demodulators.

As each positive peak of the control voltage is applied to the grid of V1, this tube conducts. Each time V1 conducts, a voltage, proportional to the instantaneous voltage of the color subcarrier at the time of the conduction, is applied across resistor R2 and capacitor C2. This resistor-capacitor combination retains the output voltage until the next instantaneous voltage is received, at which time the output voltage increases or decreases, depending on whether the previous instantaneous voltage was respectively less or greater.

In this manner the R-Y demodulator provides an output voltage proportional to the original R-Y color-difference signal. The B-Y color-difference signal modulated its suppressed carrier ninety-carrier degrees later than the R-Y color-difference signal modulated its suppressed carrier, so the B-Y color-difference signal is demodulated ninety-carrier degrees after the R-Y color-difference signal.

The control voltage at the grid of tube V2 is in phase with the B-Y suppressed carrier. As each positive peak of the delayed control voltage is applied to the grid of tube V2, this tube conducts. Each time tube V2 conducts, a voltage, proportional to the instantaneous voltage of the color-subcarrier at the time of conduction, is applied across resistor R1 and capacitor C1. This resistor-capacitor combination retains the output voltage until the next instantaneous voltage is received at which time the output voltage increases or decreases, depending on whether the previous instantaneous voltage was respectively less or greater. In this manner the B-Y demodulator provides an output voltage proportional to the original B-Y color-difference signal.

Detecting the G-Y Color-Difference Signal

In the basic study of the color circuits, it was stated that the R-Y and B-Y color-difference signals are applied to a matrix circuit in which the G-Y color-difference signal is derived. In reality, the matrix circuit is a part of the demodulator circuit. It is recalled that the G-Y color-difference signal is derived by satisfying the formula G-Y = –0.51 (R-Y) –0.19 (B-Y). This formula can be satisfied by many different methods. One of the most practical and simplest methods is to obtain the proper proportions of the R-Y and B-Y signals from the cathode circuits of their respective demodulators.

Figure 4-17 represents either the R-Y or B-Y demodulator. By selecting the proper ratio between the cathode resistor and the plate resistor, a voltage equal to 51% of the R-Y output voltage or a voltage equal to 19% of the B-Y output voltage can be developed across the cathode resistor. Since the voltage variations across the cathode resistor are 180° out-of-phase with the output voltage variations, a –(R-Y) quantity is developed across the cathode resistor if the output signal is a +(R-Y) quantity and similarly, a –(B-Y) quantity is developed across the cathode resistor if the output signal is a +(B-Y) quantity. Therefore, the circuit of figure 4-17 can be used equally well to obtain either the R-Y signal and the –0.51 (R-Y) signal or the B-Y signal and the –0.19 (B-Y) signal. It is necessary only to change the values of the components, particularly resistors R1 and R2, since it is the ratio of these resistors that determines the percentage of the output voltage that is developed across the cathode resistor (R2).

The following explanation applies equally well to either the R-Y or B-Y demodulator; R-Y is used in the example. The theory of operation can be expressed in terms of B-Y by substituting B-Y for R-Y and –0.19 (B-Y) for –0.51 (R-Y).

If the instantaneous voltage of the color subcarrier is negative, as it is applied to the plate circuit in figure 4-17, the plate voltage increases. The polarity of the induced color-subcarrier voltage is indicated in figure 4-17. The increased plate voltage increases the plate current. Current flow is from ground through resistor R2, the tube, the secondary of the transformer, resistor R1 and the B-plus supply to ground. This increased plate current flow increases the voltage drops across resistors R1 and R2. Hence the R-Y

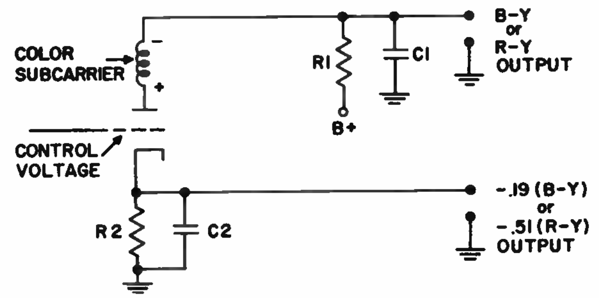


Figure 4-17. Obtaining the G-Y color-difference signal.

output voltage (B-plus voltage minus the voltage drop across R1) decreased while the –0.51 (R-Y) output voltage (voltage drop across R2) increased. The time constant of resistor R2 and capacitor C2 is approximately the same as the time constant of resistor R1 and capacitor C1. Therefore, when the triode is not conducting, the voltage across capacitor C1 is increasing slightly and the voltage across capacitor C2 is decreasing slightly until the next positive peak of the control voltage permits current flow. Then the next R-Y portion of the color subcarrier, simultaneously arriving with the control voltage positive peak, determines the amount of current flow.

The cathode voltage opposes any current change in the circuit. As the input signal voltage goes positive, the current should decrease. However, decreasing current through resistor R2 reduces its voltage drop, thereby effectively increasing the plate voltage which, in turn, increases the plate current. The over-all change is a lesser decrease in plate current; thereby reducing the signal voltages at the plate and cathode. As the input signal voltage goes negative, the current should increase. However, increasing current through resistor R2 increases its voltage drop, thereby effectively decreasing the plate voltage which, in turn, decreases the plate current. The over-all change is a lesser increase in plate current, thereby again reducing the signal voltages at the plate and cathode. Since the signal variations in the cathode circuit are the same as those in the plate circuit, only their amplitudes are reduced. Increased signal voltage, to compensate for the signal voltage across the cathode and the losses due to the cathode voltage, is supplied by the step-up ratio of the color-subcarrier transformer.

Complete Demodulator Circuit

If the values of the plate and cathode resistors for the R-Y and B-Y demodulators are calculated for equal values of the cathode resistors, the cathodes can be returned to ground through a common cathode resistor. In this manner, the –0.19 (B-Y) quantity

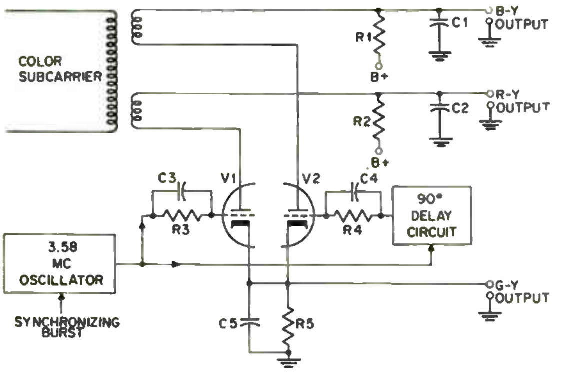


Figure 4-18. Complete demodulator circuit.

and the –0.51 (R-Y) quantity are developed jointly across the common cathode resistor. Since G-Y = –0.19 (B-Y), –0.51 (R-Y), the voltage across the common cathode resistor is the G-Y color-difference signal.

Examination of the complete demodulator in figure 4-18 reveals the R-Y portion and the B-Y portion are each similar to figure 4-17. Each section operates as explained previously except for the affects of the voltage across the common cathode resistor. When the R-Y tube is conducting its plate current is affected by the G-Y signal. The –0.51 (R-Y) portion of the G-Y signal only reduces the amplitude of the R-Y output signal as explained previously; however, the –0.19 (B-Y) portion of the G-Y signal changes the frequency of the output signal since there usually is a frequency difference between the R-Y and B-Y signals. Therefore, the output of the R-Y demodulator is no longer the R-Y signal but (R-Y) –0.19 (B-Y). Similarly, when the B-Y tube is conducting its plate current is affected by the G-Y signal. The –0.19 (B-Y) portion of the G-Y signal only reduces the amplitude of the B-Y output signal; however, the –0.51 (R-Y) portion of the G-Y signal changes the frequency of the output signal for the same reason given above.

Since the output voltages are as stated above and also as illustrated in figure 4-19, it would seem that the color subcarrier is not demodulated at a time coincident with the positive peaks of the R-Y and B-Y suppressed carriers. Figure 4-20 is the vector diagram. The solid red vector denotes that the R-Y signal is demodulated when its suppressed carrier is at 90°. From the output obtained from the R-Y demodulator it would seem that the color subcarrier is being demodulated when the R-Y suppressed carrier is at a relative phase angle of slightly greater than 90°. The apparent phase angle of demodulation is indicated by the dashed red and blue vector.

As noted in figure 4-20, demodulation at this particular phase angle produces one unit of R-Y and 0.19 unit of –(B-Y). Demodulating the color subcarrier when the R-Y suppressed carrier is slightly less than 90° (dashed red vector in figure 4-20) produces one unit of R-Y and 0.19 unit of B-Y. The amount of B-Y signal that is demodulated in the R-Y demodulator is equal to the –(B-Y) signal reflected from the common cathode resistor. The B-Y signal cancels the –(B-Y) signal leaving only the R-Y signal in the plate output circuit of the R-Y demodulator. Demodulating a portion of the B-Y signal in the R-Y demodulator affects the ratio of R-Y and B-Y signals in the cathode circuit since a percentage of the B-Y signal also appears in the cathode circuit which aids the B-Y signal from the B-Y demodulator. Hence, for effective cancellation of unwanted signals in the plate circuit the revised phase angle produces approximately (R-Y) +0.19 (B-Y).

The exact derivation of the revised phase angle is involved and is of very little use to the practical

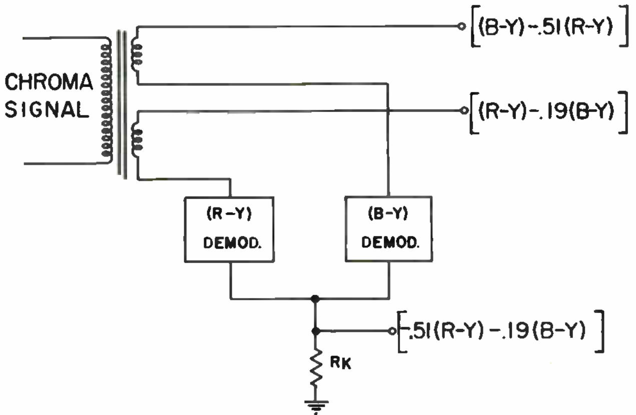


Figure 4-19. Plate output signals indicate the need for a revision of the demodulation phase angles.

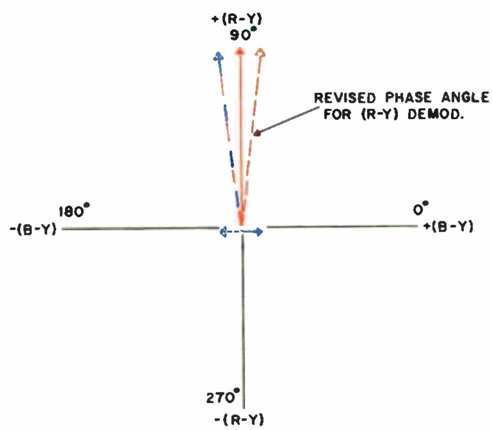


Figure 4-20. Revised phase angle for the R-Y demodulator.

service technician. It is sufficient to note that this phase angle is varied by adjusting the phase of the reference burst which, in turn, controls the phase of the signal applied to the R-Y demodulator. Procedures for obtaining the proper phase angle are explained in Chapter 7.

Figure 4-21 is a vector diagram in which the dashed red and blue vector represents the apparent phase angle of demodulation in the B-Y demodulator. This apparent phase angle, similar to the one in the R-Y demodulator, is caused by a portion of the –(R-Y) signal being reflected from the common cathode circuit into the plate circuit. Shifting the actual phase angle of demodulation from that indicated by the solid blue vector to a phase angle represented by the dashed blue vector eliminates the –(R-Y) signal from the plate circuit of the B-Y demodulator. The proper phase angle is obtained by adjusting the delay time of the reference oscillator signal applied to the B-Y demodulator.

Phasing the R-Y and B-Y Carriers

The R-Y and B-Y carriers are shifted in phase to compensate for the "cross-talk" between the two demodulators caused by the common cathode resistor. The R-Y carrier is delayed and the B-Y carrier is advanced. The exact phase angles are not of importance, only the effects of the phase angle are of importance.

The small vectors associated with the blocks of figure 4-22 denote the approximate phase angles of the signals between the burst amplifier and the demodulators. The burst is applied to the burst amplifier at a relative phase of 180°. (This is a reference phase from which the phase of all signals in this circuit are referenced.) The burst is transformer coupled to the phase detector. This adjustable transformer (master phase control) delays the burst and thereby controls the phase of the 3.58-mc carrier signal from the 3.58-mc oscillator. The inherent 90° phase delay of the phase detector synchronizes the 3.58-mc oscillator at a phase angle 90° delayed from the burst. The carrier is applied to the c-w amplifier and then transformer coupled to the R-Y demodulator. The master phase control is adjusted to delay the burst the same number of degrees that the R-Y carrier must be delayed from its 90° reference phase. It also compensates for any unwanted phase shift of the burst or 3.58-mc carrier signal between the phase detector and R-Y demodulator. The R-Y carrier is applied to a phase delay network. This adjustable network delays the carrier the prescribed number of degrees before it is applied, as the B-Y carrier, to the B-Y demodulator.

Application of the Color-Difference Signal to the Cathode Ray Tube

In the video section it was stated that the luminance signal is not fed equally to all three guns of the cathode ray tube. The blue cathode receives one unit of signal; the green cathode receives 1.2 units of signal; and the red cathode receives 1.5 units of signal. This ratio, as will be recalled, is determined by the respective phosphor efficiencies. As noted in figure 4-23, the color-difference signals are developed across resistors, R1, R2, and R3. The values of these resistors are changed in addition to a turns ratio change in transformer T-1 to provide the proper ratio among the color-difference signals. However, this change does not affect the theory of operation as explained in the preceding text.

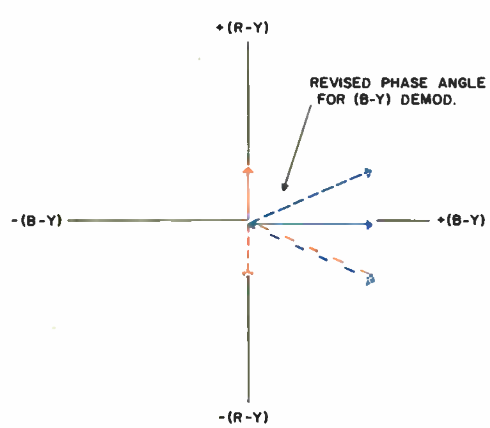


Figure 4-21. Revised phase angle for the B-Y demodulator.

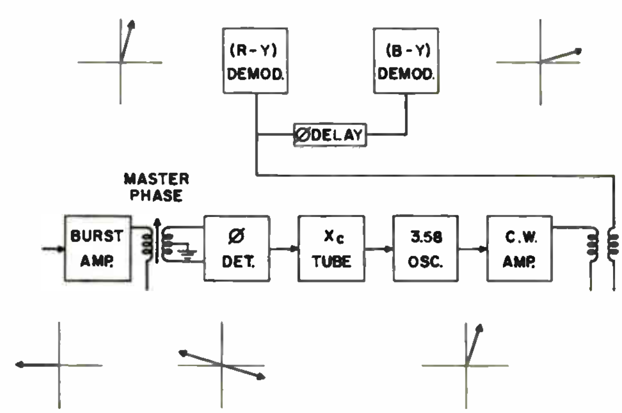


Figure 4-22. Phase angles of the burst and the R-Y and B-Y carriers.

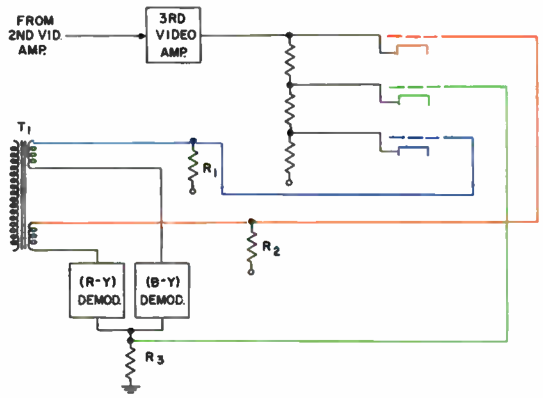


Figure 4-23. Applying the color-difference signals to the cathode ray tube.

SECTION 9.
THE REFERENCE OSCILLATOR SECTION

Frequency and phase stability of the 3.58-mc reference oscillator are of paramount importance. This c-w signal must demodulate the color subcarrier at the precise moment that the required color-difference signals appear in the plate circuit of the demodulator. The gate clamp, burst amplifier, phase detector and reactance tube are the stages required to control the phase and frequency of the 3.58-mc oscillator. The oscillator is crystal controlled to improve frequency stability. The output of the oscillator is amplified in the 3.58-mc amplifier, sometimes called the c-w amplifier, and then applied to the color-separation section. The color-killer stage disables the chroma amplifier when the color television receiver is receiving a monochrome signal. The automatic chroma control circuit adjusts the gain of the second chroma and sound i-f amplifier to compensate for differences in signal level.

Gate Clamp and Burst Amplifier

The gate clamp, figure 4-24, shapes a horizontal output pulse into a positive, pedestal-shaped output wave. This pedestal is directly coupled to the grid of the burst amplifier. The chroma signal also is applied to the burst amplifier. The burst portion of the chroma signal arrives at the grid of the burst amplifier at the same time as the pedestal. The burst amplifier is biased below cutoff. The amplitude of the chroma signal is not large enough to cause plate current; however, the pedestal, whose amplitude is many times greater than the chroma signal, causes the tube to conduct. Since the burst is coincident with the pedestal, the burst, but not the chroma information, appears in the output circuit of the burst amplifier. A small variable capacitor, the hue control, in series with a fixed capacitor from the plate to ground provides a means of shifting the phase of the burst. The separated burst is transformer-coupled to the phase detector.

The pulse for the gate clamp is obtained from a winding on the horizontal output transformer. It would appear that the burst always is coincident with the pedestal. However, if the horizontal hold control is not precisely adjusted, there is a time (phase) difference between the sync pulse and the horizontal output pulse. This time difference is evidenced as the picture is moved to the left or right without losing sync by adjustment of the horizontal hold control. The horizontal hold control seldom is adjusted precisely since it is a customer adjustment. The horizontal oscillator is precisely adjusted only when it will oscillate in a free running condition at the exact horizontal sweep frequency. The time difference between the horizontal sync pulse and the horizontal output pulse also exists between the pedestal and the burst. Therefore, the width of the pedestal is controlled by the potentiometer in the grid circuit of the gate clamp. Proper adjustment of this potentiometer provides a range over which the horizontal hold control can be varied without adversely affecting coincidence of the pedestal and burst.

Phase Detector

The phase detector receives the burst from the burst amplifier and a sampling of the signal from the 3.58-mc reference-signal amplifier. If the 3.58-mc signal is not of the proper phase, the phase detector applies a d-c control voltage to the reactance tube which, in turn, causes the 3.58-mc reference oscillator to operate at the proper phase. If the 3.58-mc oscillator is operating at the correct phase, a control voltage

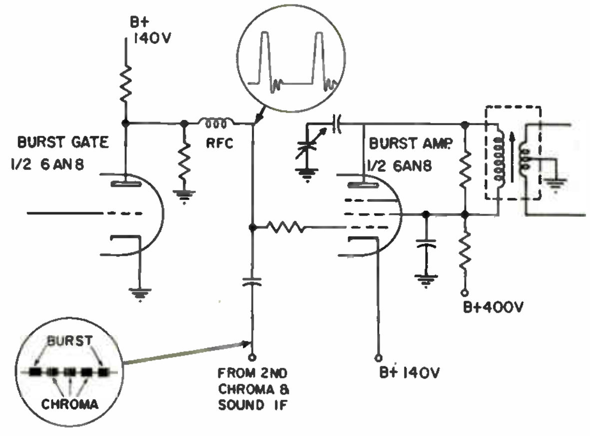


Figure 4-24. The gate clamp and burst amplifier.

is not developed and the 3.58-mc oscillator is not effected.

Before discussing the phase detector action, it is important to note the current paths through the detector circuit. Referring to figure 4-25, the current through tube V1 flows from ground, through the input transformer, tube V1, resistors R1, R3 and R4 and then through capacitor C1 to ground. The current through tube V2 flows from ground, through capacitor C1, resistors R4, R3 and R2, through tube V2 and the input transformer to ground. The current through tube V1 develops a negative voltage across resistor R4 (output circuit) and the current through tube V2 develops a positive voltage across resistor R4. If the diode currents are equal, the voltage drops across resistor R4 cancel. If the currents are not equal, either a positive or negative voltage is developed across resistor R4. Polarity depends on the predominating current. Resistor R4 and capacitor C2 form a filter network. Capacitor C1 has negligible reactance for the 3.58-mc signal, hence it may be considered a short circuit for the signal voltages. Resistor R5 is a balancing resistor to compensate for the automatic chroma control circuit connected to the opposite side of the phase detector.

The burst signal is transformer-coupled to the phase detector, hence the burst signal on the cathode of tube V1 is 180° out-of-phase with the burst signal on the plate of tube V2. The signal from the 3.58-mc amplifier is coupled capacitively to the plate of tube V1 and the cathode of tube V2; hence, these signals are in phase. The above conditions are graphically illustrated in figure 4-26. K1 is the voltage on the cathode of tube V1; P1-K2 is the voltage on the plate of tube V1 and the cathode of tube V2; and P2 is the voltage on the plate of tube V2.

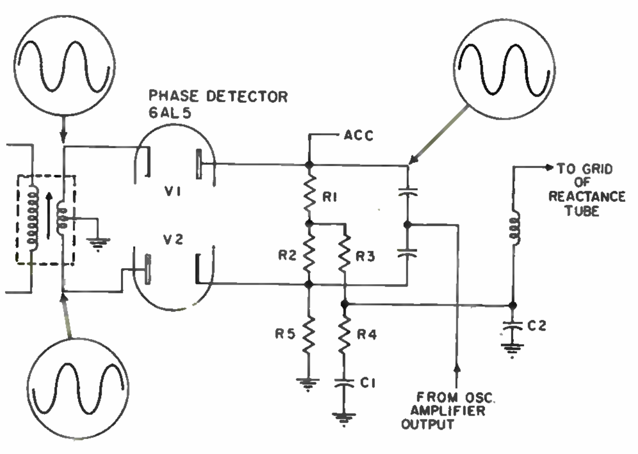


Figure 4-25. Phase detector.

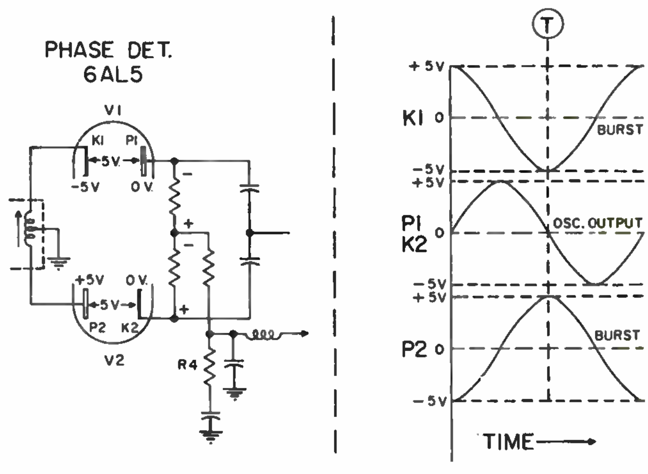


Figure 4-26. Phase detector in balanced condition.

Assume that all signals are ten volts peak-to-peak, as illustrated in figure 4-26. Examination of these waveforms at time T reveals there is five volts across each diode as indicated in the left-hand portion of figure 4-26. This causes the same amount of current to flow through each diode. Since both currents are equal and they flow through resistor R4 in opposite directions, there is no voltage developed across resistor R4. Consequently, there is no d-c voltage applied to the reactance tube and the 3.58-mc oscillator continues to operate at the correct frequency and phase.

The P1-K2 continuous waveform in figure 4-27 represents a frequency slightly lower than 3.58 mc. The P1-K2 dotted waveform represents 3.58 mc. The reactance tube requires a negative voltage to increase the frequency of the 3.58-mc oscillator from the frequency represented by the continuous waveform to the frequency represented by the dotted waveform (3.58 mc). At time T, the voltages on the tube elements are as indicated in the left-hand portion of figure 4-27. It is noted that tube V1 has a potential difference of nine volts and tube V2 has a potential difference of one volt. Therefore, the more heavily conducting tube, tube V1, develops a negative voltage drop across resistor R4. This negative voltage applied to the reactance tube increases the frequency of the 3.58-mc oscillator to 3.58 mc. As the output frequency approaches 3.58 mc, the negative d-c voltage decreases until it reaches zero when the output frequency is 3.58 mc.

If the frequency of the output signal from the 3.58-mc oscillator is higher than 3.58 mc, the reactance tube requires a positive voltage to decrease the output

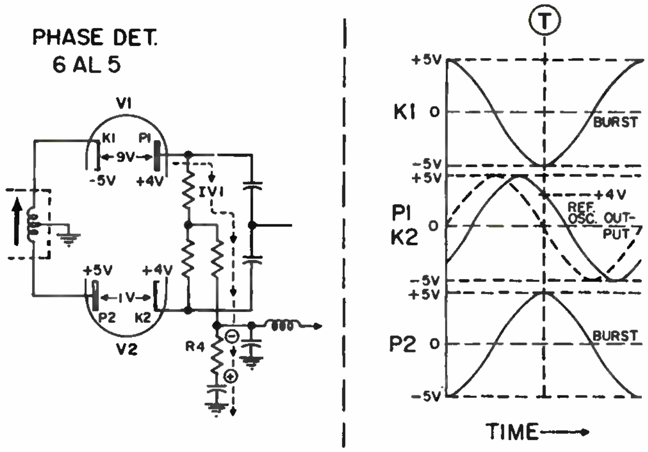


Figure 4-27. Phase detector in unbalanced condition.

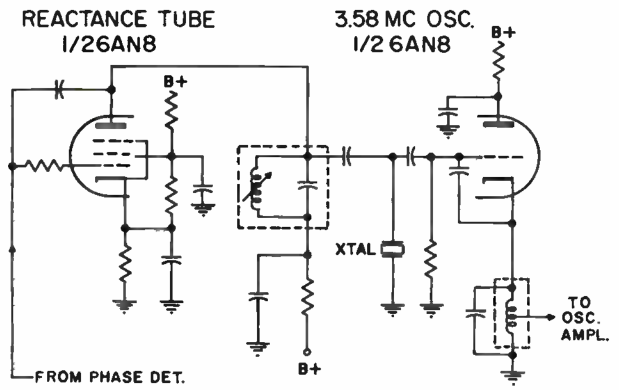


Figure 4-28. Reactance tube and 3.58-mc oscillator.

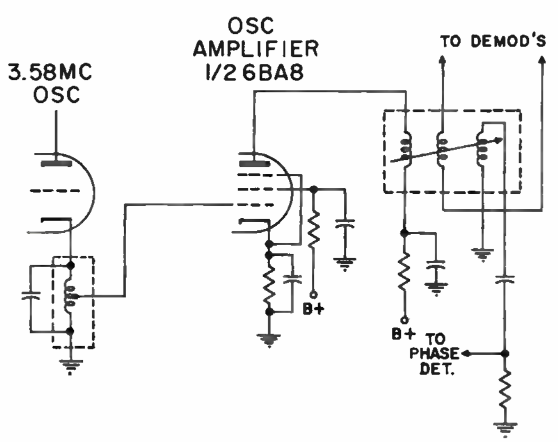


Figure 4-29. 3.58-mc amplifier.

frequency. A higher frequency might be portrayed in figure 4-27 as having an instantaneous voltage of minus four volts at time T. In this case, the voltages of P1 and K2 in figure 4-27 would both be minus four volts. The potential difference across tube V1 now would be one volt and the potential difference across tube V2 now would be nine volts. This time, tube V2, conducting more heavily than tube V1, develops a positive voltage drop across resistor R4. This positive voltage applied to the reactance tube decreases the frequency of the 3.58-mc oscillator to 3.58 mc. As the output frequency approaches 3.58 mc, the positive d-c voltage decreases until it reaches zero when the output frequency is 3.58 mc.

Reactance Tube and 3.58-mc Oscillator

The reactance tube, as shown in figure 4-28, is connected across the crystal oscillator tank circuit. The reactance circuit presents a capacitive reactance across the oscillator tank circuit. If the grid voltage of the reactance tube is varied, its plate current also will vary. Since the 90° phase relationship between the plate current and the oscillator signal voltage across the plate forms the apparent reactance effect, the reactance also will vary. A positive signal on the grid of the reactance tube increases its plate current and lowers the effective reactance.

This is the same as increasing the capacity across the oscillator tank circuit; hence, the oscillator frequency is decreased. If the reactance tube grid swings in a negative direction, there is a decrease in plate current and an increase in reactance. The capacity across the oscillator tank circuit is reduced and the oscillator frequency is increased.

The 3.58-mc signal from the cathode circuit of the oscillator is applied to the 3.58-mc amplifier.

3.58-mc Amplifier

The function of this stage is to amplify the 3.58-mc signal for application to the demodulators and the phase detector. This stage also commonly is known as the c-w amplifier and the 3.58-mc reference oscillator also is referred to as the c-w oscillator. The output signal from the oscillator cathode circuit is applied to the amplifier control grid as shown in figure 4-29. This stage employs the pentode section of a 6BA8 tube. The output signal is developed across the primary winding of the transformer and inductively coupled to the secondary and tertiary windings. The secondary winding applies the signal to the demodulator circuit. The tertiary winding supplies the sampling voltage for the phase detector.

Automatic Chroma Control

The acc circuit, figure 4-30, utilizes the voltage developed on the negative voltage-forming side of the phase detector. During normal operation of the 3.58-mc oscillator (in-phase condition) conduction through the diode is governed by the amplitude of the burst applied to the cathode, which, in turn, is proportional to signal strength. Thus, the amount of negative voltage developed across the balancing resistor is proportional to the signal strength. This negative voltage is fed through a resistor divider network and filter to the grid of the second chroma and sound i-f amplifier. When the signal strength decreases, the acc voltage becomes less negative and increases the gain of the second chroma and sound i-f amplifier. The B-plus voltage in the resistor divider network provides a small positive delay voltage to lower acc action during weak signal conditions.

Color-Killer Stage

The color-killer stage is designed to cut off the chroma amplifier when the burst signal is not transmitted, as during black-and-white programs. The color-killer stage utilizes the same control voltage as the acc circuit previously discussed. The negative voltage from the phase detector is present only when burst signal is being received. This voltage is applied, through a filter, to the grid of the color-killer stage. As illustrated in figure 4-31, the grid is returned to B-plus through a high resistance. When the burst is missing, the B-plus voltage on the grid permits tube conduction. The plate receives its voltage from a winding on the horizontal output transformer; hence, the color-killer tube conducts only when the horizontal pulse is on the plate and the negative voltage from the phase detector is not applied to the grid.

During conduction, current flow through the plate resistor produces a large negative voltage which is fed, through a filter, to the grid of the chroma amplifier. This negative voltage drives the chroma amplifier into cut off. When the burst is present in the transmitted signal, a negative voltage from the phase detector is applied to the grid of the color-killer tube. This negative voltage drives the color-killer tube into cut off, thus reducing its negative output voltage. The grid of the chroma amplifier returns to its normal bias and the stage amplifies the received chroma signal.

SECTION 10. THE DEFLECTION SECTION

The deflection section provides horizontal and vertical sweep voltages for deflection of the electron

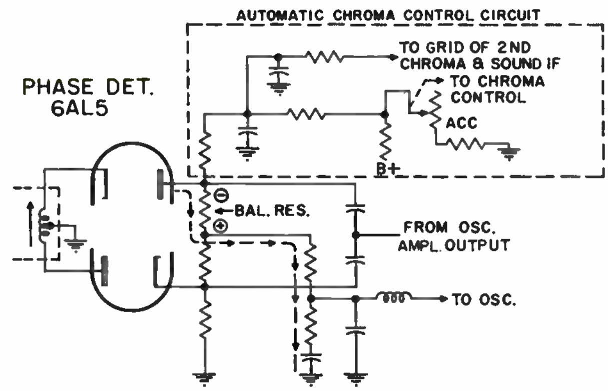


Figure 4-30. Automatic chroma control.

beams of the cathode ray tube. It also provides voltages for convergence of the electron beams. Convergence voltages are discussed in the next chapter. The horizontal and vertical sync pulses from the sync separator in the video section are applied to the phase splitter. The vertical sync pulses synchronize the vertical oscillator which applies its signal, through the vertical output stage, to the vertical deflection coils. The horizontal sync pulses synchronize the horizontal oscillator. Synchronism is accomplished by the phase comparer. The signal from the horizontal oscillator is amplified in the horizontal output stage and then applied to the horizontal deflection coils. High voltage and B-plus boost circuits also are incorporated in the horizontal output circuit.

Phase Splitter

The primary purpose of the phase splitter is to provide sync pulses of the proper polarity for application to the vertical oscillator and the phase comparer. The phase comparer receives the sync pulses from the sync separator. As shown in figure 4-32, this stage uses the triode section of a 6BJ8 tube. Positive

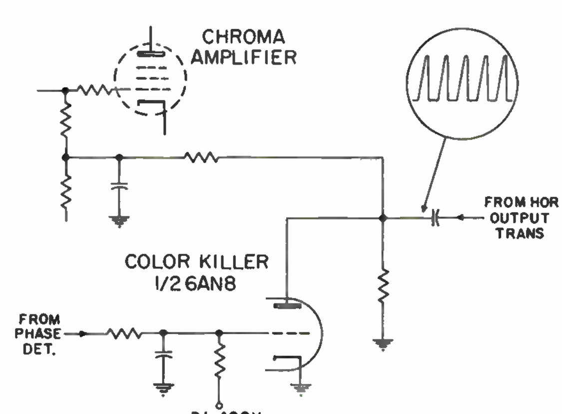


Figure 4-31. Color-killer stage.

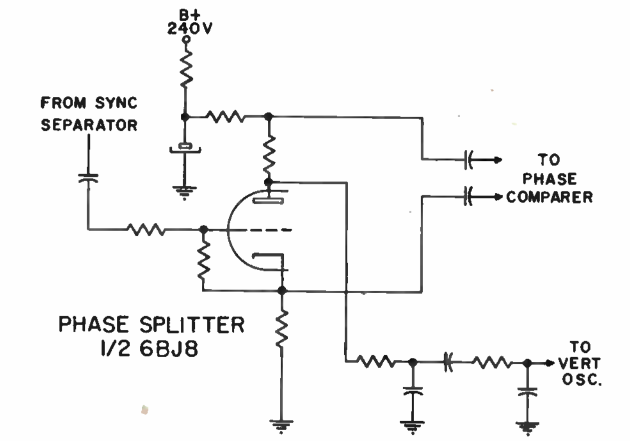


Figure 4-32. Phase splitter.

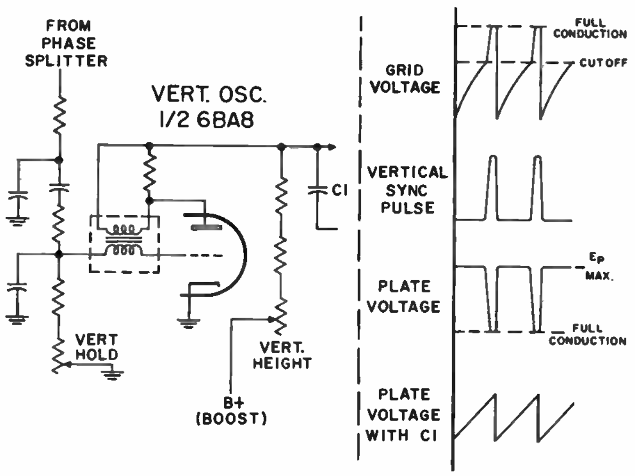


Figure 4-33. Vertical oscillator.

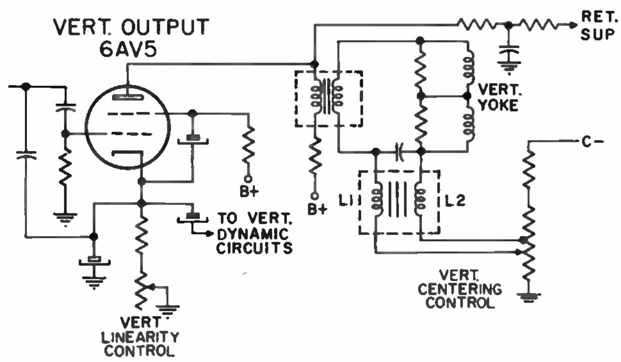


Figure 4-34. Vertical output stage.

horizontal sync pulses from the plate and negative horizontal sync pulses from the cathode are applied to the phase comparer. Positive vertical sync pulses are applied from the plate, through an integrator network, to the vertical oscillator.

Vertical Oscillator

The vertical oscillator, a blocking oscillator illustrated in figure 4-33, provides a synchronized sawtoothed wave which is applied through the vertical output stage to the vertical deflection coils. The vertical oscillator tube, the triode section of a 6BA8 tube, rapidly changes from cut off to saturation and then returns to cut off at controlled time intervals. The vertical sync pulses, applied to the grid, trigger the blocking oscillator thereby synchronizing the oscillations to the vertical sync pulse frequency. The grid and plate voltage waveforms are illustrated in figure 4-33. Capacitor C1, slowly charging to B-plus boost voltage through the vertical height control and associated resistors, provides a sawtoothed output voltage. The output voltage is applied to the vertical output stage.

Vertical Output Circuit

The vertical output circuit, as illustrated in figure 4-34, employs a 6AV5 tube. This stage amplifies the vertical sweep voltage for application, through the vertical output transformer, to the vertical deflection coils. The potentiometer in the cathode circuit, the linearity control, controls the bias of the tube such that this stage provides an output signal that vertically sweeps the electron beams of the cathode ray tube at a uniform rate. A d-c centering voltage from a voltage divider network is applied to the vertical deflection coils. This voltage is applied through isolating inductors L1 and L2. The amount of d-c voltage applied to the deflection coils is determined by the position of the vertical centering control.

A portion of the signal from the plate circuit is applied, through a filter network, to the grid circuit of the second video amplifier. This signal, together with the vertical blanking pulses, drives the cathode ray tube below cut off, thereby eliminating the possibility of the vertical retrace sweep being observed on the cathode ray tube. A portion of the signal from the cathode is applied to the vertical dynamic convergence circuits. The vertical dynamic convergence circuits are discussed in the next chapter.

Horizontal Phase Comparer

The horizontal phase comparer, as illustrated in figure 4-35, uses both diode sections of a 6BJ8. Positive horizontal sync pulses from the phase splitter are applied to the plate of one diode and negative horizontal sync pulses from the phase splitter are applied to the cathode of the other diode. The remaining plate and cathode are connected to ground through a common load resistor. The d-c voltage developed across this resistor is applied to the horizontal oscillator as a control voltage. A portion of the horizontal oscillator signal, from the screen grid of the oscillator pentode section, is applied to the common plate and cathode connection. When the oscillator signal is synchronized with the sync pulses, no control voltage is developed across the common load resistor. If the oscillator is not synchronized with the sync pulses, a control voltage is developed across the common load resistor. This control voltage applied to the horizontal oscillator, changes the frequency of the horizontal oscillator to bring it into synchronism with the sync pulses.

As shown in figure 4-35, the plate current of tube V1 flows through resistor R1 in one direction while the plate current of tube V2 flows through resistor R1 in the opposite direction. Hence, when the diode currents are equal, there is no voltage drop across resistor R1. Unequal diode currents produce a voltage drop. The polarity and magnitude depend respectively on the predominating current and the difference between the current values. Therefore, if the current through tube V1 is greater than the current through tube V2, there is a positive voltage drop across resistor R1. The amount of voltage drop is proportional to the difference between the current through tube V1 and the current through tube V2. Similarly, if the current through tube V2 is greater than the current through tube V1, there is a negative voltage drop across resistor R1. The amount of voltage drop is proportional to the difference between the current through tube V1 and the current through tube V2.

The amplitudes of the positive and negative sync pulses applied to the diodes are equal. Therefore, when the signal from the oscillator is zero, the potential difference across each diode is equal; the diode currents are equal; and there is no voltage drop across resistor R1. This is illustrated in figure 4-36.

Assume the peak value of each sync pulse is two volts and the signals are phased as shown in the graphic illustration of figure 4-36. The plate of tube V1 is at 2 volts and its cathode is at zero volts. The cathode of tube V2 is at -2 volts and its plate is at zero volts. Hence, there is two volts across each diode and consequently, the same amount of current flows through each diode which results in zero volts across resistor R1.

At sync time, if the oscillator signal is advanced

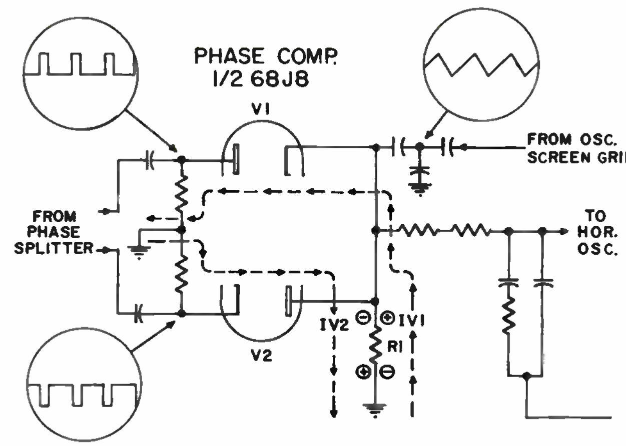


Figure 4-35. Horizontal phase comparer.

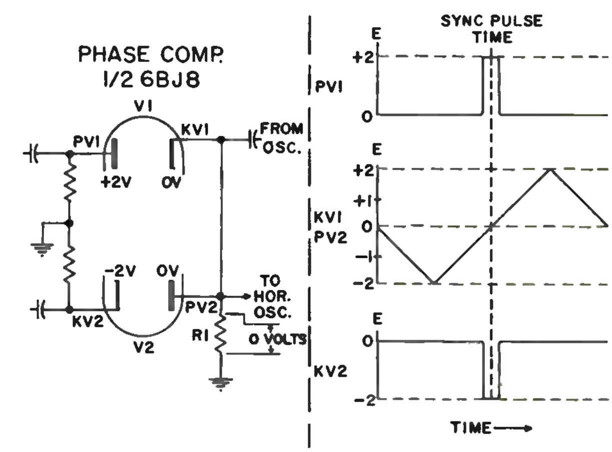


Figure 4-36. Oscillator frequency in synchronism with sync pulses.

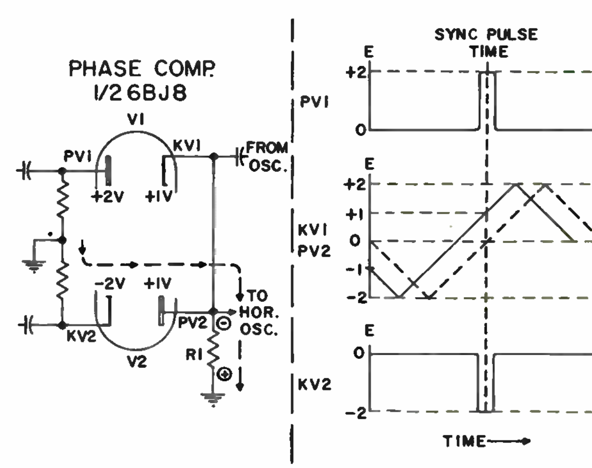


Figure 4-37. Oscillator frequency higher than sync pulse frequency.

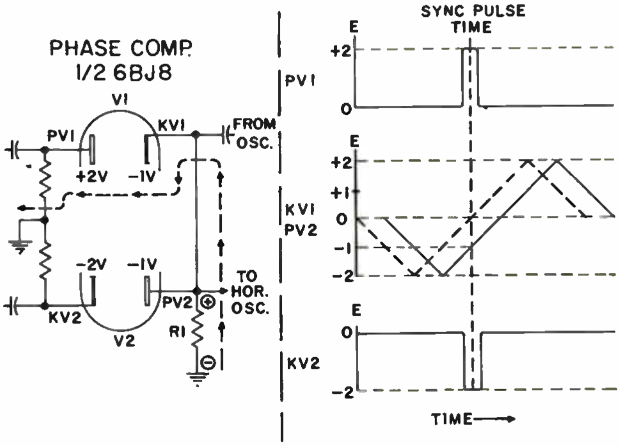


Figure 4-38. Oscillator frequency lower than sync pulse frequency.

as illustrated by the solid sawtoothed waveform in figure 4-37, one volt is applied to the cathode of tube V1 and the plate of tube V2. The potential difference across tube V1 is one volt and the potential difference across tube V2 is three volts. The current flow through tube V2 is greater than that through tube V1; thus, a negative potential is developed across resistor R1. This negative voltage, applied to the horizontal oscillator, decreases the oscillator frequency until the oscillator again is synchronized with the sync pulses as illustrated by the dotted sawtoothed waveform.

At sync time, if the oscillator signal is delayed as illustrated by the solid sawtoothed waveform in figure 4-38, a negative one volt is applied to the cathode of tube V1 and the plate of tube V2. The potential difference across tube V1 now is three volts while the potential difference across tube V2 is one volt. The current flow through tube V1 is greater than the current flow through tube V2; thus, a positive potential is developed across resistor R1. This positive voltage, applied to the horizontal oscillator, increases the oscillator frequency until the oscillator again is synchronized with the sync pulses as illustrated by the dotted sawtoothed waveform.

Horizontal Oscillator

The horizontal oscillator circuit, as illustrated in figure 4-39, employs the triode and pentode sections of a 6BA8 tube. Both sections form a cathode coupled multivibrator. Each tube alternately is cut off and driven to saturation. Circuit components are selected such that the pentode is cut off for a much longer time than it is in conduction. This would produce a nonsymmetrical rectangular waveform. Due to the resistor-capacitor combination in the pentode plate circuit, the output waveform is as illustrated in figure 4-39. The fixed bias of the pentode section is determined by the horizontal hold control. This control, a customer adjustment, controls the frequency of the oscillator within a limited range.

The horizontal hold control might be termed a vernier control for the frequency control in the same circuit. The frequency control determines the charge and discharge times of the coupling capacitor between the triode plate and the pentode grid; hence, this control also determines the oscillator frequency. However, the frequency control, a service adjustment, controls the frequency over a greater range than the horizontal hold control. The horizontal hold control normally is positioned at the center of its range before the frequency control is adjusted. Adjusting the controls in this manner permits the customer to vary the oscillator frequency slightly above and below the horizontal sweep frequency to compensate for slight circuit variations.

The sampling of the oscillator frequency required for the phase comparer is obtained from the pentode screen grid. A d-c signal from the phase comparer is applied to the triode grid. A positive d-c signal causes the triode to conduct before the positive voltage on the pentode grid reduces sufficiently to allow triode conduction; hence the frequency of the oscillator is increased. A negative d-c signal increases the triode cut-off time from that allowed by the decreasing positive voltage on the pentode grid; hence, the frequency of the oscillator is decreased.

The drive control in the pentode plate circuit controls the rate of increase (RC time constant) of the output voltage, hence determines the peak value of the output signal voltage that is applied to the hori-

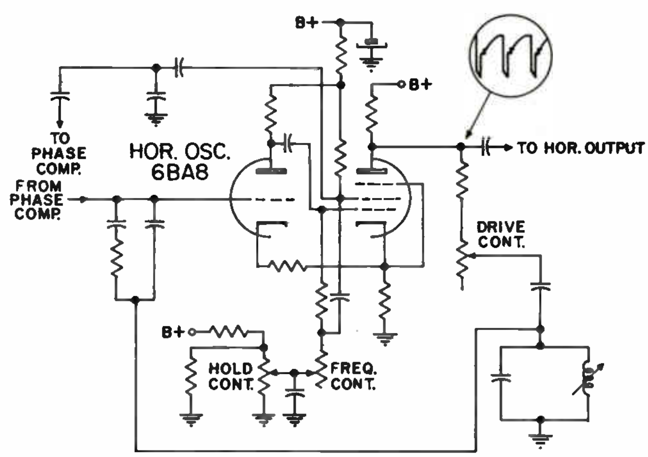


Figure 4-39. The horizontal oscillator.

zontal output tube. The horizontal ringing circuit, also in the pentode plate circuit, is tuned to the horizontal sweep frequency. During the transition period, this tuned circuit is shock excited and applies a sinewave, at horizontal oscillator frequency, to the triode grid. The phase of this sinewave is such to aid the normal action of the multivibrator during the transition period, thereby increasing the stability of the horizontal oscillator.

Horizontal Output Circuit

The horizontal output tube, a 6CL5 tube, amplifies the signal from the horizontal oscillator. As shown in figure 4-40, this signal (sweep voltage) is developed across a portion of the horizontal output transformer and the deflection coils. The sweep voltage across the deflection coils sweeps the electron beams horizontally across the face of the picture tube. The voltage across the portion of the horizontal output transformer causes an increased voltage to appear across the complete transformer winding. Due to the shape of the horizontal sweep voltage, a rapid collapse of current through the transformer and deflection coils develops a transient pulse which is used for development of high voltage. This rapid change of current also produces a train of damped oscillations which would be detrimental to the picture. A damper tube, a 6M3 tube, removes these oscillations. A B-plus boost voltage is obtained from the rectified current of the damper tube. A horizontal centering control and a width control also are incorporated in the horizontal output circuit. Windings on the horizontal output transformer provide signals for the gated agc amplifier, and burst gate clamp, the color-killer stage and the convergence circuits.

Figure 4-41 is the high-voltage rectifier section of the horizontal output circuit. The focus voltage, approximately 6000 volts, is rectified by a 3A2 tube. The voltage from the focus rectifier is developed across a bleeder network to B-plus. A portion of this rectified voltage across the focus potentiometer is applied to the focus anodes of the picture tube. Voltages for the red, green and blue G2 grids also are obtained from this bleeder. The plate of the high-voltage rectifier, a 3A2 tube, is connected to the focus rectifier cathode. During sweep time, the capacitor in the cathode circuit of this high-voltage rectifier is charged to approximately 6000 volts. During flyback or retrace time, approximately 19,000 volts is developed across the output transformer. These two voltages, aiding each other, are applied, through the output high-voltage rectifier, a 3A3 tube, to the picture tube anode. A 6BK4 tube regulates the high voltage before application to the picture tube.

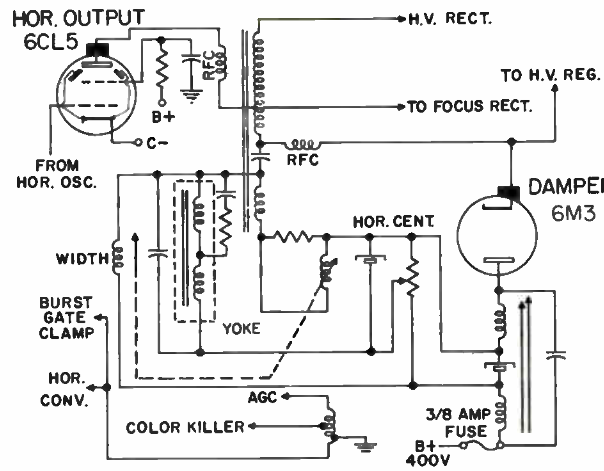


Figure 4-40. Horizontal output circuit.

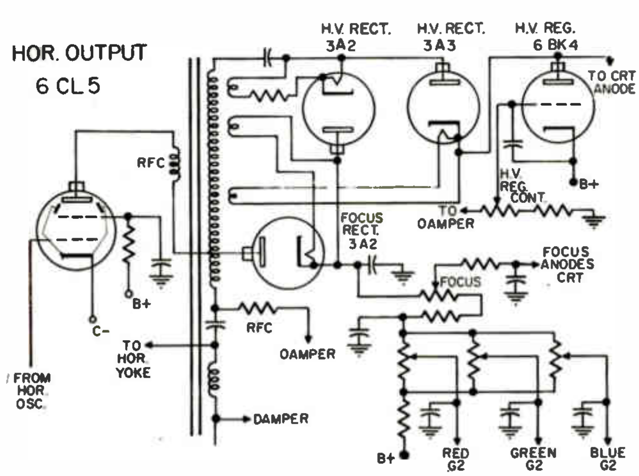


Figure 4-41. High-voltage rectifier section.

5. COLORED CATHODE TUBE ASSEMBLY AND ASSOCIATED CIRCUITS

SECTION 1. MONOCHROME CATHODE RAY TUBE OPERATION

THE ESSENTIAL FEATURES of the monochrome tube, as illustrated in figure 5-1, are an electron gun assembly and a phosphor screen. The arrangement and nomenclature of the electron gun assembly are illustrated in figure 5-2. The cathode of the electron gun assembly, heated by the filament, emits a stream of electrons which are directed toward the phosphor screen. The potential difference between the cathode and the control grid determines the amount of electrons that strike the phosphor screen, and this in turn controls the brightness produced by the screen. The electrons, passing through the screen grid, are accelerated slightly before being subjected to the focus element. The focus element directs the paths of the electrons so that they are concentrated on a small spot when they strike the phosphor screen. The electrons then pass through the accelerating anode which increases their velocity thus providing sufficient energy for the electrons to fully illuminate the phosphor screen.

The position of the electron beam on the screen is controlled by the externally mounted deflection yoke. The location of the yoke is illustrated in figure 5-1. It contains vertical and horizontal deflection windings. As current flows through these windings, corresponding magnetic fields are produced within the neck of the tube. The electron beam, passing through these magnetic fields, is deflected in the predetermined scanning pattern required to assemble the signal components of the televised scene which are applied between the cathode and the control grid.

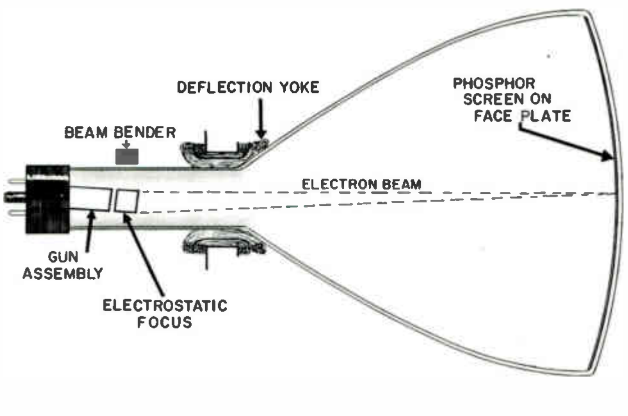


Figure 5-1. Monochrome cathode ray tube.

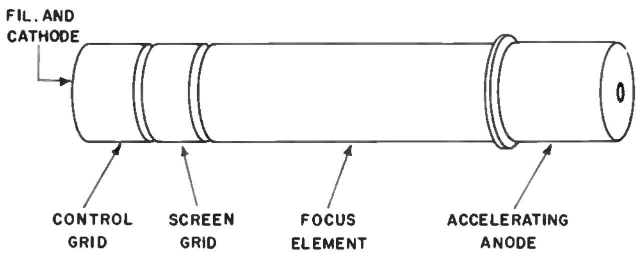


Figure 5-2. Electron gun assembly.

SECTION 2. THE TRI-GUN COLOR CATHODE RAY TUBE

Color Electron Gun Assembly

The tri-color cathode ray tube contains three electron gun assemblies as shown in figure 5-3. Each electron gun assembly is similar to the electron gun assembly in a monochrome tube. The three electron gun assemblies are mounted together, forming a triad, as illustrated in figure 5-4. Since the radial axis of each gun is spaced 120 degrees from the others, the gun centers form the corners of an equilateral triangle. When viewing the cathode ray tube from the base end, the blue gun is at the top. The electron guns are not mounted parallel to each other or to the axis of the tube. The forward end of each gun is tilted, slightly more than one degree, toward the axis of the tube as illustrated in figure 5-5. This produces better static convergence of the three electron beams, independent of line voltage or B-plus fluctuations.

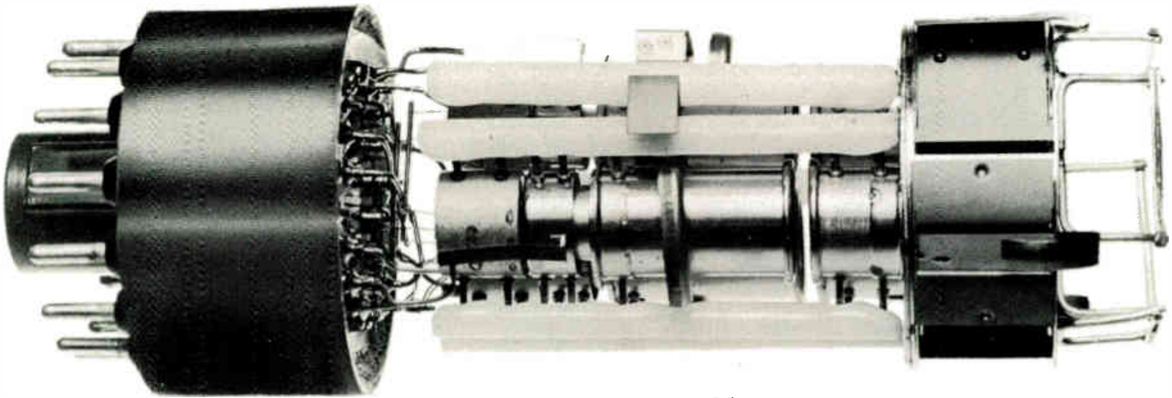


Figure 5-3. Tri-gun assembly.

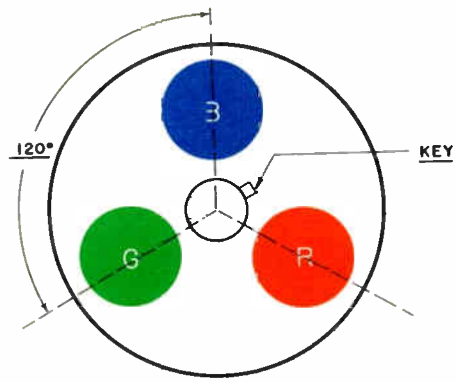


Figure 5-4. Relative position of electron guns.

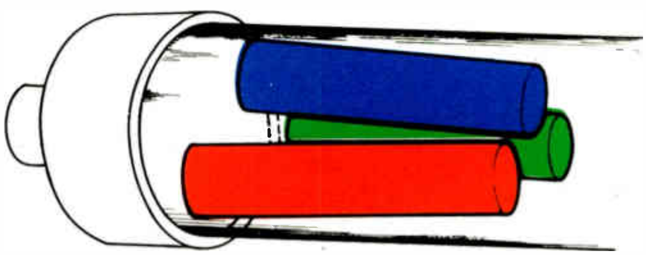


Figure 5-5. Axial tilt of electron guns.

The Shadow Mask and Phosphor Dot Screen Assembly

The screen of the tri-gun color cathode ray tube is likewise different from that of a monochrome cathode ray tube. Instead of a single phosphor application to the face plate, three different phosphors, capable of emitting three different colors of light, are applied in the form of dots. Directly behind the face plate, at a fixed distance, a shadow mask is mounted. This mask contains a multitude of tiny holes through which the electron streams must pass to strike the phosphors on the face plate. The location of the components which make up the screen assembly of the tri-gun color cathode ray tube can be seen in the cutaway illustration of figure 5-6.

The face plate is covered with small dots of phosphor material. Each dot is nearly tangent to the adjacent dots which surround it. The dots are 16 mils in diameter, spaced 29 mils apart, center to center, as illustrated in figure 5-7. Each group of three adjacent dots form the apexes of an equilateral triangle, and is referred to as a triad. Appropriate

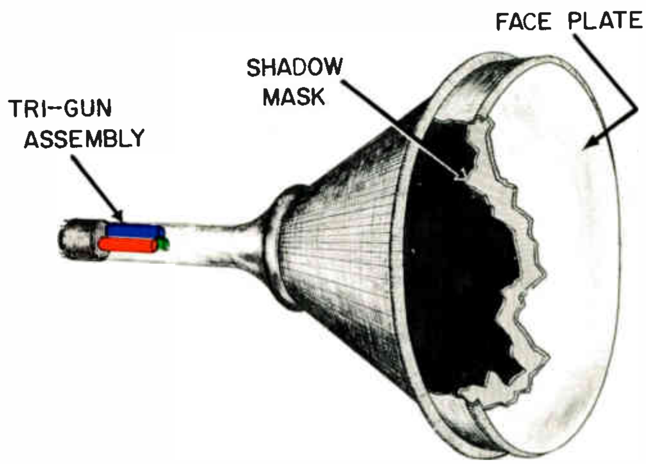


Figure 5-6. Location of shadow mask to face plate.

mixtures of the light output of these three phosphors can produce all the hues and saturations necessary to meet the F.C.C. requirements for color television.

Function of the Shadow Mask

The three electron beams must be so controlled that the electron beam from each gun strikes the phosphor dots of only one color. The shadow mask

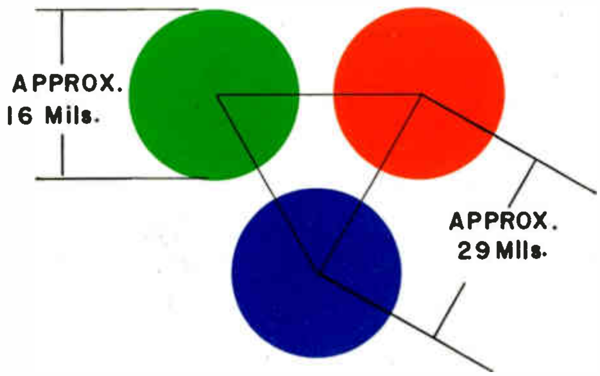


Figure 5-7. Phosphor dot triad.

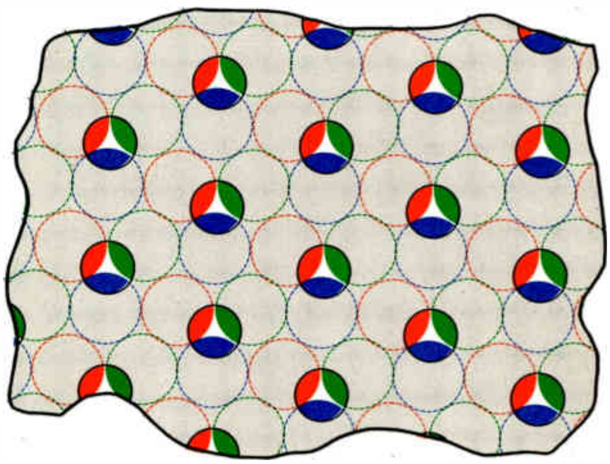


Figure 5-8. Relative placement of shadow mask to phosphor screen.

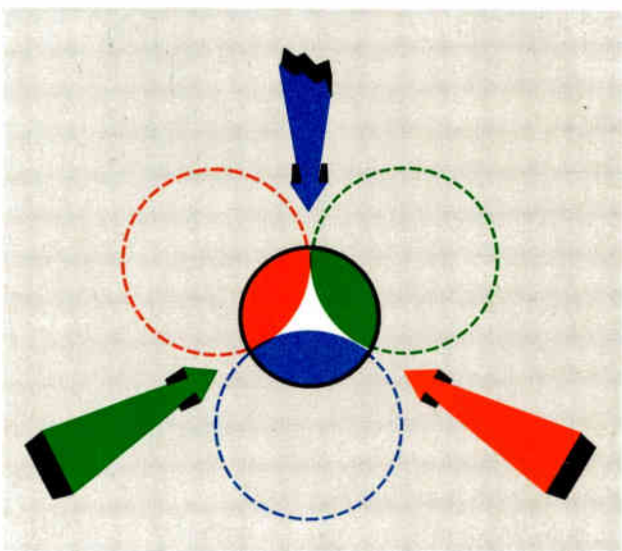


Figure 5-9. Principle of shadow mask operation.

accomplishes this purpose. The shadow mask is perforated with holes 12 mils in diameter, and is precisely positioned in relation to the phosphor dot plate. To illustrate this relationship, a segment of both pieces is shown in figure 5-8 Note that the center of each aperture in the shadow mask is equidistant from the center of each phosphor dot in the color triad. Thus, a small amount of each color dot is visible through the mask openings. This is the case when the angle of vision is perpendicular to the shadow mask and the face plate. Deviation from this position results in more of one color dot being visible than the others. Figure 5-9 shows one aperture in the shadow mask directly over one triad of phosphor dots on the face plate. If the angle of incidence of the eye to the mask and face plate assembly is changed to coincide with one of the angles indicated by the arrows, the observer would be able to see only the red, blue or green phosphor dot respectively. The other two of the three dots would be obscured by the body of the shadow mask. This is the principle upon which the tri-gun color cathode ray tube functions.

If the observer in the above discussion is replaced with the three electron beams, arranged respectively at the same angles of incidence, the result is illumination of each phosphor dot by its respective electron gun. Hence, the beam coming from one electron gun can strike only the red phosphor, the beam coming from a second electron gun strikes only the blue phosphor, and the beam coming from the third electron gun strikes only the green phosphor. The shadow mask is arranged with respect to the face plate so that each of the three electron guns in the tri-color cathode ray tube illuminates only one of the phosphors.

Under normal levels of beam current, the electron beam actually encompasses more than one aperture of the shadow mask. The beam may, in fact, be large enough to cover as many as seven apertures in the mask at one time. The electrons which cannot pass through the mask are drained off as shadow-mask current. The angle at which the beams pass through the shadow mask is such that the electrons illuminate only their respective phosphor dots on the face plate as shown in figure 5-10. Note that the shadow-mask apertures are smaller in diameter than the phosphor dots on the face plate. The diameter of the electron beams after passing through the shadow mask is less than that of the respective phosphor dots. This reduces the possibility of the individual electron beams overlapping and illuminating adjacent phosphor dots of different colors.

SECTION 3.
CONTROL OF ELECTRON BEAMS

In addition to the deflection yoke and electrostatic focus element that are common to both a monochrome and color cathode ray tube for electron beam control, the color tube requires other beam controlling devices in order to obtain color purity and convergence over the entire screen of the color cathode ray tube. An explanation of the additional electron beam control requirements and the methods employed to apply these controls are presented in this section.

Color Purity

The position of all three electron beams, as they approach the shadow mask, is of prime importance. If, as shown in figure 5-11, the electron beam paths are too low and to the left, passage through the mask apertures results in color impurity, even though the electron beams are in proper relation to each other. The phosphor dots illuminated will be those above and to the right of the correct phosphor dots. Some means must therefore be provided to assure passage through the shadow mask at the proper angle and position. This must occur before sweep deflection is applied to the electron beams.

Magnetic theory states that an electron stream, when passing through a magnetic field which is perpendicular to the path of the electron stream, is deflected at right angles to the magnetic field. Simultaneous deflection of the electron beams in a direction to obtain color purity is thereby possible. The correction field must be variable not only for direction, but also for magnitude.

The color purity magnet assembly, as illustrated in figure 5-12, is the device used to produce this field. The assembly consists of two permanently magnetized rings, figure 5-12A and B, so mounted together that independent rotation of each ring is possible, figure 5-12C. Two tabs on each ring serve as leverage points and identify the north and south poles of each of the magnetic fields. The color purity magnet assembly is placed on the neck of the cathode ray tube between the convergence assemblies and the blue beam lateral assembly. Proper beam control is obtained before sweep deflection is applied. When the similarly colored tabs of each ring are opposite each other in the assembly, the addition of the magnetic fields results in maximum electron beam displacement. When the colored tabs of each ring are together in the assembly, cancellation of the magnetic fields results in no electron beam displacement. By varying the degree of ring tab separation, as illustrated in figure 5-13, the field can be adjusted

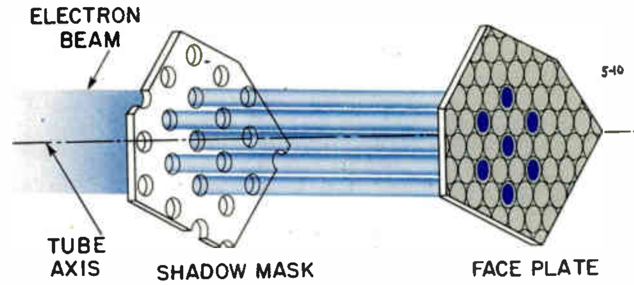


Figure 5-10. Paths of electron beams through shadow mask.

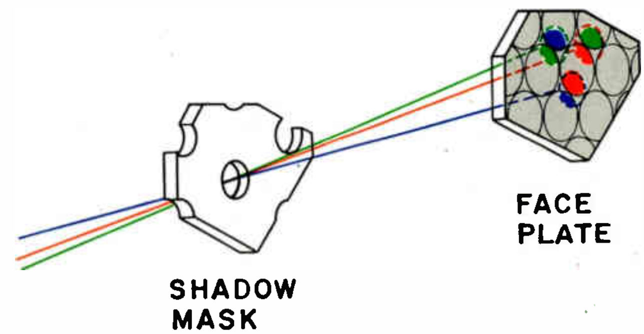


Figure 5-11. Cause of color impurity.

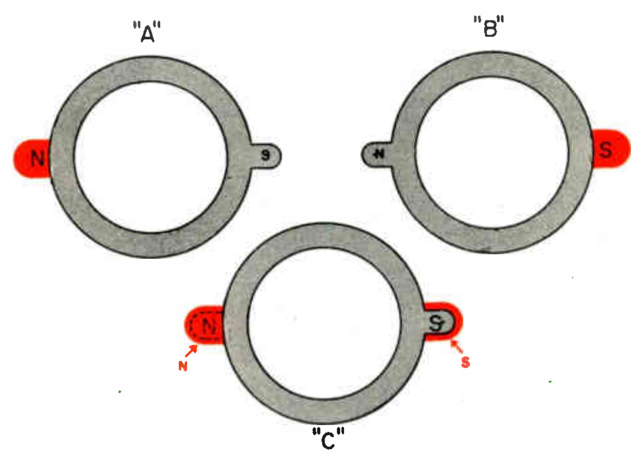


Figure 5-12. Color purity magnet assembly.

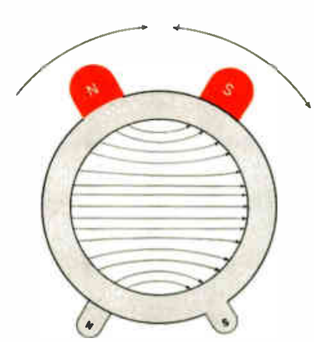


Figure 5-13. Adjustment of color purity magnet assembly.

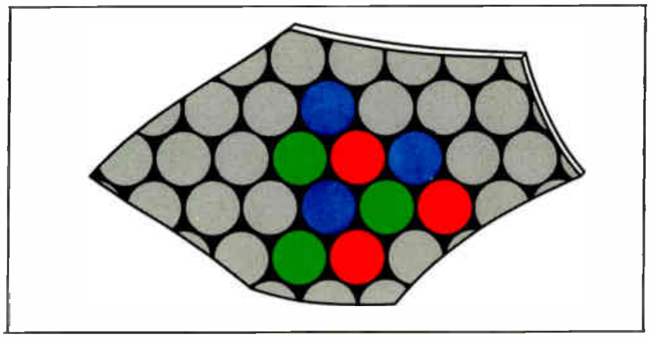


Figure 5-14. Convergence of the three electron beams.

from a no-field condition to maximum effectiveness. Further, by rotation of the entire assembly, the field can be adjusted through 360 degrees.

Static Convergence

When the electron beams, coming from the three guns, are in position to pass through the same group of apertures in the shadow mask and illuminate the respective dot triads, the beams are said to be properly converged. The term "convergence", then, deals with the proper positioning of the electron beams in relation to the shadow mask and face plate assembly, as illustrated in figure 5-14. If the intensity of all three electron beams produces equal units of illumination from each phosphor dot, the eye will view the illuminated area of the screen as white light, figure 5-15.

Mention was made in section two of this chapter that the three electron guns are tilted at a slight angle to provide better convergence of the electron beams near the center of the screen. However, due to manufacturing tolerances, perfect convergence is difficult to achieve. Hence, some means for adjusting the individual position of each electron beam becomes necessary so that convergence can be obtained. This is done by introducing magnetic fields into pole pieces mounted within the neck of the cathode ray tube. These pole pieces, also called convergence pole pieces, are mounted at the front end of each electron gun assembly. The two pole pieces in each set are parallel to each other and to the radius of the cathode ray tube which passes between them. The arrangement is illustrated in figure 5-16.

The required magnetic field is produced between the pole pieces by placing the poles of a magnet on the outside of the neck of the tube, adjacent to the internal pole pieces. Figure 5-17 illustrates a convergence magnet assembly. The magnets in each of the external convergence assemblies are cylindrical in shape, being polarized so that half of the cylinder, when viewed in cross-section is north and the other half is south. If the magnet is adjusted so that both north and south poles provide equal fields at the same time in a leg of the assembly, no magnetic force will be applied to the electron gun pole pieces due to cancellation of magnetic fields in the assembly. But, if the magnet is adjusted 90 degrees either way, full magnetic force will be applied to the electron gun pole pieces.

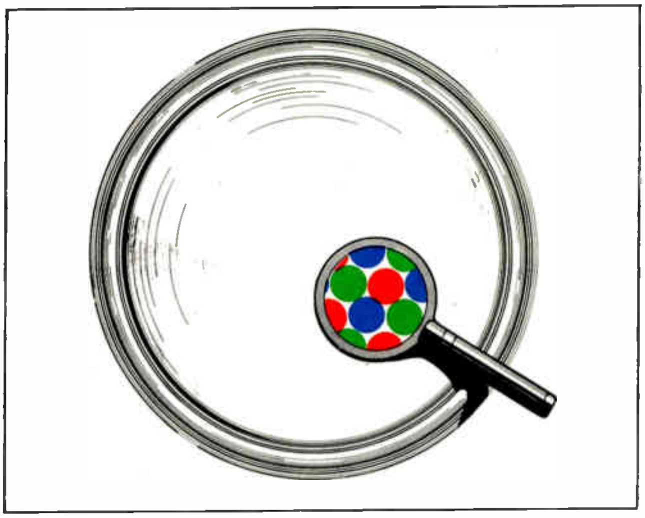


Figure 5-15. Magnified area of phosphor screen.

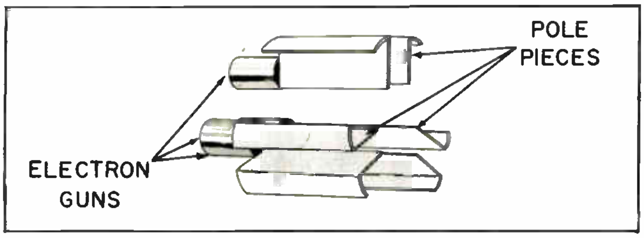


Figure 5-16. Convergence pole pieces.

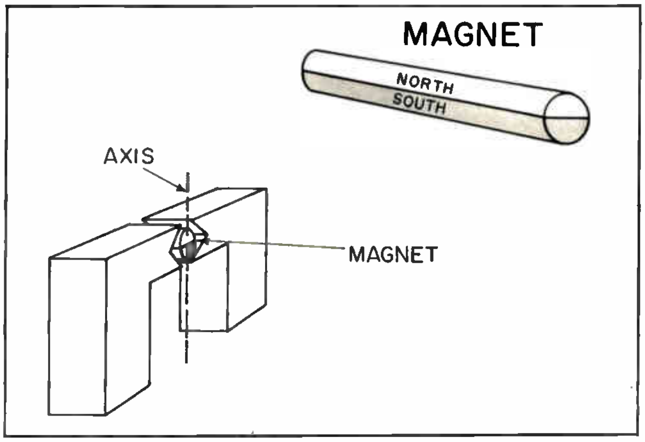


Figure 5-17. Convergence magnet assembly.

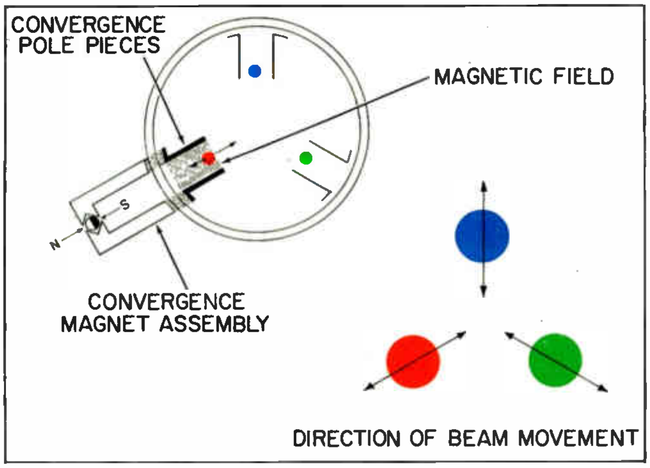


Figure 5-18. Deflection of electron beams by convergence assembly.

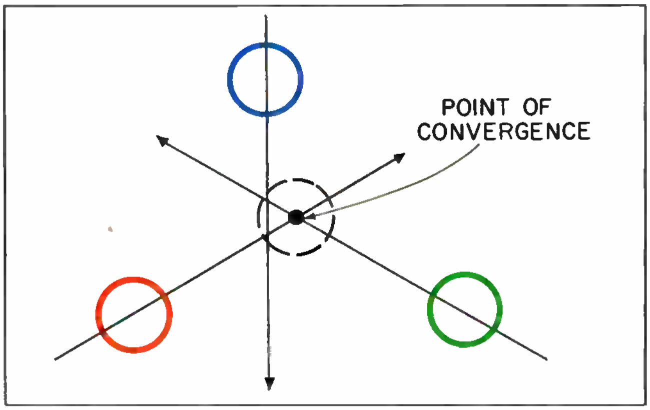


Figure 5-19. Partial convergence.

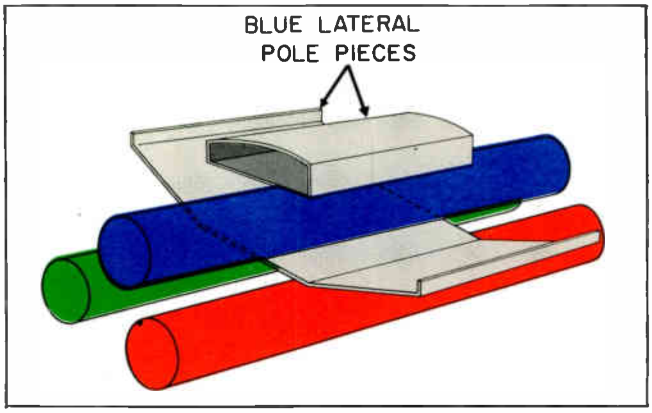


Figure 5-20. Blue beam lateral pole pieces.

The resulting movement of each electron beam is along a radial axis, as illustrated in figure 5-18, that is, in the direction which will provide convergence. Whether the beam moves inward from a no-field condition or outward from a no-field condition depends upon which way the magnet is adjusted.

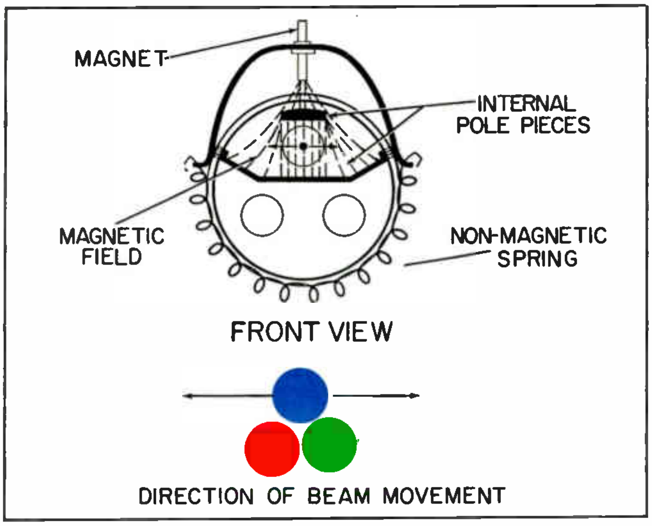


Figure 5-21. Blue lateral convergence assembly.

The strength of the field in the assembly is adjusted by intermediate positions of the magnet. Complete control of magnitude and polarity is therefore obtained. Note that the pole pieces tend to localize and prevent interaction of the magnetic fields with each other.

Convergence should be obtained if the beams are adjusted from a de-converged condition, to illuminate a triad of phosphor dots on the face plate. But, as illustrated in figure 5-19, only the red and green electron beams can be made to converge at the same point, while the blue electron beam passes to the left of the point of convergence as the correcting force is applied. Therefore, added correction must be made to the blue beam. This added correction is termed blue lateral adjustment. The method employed to obtain the blue beam correction also makes use of a magnet. The blue lateral pole pieces are mounted internally within the neck of the cathode ray tube. The two pole pieces are placed at the center of the focus anode of the blue electron gun assembly illustrated in figure 5-20. The smaller of the two pole pieces is located directly over the focus anode and tangent to the curve of the inside of the tube neck. The other pole piece extends from one side of the tube neck, between the blue focus anode and the red and green focus anodes, to the other side of the tube neck. Figure 5-21 shows a cross-section of the blue lateral convergence assembly. The shape of these pole pieces tends to confine this additional magnetic field, preventing any affect upon the red and green beams. The strength of the magnetic field is varied by spacing the magnet from the neck of the tube. The direction of the magnetic field is changed by reversal of the magnet in its mounting.

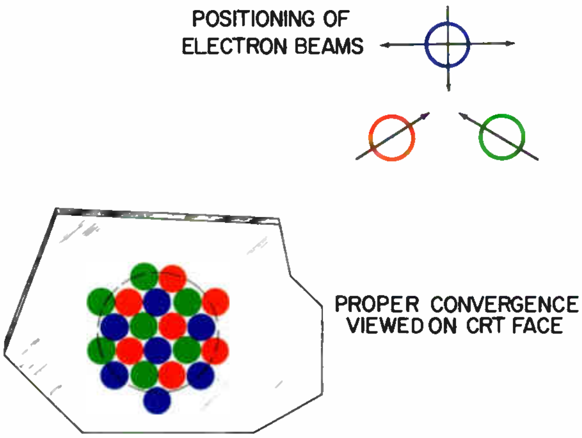


Figure 5-22. Static convergence.

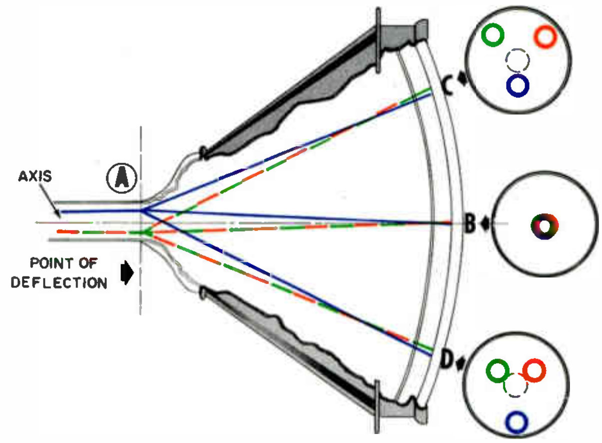


Figure 5-23. Vertical de-convergence.

In summation, the three convergence assemblies move all three beams independently in a radial direction, while one additional assembly moves the blue beam laterally into position, to allow the three beams to converge at the same point. Proper convergence is illustrated in figure 5-22.

Effect of Deflection

When convergence has thus been obtained in the central area of the picture tube screen, misconvergence occurs as the electron beams are deflected toward the outer extremities of the screen. Observe the electron beams coming from the red, green and blue electron guns, as illustrated in figure 5-23. The paths of the red and green electron beams are coincidental in this illustration, since the red and green electron beams are on the same plane when viewing the tube from the side. Next, observe the beam paths when deflected upward or downward. Since the face plate has only slight curvature, all three beams must travel farther to reach point C or D than was necessary to reach point B of the same illustration.

Although all three beams are deflected toward the top of the screen the same number of degrees from their original paths, the angle between the axis of the tube and the path of the blue beam is less than the angle between either the red or green beam path and the tube axis. This is due to the tilt of the electron beams toward the tube's center axis.

The tilt of the beam is a result of the deflection of each individual beam toward the axis by the static convergence assemblies when obtaining center convergence. When the electron beams are deflected downward, the angle between the tube axis and the path of the blue beam is greater than that made by either the red or green beam path to the axis of the tube. As the angle of deflection increases, the distance between the point of deflection at A and the crossover point of the beams will decrease. This, and the additional distance the beams are required to travel, will result in de-convergence before reaching the screen. Also, the red and green beams must travel farther than the blue beam when deflected upward, resulting in an increased separation of the red and green beams. This condition is reversed when the beams are deflected toward the bottom of the screen and the blue beam is farther out of convergence than the red and green beams.

In addition to vertical de-convergence due to the geometrics of the tube, the deflection yoke may cause some de-convergence. However, the deflection yoke is designed to compensate for convergence errors in the corners through controlled astigmatism.

The geometrics of the cathode ray tube also affects the horizontal convergence of the electron beams. The top view cross-section in figure 5-24 shows the electron beams converged in the center of the screen, as well as the de-convergence which results when the beams are deflected to the right and left of the tube screen. The similarity of de-convergence at both extremes is readily discernible. The deflection yoke and associated circuits also affect the horizontal de-convergence, causing the red beam on the right side to be further out of convergence than on the left, and the green beam to be further out of convergence on the left than on the right.

This non-linearity of de-convergence varies with cathode ray tubes, yokes and associated circuitry. The deflection yoke, which is designed to aid convergence at the corners, results in the non-linear beam displacement along the horizontal axis. This is not serious, however, and can be readily compensated.

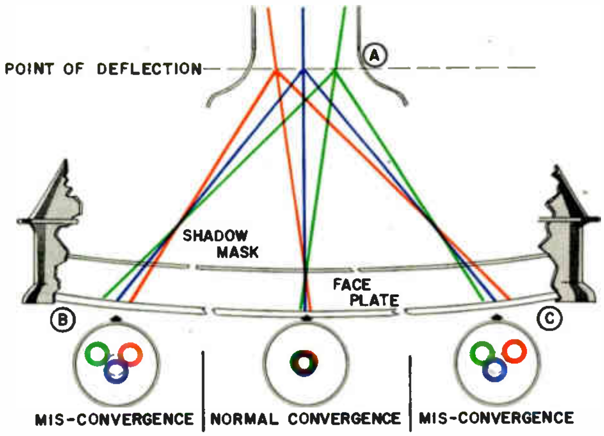


Figure 5-24. Horizontal de-convergence.

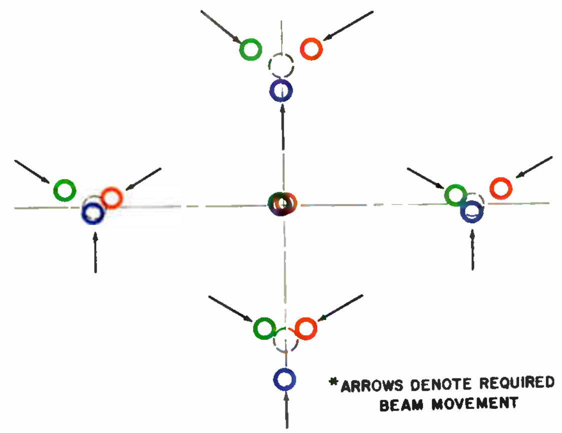


Figure 5-25. Horizontal and vertical convergence corrective forces.

Since the de-convergence of the beams along both the vertical and horizontal planes follows specific patterns, the corrective action applied to the electron beams is discussed here in two parts, vertical and horizontal. This corrective action is called dynamic convergence.

Figure 5-25, shows the corrective forces necessary to converge the three beams at the outer area of the screen. Note that the amount of de-convergence at the extreme top and bottom and each side is similar though not identical. Also note the relative positions of the de-converged beams. All three beams have moved away from their point of convergence in a radial direction and exhibit varying degrees of displacement. Separate correcting forces are necessary, since the amount of correction for each beam is not equal.

Vertical Dynamic Convergence

The individual vertical correcting forces are applied to each electron beam through the previously discussed convergence magnet assemblies by the addition of a winding mounted on one leg of each magnetic assembly. The blue convergence assembly with the added coil is illustrated in figure 5-26. The other two assemblies are similar. Separately derived sources of vertical dynamic voltages are connected to these windings. The internal fields produced, which are in addition to the established convergence obtained by the permanent magnets of each assembly, deflect the beams in radial directions. The direction of current flow in the winding determines whether the beam is deflected away from or toward the tube axis, while the current magnitude governs the amount of deflection.

The amplitude of the required correction force varies with each of the electron beams. However, the vertical dynamic convergence of the blue beam is arbitrarily chosen here to demonstrate the corrective methods. To be in the proper relative position for convergence, the blue electron beam must be moved upward to the position indicated by the dotted blue circles of figure 5-27. Hence, the current producing convergence must be relatively large when the blue beam is scanning the top and bottom portions of the screen, but must be zero when scanning the center portion of the screen, to prevent de-convergence in this region. Also, the force must be greater when scanning the bottom of the screen than when scanning the top, since at the bottom the beam is further out of convergence and requires more correction. The force fulfilling this requirement is a parabolic waveform. This waveform is plotted in figure 5-27 to show its relation to the convergence requirements.

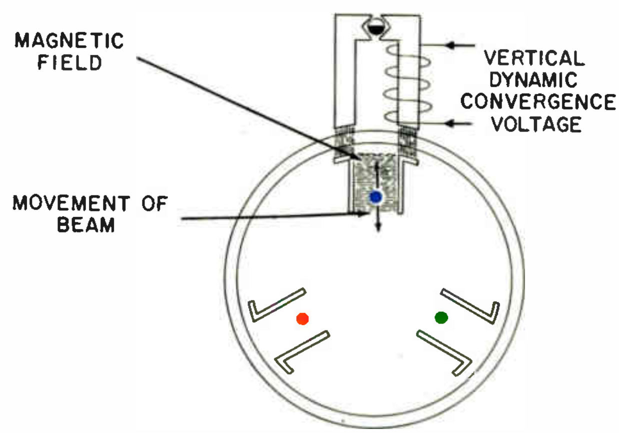


Figure 5-26. Blue convergence assembly with winding for vertical dynamic convergence.

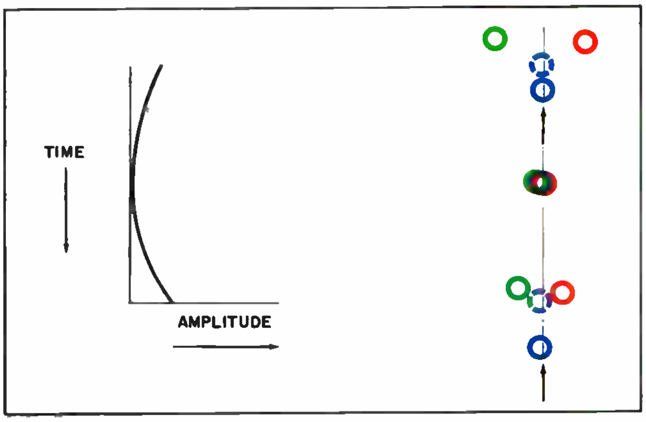


Figure 5-27. Vertical dynamic convergence of blue beam.

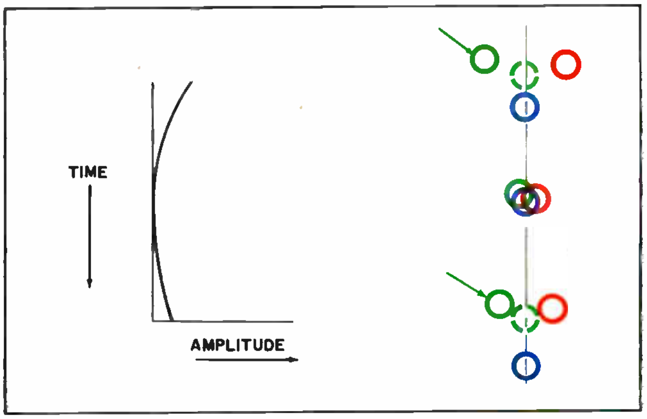


Figure 5-28. Vertical dynamic convergence of green beam.

The vertical dynamic correcting force must occur at the vertical scanning rate. Therefore the parabolic wave must have the same repetition rate as the vertical deflection voltage.

The green and red electron beams, which must be shifted in a radial direction to the dotted circles at the top and bottom portions of the screen as shown in figure 5-28 and 5-29, require similar treatment. Thus, with the correct amplitude of corrective forces applied to all three convergence assemblies, the three beams become converged in the vertical plane.

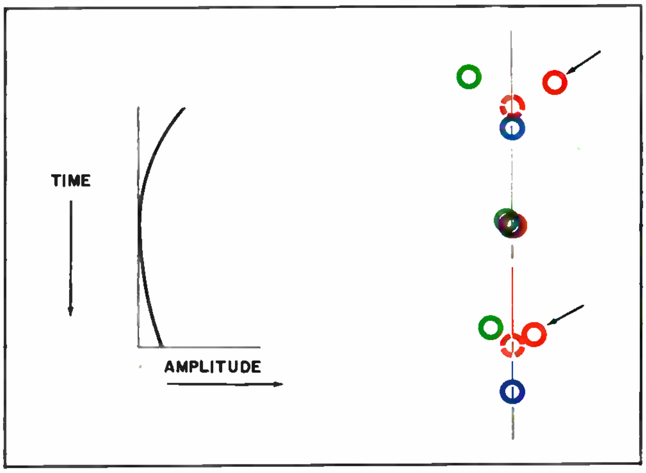


Figure 5-29. Vertical dynamic convergence of red beam.

Horizontal Dynamic Convergence

Although the beams are now converged vertically, de-convergence at the sides of the screen in a horizontal plane still exists. Observe that, in this plane, the red and green electron beams require considerably more correction than does the blue electron beam, and that the amount of correction for the red and green beams is not equal. The individual correcting forces are applied to each electron beam through the same convergence magnet assemblies by a second winding mounted on the other leg of each magnetic assembly, as shown in figure 5-30. Only the blue assembly is illustrated since the other two assemblies are similar. In the actual circuitry, the coils on the two legs of a convergence magnet assembly are in series and therefore both the horizontal and vertical correction voltages are applied to the same coils. The internal fields produced as a result of the horizontal dynamic voltages are in addition to the convergence established by the permanent magnets and by the vertical dynamic fields.

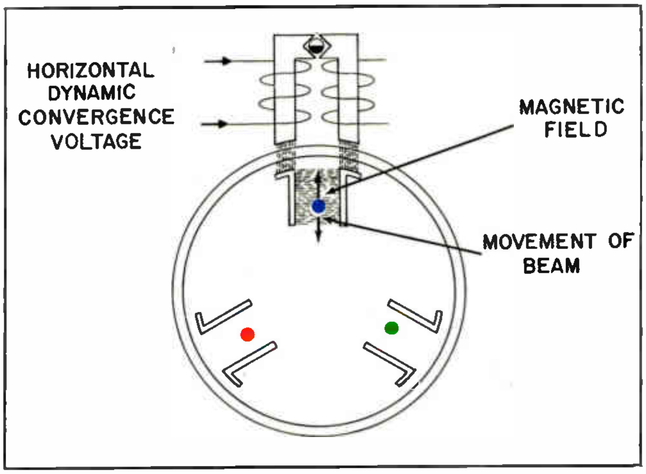


Figure 5-30. Blue convergence assembly with winding for horizontal dynamic convergence.

As with vertical dynamic convergence, one electron beam, chosen arbitrarily, is discussed to show corrective action. Consider the blue beam, which is in proper relative position for convergence at the center

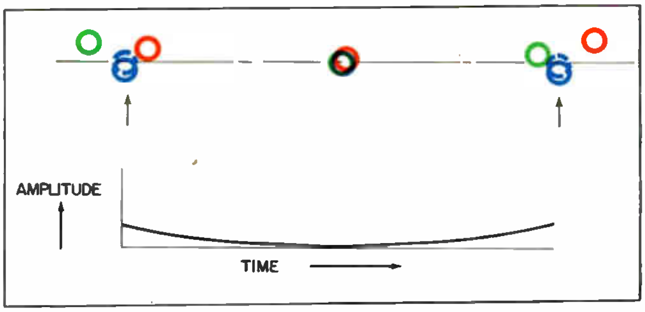


Figure 5-31. Horizontal dynamic convergence of blue beam.

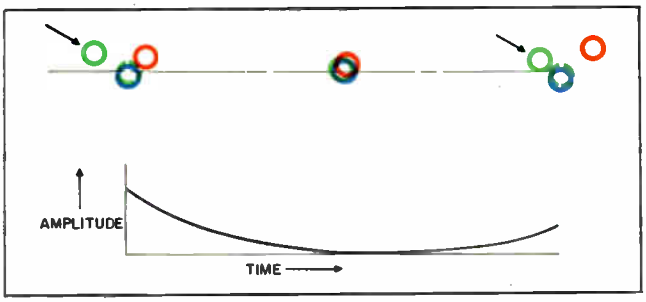


Figure 5-32. Horizontal dynamic convergence of green beam.

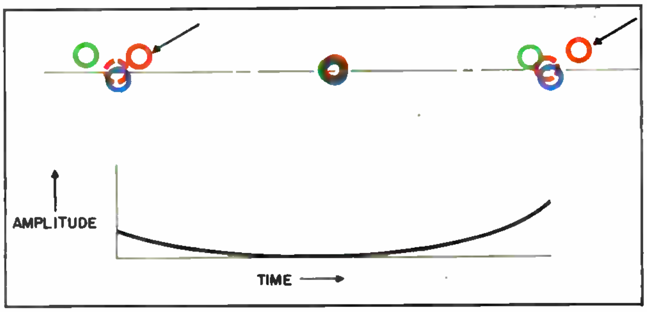


Figure 5-33. Horizontal dynamic convergence of red beam.

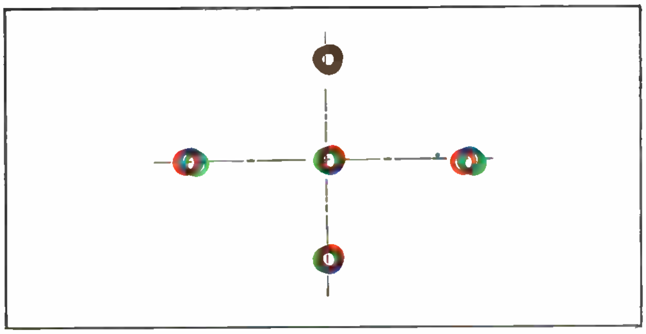


Figure 5-34. Overall convergence.

of the screen. However, at the sides of the screen, the blue beam is displaced below the center line. This displacement is not large and therefore will not require a large correcting force. This force must vary in a manner similar to vertical dynamic convergence so that less correction is applied at the center of the screen since magnetic convergence here has already been obtained.

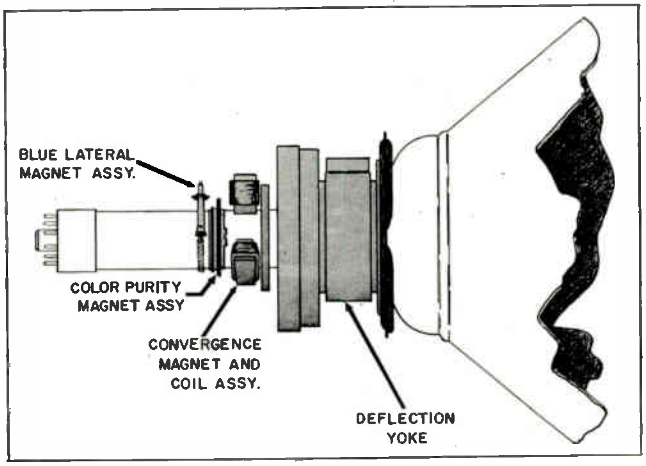


Figure 5-35. Location of electron beam deflection assemblies.

The force that fulfills this requirement for horizontal dynamic convergence is again a parabolically varying wave. When this waveform is applied to the horizontal dynamic convergence coil of the blue beam convergence assembly, the internally induced field moves the beam into position for convergence. The waveform for the blue beam is plotted in figure 5-31 to show the relation to convergence requirements. The horizontal dynamic convergence waveform repetition rate is the same as the horizontal sweep frequency.

The green and red electron beams are de-converged to a much greater degree than the blue electron beam, that is, they require a correcting force of greater amplitude, as shown in figure 5-32 and 5-33.

In summation, static correction is obtained at the center of the screen through the application of magnetic convergence. Vertical dynamic correction is applied to all three electron beams, resulting in convergence in the vertical direction from the center of the screen. Horizontal dynamic correction is applied to all three electron beams, resulting in convergence in the horizontal direction from the center of the screen. The net result is over-all convergence everywhere on the picture tube screen, as illustrated in figure 5-34.

The illustration of figure 5-35 shows the relative position of the deflection yoke, the convergence assemblies, the color purity assembly and the blue lateral adjustment assembly.

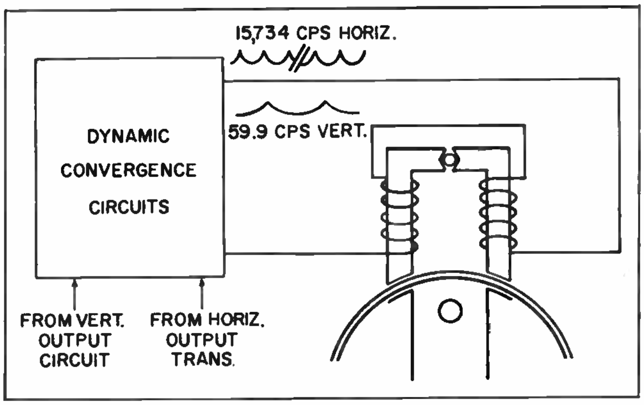


Figure 5-36. Sources of dynamic convergence voltages.

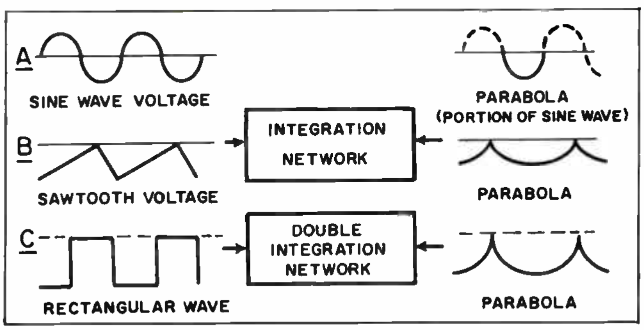


Figure 5-37. Development of parabolic voltages.

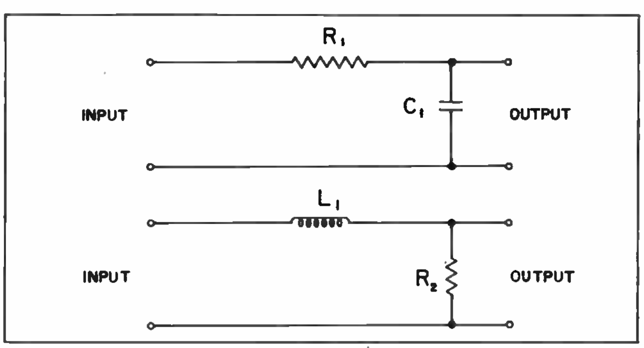


Figure 5-38. Methods of integration.

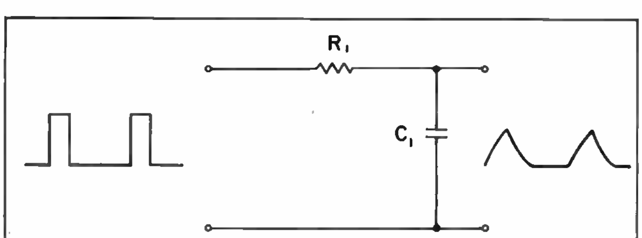


Figure 5-39. Integration of a rectangular wave.

SECTION 4. CONVERGENCE CIRCUITRY

The parabolically varying voltages which provide proper vertical and horizontal dynamic convergence are developed and shaped in the dynamic convergence circuits. The repetition rates of these dynamic convergence voltages must be synchronized with the vertical and horizontal sweep rates. The voltages, which ultimately provide convergence, are derived from sources which provide this synchronism, and are shaped in the dynamic convergence circuits for convergence control, figure 5-36. Methods of developing the parabolic voltages necessary for dynamic convergence are (1) integration of a sawtoothed wave, (2) double integration of a rectangular wave and (3) use of the proper portion of a sine wave which is parabolic in nature. Figure 5-37 illustrates these methods which produce parabolically varying voltages.

Review of Integration Networks

A brief review of integration networks is helpful in understanding the convergence circuits. Figure 5-38 illustrates resistance-capacitance and inductance-capacitance fundamental integration networks; use of either of these circuits produces integration of a given voltage. If the components of each circuit are chosen to obtain similar time constants, and the same voltage is applied to each, the output of each circuit is similar.

Next, consider the integration of a rectangular wave using the R-C network. During the time the leading edge of the rectangular wave is rising, capacitor C1 starts to charge, continuing to build up for the duration of the flat top portion of the rectangular wave, as illustrated in figure 5-39. The charging ceases when the trailing edge of the rectangular wave drops to the base line. Capacitor C1 now discharges. The result of charging and discharging a capacitor by a rectangular wave is the production of a sawtoothed wave.

The time constant, an important consideration, is determined by the resistance and capacitance values. In figure 5-40A, the time constant has been made equal to time t1, which is the width of the rectangular pulses being applied to the network. Capacitor C1 charges through resistor R1 during the time between leading and trailing edges of each rectangular pulse, resulting in the formation of the leading edge of the sawtoothed wave. When the trailing edge of the rectangular pulse falls to the base line, capacitor C1 discharges through resistor R1, resulting in the trailing edge of the sawtoothed wave. Since the time constant is the same as the width of the rectangular pulse, the charge and discharge time is the same, that is, the leading and trailing edges of the sawtoothed wave occupy the same time.

Now, assume the R-C time constant to be much larger than the pulse width time. In figure 5-40B, the time constant is equal to time t2, the time between the leading edges of successive rectangular pulses. Capacitor C2 now charges through resistance R2 during the rise time and flat top portion of the rectangular pulse. Since this time is rather short in comparison with the time constant of the circuit, a relatively small charge will be accumulated by capacitor C2. The trailing edge of the rectangular pulse returns rapidly to the base line, but the charge of capacitor C2 is dissipated slowly due to the value of resistance R2, retarding the return of the sawtoothed wave to the base line until the end of time t2.

The general statement can be made that the length in time of the leading edge of the produced sawtoothed wave is determined by the rectangular pulse width, and the trailing edge of the produced sawtoothed wave is determined by the time constant of the R-C network.

As mentioned earlier, double integration of a rectangular pulse is employed to produce a parabolically varying voltage for convergence control. The discussion to this point has integrated the rectangular pulse once into a sawtooth. The second step of the process is integration of the resulting sawtooth to produce the parabolic waveform, as illustrated in figure 5-41. Assume the time constant of the R-C network to be equal to time t, as illustrated in figure 5-42. The gradual rise of the sawtooth leading edge causes capacitor C1 to charge slower than would be the case with the steep front of the previous rectangular pulse. Next, the gradual drop of the sawtooth trailing edge allows capacitor C1 to discharge through resistance R1 more slowly than was the case of the rectangular pulse which produced a falling charge about equal to the rising charge. Therefore, a parabolically rounded voltage output is the result of the charge and discharge of a resistance-capacitance network by a sawtooth voltage.

By changing the time constant of the R-C network to equal time t2, figure 5-43, the time constant endures from start to finish of one sawtoothed wave instead of from the start to the peak of the sawtoothed wave. Capacitor C2 charges as the leading edge of the sawtoothed wave rises and discharges through resistance R2 even more slowly than before. The output

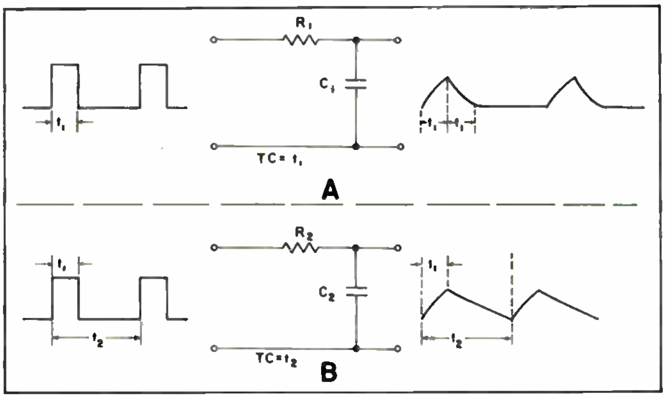


Figure 5-40. Effect of time constant to sawtooth output.

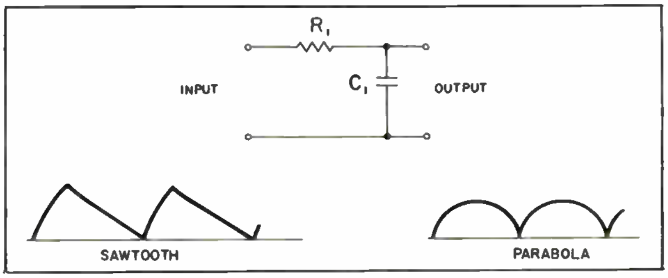


Figure 5-41. Integration of a sawtoothed wave.

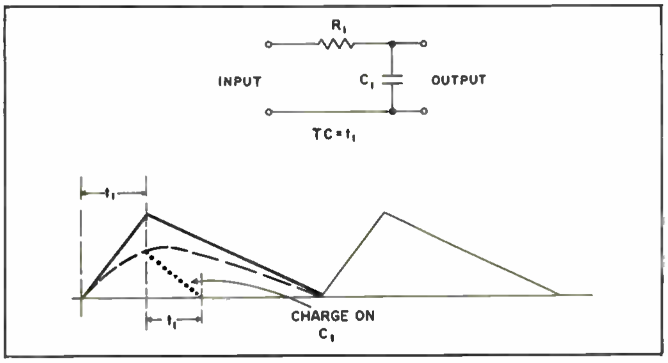


Figure 5-42. Development of a parabolic from a sawtooth.

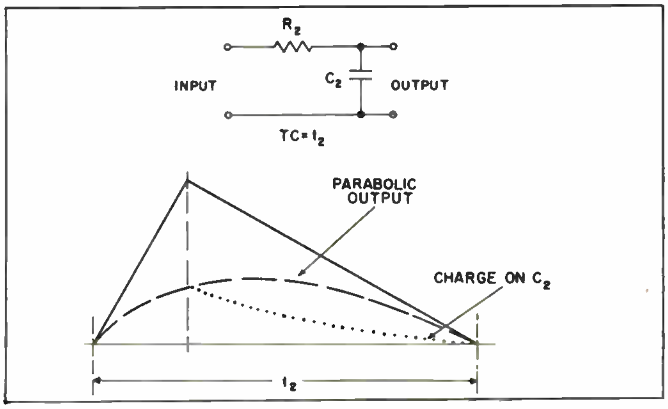


Figure 5-43. Effect of time constant to parabolic output.

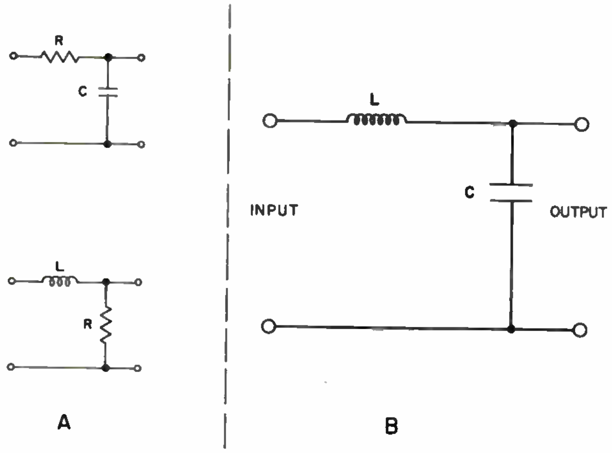


Figure 5-44. Double integration network.

voltage is again parabolic in shape, but of a more symmetrical nature. Therefore, the time constant of the R-C network has a decided effect upon the shape of the parabolic output voltage.

In the beginning of this review, two types of integration networks were mentioned as possible circuits which could be used. These were resistance-capacitance type and the inductance-capacitance type of networks. If the inductance of the L-C network is substituted in the R-C network in place of the resistance, the a-c resistance (impedance) of the inductance replaces the ohmic resistance. Thus, the two circuits are combined, as shown in figure 5-44. Since each type of circuit could perform integration in its own right, double integration results from the combination. When the input is a rectangular pulse the output is parabolic in nature, as shown in figure 5-45.

Vertical Dynamic Convergence Circuits

Since a sawtoothed wave is present at the cathode of the vertical sweep output amplifier, integration of this voltage results in the appearance of a parabolic shaped voltage at the cathode. This is due largely to the presence of capacitor C1 connected across the vertical output cathode resistance, as shown in figure 5-46. C2, a d-c blocking capacitor, couples this voltage to R2. The combination of the two components provide a differentiating network which presents an action opposite to integration and therefore produces an unsymmetrical or tilted parabolic voltage at the output of capacitor C2. But, resistor R2 and capacitor C3, an integrating network, return the tilted parabolic voltage to a symmetrical condition. Note that a variation of the degree of tilt can be

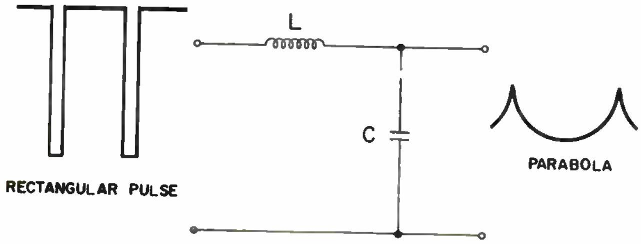


Figure 5-45. Double integration of a rectangular pulse.

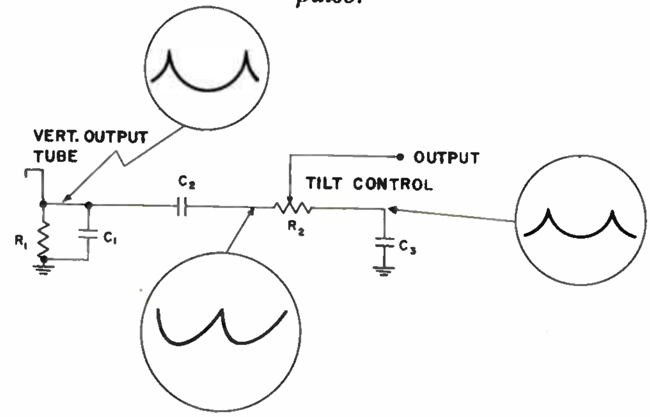


Figure 5-46. Basic vertical dynamic convergence circuit.

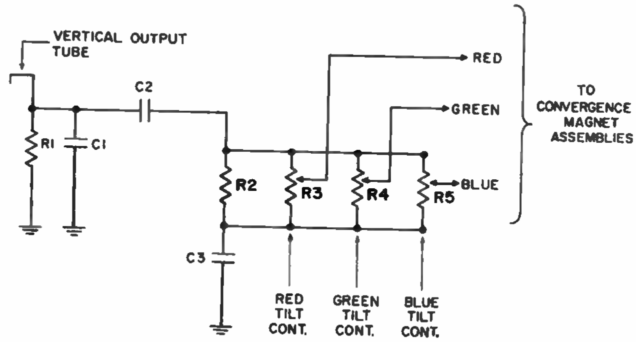


Figure 5-47. Vertical dynamic tilt control circuit.

obtained along resistance R2, which is variable.

Separate and independent sources of voltage for vertical convergence control are required for the red, green and blue convergence windings and are obtained by placing three relatively high-valued variable resistances across resistance R2, which is fixed, as in figure 5-47. Thus, separate red, green and blue vertical dynamic tilt controls are provided.

To vary the amplitude of the red and green vertical convergence voltages, series, variable resistances are placed in the circuit ahead of the convergence windings, as shown in figure 5-48. The blue amplitude control consists of variable resistance R8 connected from the blue tilt control output to ground, through capacitor C4; this is a d-c blocking capacitor. Since the required vertical dynamic correction for the blue beam is generally very small, this circuit allows control of the blue amplitude convergence voltage to zero.

Horizontal Dynamic Convergence Circuits

The circuitry of figure 5-49 shows the application of a double integration network to obtain a parabolic shaped voltage for use in the horizontal dynamic convergence control circuits. Inductance L11, a small winding on the horizontal output transformer, provides rectangular pulses to the input of the double integration network consisting of inductance L10 and capacitor C11. The parabolic voltage output from this network is applied equally across three variable resistances. These variable resistances are the red, green and blue horizontal amplitude controls.

Since all three horizontal dynamic convergence circuits are similar, the red dynamic convergence circuit, figure 5-50 is developed here as indicative of all three circuits. The parabolic voltage from the red horizontal convergence amplitude control, R18, is coupled to the convergence windings through capacitor C9. This capacitor, together with inductance L5, forms a circuit which is series-resonant at the horizontal sweep frequency. Sine wave oscillation results, due to pulsing by the parabolic voltage peaks. Capacitor C5 is connected across the convergence windings, which are series-connected. Inductance L1, which prevents the upper end of inductance L4 from being grounded at the horizontal sweep frequency, due to the low impedance of the vertical convergence circuits, can be also considered as being in parallel with L4 and L5. Therefore, L1, L4, L5 and C5 form a parallel resonant circuit, such that the sine wave oscillation across inductance L5 develops a larger oscillation in the entire parallel resonant circuit.

Inductance L1 is the variable horizontal dynamic phasing control, as indicated in figure 5-51. This sine-wave oscillation provides horizontal dynamic convergence control since the portion of the sine wave occuring during active horizontal scanning time varies parabolically. Figure 5-52 illustrates the sine-wave voltages present in the convergence windings when in-phase, advanced-in-phase and delayed-in-phase with the active horizontal scanning time. The latter two appear as tilted parabolically shaped voltages.

In summation, parabolically varying voltages are developed as a means of overcoming de-convergence at repetition rates corresponding to the vertical and horizontal sweep frequencies. Amplitude and tilt controls for both vertical and horizontal convergence

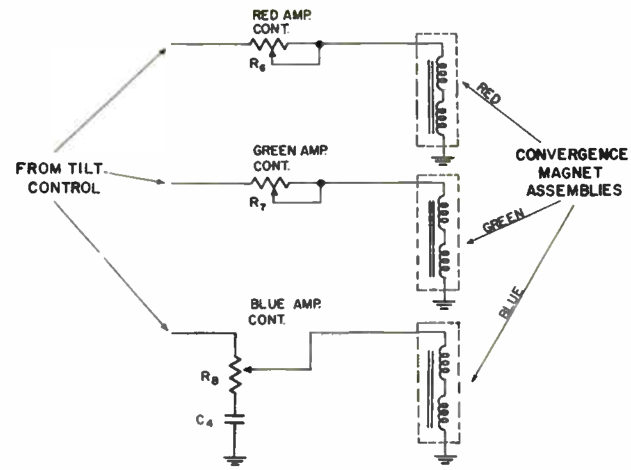


Figure 5-48. Vertical dynamic amplitude control circuit.

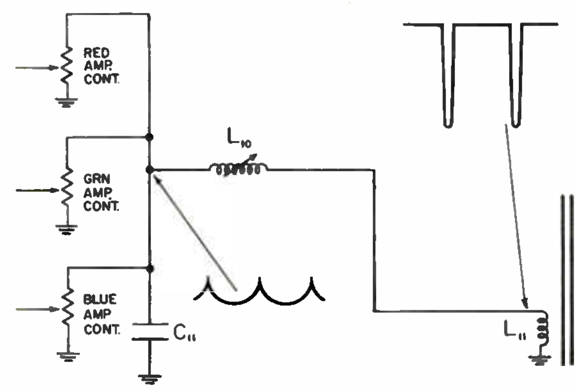


Figure 5-49. Horizontal dynamic amplitude control circuit.

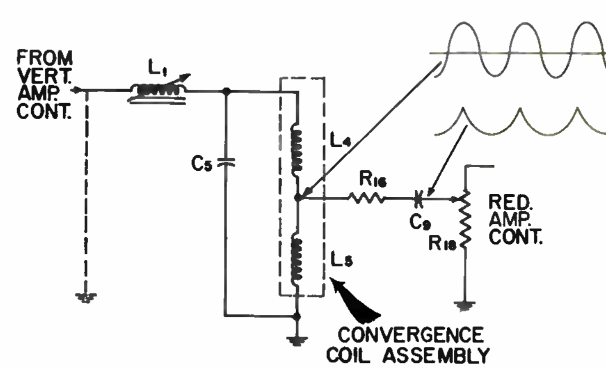


Figure 5-50. Development of horizontal dynamic convergence voltage.

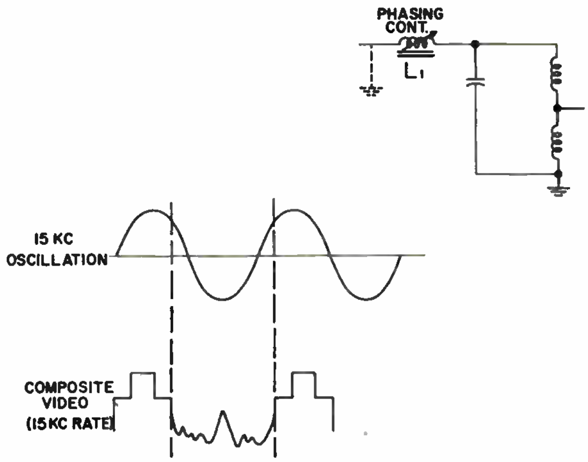


Figure 5-51. Horizontal dynamic phasing control circuit.

are provided. Since both dynamic convergence voltages are applied to the convergence windings simultaneously, the net voltage wave form is a composite of the two impressed voltages, figure 5-53. The voltages developed in the study of vertical and horizontal dynamic convergence circuits fulfill the requirements established in the earlier study of the tri-gun color cathode ray tube.

Convergence Stabilization

By design, the vertical and horizontal dynamic convergence voltages are automatically compensated for changes due to line voltage fluctuations. When the line voltage changes, the B-plus voltage varies in direct proportion. Any change in B-plus affects the amplitude of the horizontal and vertical sweep signals resulting in a change of raster size on the picture tube. This would upset dynamic convergence were it not for the fact that the sources of the dynamic convergence voltages are the vertical and

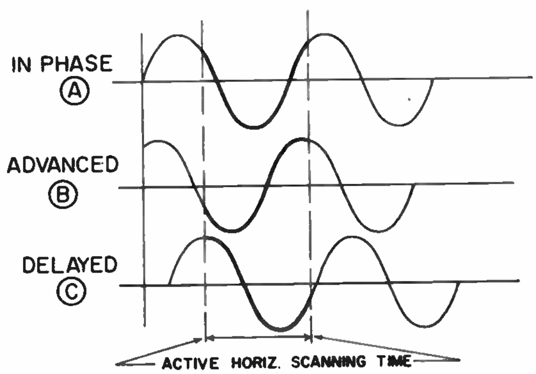


Figure 5-52. Relation of horizontal dynamic convergence voltage to active horizontal scanning time.

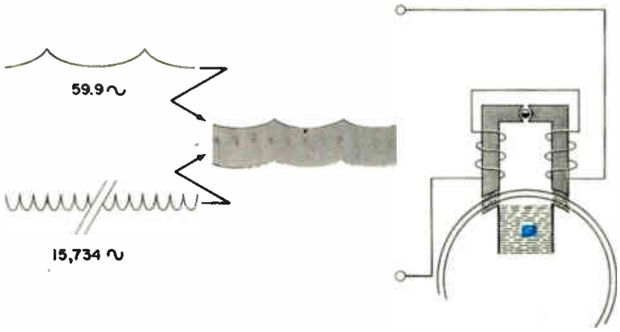


Figure 5-53. Dynamic convergence assembly and applied voltages.

horizontal sweep sections and any variation in sweep causes a proportional change to the dynamic convergence voltages, thereby maintaining dynamic convergence.

To maintain static convergence when the line voltage fluctuates, a small amount of B-plus is applied to each convergence circuit, as illustrated in figure 5-54. R9 and R10 are resistances providing B-plus for the red circuit, R11 and R12 are resistances providing B-plus for the green circuit, while R13 and R14 are resistances providing B-plus for the blue circuit. As the line voltage decreases, B-plus drops, lowering the B-plus in the convergence circuits, which reduces the amount of static correction. This reduction, although small, follows the variations in the vertical and horizontal sweeps due to line voltage changes, thereby maintaining proper convergence. If the line voltage rises, the action is reversed, and follows changes in the sweeps.

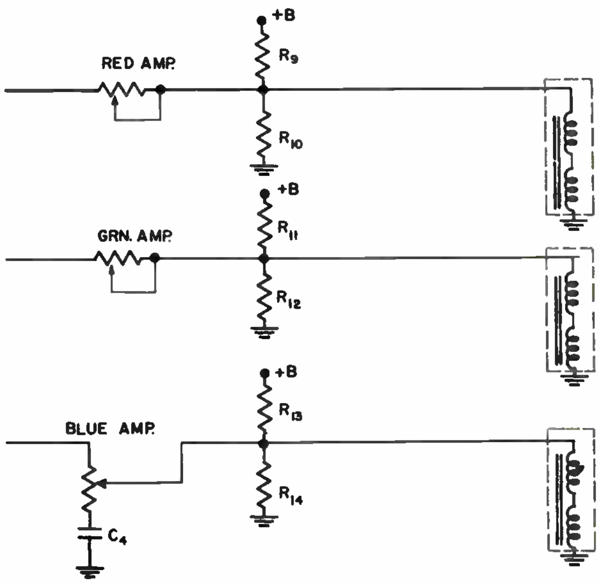


Figure 5-54. Static convergence stabilization.

6. COLOR CATHODE RAY TUBE AND RECEIVER ADJUSTMENTS

THE ADJUSTMENTS in setting up a color television receiver are made to obtain the following results: (1) good color purity, (2) proper convergence of the three electron beams over the entire area of the cathode ray tube screen, and (3) correct white balance. The adjustments are either mechanical or electrical. The mechanical adjustments are associated with the cathode ray tube assembly and are discussed in section 1 of this chapter. The electrical adjustments covering the receiver proper are discussed in section 2. The controls for the above adjustments are located, for the most part, on the front of the receiver chassis. This allows critical adjustments to be made while the results are viewed directly on the screen of the cathode ray tube.

SECTION 1. CATHODE RAY TUBE ADJUSTMENTS

The adjustments made on the cathode ray tube assembly are mechanical, with the exception of the neutralizing coils, which are adjusted by means of a dual potentiometer. In the mechanical group are: the deflection yoke, the convergence coil and magnet assembly, the color purity magnet assembly, the blue lateral magnet assembly, and the field neutralizing (or equalizer) magnet assembly. These assemblies are shown in figure 6-1.

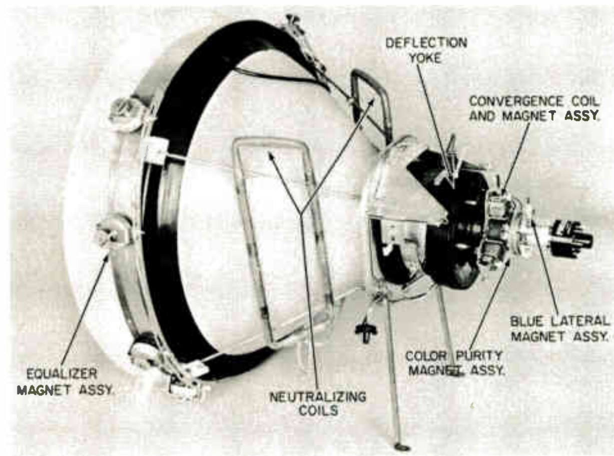


Figure 6-1. Adjustments for color cathode ray tube assembly.

Deflection Yoke

The deflection yoke used with the color cathode ray tube functions in the same manner as its counterpart in a monochrome receiver. A copper shield is installed at the rear of the yoke to prevent the field of the yoke from affecting the pole pieces of the electron gun structure. The deflection yoke is positioned next to the bell-shaped portion of the cathode ray tube and is centered around the neck of the tube. When initially adjusted, the yoke should not be positioned tight against the tube as it may have to be repositioned later to obtain good color purity.

The metal housing, which holds the deflection yoke in position, permits adjustment in the following directions: (1) horizontally along the axis of the neck of the cathode ray tube, (2) from side to side, and (3) vertically up and down from the neck of the tube.

Convergence Coil and Magnet Assembly

The convergence coil and magnet assembly is positioned on the neck of the cathode ray tube next to the deflection yoke, directly over the convergence pole pieces located within the tube at the electron gun structure. The coil assembly with the dark-metal wing nut is positioned directly above the blue electron gun. The wing nuts located on top of each coil are used to hold the assembly firmly in place against the neck of the tube. The static-convergence magnets associated with each electron gun are part of this assembly.

Color Purity Magnet Assembly

The color purity magnet assembly is mounted on the cathode ray tube neck close to the convergence coil assembly. There are two ring magnets to the assembly, each having a north and south pole. The magnets are contained on a single spring assembly used to hold them firmly in position. Each magnet can be rotated through 360 degrees independent of the other.

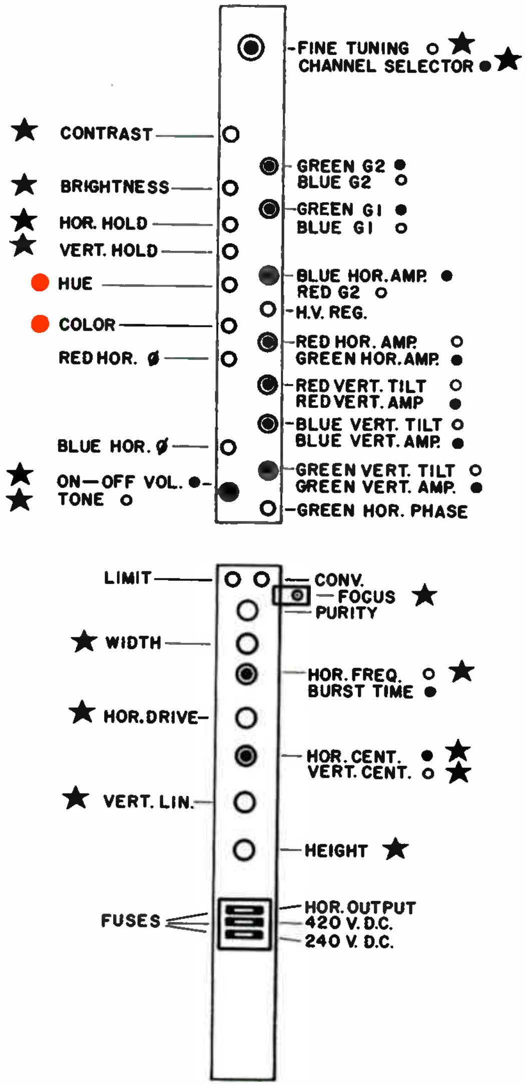


Figure 6-2. Location of receiver chassis adjustment controls.

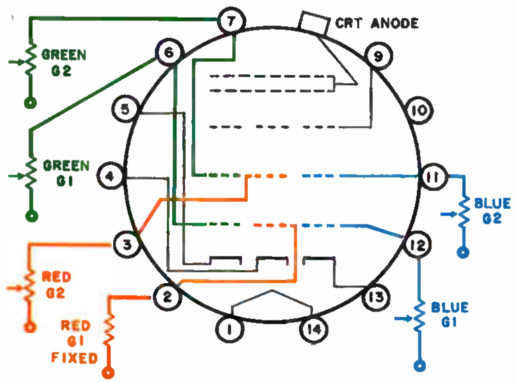


Figure 6-3. G1 and G2 control circuitry.

Blue Lateral Magnet Assembly

The blue lateral magnet permits the blue beam to be positioned in a lateral direction. The range of the lateral movement is controlled by pushing the magnet closer to or pulling it further from the neck of the cathode ray tube. The assembly is positioned over the blue corrector pole pieces in the gun structure along the axis of the neck of the tube. The adjustable magnet is positioned directly over the blue gun.

Field Neutralizing Magnet Assembly

Eight field neutralizing magnets, located four on each side of the cathode ray tube, are mounted on a metal band which fits around the circumference of the bell-shaped portion of the tube, close to the screen. Each magnet can be adjusted by a rotational adjustment which changes the direction of the field with respect to the three color beams and by an "in" or "out" adjustment which controls the intensity of the field. Additionally, each magnet can be moved around the circumference of the tube within a limited range permitting it to affect a particular area of the screen as required.

Neutralizing Coils

The neutralizing coils, which are mounted on either side of the cathode ray tube, serve to counteract the effects of the earth's magnetic field on the electron beams, preventing color impurities from occurring at the edges of the screen. When the color receiver is moved to a different locality (or its position changed) after color purity adjustments have been made, the fields of the neutralizing coils can be changed to conform with the new position of the receiver, thus eliminating the necessity of major re-adjustments for color purity.

Control is effected by means of a dual potentiometer which varies the intensity and polarity of d-c current fed through the coils and thus controls the strength and polarity of the magnetic field around the coils.

SECTION 2.
RECEIVER ADJUSTMENTS

Due to the large number of adjustments required to obtain good color purity, proper beam convergence and correct white balance, the technician should be completely familiar with the various controls and their functions, the test equipment required to perform the necessary adjustments and the procedures for preliminary and final receiver setup. These points are considered for a representative color television receiver.

Description of Controls

The majority of the controls of a color television receiver are located on the front of the receiver chassis and are accessible from the front of the receiver. Some electrical controls are mounted on the rear. Figure 6-2 shows the locations of the front and rear controls of a typical Philco Color Television Receiver. Because of the basic similarity between color and black-and-white television, a number of the controls perform identical functions in both types of sets. In figure 6-2, these controls are identified by the star markings on the illustration.

The HUE and COLOR controls, the only additional customer controls, are identified by the red-dot markings in figure 6-2. Using the flesh tones of individuals as a reference when viewing a color telecast, the HUE control is adjusted to attain proper color tone. The COLOR control provides a means of adjusting the vividness (saturation) of the colors in a scene.

The terms G1 and G2 are used to designate the control grids and screen grids respectively of the cathode ray tube. The controls on the front of the receiver labeled green (GG1), and blue (BG1) are used to adjust the bias applied to these control grids. The control grid bias of the red electron gun has a fixed value and is not adjustable. The red (R), green (G) and blue (B) G2 controls vary the amplitude of the voltage applied to the respective screen grids of the cathode ray tube. Figure 6-3 is a schematic diagram of the above controls.

The AGC control is located on the top of the receiver chassis, as shown in figure 6-4. This control varies the amplitude of the grid bias applied to the agc amplifier tube, permitting more or less agc voltage to be fed back to the tuner and the first and second video i-f stages.

The high voltage regulator (H.V. REG) control, figure 6-5, is a potentiometer connected in the grid circuit of the high voltage regulator tube. This control changes the conduction level of the regulator tube which, when properly set, maintains a regulated output of 25 KV.

The horizontal drive (HOR. DRIVE) control is connected in series with a capacitor to ground and forms a variable time constant network for the shaping circuit of the horizontal oscillator, as illustrated in figure 6-6. Varying the HOR. DRIVE control changes the peak-to-peak amplitude of the horizontal oscillator output, with an accompanying slight change in the shape of the waveform.

The horizontal stabilizing coil adjustment, figure 6-7, is also located on the top of the receiver chassis. The stabilizing coil is connected to the grid circuit

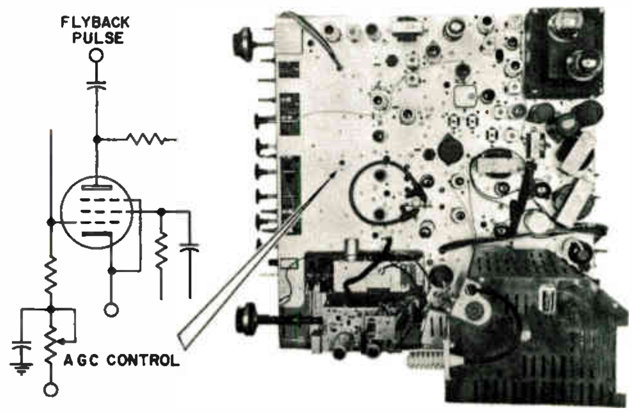


Figure 6-4. AGC control, location and circuitry.

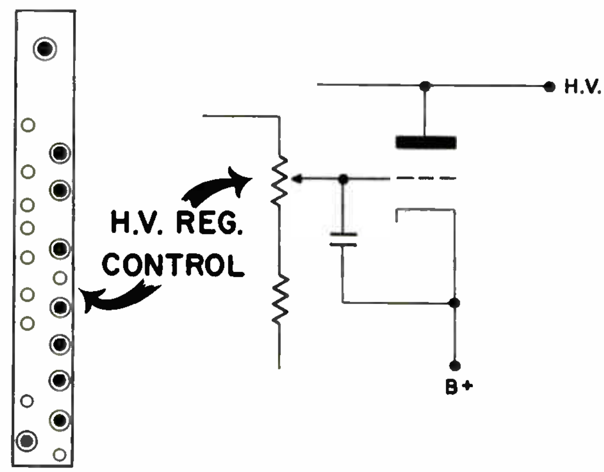


Figure 6-5. H.V. regulator control, location and circuitry.

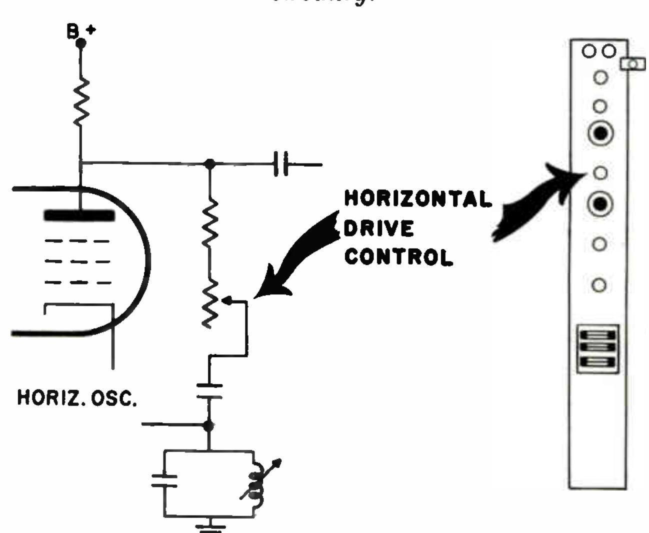


Figure 6-6. Horizontal drive control, location and circuitry.

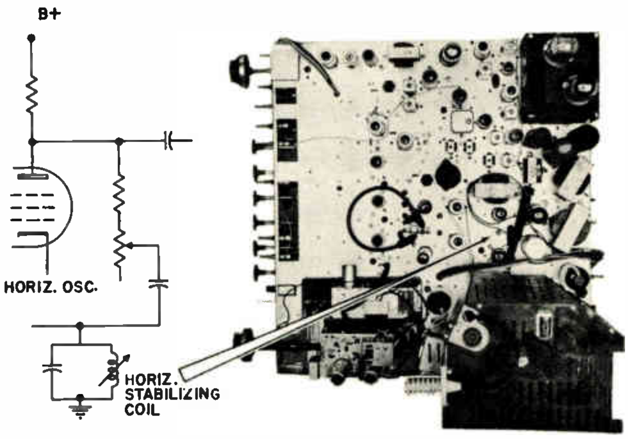


Figure 6-7. Horizontal stabilizing coil, location and circuitry.

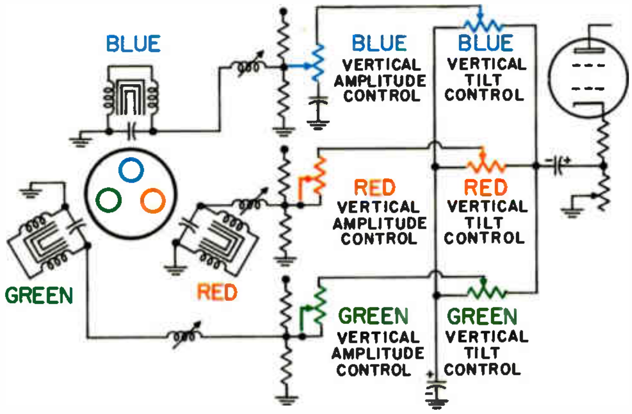


Figure 6-8. Vertical dynamic convergence controls, schematic diagram.

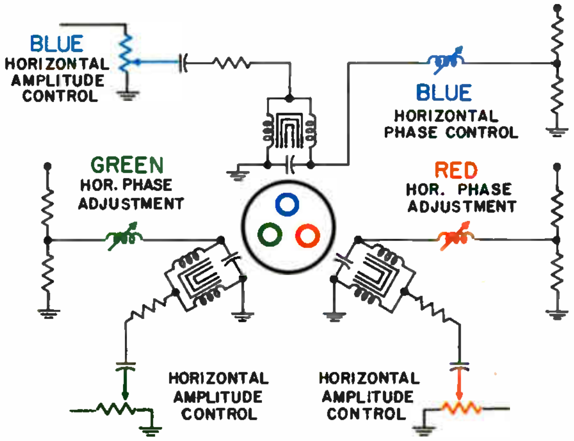


Figure 6-9. Horizontal dynamic convergence controls, schematic diagram.

of the horizontal oscillator and is also in series with the horizontal drive control to ground. The discharge of the sawtooth voltage in the horizontal drive circuit causes the stabilizing coil to resonate at its natural frequency, the horizontal scanning frequency. The sine wave thereby produced is fed to the grid of the horizontal oscillator and thus aids in the stabilization of the horizontal oscillator frequency.

To achieve convergence of all three color beams over the entire screen of the cathode ray tube, dynamic as well as static corrective forces are applied to the three color beams. These forces, in the form of correction voltages, are applied in the shape of parabolic waveforms which affect both the horizontal and vertical scanning actions of each color beam. These waveforms can be varied both in amplitude and tilt or phase.

The vertical amplitude (VERT. AMP) controls vary the amplitude of the vertical dynamic convergence parabolic waveform applied to each color beam. The vertical tilt (VERT. TILT) controls adjust the tilt of the parabolic waveforms. Refer to figure 6-2 for location of the vertical dynamic convergence controls and figure 6-8 for the schematic diagram.

The horizontal amplitude (HOR. AMP) controls vary the amplitude of the horizontal dynamic convergence waveform applied to each dynamic convergence magnet assembly. The horizontal phase (HOR. PHASE) controls adjust the phase of the waveforms. Refer to figure 6-2 for location of the horizontal dynamic convergence controls and figure 6-9 for the schematic diagram.

The PURITY control, illustrated in figure 6-10, is used to vary the amount of d-c voltage applied to the neutralizing coils. The neutralizing coils are used to prevent the earth's magnetic field (or any other external magnetic field) from affecting the path of travel of the three electron beams. The latter condition would cause color impurities to be visible at the edges of the cathode ray tube screen.

Test Equipment Required

The following test equipment is required to perform the receiver adjustments which follow:

(1) A cross-hatch generator. The Philco Color Bar and Dot Bar Generator, Model 7100, creates a cross-hatch pattern as one of its functions.

(2) An oscilloscope having a 4-mc bandpass or the Philco Oscilloscope Model 8202 used in conjunction with a wide-band oscilloscope amplifier similar to Philco Model 8300.

(3) A direct current meter with a 300-ma scale.

(4) A high-voltage probe capable of indicating voltage up to 30 KV used with a vacuum tube voltmeter.

(5) A means of calibrating the oscilloscope for peak-to-peak voltages.

Preliminary Chassis Adjustments

It is necessary to perform the following adjustments before starting the convergence adjustments: high voltage regulator, height, width, linearity, horizontal frequency and drive, and burst timing.

The first adjustment to be made on the color television receiver is to set the high voltage to the cathode ray tube anode to a value of 25 KV.

WARNING

A safety interlock spring mounted on the high voltage enclosure grounds the high voltage when the cabinet back is removed. To measure the high voltage, the spring device must be disabled to prevent grounding of the high voltage. USE CAUTION.

The BRIGHTNESS control should be rotated so as to produce a dim raster on the cathode ray tube screen (low beam current). Connect the high voltage probe, which is in series with the voltmeter lead, to the corona shield, figure 6-11, and then adjust the H.V. REG. control until the meter indicates 25 KV. Disconnect the HV probe from the corona shield.

Next, the horizontal output circuit is adjusted for maximum efficiency by metering the horizontal output tube screen grid current while adjusting the plate limiting coil (horizontal linearity coil). Refer to figure 6-12 for test equipment setup. Using a Variac, adjust the line voltage until the receiver input is 117 volts a-c. Tune in a station signal and adjust both the horizontal and vertical hold controls until the picture is locked in. Turn the receiver off. Then, remove the 0.25 ampere horizontal output fuse located on the rear apron of the chassis under a metal cover. Connect a 300-ma current meter in place of the fuse, turn the receiver on and adjust the plate limiting coil for 210 ma. If a current meter is not available, connect a 10-ohm resistor across the fuse terminals in place of the fuse. Then connect the leads from a d-c voltmeter across the fuse terminals. Turn the receiver on and adjust the plate limiting coil until the volt meter indicates 2.10 volts.

After this adjustment is completed, do not disconnect the meter as additional adjustment may be necessary following the next step which is the horizontal drive adjustment. Rotate the HOR. DRIVE

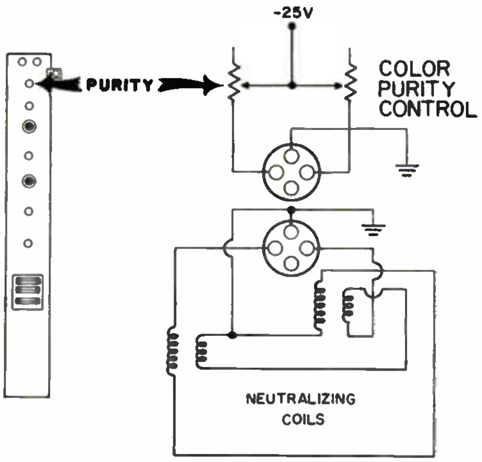


Figure 6-10. Color purity control, location and circuitry.

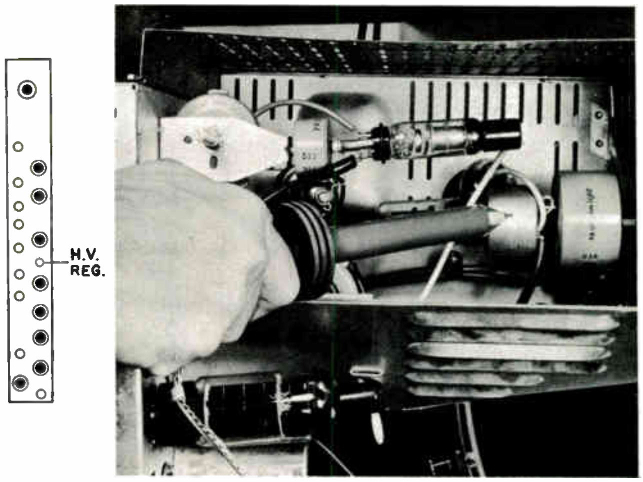


Figure 6-11. Test point for measuring the high voltage.

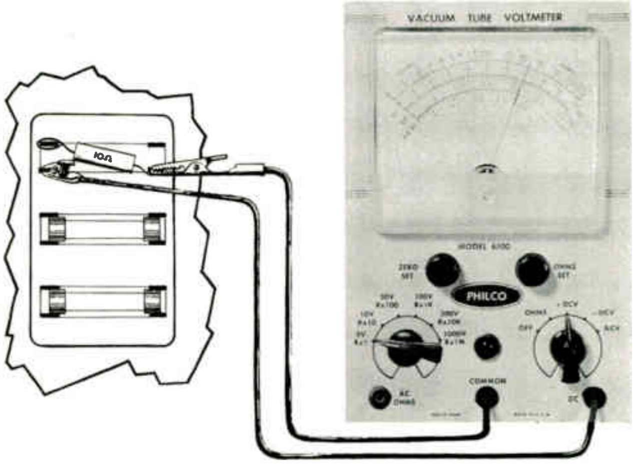


Figure 6-12. Measuring the horizontal output circuit current.

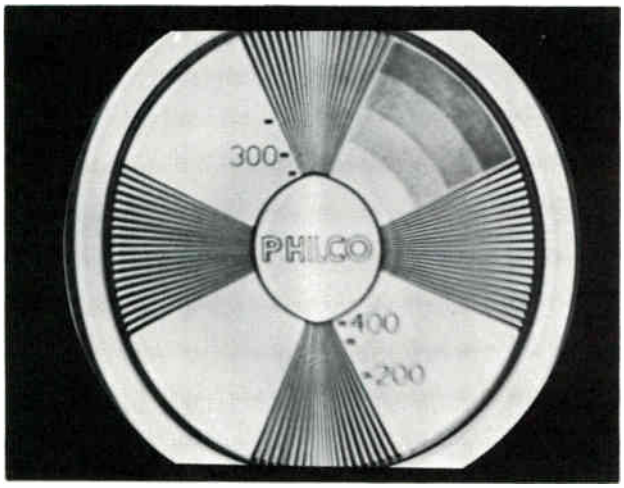


Figure 6-13. Horizontal drive line.

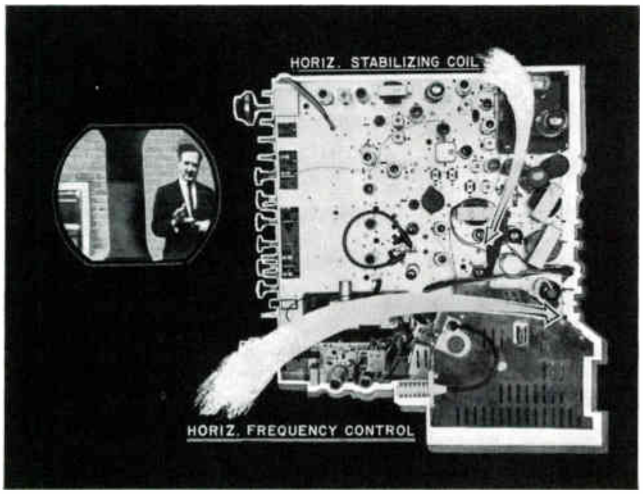


Figure 6-14. Adjustment of horizontal oscillator circuit.

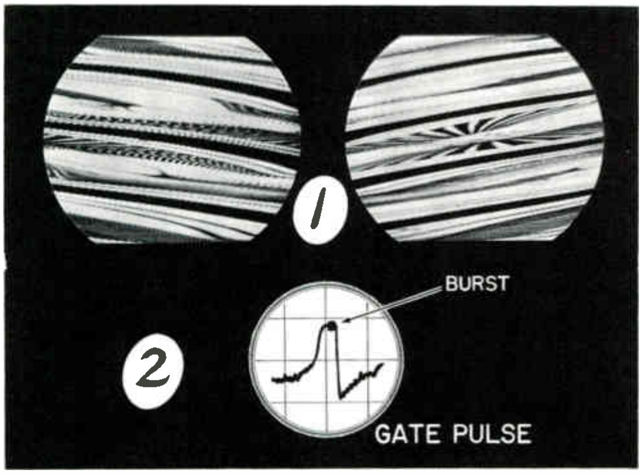


Figure 6-15. Horizontal frequency and burst timing adjustments.

control until a vertical white drive line appears near the center of the screen, figure 6-13. Then, readjust the HOR. DRIVE control until the white drive line just disappears. Observe the indication on the milliameter or voltmeter used in the previous adjustment. The indication should be 210 ma. or 2.10 volts. If the indication is different, readjust the plate limiting coil until the proper value is obtained. Finally, disconnect the meter, remove the resistor (if used) and replace the 0.25 ampere fuse.

Before proceeding with the final high voltage adjustment, the horizontal WIDTH, vertical HEIGHT, and the VERTical LINearity should be adjusted. These controls are common to color and black-and-white television receivers and are adjusted in the same manner. Set the BRIGHTNESS and the CONTRAST controls to midrange and remeasure the high voltage output at the corona shield. The indication should be 25 KV. If other than 25 KV is measured, adjust the H.V. REG until the correct indication is obtained. Rotate the BRIGHTNESS control fully counterclockwise. The meter indication should not exceed 26 KV.

The final preliminary adjustments are the horizontal oscillator and burst timing. With the HOR. HOLD control set to midrange, place a jumper wire across the stabilizing coil and ground the control voltage from the horizontal phase comparer. Then adjust the HOR. FREQ control on the rear apron of the chassis until the horizontal oscillator frequency is correct. When the horizontal oscillator is off frequency, the picture, as viewed on the cathode ray tube screen, will run rapidly across the screen. As the proper frequency is approached, the picture becomes almost synchronized horizontally, figure 6-14, but due to the shorted correction voltage it will not remain stationary. Remove the jumper wire from the stabilizing coil and adjust the stabilizing coil so that the picture is again as stationary as possible. Rotate the HOR. HOLD control to either extreme of its range, and observe if the number of blanking bars on the cathode ray tube screen is equal within one bar at the extreme points of the control range. For example, four bars at one end of the control range and three bars at the other end are illustrated in the upper portion of figure 6-15. If this condition is not present, readjust the HOR. FREQ control. Remove the ground from the horizontal phase comparer control voltage and connect the oscilloscope to the grid of the burst gate amplifier tube. With the HOR. HOLD control turned to its fullly clockwise position, the BURST TIME control is adjusted until the right-hand edge of the burst signal falls at the right-hand edge of the gate pulse as indicated at the bottom of figure 6-15.

Preliminary Convergence Adjustments

The convergence procedure is performed twice. The first time the procedure is rough; later adjustments are finer and more accurate. The rough adjustments insure that, in the final color purity adjustment, color impurities do not exist because of misalignment of the color beams.

The color receiver should be turned on for a five-minute warmup period. Then, connect the output cable of the Philco Color Bar Generator, Model 7100, to the receiver antenna terminals and set the function switch of the generator to obtain a cross-hatch pattern on the screen of the cathode ray tube. During the receiver warmup period, preset the following controls. Refer to figure 6-2. Turn the red (R), green (G) and blue (B) G2 controls for approximate equal brightness of the three beams. Set the red (R), green (G) and blue (B) VERT. AMP controls to minimum. Position the red (R), green (G) and blue (B) HOR. AMP controls to minimum. Set the red (R), green (G) and blue (B) VERT. TILT controls to misposition.

After receiver warmup, the three beams must be converged at the center of the cathode ray tube screen. This is accomplished by adjusting the static convergence magnets, which are part of the convergence coil assembly, on the neck of the cathode ray tube. Convergence is brought about by superimposing the junctions formed by the red, blue and green lines at the center of the screen directly on top of each other, as shown in figure 6-16. It may be necessary to adjust the blue lateral magnet in order to position the blue vertical line precisely in line with the junction formed by the red-green line.

As is evident from inspection of figure 6-16, the red, green and blue beams are converged at the center of the screen, but the four corner areas are not in convergence. This is an inherent characteristic, due to the geometrics of the tube, when no dynamic convergence voltage is applied. However, it is important that the amount of misconvergence of the three beams at the corner areas be equal, i.e., the red, green and blue cross-hatch in any one corner should be misconverged by the same amount both horizontally and vertically as in the other corner areas. If the above condition does not exist, equal misconvergence is brought about by repositioning the deflection yoke either from side to side or vertically up and down on the neck of the cathode ray tube.

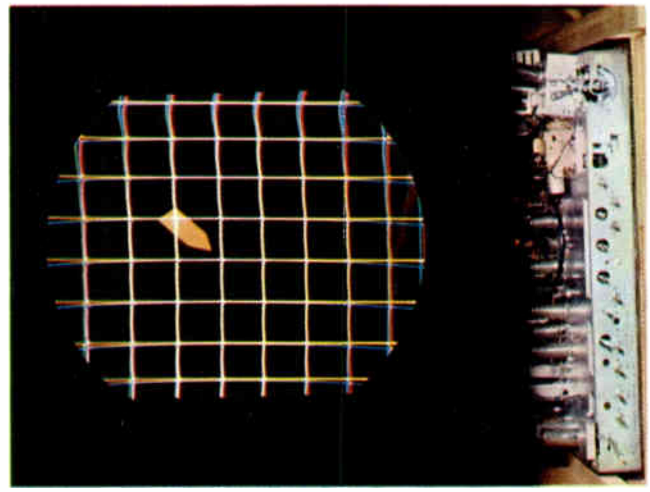


Figure 6-16. Preliminary static convergence.

When the three color beams have been statically converged at the center of the screen, the cross-hatch pattern is used to recheck and, if necessary, readjust the receiver for proper height, vertical linearity and width. The picture is also centered horizontally and vertically within the cathode ray tube mask. The FOCUS control is then properly set. The controls for the above adjustments are located at the rear of the chassis. Refer to figure 6-2.

The blue (B) G2 control is then turned to minimum so that only the red and green cross-hatch lines are visible. Using the vertical red and green lines in the center of the tube as a reference, adjust the red (R) VERT. AMP and green (G) VERT. AMP controls until the respective lines are as nearly parallel as possible, as illustrated in figure 6-17.

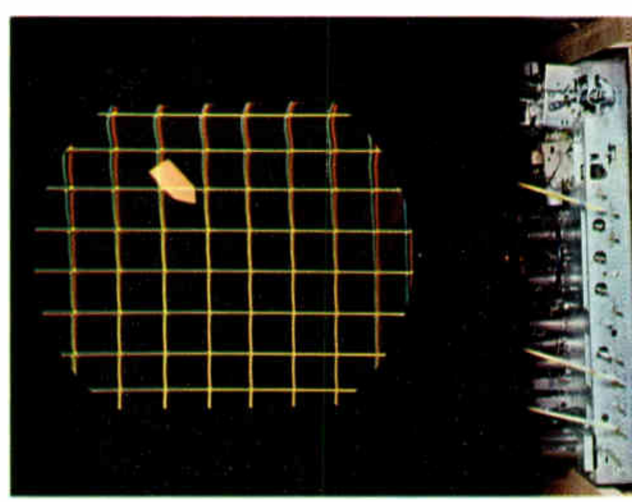


Figure 6-17. Adjustment of red and green vertical dynamic amplitude controls.

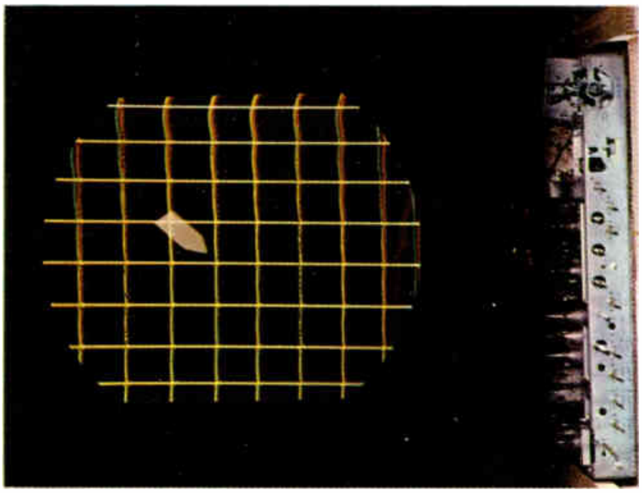


Figure 6-18. Red and green static convergence.

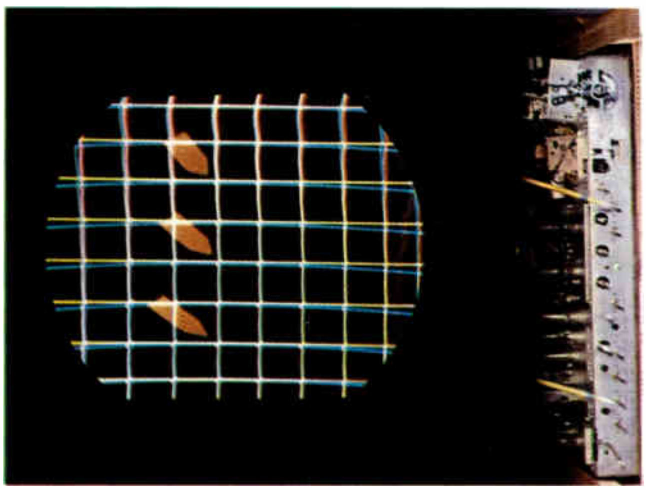


Figure 6-19. Adjustment of blue vertical dynamic amplitude control.

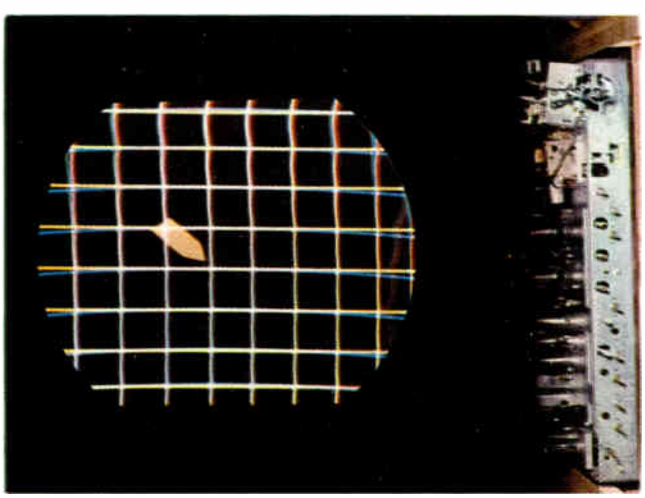


Figure 6-20. Red, green and blue static convergence.

The red and green parallel lines should be converged at the center of the tube by adjusting the red and green static convergence magnets, figure 6-18.

With the blue (B) G2 control readjusted so that the blue lines are visible on the screen, with the red (R) G2 and green (G) G2 controls remaining as previously set so that all beams are equally bright, adjust the blue (B) VERT. AMP control until the blue horizontal lines are approximately equally displaced from the red-green vertical line in the center of the screen, figure 6-19. The blue lines referred to are the segments of the horizontal lines that cross the vertical red-green line down the center of the screen.

The three beams are again converged at the center of the screen, figure 6-20, by adjusting the red, green and blue static convergence magnets.

The blue (B) G2 control is again set to minimum, and the red (R) G2 and green (G) G2 controls remain set for equal brightness. With the red (R) HOR. AMP control set to maximum and the green (G) HOR. AMP remaining at minimum, the red (R) HOR. PHASE control is adjusted to provide a symmetrical displacement (in the same direction) of the red vertical lines with respect to the corresponding green vertical lines across the center of the screen, as indicated in figure 6-21. The red and green vertical lines referred to are the segments of the vertical lines that intersect the horizontal line which crosses the center of the screen.

The red (R) HOR. AMP control is now turned to minimum and the green (G) HOR. AMP control is turned to maximum. As illustrated in figure 6-22, the green (G) HOR. PHASE control is adjusted for a symmetrical displacement (in the same direction) of the green vertical lines with respect to the corresponding red vertical lines across the center of the screen. Both the red (R) HOR. AMP and green (G) HOR. AMP controls are adjusted for equal displacement of the red and green vertical lines across the screen. The red and green horizontal lines across the center of the screen should be checked to ensure that they are parallel to each other. If the red and green horizontal lines are bowed with respect to one another, the amplitude ratio of red to green is incorrect and should be readjusted. The beams are then reconverged statically in the screen center.

The blue (B) G2 control is again readjusted, so that the red, blue and green beams are equally bright, and the blue (B) HOR. AMP control is set to maximum. The blue (B) HOR. PHASE control is then adjusted for symmetrical bowing from the red-green

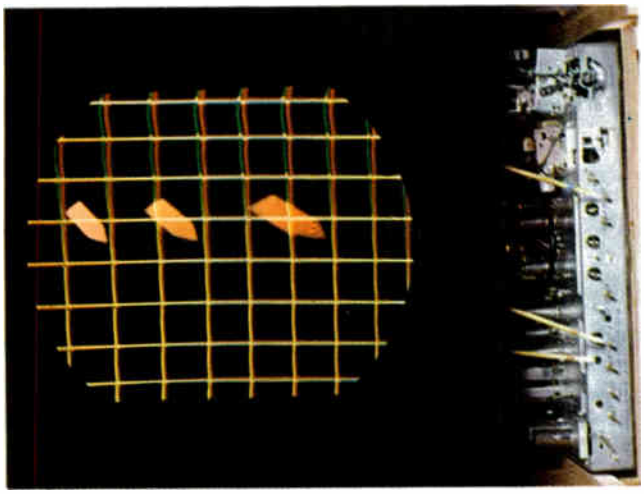


Figure 6-21. Adjustment of red horizontal dynamic phase control.

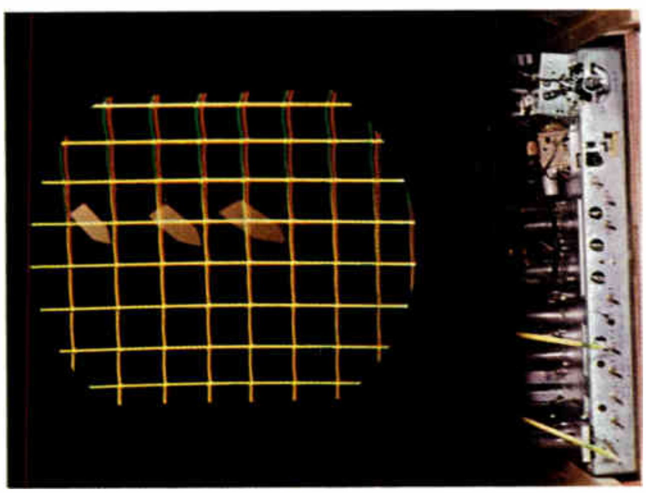


Figure 6-22. Adjustment of green horizontal dynamic phase control.

horizontal line at the center of the cathode ray tube screen, figure 6-23. The blue (B) HOR. AMP control is next adjusted so that the blue horizontal line and the red-green horizontal line, across the center of the screen, are made as nearly parallel to each other as possible, figure 6-24.

The red, green and blue static convergence adjustments are again made to converge all beams at the center of the screen, figure 6-25. This completes the preliminary convergence adjustments.

Color Purity Adjustments

The color bar generator is not used for the color purity adjustments, which are made using a red field. To present only a red field, the green (G) G2 and blue (B) G2 controls are set to minimum. Prior to making any color purity adjustments, the

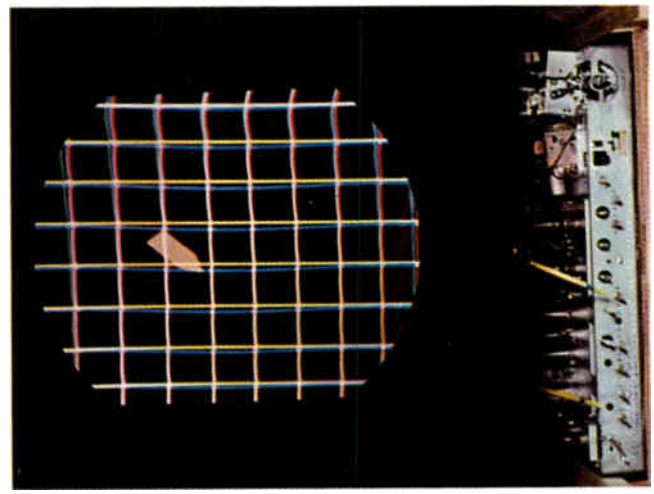


Figure 6-23. Adjustment of blue horizontal dynamic phase control.

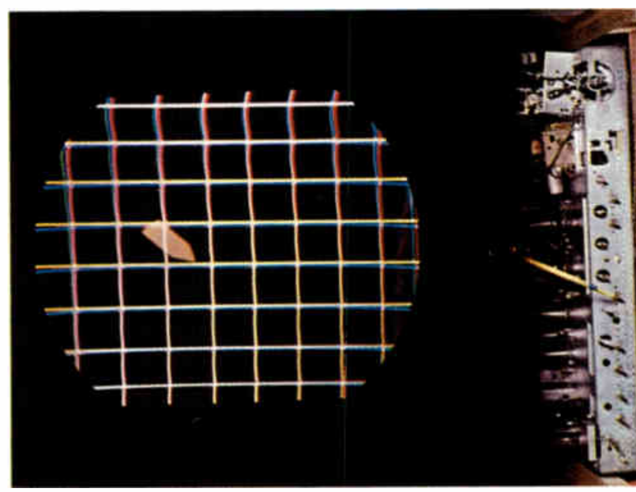


Figure 6-24. Adjustment of blue horizontal dynamic amplitude control.

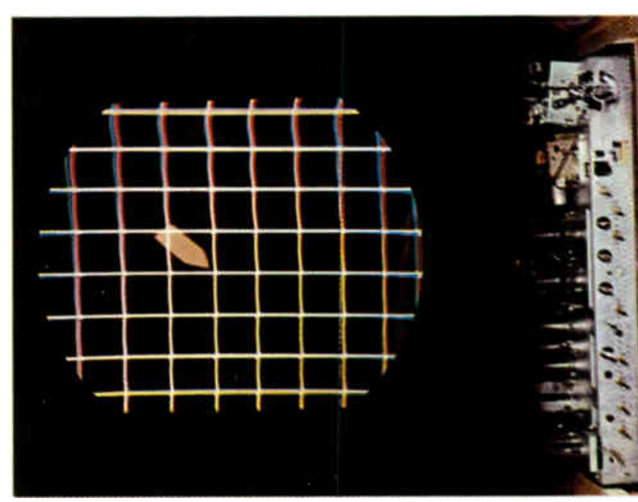


Figure 6-25. Final red, green, blue static convergence of preliminary convergence procedure.

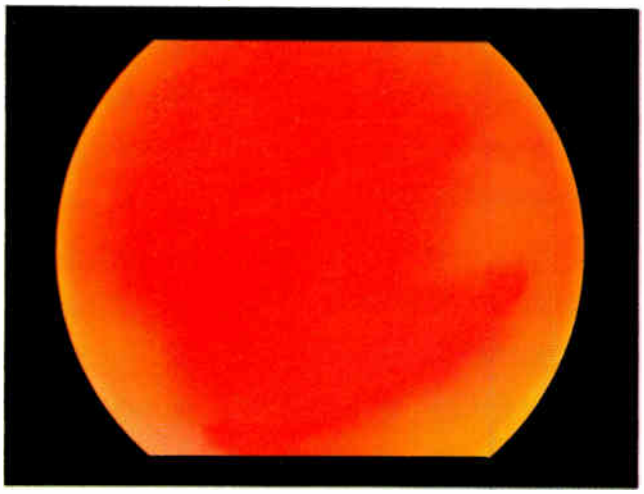


Figure 6-26. Preliminary red field purity.

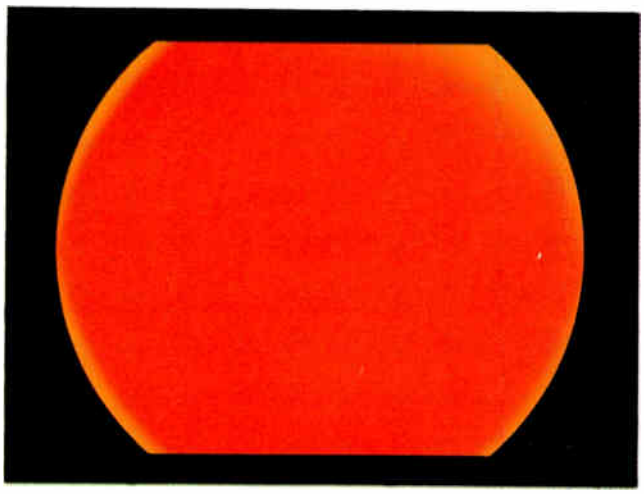


Figure 6-27. Improved red field purity by deflection yoke adjustment.

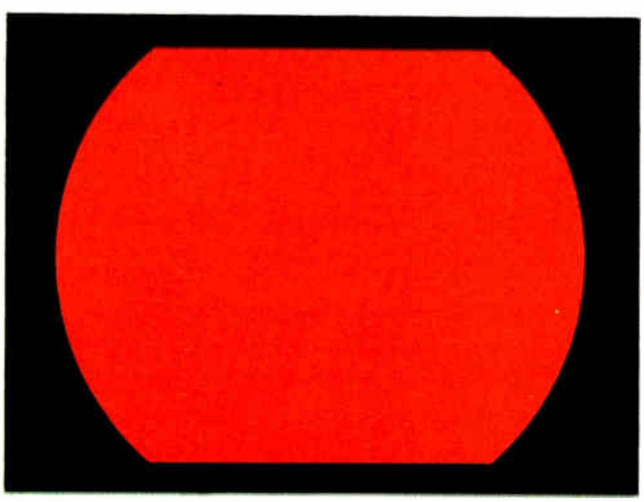


Figure 6-28. Final red field purity.

equalizer magnets, which are positioned around the bell-shaped portion of the cathode ray tube close to the front, are pulled all the way out so as to produce minimum effect on the three color beams, and the color purity control is centered to its midrange position. The color purity ring magnet assembly is then rotated around the neck of the cathode ray tube and each ring magnet is rotated with respect to the other until the purest possible red field is obtained at the center of the cathode ray tube screen with minimum magnetic correction, figure 6-26.

After the most uniform red field is obtained at the center of the screen, some color impurities may exist around the edges of the screen. A more uniform overall red color may be obtained, as illustrated in figure 6-27, by moving the deflection yoke either backward or forward. Do not shift the yoke laterally or vertically as the symmetry of convergence will be upset. Moving the yoke too far back on the neck of the tube may cause a shadow to appear in the corner of the screen. This shadow may appear on one of the color fields without showing up on the others.

If color impurities still exist that cannot be corrected by the yoke adjustment, the equalizer magnets can be positioned to eliminate the remaining inequalities, figure 6-28. Best results are obtained by using the least possible correction.

The green and blue fields also must be checked for color purity. The green field purity is checked by setting the red (R) and blue (B) G2 controls to minimum and the green (G) G2 control to maximum. The blue field is examined by setting the red (R) G2 and green (G) G2 controls to minimum and the blue (B) G2 control to maximum. When some color contamination exists in either of the above fields, a compromise setting of the equalizer magnets is necessary for best results on all three fields. Figure 6-29 illustrates proper color purity for the green and blue fields.

A preliminary white balance is obtained by setting the red (R) G2 control approximately midrange and both the green and blue G2 controls to minimum, then turning up the green (G) G2 control to obtain a yellow field, and turning up the blue (B) G2 control to obtain approximately white. If color impurities exist in any part of the white field, the equalizer magnets affecting that particular area of the screen are adjusted to compensate for this condition. The PURITY control is then rotated through its complete range. A definite color purity change should occur. Reset the PURITY control for the most uniform white field.

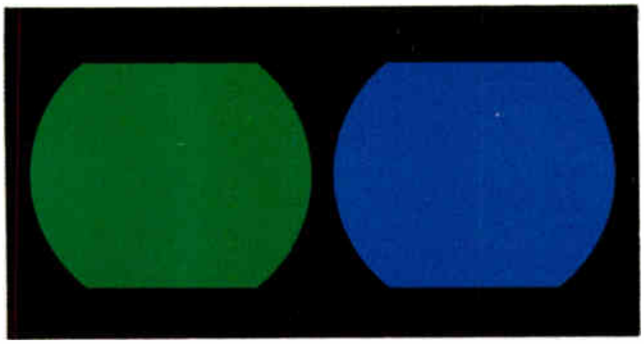


Figure 6-29. Final green and blue field purity.

Final Convergence Adjustments

The initial convergence adjustments were made to remove the possibility of beam misalignment causing color impurities. In addition, there is a slight interaction between the convergence magnetic fields in the convergence pole pieces. The result of this effect is minimized when the beams are close to convergence.

The cross-hatch pattern is used to make final convergence adjustments. The convergence controls are again preset before any adjustments are made. The red (R) VERT. AMP, green (G) VERT. AMP and blue (B) VERT. AMP controls are turned to minimum; the red (R) VERT. TILT, green (G) VERT. TILT and blue (B) VERT. TILT controls are set to the center of their ranges; and the static convergence magnets are adjusted to bring about convergence of the red, green and blue beams at the center of the screen as illustrated in figure 6-30.

With the blue (B) G2 control turned to minimum and the red (R) VERT. AMP control set to maximum, observe the red and green vertical lines down the center of the screen and adjust the red (R) VERT. TILT control. As shown in figure 6-31, this should produce a symmetrical bowing of the red vertical line about the green vertical line. The red (R) VERT. AMP control is readjusted to minimum and the green (G) VERT. AMP is set to maximum.

By adjusting the green (G) VERT. TILT control, produce a symmetrical bowing of the green vertical line about the red vertical line down the center of the screen, figure 6-32. With both the red (R) VERT. AMP and green (G) VERT. AMP controls reset to minimum, alternately advance both controls a small amount at a time, until the red and green vertical

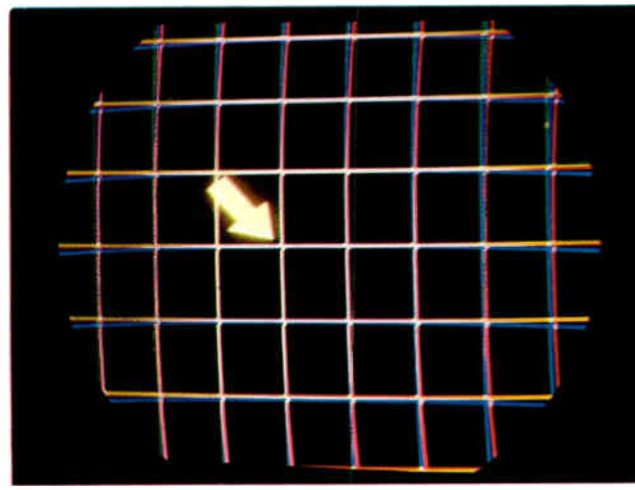


Figure 6-30. Static convergence of red, green and blue beams.

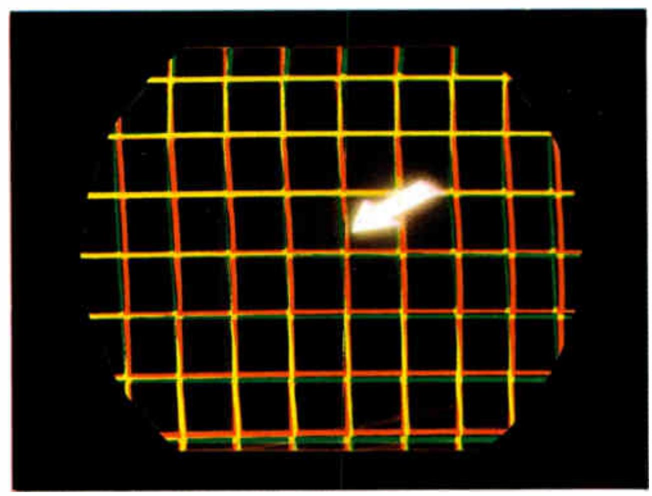


Figure 6-31. Adjustment of red vertical tilt control.

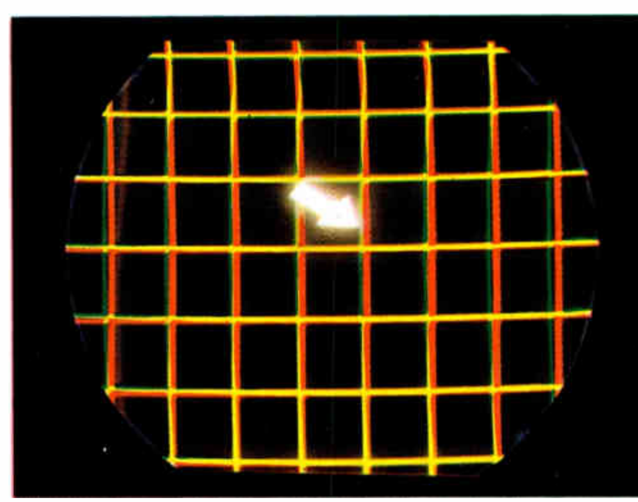


Figure 6-32. Adjustment of green vertical tilt control.

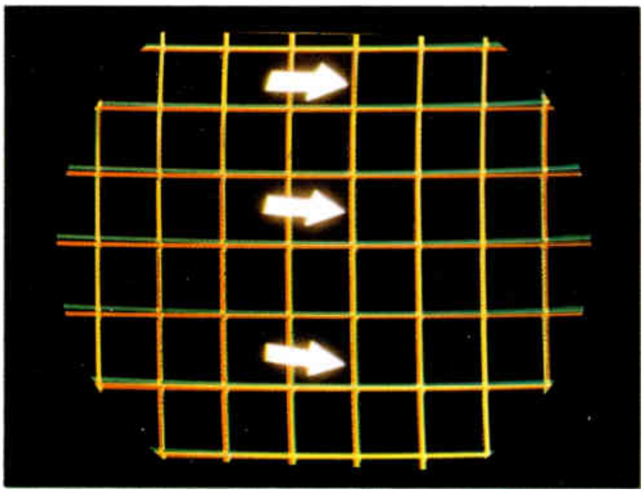


Figure 6-33. Final adjustment of red and green vertical amplitude controls.

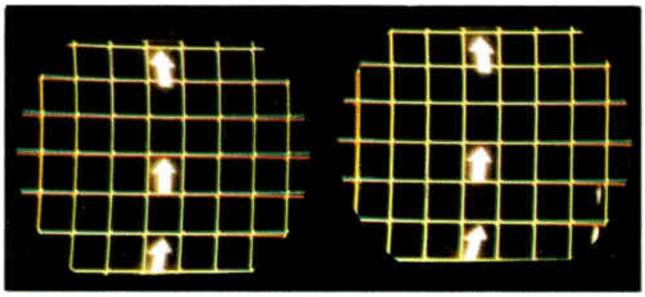


Figure 6-34. Incorrect (left) and correct (right) ratio of red to green vertical amplitude.

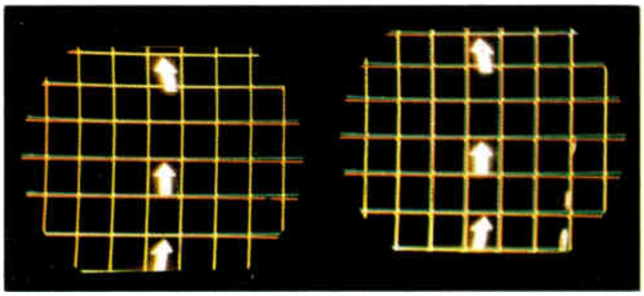


Figure 6-35. Incorrect (left) and correct (right) ratio of red to green vertical tilt.

lines, at the center of the screen, are parallel from top to bottom as in figure 6-33.

Check the segments of each horizontal line, at the center of the screen, where the horizontal lines cross the parallel red and green vertical lines. The red and green lines in each of the horizontal lines referred to may be so close together that they form continuous yellow lines; however, the degree of spacing may vary from very close to widely separated. The important consideration is the amount of separation between the red and green lines of one horizontal line segment with respect to the separation between the red and green lines in the other horizontal line segments. The amount of separation, if any, should be equal for each horizontal line from top to bottom of the screen. If they are not equally separated, i.e., greater or lesser spacing near the center than at the top and bottom, then the ratio of red to green VERT. AMP controls is incorrect and the controls must be varied with respect to each other until equal spacing is obtained, while maintaining parallel red and green vertical lines.

In figure 6-34, the left-hand illustration shows unequal separation of the horizontal red-green lines from top to bottom; the right-hand illustration shows equal separation from top to bottom. If the error in separation of the lines is a gradual increase or decrease from top to bottom, then the red and green VERT. TILT controls are varied with respect to each other to obtain the required equal separation. However, the red and green vertical lines must be maintained parallel; therefore, the red and green VERT. AMP controls must also be readjusted. The left-hand illustration of figure 6-35 shows incorrect separation; the right-hand illustration shows corrected separation.

After all the horizontal lines down the center portion of the screen display equal red-green displacement and the red and green vertical lines are parallel from top to bottom, the beams are converged at the center of the screen using the static convergence magnets for the red and green beams. Figure 6-36 illustrates the degree of convergence thus far obtained.

The blue (B) G2 control is now turned up so that the blue lines are equally as bright as the red and green lines. If necessary, adjust the blue lateral convergence magnet to superimpose the center blue vertical line over the center yellow line. Advance the blue (B) VERT. AMP control to maximum and observe the portions of the horizontal lines that intersect the vertical line down the center of the screen and adjust the blue (B) VERT. TILT control so that there is an equal displacement (in the same direction) of the blue horizontal line from the red-green (yellow) horizontal line at the top and bottom of the crosshatch pattern as indicated in figure 6-37.

The blue (B) VERT. AMP control is then adjusted so that the blue horizontal lines are equally displaced (in the same direction) from the red-green (yellow) horizontal lines from the top to the bottom of the cathode ray tube screen, figure 6-38. All three beams are then converged at the center of the screen by

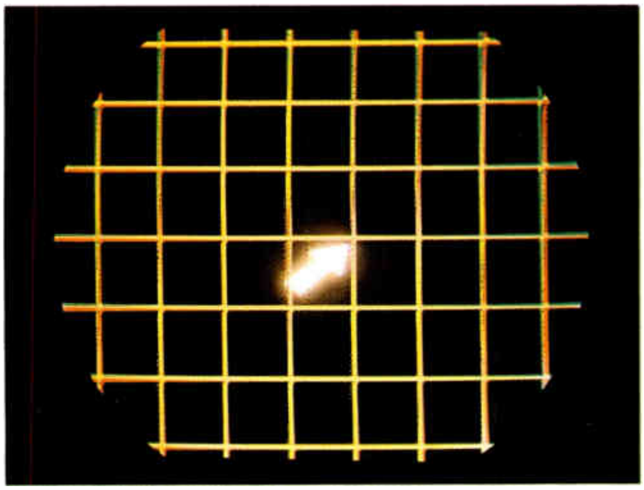


Figure 6-36. Static convergence of the red and green beams at center of screen.

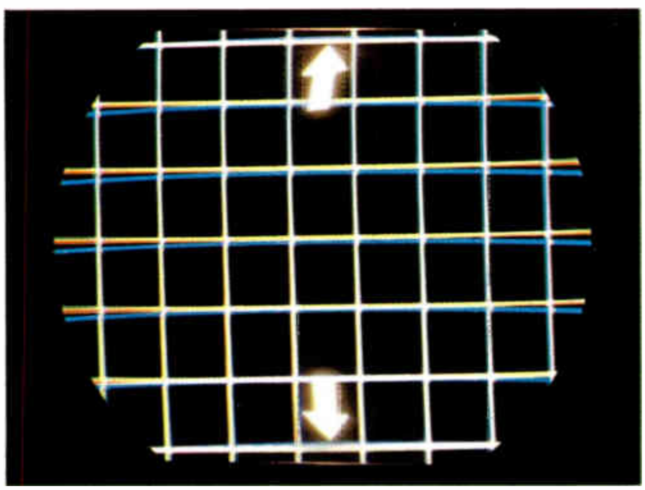


Figure 6-37. Adjustment of blue vertical tilt control.

adjusting the static convergence magnets, thereby completing the vertical dynamic convergence adjustments. Figure 6-39 illustrates the appearance of the cross-hatch pattern on the cathode ray tube screen after completion of the preceding adjustments.

The horizontal dynamic convergence adjustments described below complete the convergence procedure. The red (R) HOR. AMP control is set to maximum and the green (G) HOR. AMP and blue (B) HOR. AMP controls remain at their minimum settings. Observe a segment of each vertical line intersecting the horizontal line across the center of the screen, figure 6-40. Adjust the red (R) HOR. PHASE control so that there is an equal displacement (in the same direction) of the red vertical lines from the corresponding green vertical lines. The red (R) HOR. AMP control is then readjusted to minimum and the green (G) HOR. AMP control is set to maxi-

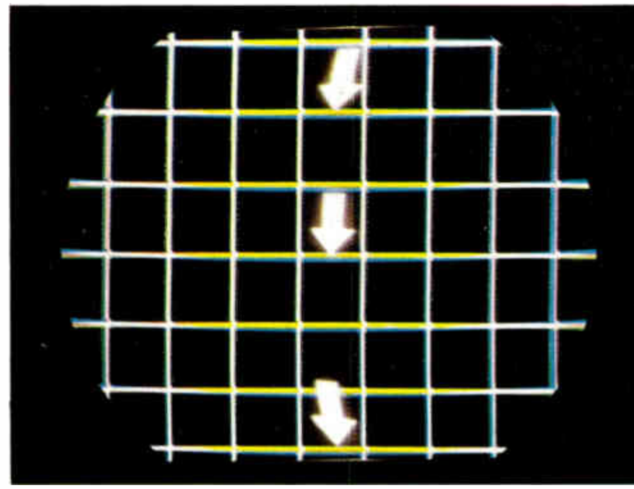


Figure 6-38. Adjustment of blue vertical amplitude control.

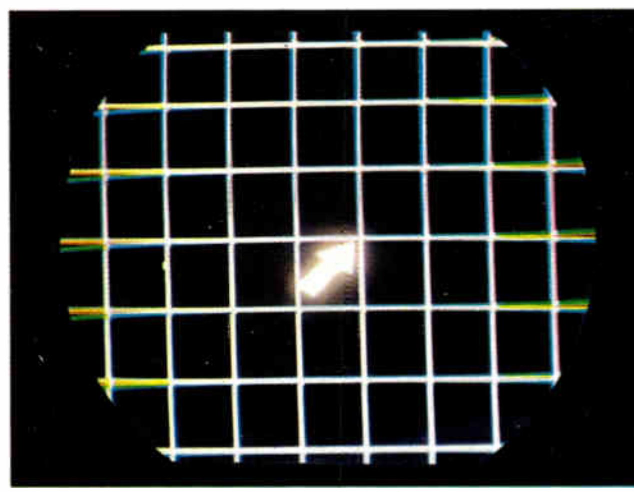


Figure 6-39. Static convergence of the red, green and blue beams at center of screen.

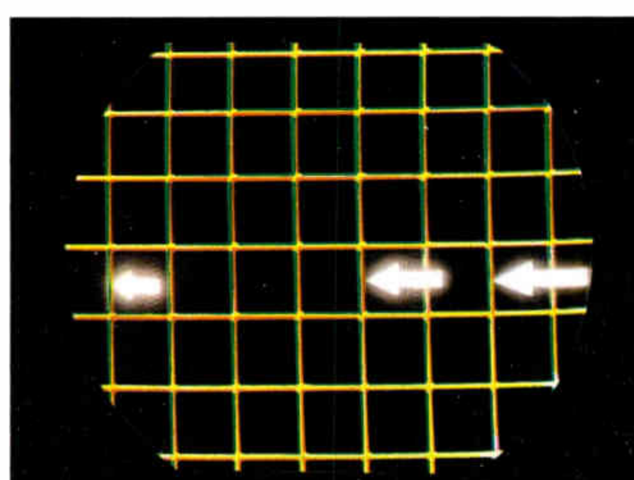


Figure 6-40. Adjustment of red horizontal phase control.

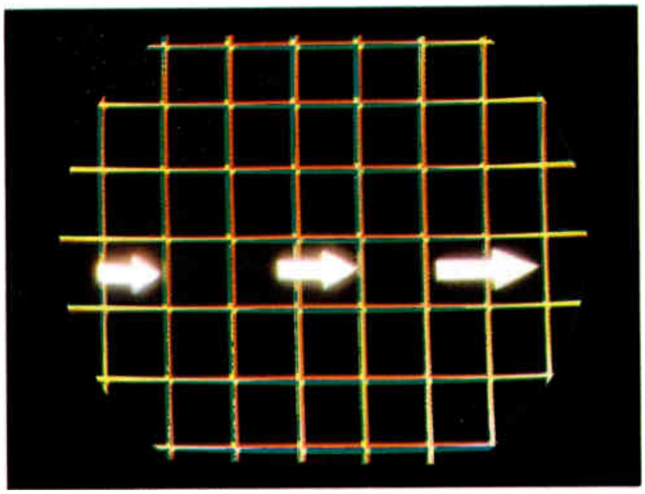


Figure 6-41. Adjustment of green horizontal phase control.

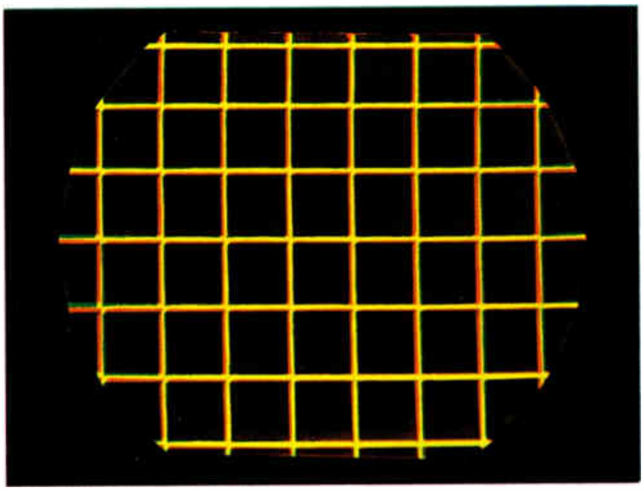


Figure 6-42. Adjustment of red and green horizontal amplitude controls.

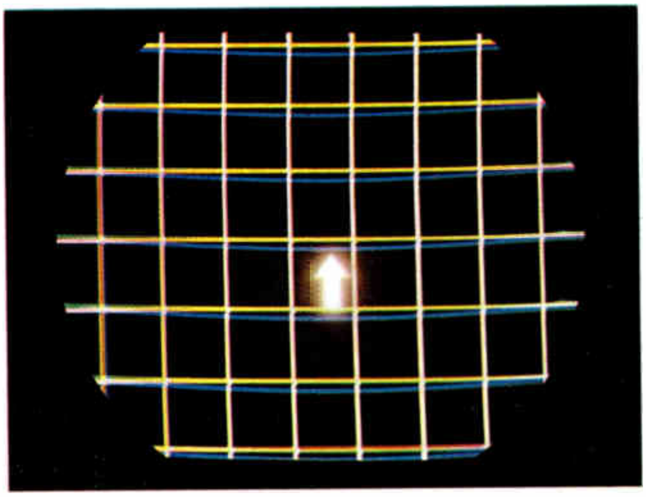


Figure 6-43. Adjustment of blue horizontal phase control.

mum. The green (G) HOR. PHASE control is adjusted for an equal displacement (in the same direction) of the green vertical lines with respect to the red vertical lines intersecting the horizontal line across the center of the screen as indicated in figure 6-41.

The green (G) HOR. AMP control is then returned to minimum. The red (R) HOR. AMP and green (G) HOR. AMP controls are alternately increased, a small amount at a time, until there is equal separation of the red and green vertical lines across the cathode ray tube screen. The horizontal red and green lines across the center of the screen should be parallel to each other as illustrated in figure 6-42.

If the horizontal red and green lines are bowed with respect to each other, the amplitude ratio of red to green is incorrect. If the lines are not bowed but are crossed, the red (R) HOR. PHASE and green (G) HOR. PHASE controls should be readjusted, with slight readjustment of the amplitude controls, to obtain equally spaced vertical lines along with parallel horizontal lines. The red and green lines are again reconverged in the center of the screen by adjusting the static convergence magnets.

The blue (B) G2 control is again turned up and the blue (B) HOR. AMP control is set to maximum. The blue (B) HOR. PHASE control is adjusted for a symmetrical bowing of the horizontal blue line about the corresponding horizontal red-green (yellow) line across the center of the cathode ray tube screen, figure 6-43. The blue (B) HOR. AMP control then is readjusted, as indicated in the right-hand illustration of figure 6-44, so that the horizontal blue lines are parallel to the red-green (yellow) lines across the screen of the cathode ray tube. Finally, the three beams are converged at the center of the screen by adjusting the static convergence magnets, left-hand illustration of figure 6-44.

The above adjustments complete the final convergence. Figure 6-45 illustrates the overall con-

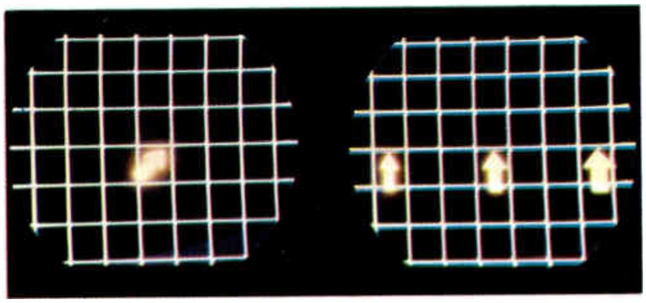


Figure 6-44. Adjustment of blue horizontal amplitude control (right) and final static convergence (left).

vergence of the three beams on the cathode ray tube screen. Any slight misconvergence remaining in the corners will not be seen in the normal viewing area of the screen and must be disregarded, since further convergence adjustments cannot correct this condition.

AGC Adjustment

The agc control is properly set by using a calibrated oscilloscope and a test lead which is used as an intermittent shorting device. Set the station selector to receive a normal signal. Calibrate the oscilloscope to indicate a voltage of 35 volts, peak-to-peak. Connect the oscilloscope to the plate of the first video amplifier tube. The signal present is a composite video signal. As shown in figure 6-46, by the arrow marked A, use the centering control on the oscilloscope and position the tips of the sync pulses just even with the bottom reference line (marked during calibration).

With one end of the test lead connected to B-minus (–25V), the other end of the test lead is used to short the video detector output intermittently to B-minus. While this is done, observe the action of the signal on the oscilloscope screen. The signal momentarily collapses to a straight horizontal line and the line moves suddenly to the top of the oscilloscope screen as shown in figure 6-46 by the arrow marked B; then quickly reverses its direction and moves toward the bottom of the screen and finally comes to rest at the center of the screen. Adjust the agc control so that when the video detector output is momentarily shorted to B-minus, the maximum upward travel of the oscilloscope trace coincides with the upper marking of the 35-volt peak-to-peak calibration. This adjustment places the maximum positive excursion of the video signal on the plate of the 1st video amplifier 35-volts below B-plus.

White Balance Adjustments

It is necessary to white balance the color television receiver to establish the proper operating characteristics of the three electron guns of the cathode ray tube for proper luminance level under varying signal amplitudes. Prior to making the white balance adjustments, the BRIGHTNESS and CONTRAST controls must be preset. Calibrate and mark the oscilloscope to provide a 65-volt peak-to-peak indication. Tune the television receiver to a station transmitting a picture which contains black and white signal information. Preset the BRIGHTNESS control of the receiver to approximately midrange. Connect the oscilloscope to the cathode of the red

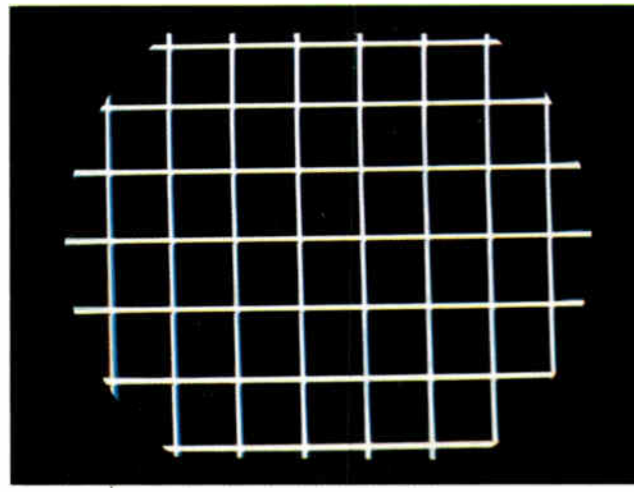


Figure 6-45. Overall convergence of the red, green and blue beams.

electron gun of the cathode ray tube. Set the CONTRAST control so that the white-to-black video information on the oscilloscope screen occupies the space between the calibration markings as shown in figure 6-47. The BRIGHTNESS control is then advanced from midrange to a point at which the sync pulse tips just start to compress. Turn the BRIGHTNESS control toward minimum until the sync tips are just out of compression.

The first step in setting up the white balance of the receiver is to turn the blue (B) G1 and (B) G2 controls to minimum and the green (G) G1 and (G) G2 to minimum (fully counterclockwise). Adjust the VERT. HOLD control so that the vertical blanking bar is midway between the top and bottom of the cathode ray tube screen. Adjust the red (R) G2 control until the vertical blanking bar just goes black

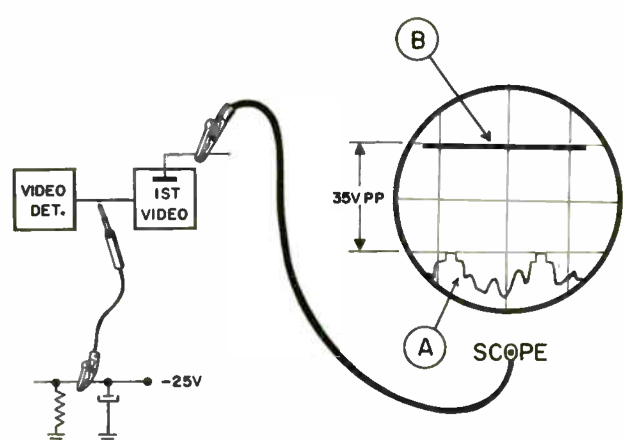


Figure 6-46. Adjustment of agc control

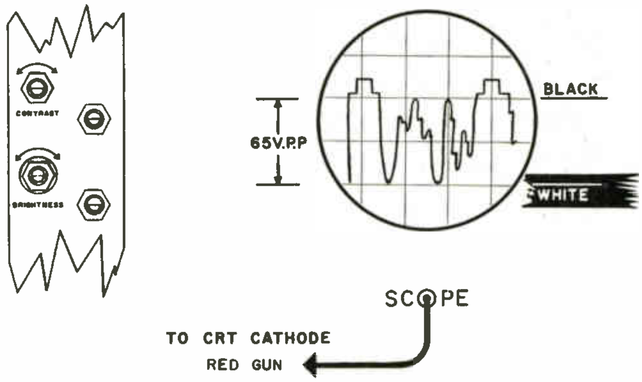


Figure 6-47. Pre-white balance adjustment of brightness and contrast controls.

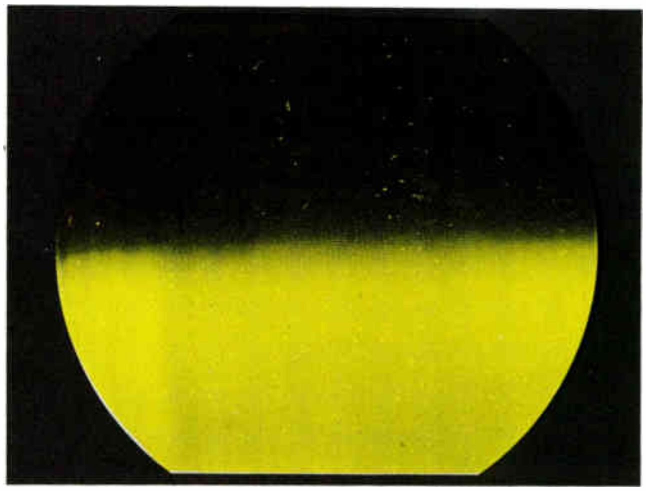


Figure 6-49. Adjustment of green G1 and G2 controls for yellow field.

as illustrated in figure 6-48. Then, readjust the VERT. HOLD to again synchronize the picture vertically.

With the Color Bar and Dot Bar Generator, Philco Model 7100, connected to the receiver antenna terminals, set the function switch to black and white bars. The function switch in this position provides a pattern which is black in the upper portion and progressively increases in brightness in the lower screen area. Adjust the green (G) G1 and (G) G2 controls so that the graduations of brightness levels are similar shades of yellow as in figure 6-49. It is important to note that the green (G) G2 control primarily affects the darker portion of the pattern while the green (G) G1 control primarily affects the lighter area. For example, if the light part of the screen is too green and the dark part too red, the green (G) G1 control should be decreased and the green (G) G2 control increased.

The blue (B) G1 and (B) G2 controls are then adjusted for a neutral white through gray to black over the entire bar pattern as illustrated in figure 6-50.

When adjusting the blue G1 and G2 controls for a white through gray to black pattern, bear in mind that the G1 control primarily affects the high level or white areas of the pattern, and the G2 control primarily affects the low level or dark portions. Therefore, if the dark part of the pattern is too blue and the light area is too yellow, decrease the blue (B) G2 control and increase the blue (B) G1 control slightly. The color television receiver is then white balanced.

Figure 6-48. Adjustment of red G2 control.

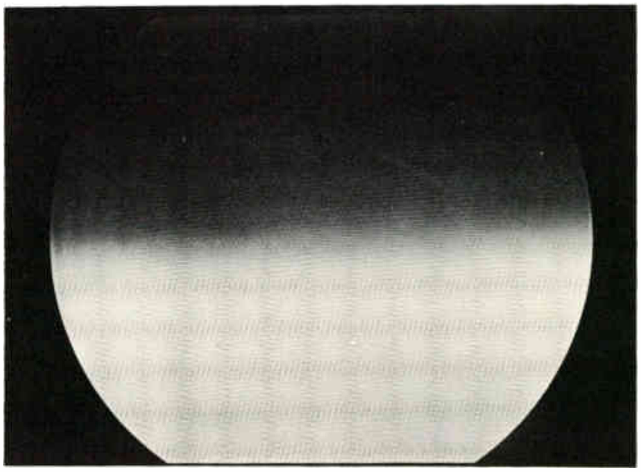


Figure 6-50. Adjustment of blue G1 and G2 controls for final white balance.

7. RECEIVER ALIGNMENT

PROPER ALIGNMENT of the color television receiver is essential to obtain satisfactory reproduction of the color picture. The response curves of the various sections of the receiver must fall within the tolerance limits indicated in the alignment specifications to obtain the desired color fidelity. Color receiver alignment is similar in many respects to that of a black and white receiver. The difference exists in the additional steps necessary to align the chroma and burst sections of the receiver and in the required precision.

Best picture quality is obtained when the sections of a color television receiver are aligned in the following squence:

1—Tuning Unit
2—Video I-F Stages
3—Sound I-F Stages
4—Chroma Channel
5—Burst and 3.58-mc Oscillator Section
6—Demodulator Stages

If a tube or component in a section is replaced so that a touch-up of the alignment of that section is required, it is good practice to check the alignment of all sections.

SECTION 1. TEST EQUIPMENT AND ACCESSORIES

The test equipment employed in the alignment of a black and white receiver will, in most cases, also serve in the alignment of the color receiver, with the addition of a signal generator which provides a chroma signal comprised of color bars. Connection of the test equipment to the receiver, in some instances, must be made by means of detectors or impedance matching networks.

Test Equipment

Alignment of the color television receiver requires the following equipment:

Sweep Generator
R-F Marker Generator
Color Bar Generator
Oscilloscope
Vacuum Tube Voltmeter

The following Philco test equipments, illustrated in figure 7-1, are particularly suited for color receiver alignment:

Model 7300 Sweep and Marker Generator, modified.

Model S8202 Oscilloscope.

Model 7100 Color-Bar and Dot-Bar Generator.

Model 6100 Vacuum Tube Voltmeter.

The modified Model 7300 Sweep and Marker Generator contains the color conversion kit. The conversion kit extends the limits of the generator's low-frequency range, making it adaptable for color receiver alignment. The marker generator should be calibrated accurately to the i-f and trap frequencies of the receiver as well as the sound and video r-f carriers of each channel used during alignment. The Model 7300 Sweep and Marker Generator contains a crystal calibrator for this purpose.

Good bonding is necessary at all times between the receiver chassis and the test equipment. This condition is most easily satisfied if the work bench employed has a metallic top. If the bench is not equipped with a metallic top, copper bonding straps should be used between the equipment and the receiver. Allow the receiver and test equipment to warm up for 15 minutes before starting the alignment. The alignment procedure in this chapter is based upon a representative Philco Color Television Receiver.

Bias Voltage Source

A variable source of bias voltage is necessary for application to the agc circuits during the alignment of a receiver. This bias source should be capable of an output of at least 35 volts negative d-c. A simple bias supply can be constructed, employing a 67.5-volt "B" battery, a 10,000-ohm, ½-watt resistor and a 50,000-ohm potentiometer with switch, figure 7-2. The switch permits the circuit to be opened when the supply is not in use, thus eliminating battery drain. A voltmeter should be employed when setting the amount of bias voltage fed to the agc circuit.

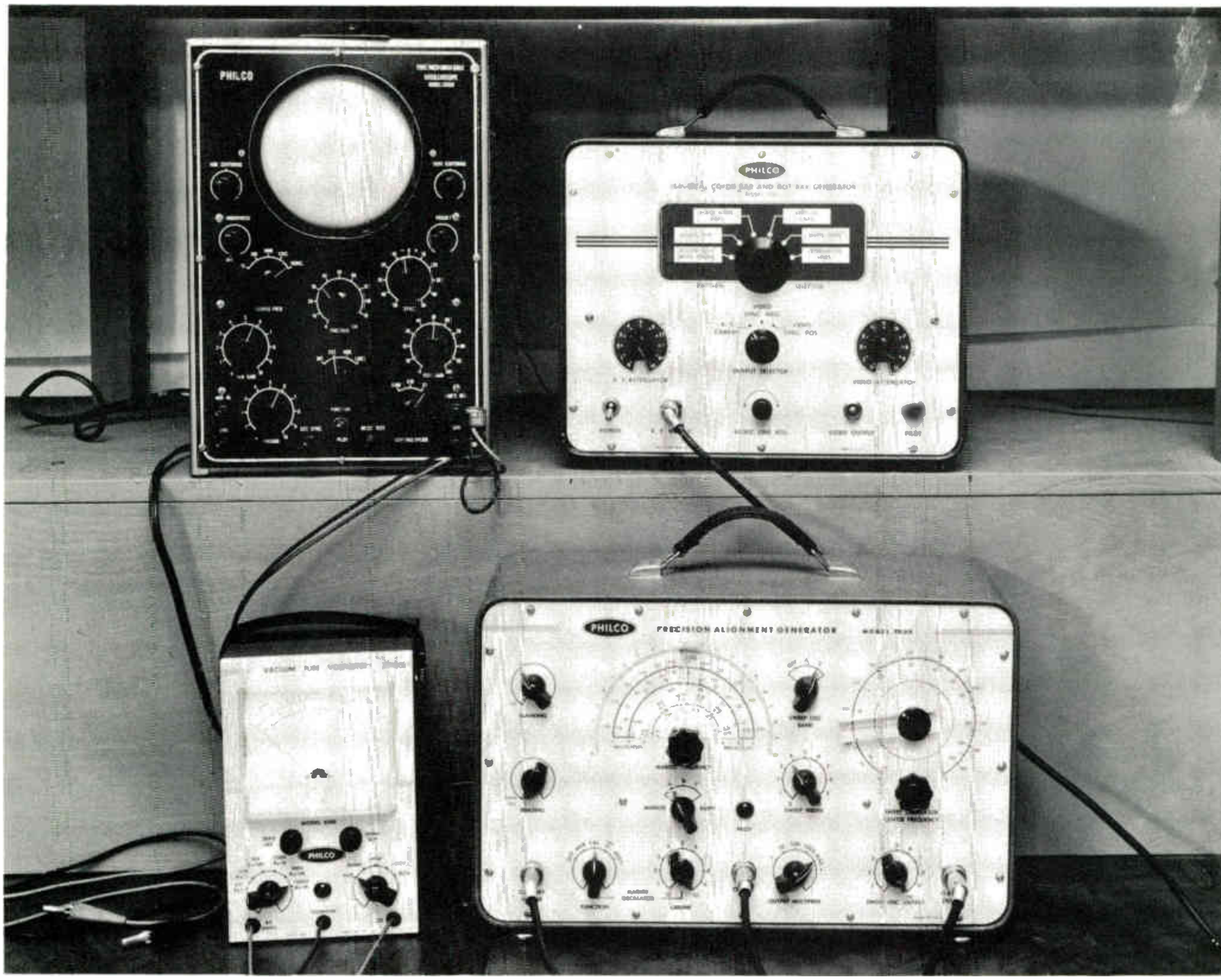


Figure 7-1. Test equipment.

Antenna-Matching Network

The alignment of the color receiver tuner, as in the case of the black and white receiver tuner, requires the use of an impedance-matching network to match the 75-ohm output impedance of the sweep and marker generator to the usual 300-ohm input impedance of the receiver's antenna terminals. The 72- to 300-ohm matching network (balun) prevents false response indications due to standing waves on the connecting cable. If a commercial antenna-matching network is not available, one can be constructed from two 106-ohm resistors and a 150-ohm resistor, figure

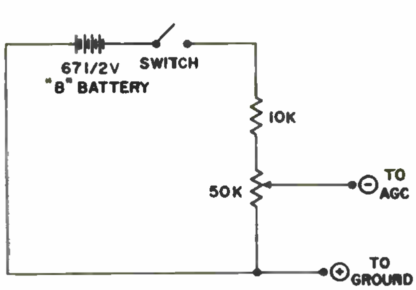


Figure 7-2. Bias supply circuit.

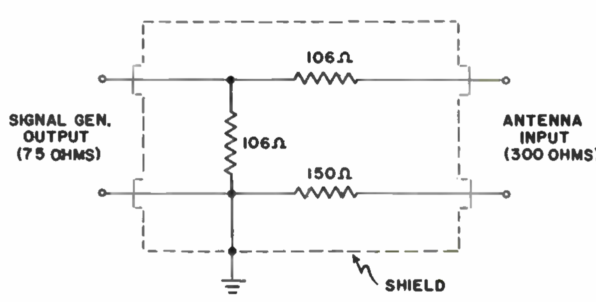


Figure 7-3. Antenna-matching network.

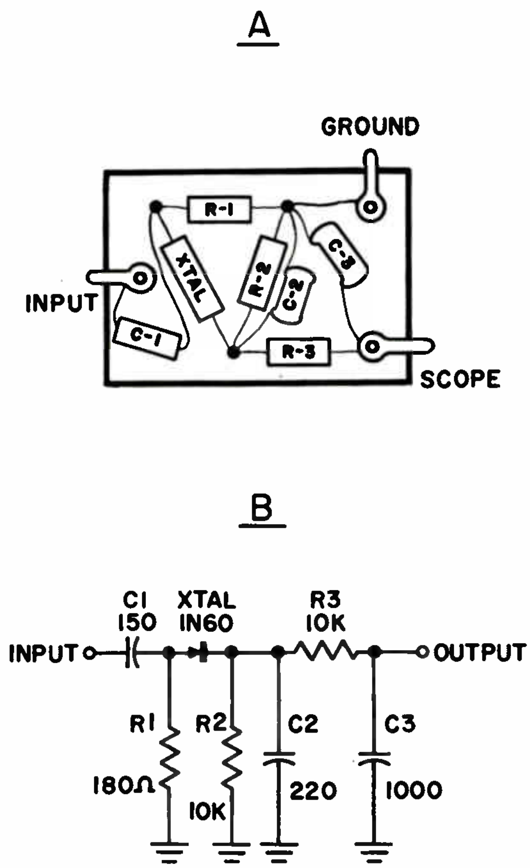


Figure 7-4. Low-impedance detector.

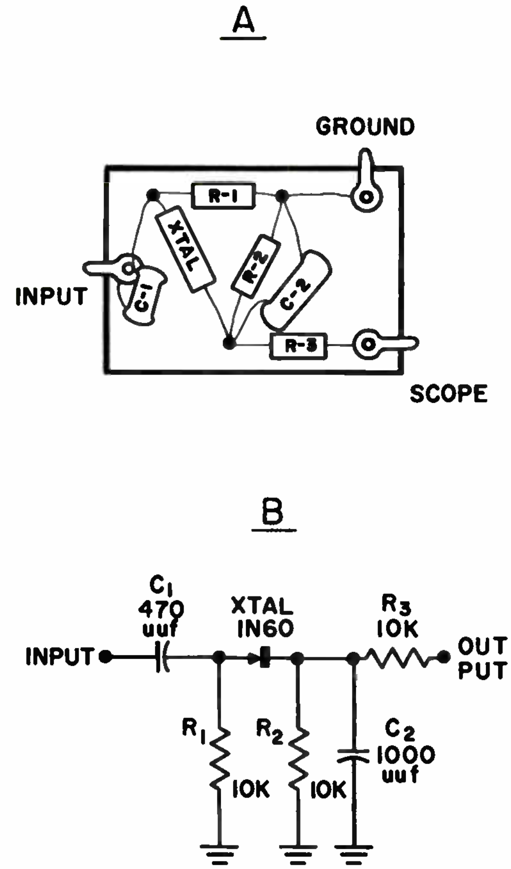


Figure 7-5. High-impedance detector.

7-3. It is important that carbon resistors (not wire-wound) be used and the values be within ten percent of those specified. The components must be enclosed in a metal shield to prevent variation in the impedance match. Some attenuation of the signal results from the use of the network; however, this loss is negligible.

Low-Impedance Detector

In certain steps of the alignment procedure it is necessary to connect the oscilloscope to the output of the video i-f stages. The connection is made through a low-impedance detector. Construction of the detector requires the following components and materials:

150 mmfd capacitor
220 mmfd capacitor
1000 mmfd capacitor
180 ohm resistor
10K ohm resistors ¼ watt (2)
1N60 crystal
Panel (1/16″ thick)

The physical layout of the parts on the panel is illustrated in figure 7-4A and the circuit of the detector is illustrated in figure 7-4B. The length and width of the panel are cut to fit the inside of a tube shield, which serves as the housing. The panel is arranged to provide a connection to the circuit test point, a ground connection and an oscilloscope connection. The ground lug on the side of the panel is shaped into a semicircle to fit the inside curvature of the tube shield and then is soldered to the shield.

High-Impedance Detector

During alignment of the chroma and sound i-f amplifier stages, a high-impedance detector is required. The components required are:

470 mmfd capacitor
1000 mmfd capacitor
10K ohm resistors, ¼ watt (3)
1N60 crystal
Panel (1/16″ thick)

The construction of this detector is similar to the low-impedance detector. The physical layout of the components on the panel is illustrated in figure 7-5A and the detector circuit diagram in figure 7-5B. The panel is designed to fit a tube shield and connections are provided for the test point connection, ground

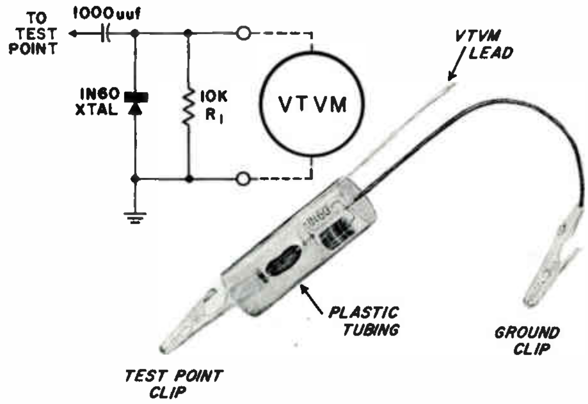


Figure 7-6. R-F probe for vacuum tube voltmeter.

and the oscilloscope. Similar to the low-impedance detector, the ground lug on the panel is shaped into a semicircle to fit the inside curvature of the shield and then is soldered to the shield along with the ground lead.

Low-Capacity Detector

A low-capacity detector (r-f probe) is required for use with the vacum tube voltmeter during alignment of the 3.58-mc oscillator. A low-capacity detector can be constructed from the following materials and components:

1000 mmfd capacitor
10K ohm resistor, ¼ watt
1N60 crystal
Alligator clips (2)

The detector and its circuit diagram are illustrated in figure 7-6. The components are housed in a piece of insulated tubing. Alligator clips on the ends of the leads provide connections to the circuit under test and ground.

SECTION 2.
TUNER ALIGNMENT

Tuner Oscillator Alignment

The r-f signal generator, with an unmodulated output, is connected to the receiver antenna terminals. A matching network is not required for this connection since the mismatch does not adversely affect the oscillator alignment. Insert a 3300-ohm 1-watt carbon resistor in series with the B-plus lead to the tuner. The oscilloscope is connected to the tuner end of the 3300-ohm resistor and ground. The signal developed across the 3300-ohm resistor is directly proportional to the output of the tuner. Disconnect the tuner agc circuit from the chassis agc voltage source and apply sufficient bias to the tuner agc circuits to prevent the tuner circuits from overloading. If regeneration occurs during the oscillator alignment, the bias voltage should be increased.

Alignment of the oscillator is accomplished by adjusting the oscillator to produce a zero beat (as indicated on the oscilloscope) with the unmodulated r-f signal from the generator at the specified frequencies. For a receiver with a 41.25-mc sound and 45.75-mc picture i-f system, the oscillator frequency is 44 mc above the center frequency of the television channel, that is, 44 mc is the center of the receiver's i-f response, which has a range of 41 through 47 mc. The relationship of the channel limits, channel center frequency and r-f generator setting (desired oscillator frequency) for channels 3, 6 and 10 is shown in the following table:

Channel	Channel Limits (MC)	Center Freq. (MC)	R-F Generator Setting (MC)
3	60-66	63	107
6	82-88	85	129
10	192-198	195	239

The oscillator adjusting slugs for each VHF channel are generally located on the front of the tuning unit, figure 7-7. When the receiver has an incremental-type tuner, it is important that adjustment of high frequency channels be performed first, beginning with channel 13 and then proceeding through the lower channels consecutively to channel 2. The receiver's fine tuning control is set to the center of its range. The r-f generator is set to the desired oscillator frequency for each channel and the oscillator is adjusted for a zero beat as indicated on the oscilloscope.

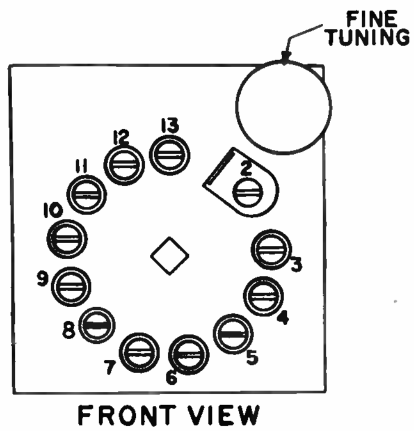


Figure 7-7. Tuner oscillator adjustments.

Alternate Method of Oscillator Adjustment

An alternate method of oscillator adjustment is available if the r-f generator used does not have a range sufficient to cover the required higher oscillator frequencies, i.e. channel 12 (251 mc) and channel 13 (257 mc). The requirements of this method are that the upper range of the r-f generator be sufficient to cover the sound carrier frequency of channel 12 (209.75 mc) and that the tuner be aligned in the chassis in order to utilize the traps in the video i-f section. Basically, this method relies upon the adjacent-channel traps in the video i-f section. These traps are tuned to 47.25 mc and are designed to attenuate the signal which occurs when the sound carrier frequency of the lower-adjacent channel is present at the receiver input. Therefore, before beginning the alignment of the tuner, the video i-f alignment must be checked to assure that the adjacent-channel traps are properly set at 47.25 mc. If it is necessary to correct any trap settings, the overall video i-f alignment must then be checked since the response may be affected.

The procedure consists of feeding the r-f generator signal, 30 percent modulated, to the tuner input with the oscilloscope connected to the output of the video detector. The fine tuning control is set to the center of its range and the tuner is set for channel 13. The signal generator is set to 209.75 mc (lower-adjacent-channel sound carrier). The oscillator tuning slug is adjusted for a minimum indication on the oscilloscope. The minimum indication occurs when the channel 13 oscillator setting produces a 47.25-mc i-f signal which is nulled by the adjacent-channel sound traps. This procedure may be used for each of the remaining channels with the generator set to the lower-adjacent-channel sound carrier, for each channel being adjusted.

Tuner Bandpass Alignment

Following the tuner oscillator adjustment, the bandpass of the tuner must be established. Both a sweep-generator signal and an r-f marker-generator signal must be employed. The oscilloscope connection and application of the bias voltage are the same as during the oscillator alignment. The tuner is isolated, signal-wise, from the video i-f section by disconnecting the output of the tuner from the video i-f input and terminating the open end of the cable from the tuner with a 40- to 70-ohm carbon resistor.

The procedure consists of first establishing the bandpass limits on the high channels (7-13) while obtaining a symmetrical response and then repeating the procedure for the low channels (2-6). A typical tuner response curve, with the bandpass limits, is illustrated in figure 7-8.

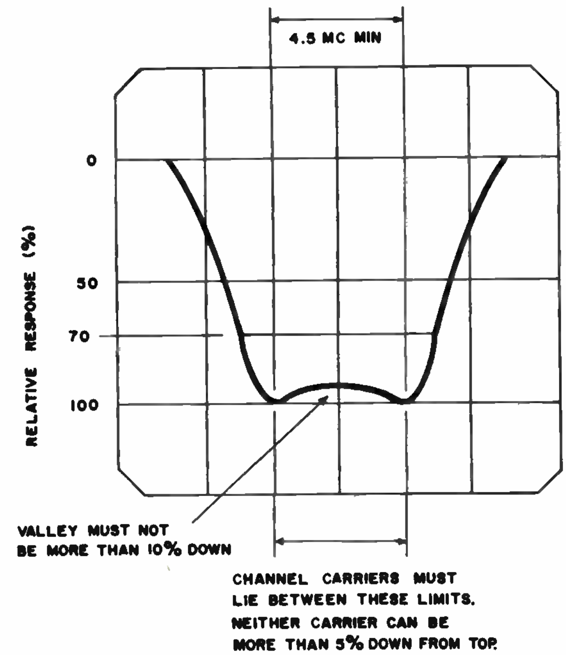


Figure 7-8. Typical tuner response curve.

SECTION 3.

VIDEO I-F ALIGNMENT

After it is established that the tuner is correctly aligned, the video i-f channel is aligned. The basic procedure consists of tuning each coil to its assigned frequency, using an a-m signal and then applying a sweep signal to the antenna terminals and retouching the adjustments to obtain the desired bandpass and response curve. The overall response curve (r-f, i-f) after alignment of the video i-f stages should appear essentially the same on all channels. Any radical differences in the response through various channels indicates that the tuner alignment should be checked.

A-M Alignment

A-m alignment of the picture i-f section is performed with the r-f generator signal, 30 percent modulated, feeding into the input of the picture i-f stages. The UHF input jack on the tuner is used as the input for the generator when aligning most Philco television chassis. A bias voltage (negative 25 volts) is applied to the video i-f agc circuit. The oscilloscope is connected either to the video detector output or to the chroma detector output through a 10,000-ohm

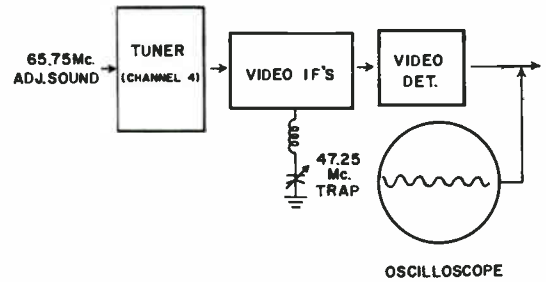


Figure 7-9. Centering the fine tuning control, block diagram.

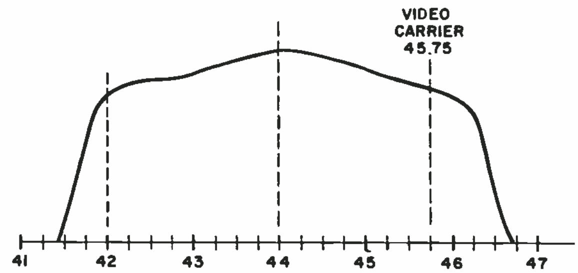


Figure 7-10. Overall response, 5th video i-f output.

isolating resistor. The horizontal output tube is removed to disable the agc-amplifier circuit.

All of the traps in the video i-f section are adjusted for minimum scope indication with the r-f generator set to the specified frequencies. The oscilloscope lead is moved alternately between the video and chroma detector outputs for the trap settings in the various circuits. The coil or pole settings then are adjusted for maximum indication on the oscilloscope with the r-f generator set to the specified frequencies. In some instances, two coils may be present in the same grid or plate circuit and very close in frequency. It is therefore necessary to dampen one coil by shunting it with a low value carbon resistor during adjustment of the other coil, to prevent interaction.

Sweep Alignment

The overall response of the system (r-f, i-f) is checked by feeding a sweep-generator signal into the antenna terminals of the receiver. Before performing the sweep alignment of the system, the fine tuning control on the tuner must be properly adjusted so that the r-f marker signals will be converted in the tuner to the proper intermediate frequencies. Set the channel selector to channel 4 and feed a channel-3 a-m sound signal (65.75 mc) to the antenna input. Since this is the lower-adjacent-channel sound, the adjacent-channel traps previously adjusted in the video i-f will nullify the signal when the fine tuning control is properly adjusted, figure 7-9. The oscilloscope, connected to the video detector output, is observed for a minimum indication while the fine tuning control is adjusted.

Three oscilloscope observations of the overall response are necessary when aligning the typical Philco receiver under discussion. Observation of the response through the first 3 video i-f stages is made at the output of the 5th video i-f. The oscilloscope connection is made through the low-impedance detector previously described. The response at this point is illustrated in figure 7-10. The response then is checked at the video detector output. The 4th video i-f is padded to produce the response indicated in figure 7-11. A final overall check of the response is made with the oscilloscope connected to the chroma detector output. The 5th video i-f is padded to produce the response indicated in figure 7-12.

SECTION 4.
SOUND I-F ALIGNMENT

Alignment of the sound i-f stages is performed with the receiver tuned to a television station signal. A vacuum tube voltmeter or 20,000-ohm/volt meter is connected from the diode plate on the output side of the ratio detector to ground. The bias voltage, applied to the agc, is adjusted to produce a meter indication of 5 to 10 volts negative. The sound i-f coil adjustments then are made for maximum negative voltage indication on the meter and for maximum sound.

SECTION 5.
CHROMA-CHANNEL ALIGNMENT

Chroma-channel alignment is performed with both an a-m generator signal and a sweep-generator signal. The generator signals are fed into the chroma-channel input through a 10,000-ohm isolating resistor. The bias voltage is adjusted for 35 volts negative to cut off the video i-f section and eliminate any noise from these stages. The oscilloscope connection is made through the high-impedance detector to the output of the R-Y demodulator. The 3.58-mc oscillator tube and the horizontal output tube are removed since certain circuits must be disabled to minimize their effect upon the chroma response curve. These circuits

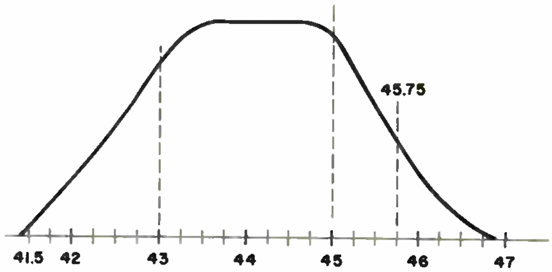


Figure 7-11. Overall response, video detector output.

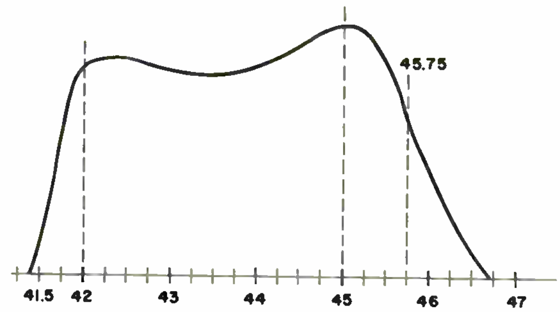


Figure 7-12. Overall response, chroma and sound detector output.

include the demodulators and the 3.58-mc oscillator amplifier (c-w amplifier).

A-M Alignment

The coils in the chroma channel are adjusted for maximum oscilloscope indication with the a-m generator set to the specified frequency for each pole. The 4.5-mc sound trap in the output of the chroma and sound i-f stages is adjusted for minimum.

Sweep Alignment

A sweep-generator signal, approximately 3.0 mc wide and centered on 3.58-mc is fed to the chroma-channel input. The coils or pole adjustments are padded to obtain the specified response band width as verified by the marker generator. The desired response is indicated in figure 7-13. When padding the response, a minimum amount of adjustment should be made to the pole in the output of the chroma amplifier (output transformer), since more than a quarter-turn of the adjustment can produce serious phase shift. The top of the response curve is affected by the setting of the chroma control, and the curve changes shape slightly with various levels of the control setting.

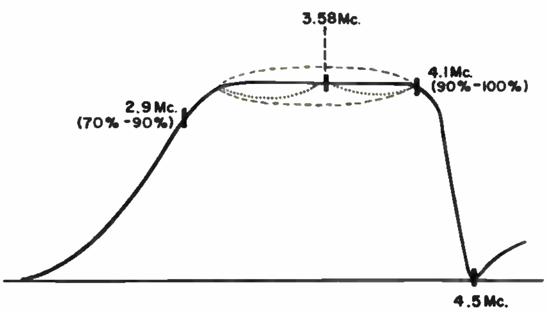


Figure 7-13. Overall response, chroma output.

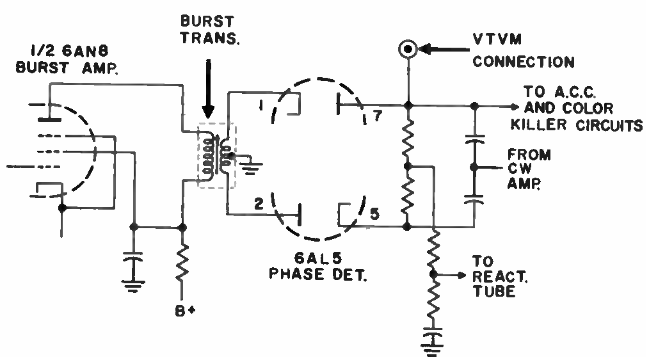


Figure 7-14. Burst phase-detector circuit with VTVM connected for test.

SECTION 6.

BURST AND 3.58-MC OSCILLATOR ALIGNMENT

Alignment of the burst channel (burst phase detector, 3.58-mc oscillator and c-w amplifier) requires the use of the color-bar generator, connected to the receiver's antenna terminals and set for Color Bars. The hue control on the receiver should be set in the center of its range. A vacuum tube voltmeter and the screen of the cathode ray tube are used for the visual indicators for the alignment of these stages.

Phase-Detector Alignment (Burst Transformer)

Alignment of the burst transformer or phase detector transformer is the first step in the procedure. Adjust the vacuum tube voltmeter for negative d-c voltage readings and connect the meter to the diode plate on the output side of the phase detector, figure 7-14. With the burst signal, from the color-bar generator, feeding through the stage, adjust the burst transformer for maximum negative indication on the vacuum tube voltmeter.

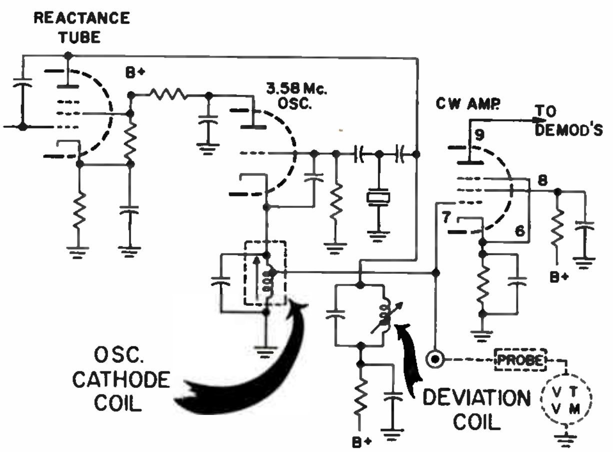


Figure 7-15. 3.58-mc oscillator adjustment.

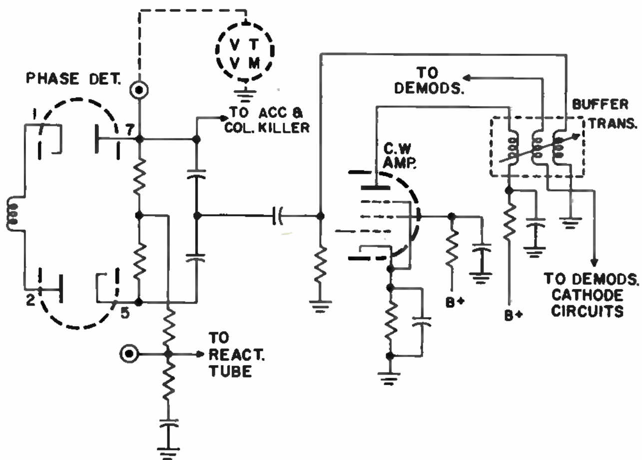
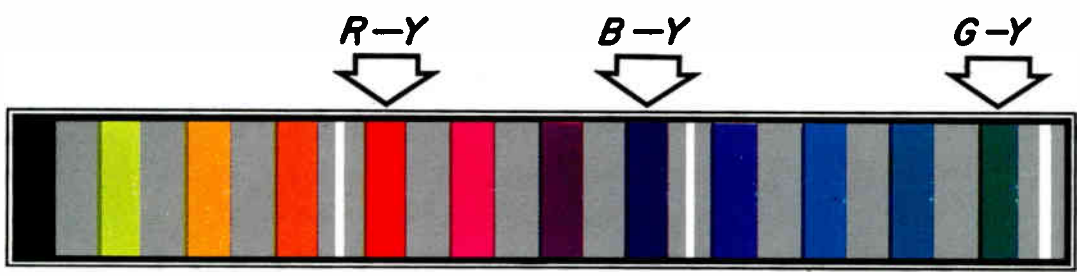


Figure 7-16. C-W amplifier adjustment.

3.58-mc Oscillator Adjustment

The frequency of the 3.58-mc oscillator must be adjusted so that it is within the control range of the phase detector and reactance tube. The vacuum tube voltmeter is connected through the low-capacity r-f probe to the control grid of the c-w amplifier, figure 7-15. Adjust the deviation coil, which is in the plate circuit of the reactance tube, approximately one-quarter of the way in from its top position. Adjust the core of the 3.58-mc oscillator cathode coil, starting with the core at its top position, one to two turns past the point where the oscillator starts to function. A more exact setting of this adjustment is given in the service manual for each receiver.



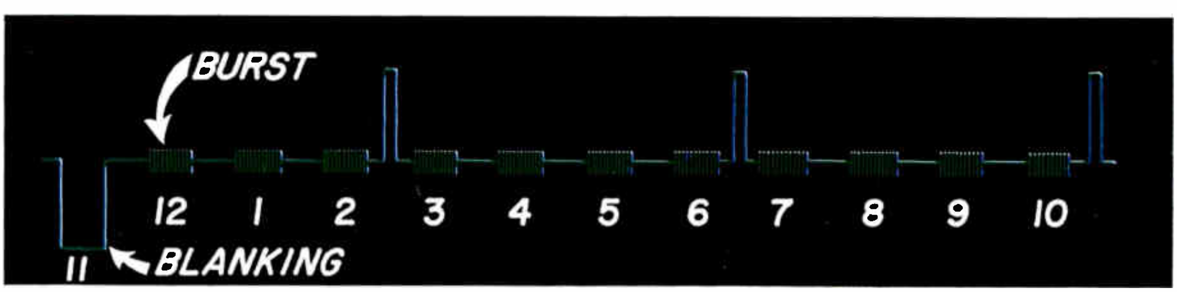


Figure 7-17. Comparison of color-bar-generator signal to color-bar chart on CRT.

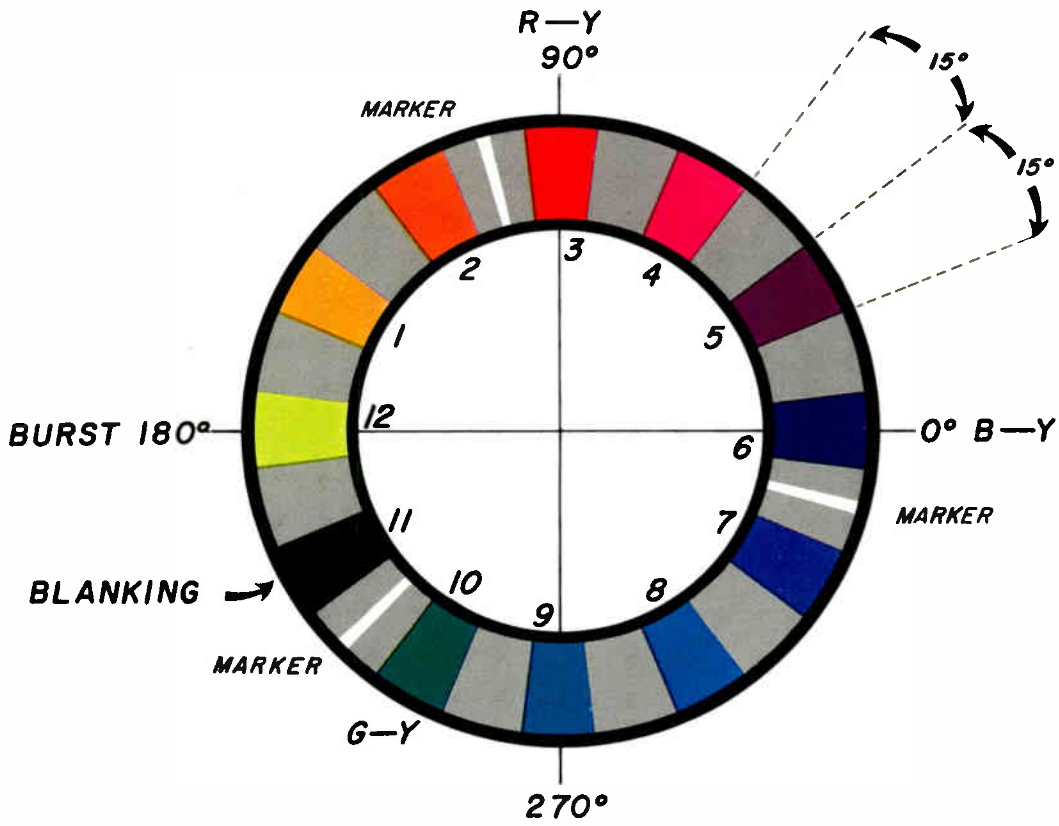


Figure 7-18. Color-bar-generator quadrature graph for master phase adjustment.

Before proceeding, ground the grid of the gate clamp to prevent any oscillator control voltage from being developed by the burst. With removal of the burst, the color-killer stage will provide a control voltage to cut off the grid of the chroma amplifier. To prevent this action, ground the color-killer voltage.

The color-bar pattern on the cathode ray tube screen is used as the visual indicator. Adjust the deviation coil, which was previously preset, until the oscillator is at 3.58 mc. When the oscillator is at the proper frequency, the color pattern on the screen will stop running through the bars and become almost stationary.

C-W Amplifier Adjustment

Adjustment of the c-w amplifier (buffer amplifier) requires that the burst be rendered inactive. This is accomplished by grounding the grid of the gate clamp stage. Connect the vacuum tube voltmeter to the output diode plate of the phase detector with the meter set for negative d-c voltage readings, figure 7-16. Adjust the output transformer of the c-w amplifier for a maximum negative d-c indication on the meter. Remove the short from the grid of the gate clamp.

SECTION 7. DEMODULATOR ALIGNMENT

Alignment of the demodulators is the final step in the procedure. The adjustments must be carefully performed in order to achieve proper color fidelity in the reproduced picture. The adjustments require adequate knowledge of the oscilloscope waveforms that will appear on the grids of the cathode ray tube, produced by the color-bar generator.

Color-Bar-Generator Waveforms

The output of the Philco Color-Bar Generator, when set for Color Bars, consists of 12 bars, eleven of which contain modulation, while the remaining bar is employed for blanking and sync, figure 7-17. The relative positions of the bars are illustrated in figure 7-18. Electrically, the centers of the bars are 30° apart with 15° spacing between bars, making each bar 15° wide. Markers are present between the 2nd and 3rd, 6th and 7th and between the 10th and 11th bars.

Figure 7-18 is useful in the alignment of the demodulators and is referred to as the color-bar-genera-

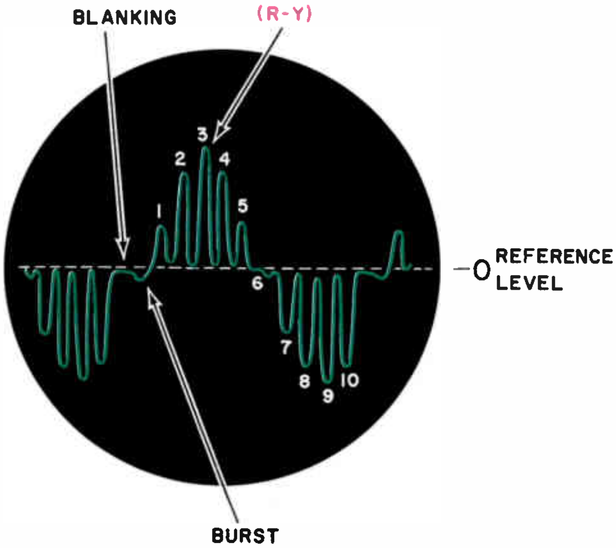


Figure 7-19. Oscilloscope waveform, grid of CRT red gun with color-bar-generator signal.

tor quadrature graph. For example, if an adjustment is being made for a maximum positive R-Y bar, then as indicated by their positions on the quadrature graph, B-Y, the number 6 bar and burst, the number 12 bar, should be at a zero level and equal, since they are each in quadrature with the R-Y modulation bar. At the same time the number 9 bar, which is at 270°, should be in the maximum negative direction. These particular relationships are important when adjusting master phase, the first step in the alignment of the demodulators.

Master-Phase Adjustment

The master-phase adjustment is performed by means of the phase detector or burst transformer. It is called "Master Phase" since it establishes the phase of the 3.58-mc oscillator or reference signal applied to the demodulators. This adjustment, therefore, affects the phase of the signal on the grids of both demodulators, which, in turn, determines the demodulation of the chroma signal.

The oscilloscope is connected to the grid of the red gun of the cathode ray tube, either at the cathode ray tube socket or at the lead tie point on the chassis. The pattern on the oscilloscope, created by the signal from the color-bar generator will be a series of modulation bars of different amplitude, in the positive and negative directions (vertical plane). The position and amplitude of each bar is directly related to the relative position of each color bar mentioned previously in the color-bar quadrature graph and is determined by the master-phase adjustment.

To locate each bar position, the blanking position is used as a reference, figure 7-19. Since this bar contains no modulation, it appears as a gap on the zero reference level of the oscilloscope waveform. The bar immediately to the right, as viewed on the oscilloscope, is the burst. The remaining bars, 1 through 10, are the chroma modulation (color bars).

The master-phase adjustment is made with respect to the R-Y modulation bar and the positions of B-Y and burst, the 6th and 12th bars. Keeping in mind the position of these bars on the quadrature graph, the burst transformer is adjusted for a zero level of the B-Y and burst bars. The R-Y bar then is the maximum modulation bar in the positive direction, and the 9th bar, which is at 270° on the color-bar quadrature graph, is the maximum modulation bar in the negative direction. Note also the relative amplitudes of the remaining bars. This adjustment establishes the proper demodulation phase angle of the R-Y demodulator.

Quadrature Adjustment

The adjustment of the R-Y demodulator phase angle (master phase) also affects the B-Y demodulator since the grids of both stages are connected through an L-C-R network. Part of this network contains a phasing coil through which the 3.58-mc oscillator signal is fed to the grid of the B-Y demodulator. The proper demodulator phase angle of the B-Y demodulator is established by adjusting the phasing or phase-shift coil, figure 7-20.

The color-bar quadrature graph now must be considered from the standpoint of the B-Y modulation bar. With the oscilloscope connected to the grid of the blue gun in the cathode ray tube, the number 6 or

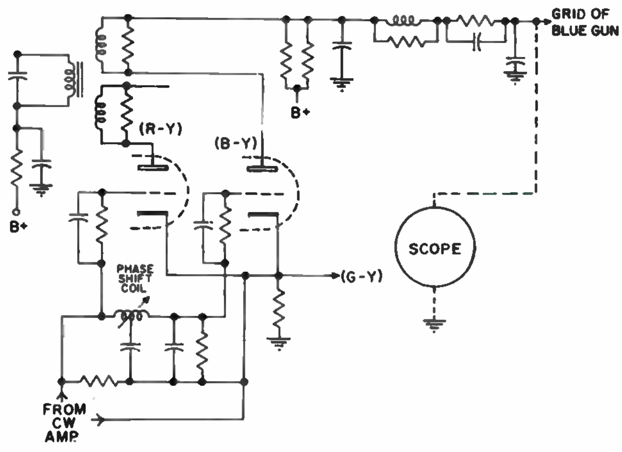


Figure 7-20. Circuit diagram, quadrature adjustment.

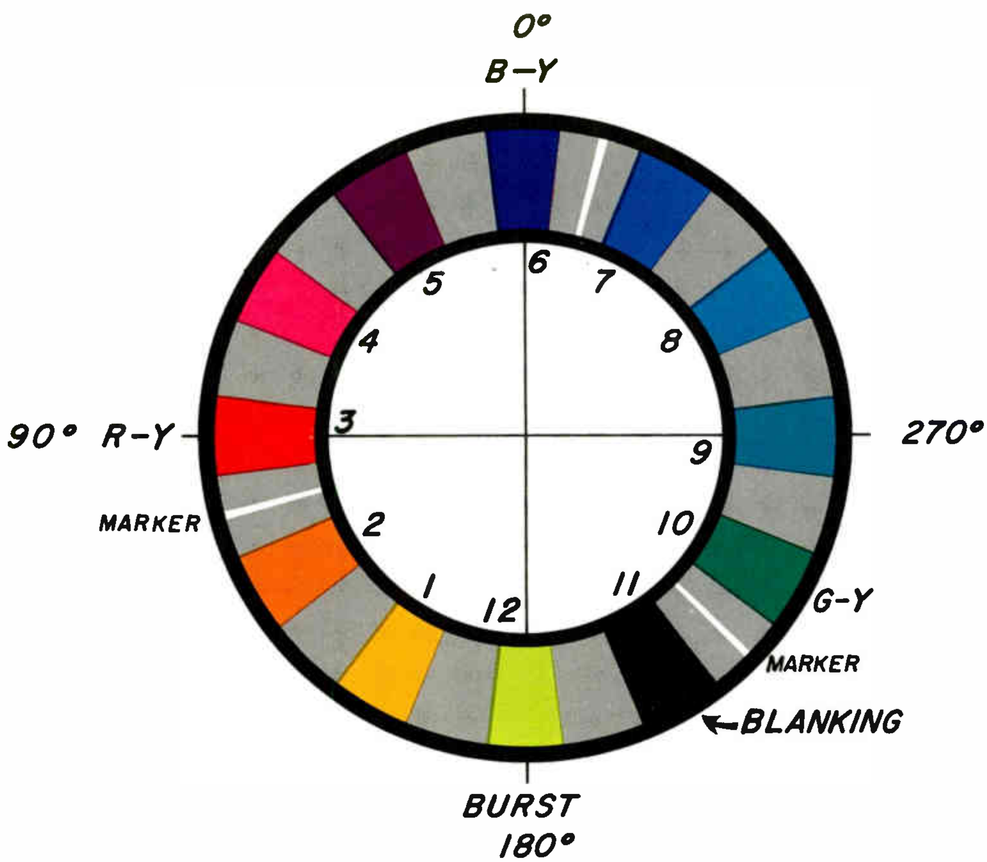


Figure 7-21. Color-bar-generator quadrature graph for quadrature adjustment.

B-Y bar is the maximum modulation bar. The 3rd (R-Y) and 9th bars, which are in quadrature with B-Y, are now at the zero reference level. To visualize this relationship more easily, simply rotate the color-bar quadrature graph 90 degrees, figure 7-21. The relationship of the modulation bars, as they appear on the grid of the blue gun, is represented by this graph.

The adjustment of the phase-shift coil is sometimes referred to as "Setting Quadrature" since it establishes the phase demodulation difference between the R-Y and B-Y demodulators. Similar to the alignment of the R-Y demodulator by the master-phase adjustment, the adjustment of the B-Y demodulator, by the phasing coil, is performed with the position of the modulation bars on the color-bar quadrature graph in mind. While observing the oscilloscope pattern, adjust the phase-shift coil for a zero level of the R-Y or 3rd bar and the 9th bar. These two bars should be at an equal level and close to the zero reference. The number 6 bar (B-Y) will be the maximum positive modulation bar, figure 7-22. The 12th bar or burst, which is at 180 degrees on the quadrature graph directly opposite to B-Y, is the maximum negative modulation bar.

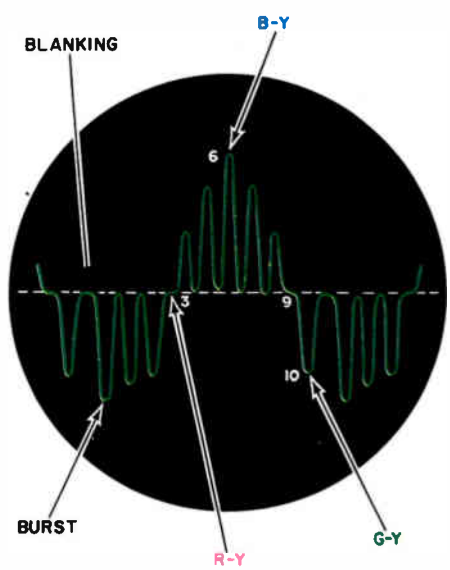


Figure 7-22. Oscilloscope waveform, grid of CRT blue gun, with color-bar-generator signal.

Phase-Detector Balance

After completion of the demodulation system alignment, the phase-detector balance is checked. The vacuum tube voltmeter is connected to the phase-detector output, figure 7-23. The balance measured at this point, with a color signal and burst being received (color-bar generator) should be within a range of plus or minus 0.5 volts. At the same point, a check for noise balance should be made with the signal removed. The phase-detector balance under these conditions should be within a range of plus or minus 0.8 volts. This completes the alignment procedure. If the voltages measured exceed the limits mentioned above, the circuit should be checked for tube or component failure.

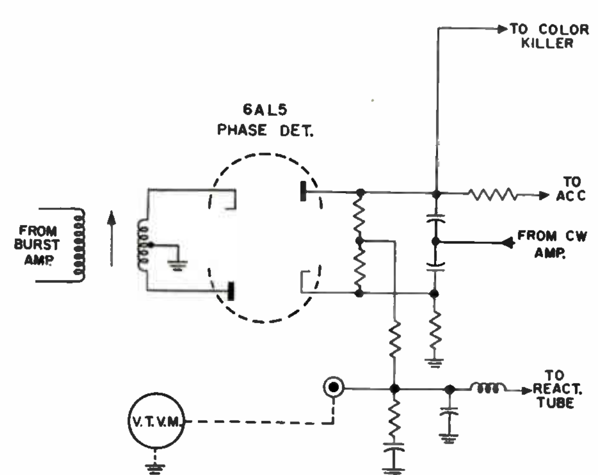


Figure 7-23. Checking the phase-detector circuit for balance.

8. SERVICING PROCEDURES

Servicing color television receivers is basically similar to servicing black and white television receivers. The same logically organized methods are employed to locate circuit malfunctions and faulty components. Normally, these consist of determining the defective section or group of sections by observing the picture tube and listening to the sound. The fault then is isolated to a section or a stage. This procedure usually requires test equipment, assuming, of course, that tube replacement does not rectify the trouble.

Test equipment used to service monochrome receivers may be utilized if the defective section or stage is similar to its counterpart in the monochrome receiver. However, new test equipment and, in some cases, adaptations of old test equipment, are required to isolate the fault within some sections of the color television receivers. After the defective or malfunctioning stage is located, the defective component is located by voltage and/or resistance measurements or the stage is adjusted in accordance with approved procedures.

Extremely high voltage (approximately 25,000 volts) is used in the color television receiver. Unlike the high voltage of the monochrome sets, color television high voltage is dangerous; therefore, extreme care should be exercised. However, the high voltage circuit, including the complete cathode ray tube assembly, should not be disconnected or disabled when performing service checks. Disabling the high voltage circuit also disables all circuits gated by the horizontal pulse, such as the agc circuit, the burst gate circuit and the color-killer circuit.

This chapter is divided into nine sections. The first section covers isolation of the defective section. The second section discusses test equipment required for servicing color television receivers and the remaining sections each are devoted to a particular functional section of the receiver. Sections 3 through 7 cover functions which are familiar to the service technician modified to process the color signal. The last sections of the chapter are associated predominantly with color signals.

SECTION 1. SECTIONALIZATION

The service technician observes the raster, picture and sound to determine what portions of a monochrome television receiver are affected. Considering all abnormalities collectively, and knowing which section is peculiar to the affected portions of the presentation and sound, the technician usually is able to isolate the abnormalities to one particular section.

In color television servicing, the service technician has another portion of the picture presentation to observe—the color information. Hence, he must understand the sections of the receiver which process the color signal and the other signals with which it combines.

The block diagram of a color television receiver in Chapter 4 (figure 4-1) is divided into functional sections. The function of each section and the signals within each section are discussed. Hence, in approaching a color-receiver service problem, it is well to review Chapter 4.

The most practical initial step in troubleshooting is to test all tubes within the suspected section, either by substitution or with a tube tester. It is a good habit to replace all good tubes in their original sockets, especially the tubes within the high-frequency portions of the receiver.

If the trouble is not located in a faulty tube, test equipment is employed. First, it must be determined if the suspected section is defective. After it is ascertained that the suspected section is defective, the defective stage, and finally the defective component, must be determined.

SECTION 2. TEST EQUIPMENT

Proper servicing of a color television receiver requires adequate test equipment, whether the service

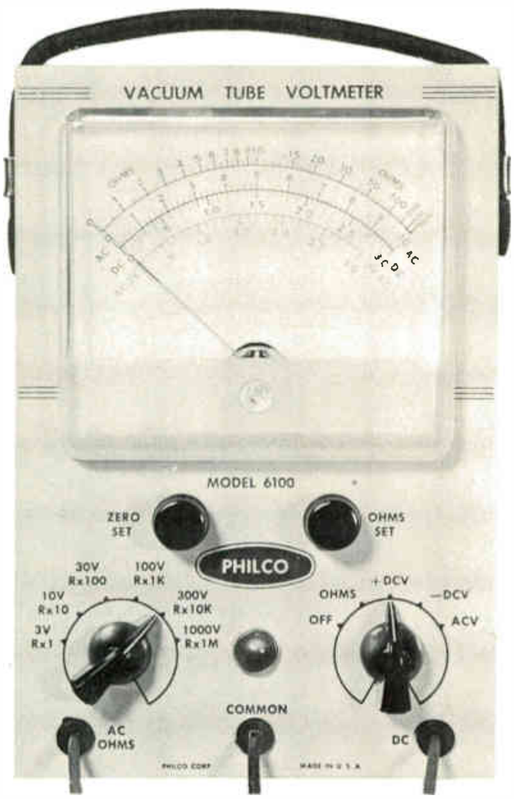


Figure 8-1. Philco Vacuum Tube Voltmeter, Model 6100.

is performed in the home or in the shop. In the discussion of servicing procedures to follow, shop methods are employed. The test equipment necessary for service in the shop is first described.

One of the most valuable assets in servicing a television receiver is a vacuum-tube voltmeter. Although a 20,000-ohms-per-volt multimeter will suffice in most instances, an accurate vacuum-tube voltmeter is more versatile and, due to its high input impedance, can be used to make many measurements not possible with other measuring devices. The Philco Vacuum Tube Voltmeter, Model 6100, illustrated in figure 8-1, is suitable for servicing color television receivers. A 30,000-volt H.V. probe is an essential accessory for the meter, since it is necessary to measure over 25,000 volts in the color receiver.

A source of color television signals also is required. The Philco Universal Color Bar and Dot Bar Generator, Model 7100, illustrated in figure 8-2 provides all the necessary signals for checking and servicing the color television receiver. The color signals produced appear on the screen of the color receiver as ten vertical color bars ranging through the color spectrum. Additional features of this generator are covered in the preceding chapter.

Dynamic servicing, afforded by the use of an oscilloscope, allows analysis of circuit faults during receiver operation. The oscilloscope used for servicing color circuits must have wide band characteristics for satisfactory observation of the burst signal and chroma information. (The vertical amplifier must have a flat frequency response up to at least 4 mc.) If the avail-

Figure 8-2. Philco Universal Color Bar and Dot Bar Generator, Model 7100.

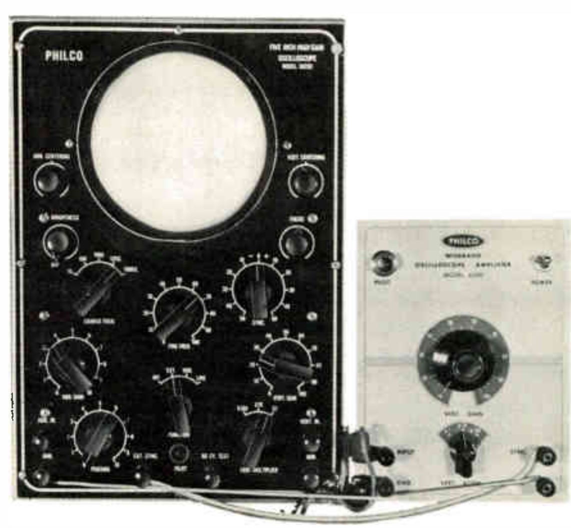


Figure 8-3. Philco Oscilloscope, Model S-8202 and Philco Wideband Oscilloscope Amplifier, Model 8300.

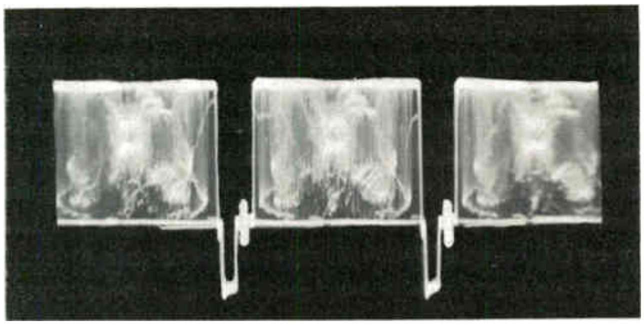


Figure 8-4. Normal composite color signal at the detector output.

able oscilloscope does not have adequate bandpass, a wide-band amplifier, connected directly to the vertical plates of an oscilloscope, provides the required bandwidth (the internal vertical amplifier of the oscilloscope is by-passed). Figure 8-3 illustrates a typical test setup using a Philco Oscilloscope, Model S-8202 and a Philco Wideband Oscilloscope Amplifier, Model 8300. The Philco Wideband Amplifier provides a sync signal to synchronize the sweep oscillator of the oscilloscope with the input signal. This sync signal is available from a terminal on the amplifier front panel. This terminal should be connected to the external sync terminal on the oscilloscope.

All waveforms in this chapter were photographed from a test setup similar to that illustrated in figure 8-3. In the following tests, the wideband amplifier is the vertical input to the oscilloscope.

SECTION 3. TUNER AND VIDEO I-F AMPLIFIERS

The tuner and video i-f stages usually are suspected if the raster is normal and the picture is missing, weak or abnormal. The sound also may be affected, although slight abnormalities in the sound are not as noticeable as abnormalities in the picture. If the tuner or video i-f stages are suspected of being defective, check the output of the video detector with an oscilloscope when the receiver is tuned to a televised color signal. (A video detector test jack is provided on all Philco Television Receivers to aid the service technician in checking the output signal of the video detector.) If the sections are operating normally, the oscilloscope presentation is similar to that observed when viewing the detector output from a monochrome receiver except, as illustrated in figure 8-4, the burst appears on the back porch of the horizontal blanking pulse. Carefully observe the composite video waveform for any indications of abnormal operation. If any abnormalities are noted, a stage-by-stage voltage and resistance check is performed until the offending stage is isolated and repaired. If a televised color signal is not available, a monochrome signal will suffice. In this case, the burst is missing.

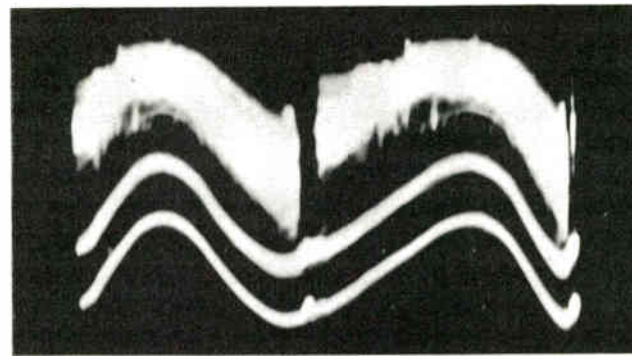


Figure 8-5. Composite color signal with 60-cycle hum.

Defective components distort the waveform. Figure 8-5 is a typical waveform resulting when one of the tubes in the r-f or video i-f section develops heater-to-cathode leakage. The excessive ripple in the waveform appears on the picture tube as light and dark horizontal bars. Testing the tubes or tube substitution in the r-f and i-f sections probably will locate this fault. However, if any other component causes this condition, the service technician should check the voltage and resistance of each stage until the defective stage and the defective component is isolated.

SECTION 4. VIDEO AMPLIFIERS

A defective component in the video amplifiers usually affects only the luminance (brightness) portion of the composite color signal. The oscilloscope presentation at the output of the last video amplifier appears quite similar to that viewed at the video detector. If there is an odd number of video ampli-

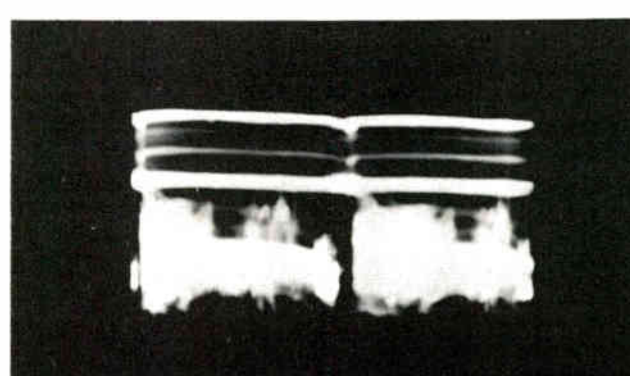


Figure 8-6. Video signal at the output of the video amplifiers.

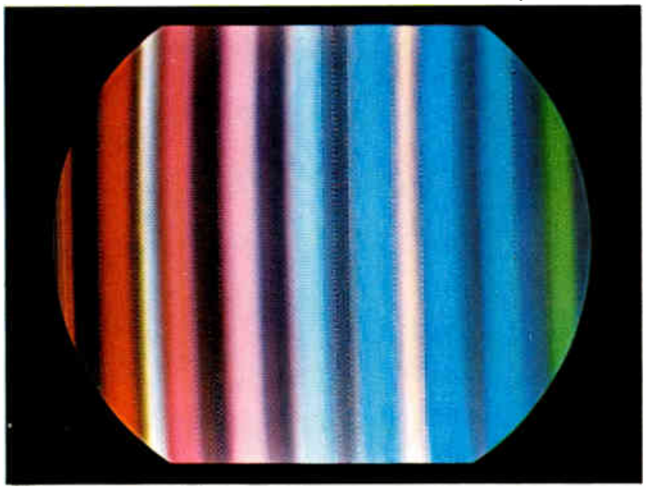


Figure 8-7. Normal color-bar pattern.

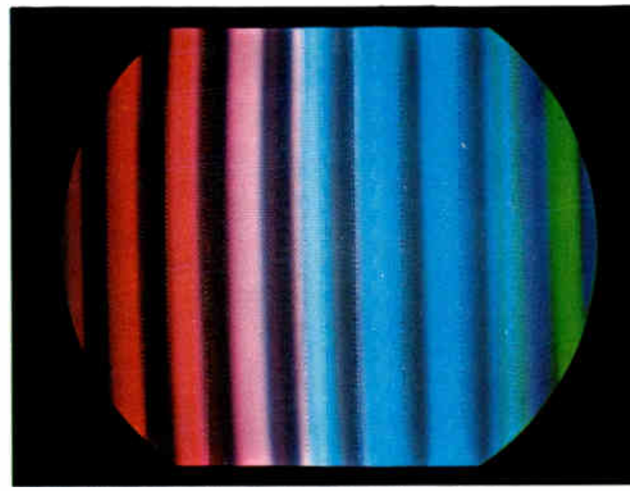


Figure 8-8. Color-bar pattern when luminance signal is missing.

fiers in the receiver, the waveform is inverted as illustrated in figure 8-6.

If there is an open circuit or short circuit in the video amplifier circuit such that the luminance signal does not appear at the picture tube, the picture is void of all gray-scale portions, the color portions of the picture are slightly darker than normal and retrace lines may appear. If monochrome signals are being received, there is a complete loss of picture. With a color-bar generator connected to the receiver, a normal picture tube presentation is as shown in figure 8-7. However, when the luminance signal is missing, the picture tube presentation is as shown in figure 8-8. Note that the white bars are missing and the color bars are darker than those of figure 8-7.

The Delay Line

The delay line is included in the video amplifier section. The powdered iron core of this delay line, although flexible, can break. The center conductor, wound in coil form, can have open or shorted turns. The connection between ground and the shield of the delay line can become loose or break.

A defect in the delay line can cause many effects on the luminance portion of the picture, including complete loss of monochrome picture. Other effects on the picture tube include attenuation of the monochrome portion of the picture, phase distortion in the monochrome portion of the picture, smearing of the monochrome portion of the picture and displacement of the luminance from the chroma information.

When receiving a monochrome test pattern, a defective delay line could cause the test pattern to appear as shown in figure 8-9. A defective delay line can be located by shunting the delay line while receiving a monochrome signal. This eliminates the possibility of the delay line adversely affecting the monochrome signal; if the delay line is defective, the abnormalities disappear from the picture. Shunting the delay line while receiving a color signal causes a displacement between the chroma and luminance presentations.

Ratio of Luminance Signals

The resistance network, across which the luminance signal is developed before the signal is applied to the color picture tube, establishes the proper ratio of luminance signal applied to each cathode of the picture tube. This ratio has been established as 1.0 unit for the blue electron gun, 1.2 units for the green electron gun and 1.5 units for the red electron gun.

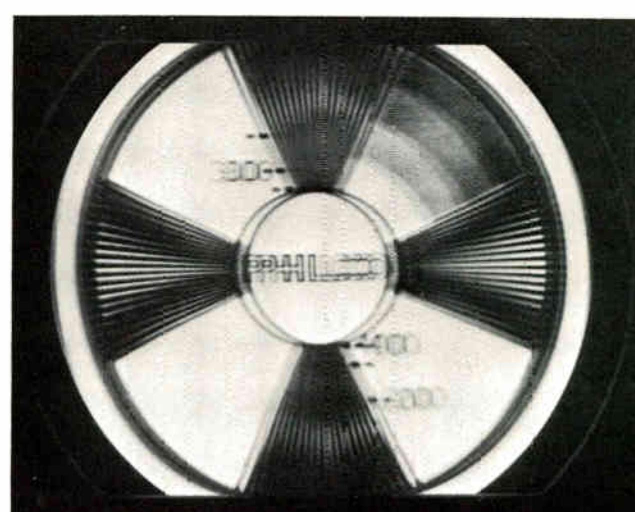


Figure 8-9. Phase distortion of the monochrome test pattern caused by a defective delay line.

A check of the video amplifier output may be made with the receiver tuned to a station signal. Connect the oscilloscope to the cathode circuit of the blue electron gun. Adjust the oscilloscope to present a fixed vertical deflection of one or two units on the scale supplied, similar to the illustration of figure 8-10. This is the unit of comparison for the signals on the other two electron guns. Retaining the oscilloscope adjustments, connect the oscilloscope to the cathode circuit of the green electron gun. The oscilloscope should show an increase in signal amplitude over that of the blue electron gun of about 20%, since the signal ratio on the green electron gun is 1.2 units as compared with the blue signal of unity. If no increase is noted, or if the increase is greatly out of proportion, check the components of the resistance network.

The luminance signal on the cathode of the red electron gun is compared with the blue electron gun cathode signal in a similar manner. Do not change the adjustments, except possibly the horizontal centering to keep the presentation centered on the base line. The red signal should show an increase of approximately 50% over the blue signal.

SECTION 5.
SYNC, NOISE INVERTER AND AGC CIRCUITS

Sync Circuit

A defective sync circuit usually is characterized by an unstable picture, either horizontal, vertical or both; it also can cause the picture to fold over, flicker, roll or jitter.

If the sync circuit is suspected of being defective, check the input signal to the sync separator. The waveform is similar to the detected signal, figure 8-4; however, the waveform is inverted. Since the sync separator conducts only when the input signal approaches sync tip level, the output waveform, (on the plate) resembles that illustrated in figure 8-11.

Noise Inverter Circuit

A defective noise inverter circuit can cause numerous sync problems ranging from complete loss of sync pulses to improper elimination of noise pulses. Usually faults in the noise inverter cause erratic operation of the horizontal and/or vertical sweep circuits. The input waveform is identical to the input waveform of the sync separator while the output waveform is identical to the input except noise pulses above sync tip level are eliminated.

AGC Circuit

A defective agc circuit affects the gain of r-f and a portion of the i-f sections. If the agc voltage is too

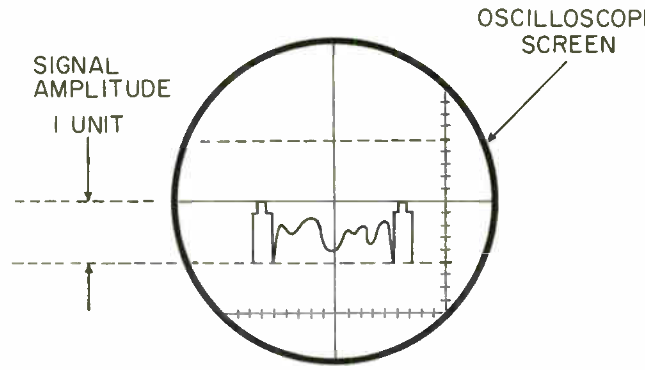


Figure 8-10. Video signal on cathode of blue gun.

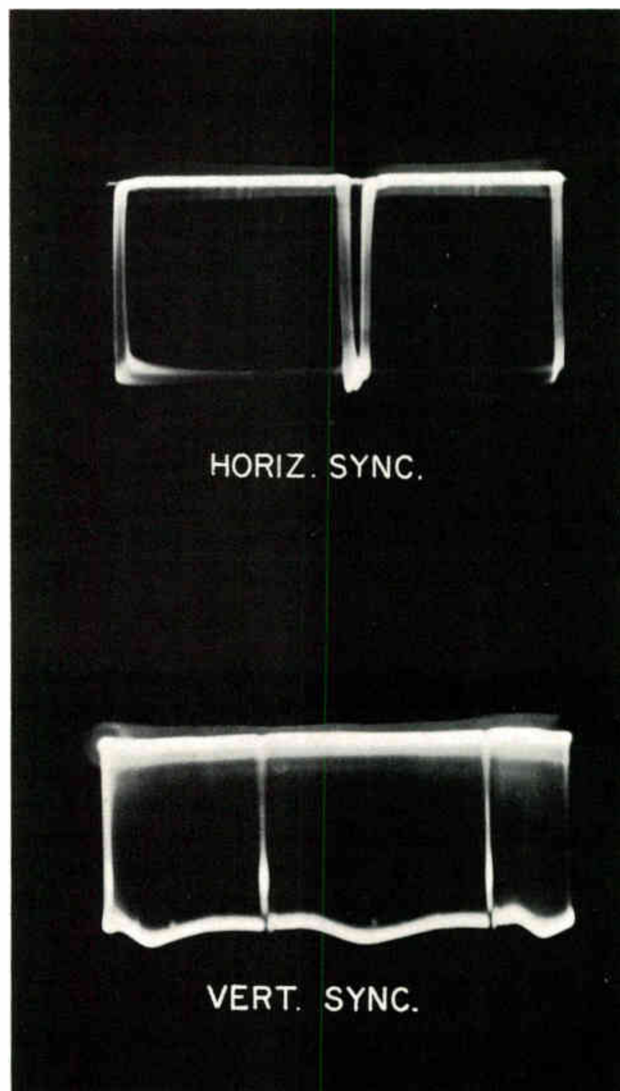


Figure 8-11. Output waveform of sync separator.

low or missing, these same sections are overloaded even with signals of low signal strength. In extreme cases, this could cause a negative picture.

Since the gain of the r-f and i-f sections affect the input to the agc circuit, substitute a fixed d-c voltage in place of the agc voltage. The amount of voltage depends on receiver specifications and the signal strength of the incoming signal. If the fixed voltage rectifies the abnormalities in the picture, a voltage and/or resistance check of the agc circuit should localize the defective component.

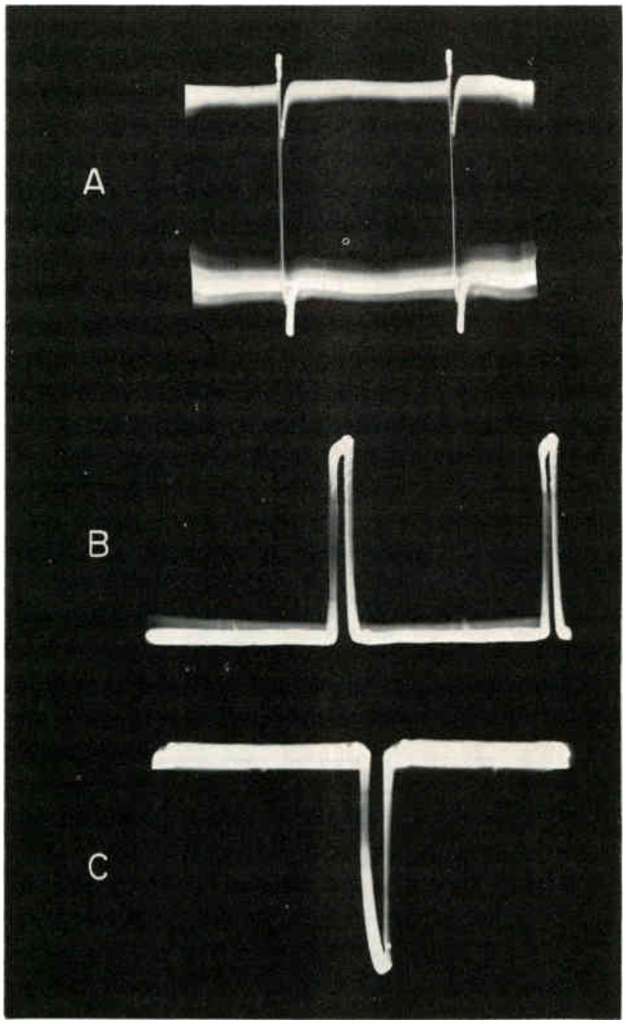


Figure 8-12. Output waveforms of phase splitter.

SECTION 6.
DEFLECTION CIRCUITS

A defective deflection circuit can cause all the symptoms mentioned in the discussion of the sync circuits as well as some symptoms which are peculiar to the deflection circuit. A defective phase splitter usually affects both the horizontal and vertical sweep circuits. A defective vertical deflection section causes such effects as a straight horizontal line, reduced vertical size or poor vertical linearity.

A defective vertical deflection section also may distort the convergence voltage, thereby causing misconvergence. Misconvergence is identified by a ghosty picture in which one ghost is green, one ghost is red and the other is blue. The amount of displacement between ghosts is proportional to the amount of misconvergence.

A defective horizontal deflection section causes such symptoms as loss of raster, reduced horizontal size, poor horizontal linearity.

Phase Splitter

A defective phase splitter stage affects only the

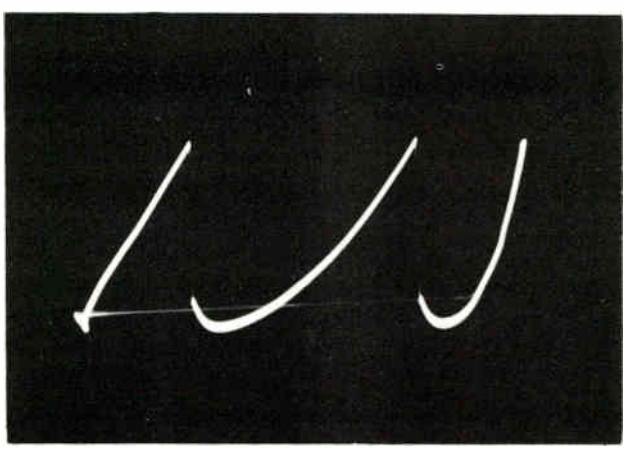


Figure 8-13. Waveform at grid of vertical output tube.

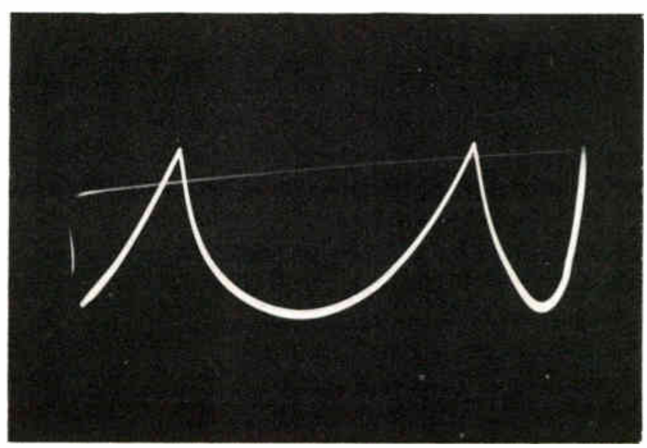


Figure 8-14. Convergence voltage at cathode of vertical output tube.

sync circuits; hence the picture is scrambled or unstable vertically and/or horizontally. If this stage is suspected of being defective, check the input and output waveforms. The input waveform, checked from the control grid, is similar to the output waveform of the sync separator, figure 8-11. The output waveforms, two in the plate circuit (A and B) and one in the cathode circuit (C), are shown in figure 8-12. The plate waveforms are positive-going and the cathode waveform is negative-going. The positive-going and negative-going waveforms feeding the phase comparer should have equal amplitudes.

Vertical Deflection Section

The vertical oscillator is checked by connecting an oscilloscope to the grid of the vertical output tube. A sawtooth waveform is observed if the oscillator is functioning properly. This waveform, as shown in figure 8-13, is slightly parabolic due to the convergence voltage on the cathode of this stage. The sweep voltage, a sawtooth with a steep trailing edge, is observed if the oscilloscope is connected between the control grid and cathode of the vertical output tube. The oscilloscope should not be connected to the plate of the vertical output tube because of the presence of high voltage. Check the convergence voltage by connecting the oscilloscope between the cathode of the vertical output tube and ground. The waveform should be parabolic with the peaks in the positive direction, as illustrated in figure 8-14.

Horizontal Deflection Section

The phase comparer stage compares the phase of the horizontal sync pulses from the phase splitter stage with the phase of the signal voltage from the horizontal oscillator. During normal operation, positive-going sync pulses appear on the input plate and negative-going sync pulses appear on the input cathode. These waveforms are illustrated in figure 8-15. The output waveform, also illustrated in 8-15, is observed by connecting the oscilloscope between the common plate-and-cathode connection and ground.

The horizontal sweep voltage is examined at the control grid of the horizontal output tube. During normal operation this waveform is trapezoidal, as illustrated in figure 8-16.

SECTION 7.
SOUND I-F AND AUDIO CIRCUITS

Defective parts in the sound i-f or audio circuits effect only the sound signal. Signal substitution is one of the best means of troubleshooting the sound i-f and audio circuits. By applying an audio signal to the control grid of the audio output tube, it can be ascertained whether this stage is operative or defective. If a clear reproduction of the audio signal is heard from the speaker, repeat the same procedure for the control grid of the preceding audio amplifier. When the defective stage is located, a voltage and/or resistance check should isolate the faulty part. If the trouble is not in the audio section, a modulated 4.5-mc r-f signal is required. This signal is applied to the sound i-f amplifier grid. As the troubleshooting procedure progresses from the output tube back to the sound i-f amplifiers, the sound level should increase for the same amount of signal input.

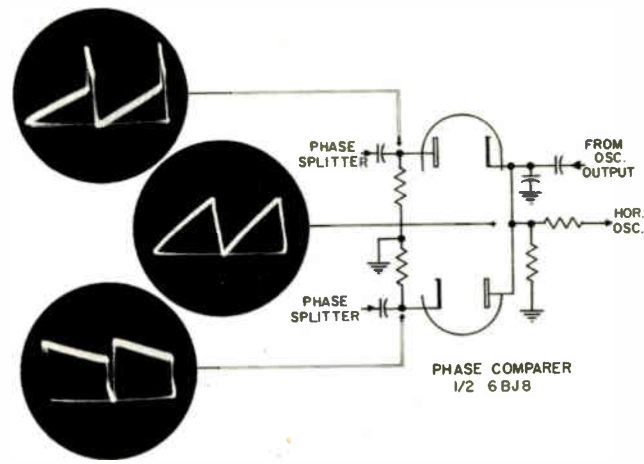


Figure 8-15. Waveforms of phase comparer.

SECTION 8.
CHROMA SECTION

The chroma section includes the chroma amplifiers and the demodulator which process the chroma signals.

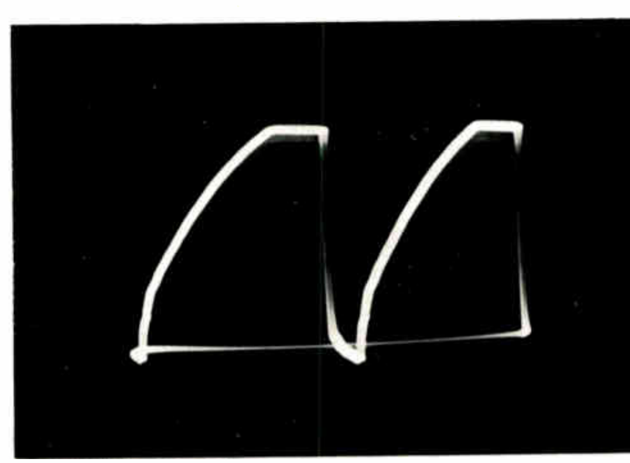


Figure 8-16. Grid waveform of horizontal output tube.

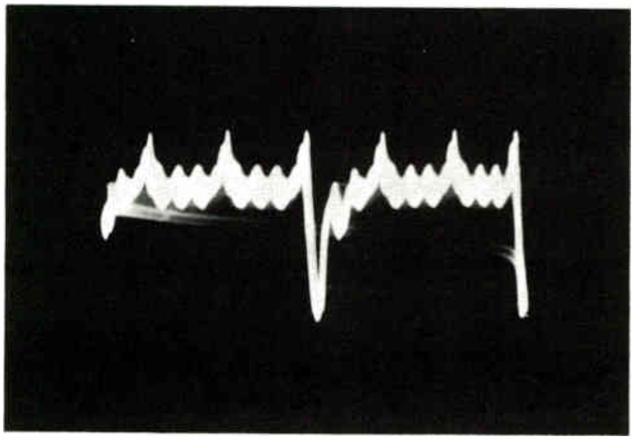


Figure 8-17. Waveform of bar pattern at plate of the chroma and sound detector.

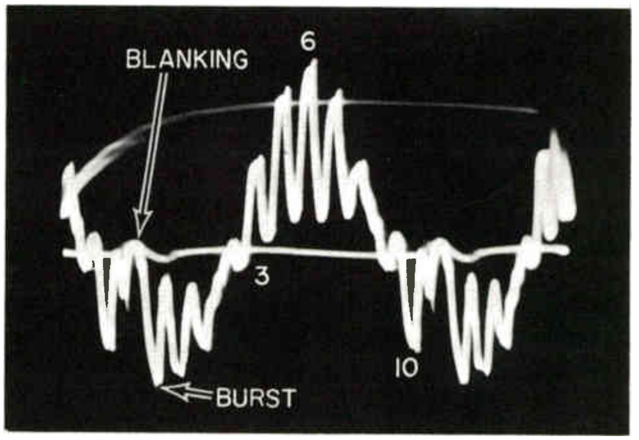


Figure 8-19. Demodulated chroma signal on grid of blue electron gun.

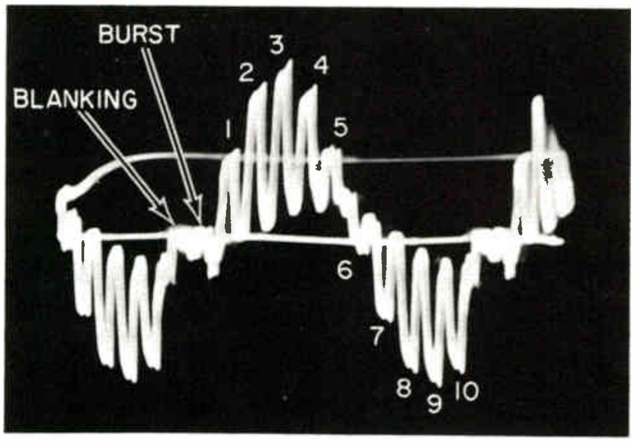


Figure 8-18. Demodulated chroma signal on grid of red electron gun.

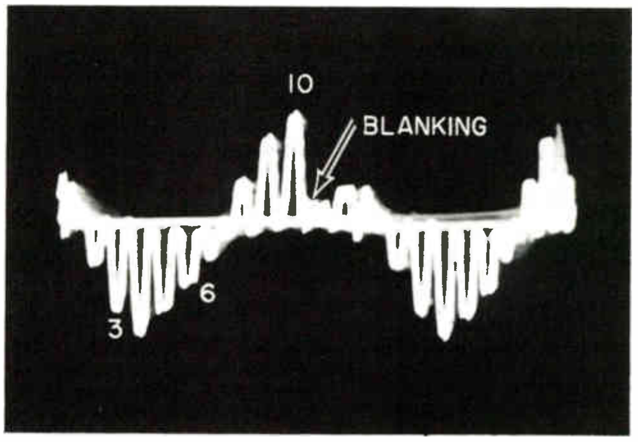


Figure 8-20. Demodulated chroma signal on grid of green electron gun.

It also includes the gate clamp, burst amplifier, phase detector, reactance tube, 3.58-mc oscillator, 3.58-mc amplifier and the color-killer stage. An abnormality in any of these stages adversely affects the color signal which in some manner distorts the color portion of the picture. Symptoms of a defective stage are loss of all color information, incorrect coloring or a predominantly red, green or blue picture.

When troubleshooting the chroma section, a color-bar generator is required to provide constant color signals. In this section, the Philco Color-Bar Generator, figure 8-2, provides the input signal for the color television receiver. Operating instructions are included in a booklet which accompanies the color-bar generator.

The following signal-tracing procedure usually is the fastest and most practical method of isolating the defective stage. When the receiver is operating normally, a bar pattern, as shown in figure 8-7, appears on the picture tube. Any deviation from this pattern indicates a faulty part or the misadjustment of one or more of the chroma circuits, assuming that the rest of the receiver is operating normally.

Chroma and Sound I-F Amplifiers

Observe the waveform at the output of the chroma and sound detector. The desired waveform is illustrated in figure 8-17. If a reasonable facsimile of the waveform is obtained, check the waveforms at the control grids of each succeeding chroma and sound i-f stage and chroma amplifiers. These latter waveforms are similar to the waveform obtained from the detector except there is an increase in amplitude and a phase reversal as each succeeding stage is checked. Sync pulses on the waveform obtained from the detector will decrease in amplitude and finally be eliminated as the signal approaches the demodulator, due to the narrowing bandwidth of the chroma section.

Demodulators

The demodulated chroma signals from the demodulator are observed at the control grids of the picture tube. The demodulated chroma signal at the red control grid is illustrated in figure 8-18. Note that the number 3 bar (R-Y) has the highest amplitude and the bars on each side of the R-Y bar are symmetrically located. The demodulated chroma signal from the blue and green guns respectively are illustrated in figures 8-19 and 8-20. In figure 8-19 the number 6 bar (B-Y) has the highest amplitude and the bars on each side of the B-Y bar are symmetrically located. In figure 8-20 the number 10 bar (G-Y) has the highest amplitude.

Very often the service technician is able to pinpoint the faulty portion of the demodulator by observing the color-bar presentation and the waveforms mentioned above. For example, if resistor R1 in figure 8-21 is decreased to a very low value, the amplitude of the G-Y signal is reduced. However, the B-plus voltage, applied through the green G1 control, increases the green grid voltage which, in turn, produces a predominantly green screen as illustrated in figure 8-22.

Referring again to figure 8-21, assume capacitor C1, shunted by resistor R2, is open. The signal path now is through resistor R2, effectively reducing the G-Y amplitude due to the voltage drop across resistor R2. D-C voltage checks reveal very little regarding this discrepancy, but an oscilloscope check shows decreased G-Y amplitude. The effect of this fault is shown in figure 8-23. The hue of all bars is affected to some degree, and the red bars display a pronounced orange cast. The reduced G-Y signal causes the magenta bar to have too much red content while the cyan bar is blue.

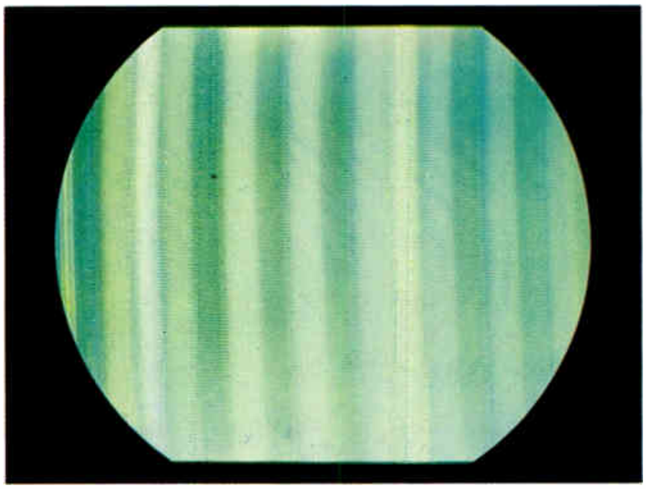


Figure 8-22. Color-bar presentation when bias on the grid of the green electron gun increases.

Assume the 10,000-ohm resistor R3, through which both demodulator cathodes are returned to ground, is open. The cathode circuit is now through the resistance network of the G1 control. The signals at the three electron gun grids are reduced considerably. However, since resistor R3 is part of a bleeder network from B-plus to ground, the bias on the grid of the green electron gun increases much more than the bias of the red and blue guns. As illustrated in figure 8-24, this produces a greenish cast throughout the color-bar presentation.

If resistor R3 drops in value to 1000 ohms, the G-Y signal is reduced, hence green is missing from the color-bar pattern as illustrated in figure 8-25. Al-

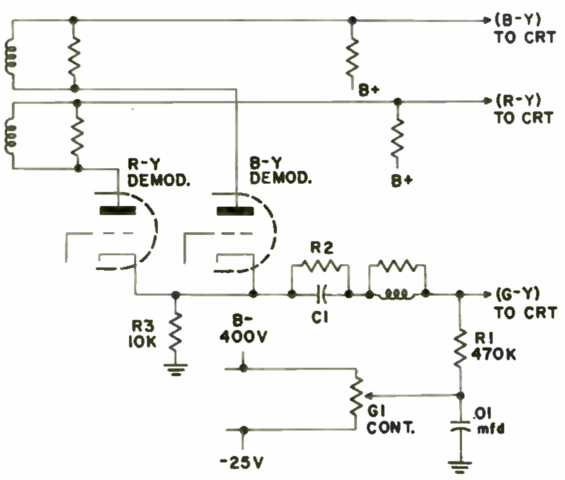


Figure 8-21. Simplified schematic of the demodulator circuit.

Figure 8-23. Color-bar presentation when G-Y signal is reduced in amplitude.

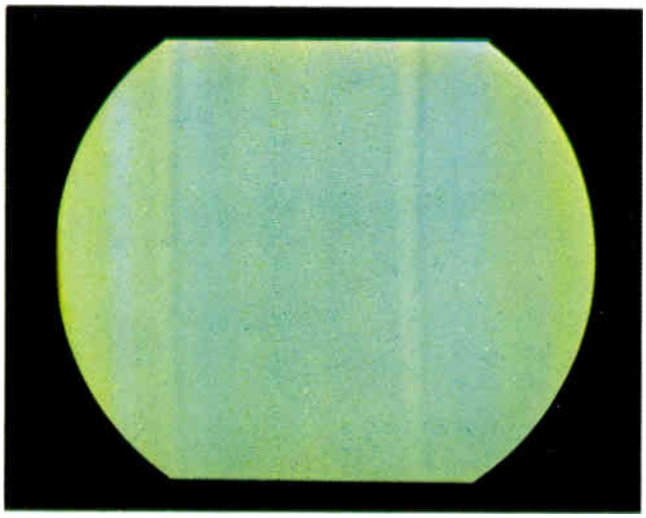
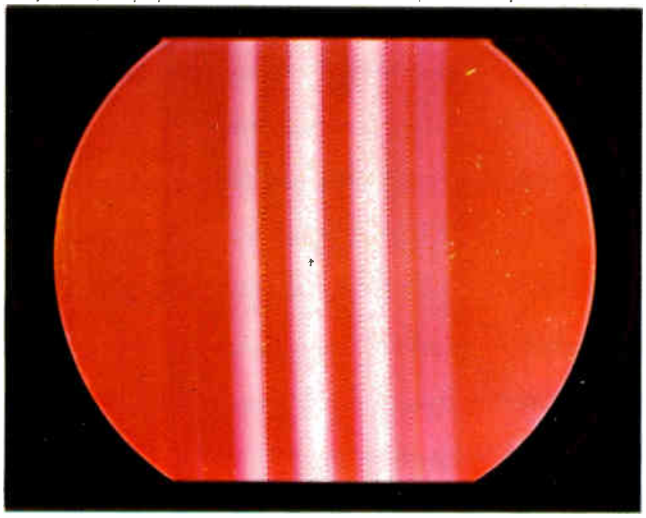


Figure 8-24. Color-bar presentation when common cathode resistor is open.

Figure 8-25. Color-bar presentation when common cathode resistor reduces in value.



though the red and blue bars appear unaffected, close examination reveals incorrect hue. The receiver chroma control is operated to maximum to view this presentation. The darkened presentation is due to the reduced grid bias for the three electron guns. The bias of the green gun is reduced much more than the bias of the other two since the bias for the green gun is determined by the resistor divider network, part of which is the faulty cathode resistance R3. If R3 were to short fully to ground, the above condition would be accentuated.

If the cathode circuit of the R-Y section is open, while the B-Y cathode circuit remains normal, connection of an oscilloscope to the grid of the red electron gun indicates a complete loss of red output. Note that the d-c voltage of the R-Y demodulator plate is coupled to the grid of the red electron gun. Since the R-Y demodulator is inoperative, its plate voltage increases, thereby increasing the positive bias on the grid of the red electron gun. Since the R-Y signal is missing from the demodulator cathode circuit, the amplitude of the G-Y signal also has decreased. The presentation on the picture tube screen is then as shown in figure 8-26. With the exception of a few bluish strips, the color-bar presentation appears as a red-cast field.

Since the demodulators are coupled directly to the grids of the picture tube, B-plus voltage appears on the picture tube grids. When there is a sharp decrease of current flow, through the R-Y demodulator the d-c plate voltage rises toward the maximum B-plus value, which, being connected to the grid of the red electron gun, causes increased red output. This results in an over-all red field. Similarly, if the B-Y demodulator were disabled, reduced plate current through the B-Y demodulator allows excessive blue electron gun drive, resulting in a predominantly blue field.

Gate Clamp Stage

The gate clamp circuit provides the high positive pedestal for separation of the burst from the chroma information. The gate pulse, from the horizonal output transformer is observed by connecting the oscilloscope to the grid of the gate clamp tube. The normal waveform is illustrated in figure 8-27, With the oscilloscope connected to the plate, the high positive pulse, as illustrated in figure 8-28, is observed.

Figure 8-26. Color-bar presentation when little or no current flows through the R-Y section of the demodulator.

Burst Amplifier Stage

The burst amplifier amplifies the burst and separates it from the chroma signal. Connection of the oscilloscope to the amplifier input grid discloses the high positive pulse, with the burst riding on top, when operation is normal and the chroma information is on the bottom of the pulse as illustrated in figure 8-29. The burst amplifier is biased for conduction on the tips of the high pulse, allowing only the burst to be amplified in the plate circuit; therefore, only the burst signal should appear in the output circuit.

Phase Detector, Reactance Tube, 3.58-MC Oscillator and 3.58-MC Amplifier

It is not recommended that an oscilloscope be used to check these stages in view of the loading effect of the oscilloscope, especially in the 3.58-mc oscillator. The 3.58-mc signal circuits should be checked with a low-capacity detector probe and a vacuum tube voltmeter. However, the output of the 3.58-mc amplifier may be checked with an oscilloscope to determine if the oscillator is operating.

If the 3.58-mc signal is not applied to the demodulator, the current through each demodulator section increases. This increased current flow decreases the plate voltage of both sections of the demodulator and increases the common cathode voltage. Since the cathodes are connected to the grid of the green electron gun, the picture tube is predominantly green. If the trouble in the oscillator control circuits are such to cause a discrepancy in the phase or frequency of the output signal, the color-bar pattern appears as if the hue control was set incorrectly. Severe cases may cause the color bars to move across the face of the picture tube.

Color-Killer Stage

If the color-killer stage does not cut off during color reception, the presentation appears in black and white. If the color-killer stage does not conduct during black-and-white reception, rainbows may appear in the picture tube presentation. If any of the above symptoms occur, check the horizontal gate pulse on the plate of this stage. Then check the d-c voltages of the remaining elements to isolate the defective circuit. A resistance check should locate the defective part.

SECTION 9. POWER SUPPLY CIRCUITS

High-Voltage Supply

The 25-kv on the picture tube anode is checked by de-energizing the receiver and then shorting the high-voltage circuit to ground. This precaution is necessary to prevent injury to the service technician. With the high-voltage circuit at ground potential, clip the high-voltage probe of the vacuum voltmeter to the high-voltage cable. Restore power to the receiver and observe the reading on the meter. The observed value should not deviate from 25-kv by more than 1000 volts. It is practically impossible to converge the color tube if the high voltage is not within this tolerance. A resistance check of the high-voltage circuit should reveal any discrepancies within the circuit.

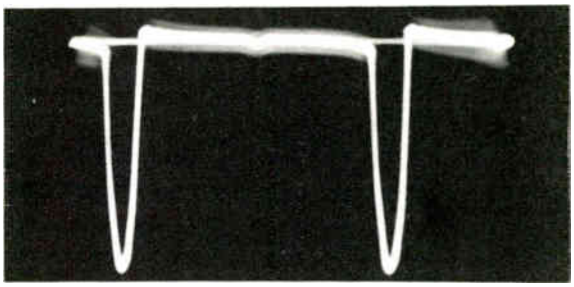


Figure 8-27. Gate clamp input signal.

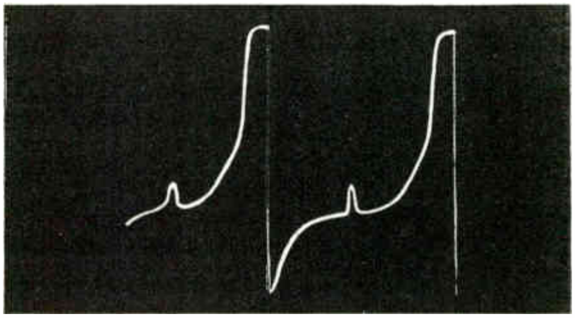


Figure 8-28. Gate clamp output signal.

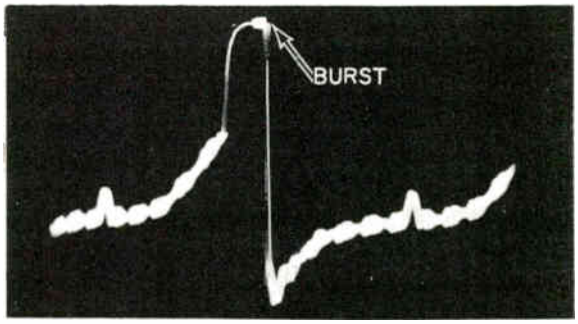


Figure 8-29. Burst amplifier input signal.

Low-Voltage Supply

A defective low-voltage supply affects all circuits. Its effect usually is observed in the picture presentation as unstable sync and possibly reduced picture size. A voltage and/or resistance check usually isolates the faulty part.

9. INSTALLING THE COLOR TELEVISION RECEIVING SYSTEM

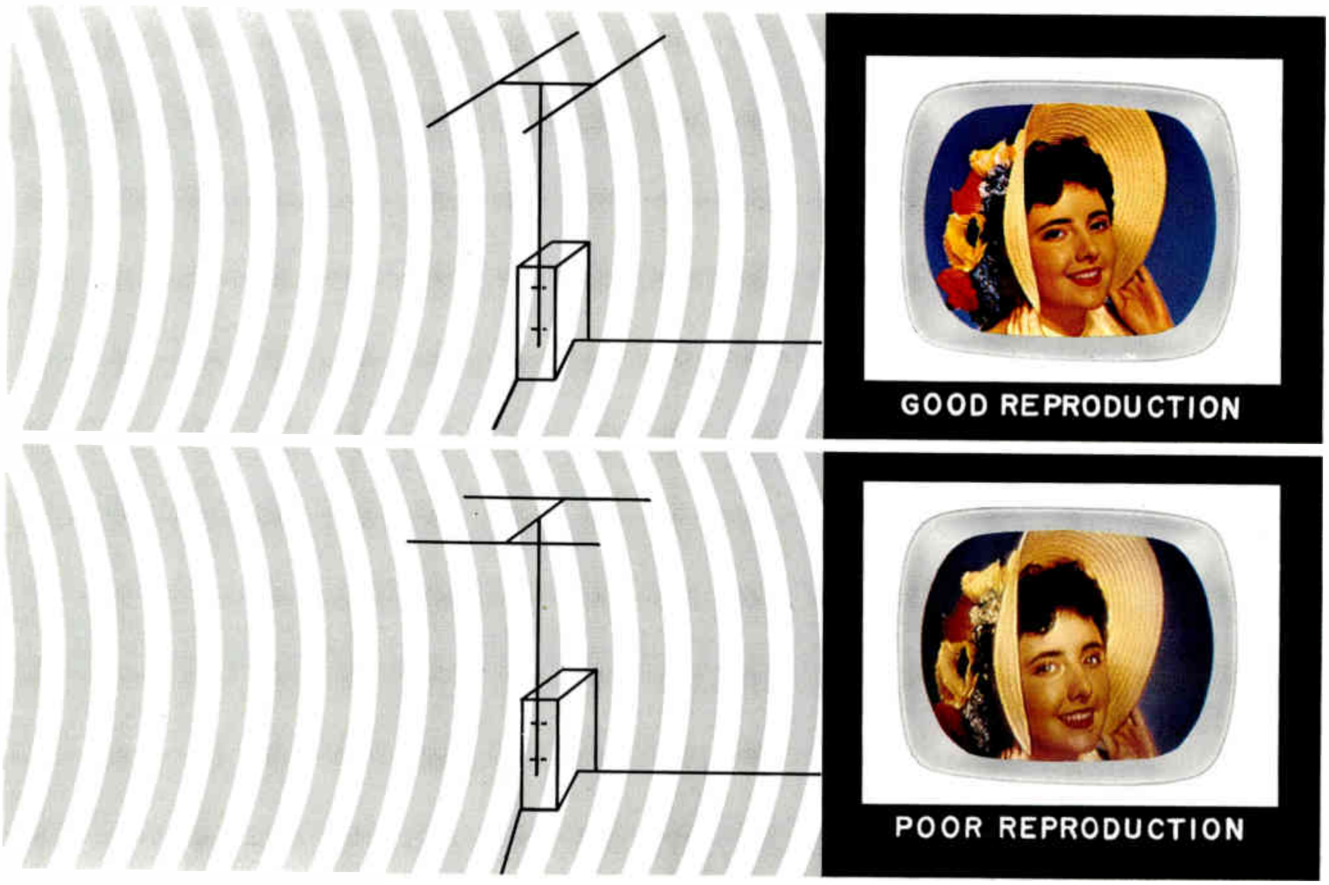


Figure 9-1. Effect of antenna installation.

Engineering advances in the design of television receivers have resulted in models having excellent sensitivity and overall gain characteristics. Manufacture of color television receivers takes full advantage of these and other advances in the field of electronics. However, this knowledge is of little value if the color receiver is set up improperly. Many problems, often peculiar to a given installation, must be solved before the color receiving system can perform in a manner satisfactory to the consumer.

Previous chapters have dealt with development of the color television receiver. This chapter presents information necessary for successful installation of the color television receiving system. The importance of proper initial installation of the television receiver cannot be over emphasized.

SECTION 1.

REQUIREMENTS FOR INSTALLATION OF THE COLOR RECEIVING SYSTEM

Since color transmission and reception are more complex than monochrome service, additional care must be exercised when installing a color television receiver for the consumer. The first impression the purchaser gets of its operation will either reaffirm his confidence in the product or cause complete dissatisfaction. If the receiver is not installed properly, not only does the manufacturer's reputation suffer, but the dealer and technician are jointly held responsible. See figure 9-1.

While advances in design of built-in antennas, along with increased receiver sensitivity, permit satisfactory reception in medium-signal level areas, the consumer should not be led to rely on the built-in antenna. In fact, a considerable number of locations require an outdoor antenna for good color reception, particularly as the distance from the transmitter increases or when terrain problems are present. Exterior antennas, installed at noise-free levels on the building structure, usually offer superior operation. They are well worth the added burden of mounting the antenna and lead-in.

The consumer should also be made to realize that the color television receiver is not to be moved about after installation, that is, the location on which the alignment is based must be the final viewing position. This is explained further under Receiver Installation.

The conditions imposed by the color television system require the use of a high quality antenna properly installed, proper choice of transmission line to allow correct impedance matching from the antenna into the receiver, and intelligent handling of the receiver setup in the customer location.

The color television receiving antenna should be mounted in a clear, isolated location and properly oriented for required signal strength and reduction of reflections or noise. The transmission line should introduce no reflections, phase shift or signal loss; the transmission line must be correctly terminated at the receiver; and, of course, the receiver itself must reproduce a high-quality color picture. See figure 9-2.

SECTION 2.
RECEIVER INSTALLATION

The service technician should check the operation of the color television receiver before delivering the

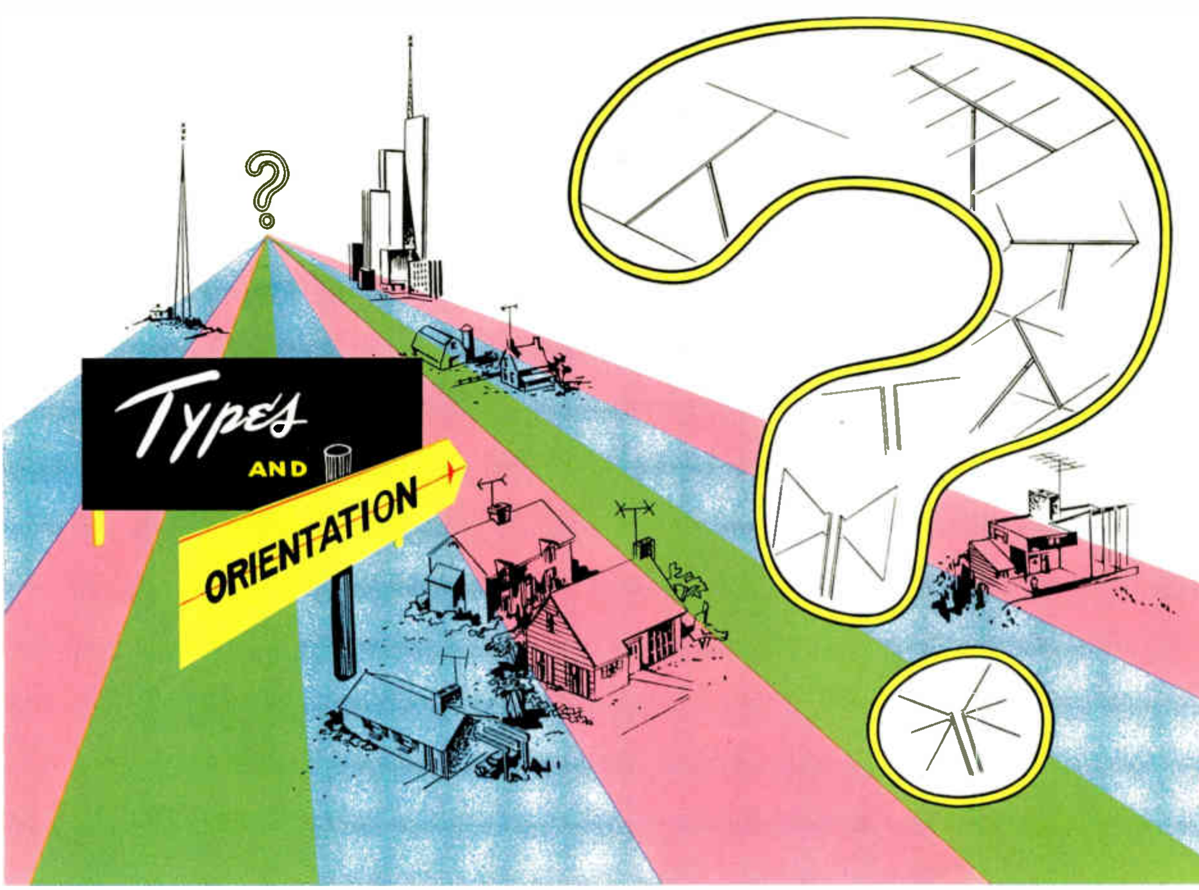


Figure 9-2. Choice of antenna and orientation.

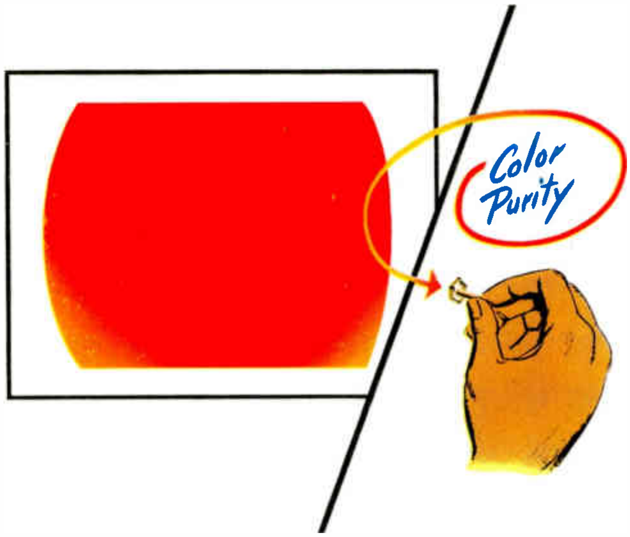


Figure 9-3. Color purity adjustment.

set to the customer's home. A good antenna system should be used for this phase of the installation. This preliminary shop check-out provides a standard of a good color picture as well as assuring the service technician that the set is operating properly. The receiver should be checked for proper picture height, width, linearity, horizontal and vertical hold ranges, channel selection, and fine tuning. Adjustments of primary interest are those of convergence, color purity and white balance. Attention to these functions leaves very little possibility that major adjustment will be required after delivery to the consumer. All normal precautions against excessive vibration in transit during delivery of the color television receiver should be taken.

The receiver, upon delivery, should be placed where directed by the customer, with the understanding that the selected location is the permanent location. The receiver should not be moved from the installed position after the final adjustments, particularly the adjustment for color purity, are completed, as the magnetic field of the earth affects operation of the receiver. This means that the receiver may not be moved about, at the viewing position, nor placed in some other location in the same room. If the receiver is moved in either fashion, a service call usually is required to restore color purity.

The purity control on the rear of the receiver, figure 9-3, usually allows adequate color purity adjustment in the customer's home. Then, the shop-checked functions should be re-checked and touched up as necessary to achieve maximum quality of reproduction.

Assuming that the antenna requirements have been satisfactorily met, preferably by an outdoor antenna, installation of which is discussed later, and that the color receiver has been adjusted for optimum functioning, proceed to connect the antenna lead-in to the terminals provided at the rear of the receiver.

The value of instructing the customer concerning proper adjustment and tuning of his new color television receiver must not be underestimated. Instruction should be accompanied by actual handling of the adjustments by the user.

The operation of the receiver's hue and color controls, figure 9-4, is best illustrated to the customer by tuning to a color program. While color program transmission is common today, customer instruction could occur at a time when a color program is not being televised. A good substitute is the Philco Color-Bar and Pattern Generator, Model 7100. This generator produces a color-bar pattern which presents an extremely good display of color for demonstrating the effects of the hue and color controls. Customer participation, when demonstrating the use of these front panel controls, reduces his reluctance to make these adjustments. Misadjustment of these controls is most often the reason for adjudged faulty operation. Much misunderstanding by the customer will then be avoided, with reduction in nuisance service calls.

SECTION 3.
LIMITATIONS IMPOSED BY TELEVISION OPERATING FREQUENCIES

The presentation of the television receiver can be only as good as the quality of reception by the antenna system, in view of the fact that the antenna is the first item in the receiving system which deals with the incoming television signal. Any adverse effect upon the received signal by the antenna system or its transmission line, with few exceptions, causes inferior picture or sound reproduction, especially in a color television receiver.

Since the chroma-information subcarrier of the transmitted color-television signal is 3.58 mc higher than the video carrier, the antenna and tuner must not discriminate against the frequencies involved in the chroma response. Also, changes in frequency response as the receiver is tuned from channel to channel may introduce chroma signal losses. Even though the tuning unit of the color television receiver has adequate sensitivity and selectivity, including the proper bandpass characteristics, a poor antenna or poor installation can affect the bandpass of the entire system. These undesirable effects need not exist if the service technician thoroughly understands basic antenna principles, and realizes their importance while installing the antenna system.

Practical antenna and transmission line information is presented in this chapter, with emphasis on color television reception, so that the technician can obtain a working knowledge of the subject and the problems involved. Much of this information has been gained by experience through practical application to monochrome reception, particularly with uhf installations.

The peculiarities involved in color television reception, then, are principally caused by the necessity of meeting the channel bandwidth requirements of the television signal.

SECTION 4. ANTENNA CONSIDERATIONS

In any receiving system, the antenna is fully as important as any circuit within the receiver; it is the device employed to intercept signals to be used by the receiver. Factors important in choosing the antenna concern its signal pickup, directional characteristics, impedance and bandwidth.

The directional characteristics of the television antenna must be considered if optimum performance of the system is to be achieved. The simple dipole antenna, while somewhat directional, may not be able to reject noise or ghosts. Special high-gain directional antenna arrangements may be needed to overcome problems concerning signal reflections, noise interference, and low-intensity signal levels.

Calculation of impedance values in a contemplated color television receiving system may indicate whether the installation will be fully successful or only mediocre. The color system requires more rigid attention to arriving at proper impedance values when choosing an antenna than does the monochrome receiving system. Bandwidth must be given special consideration due to the extremely wide frequency coverage involved in the television channel when color is transmitted. If enough bandpass is not obtained initially in the antenna system, the color picture suffers proportionately.

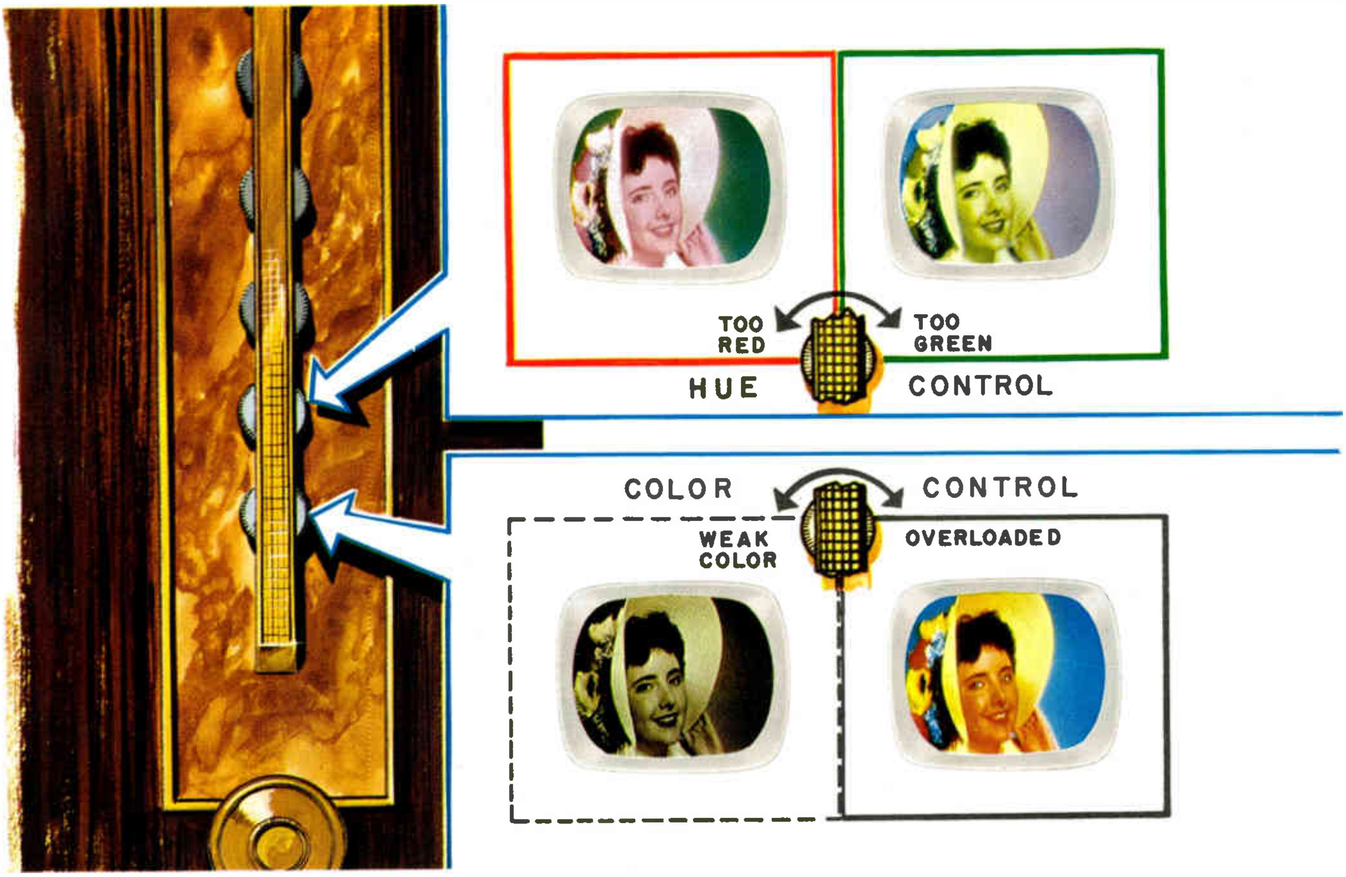


Figure 9-4. Hue and color controls.

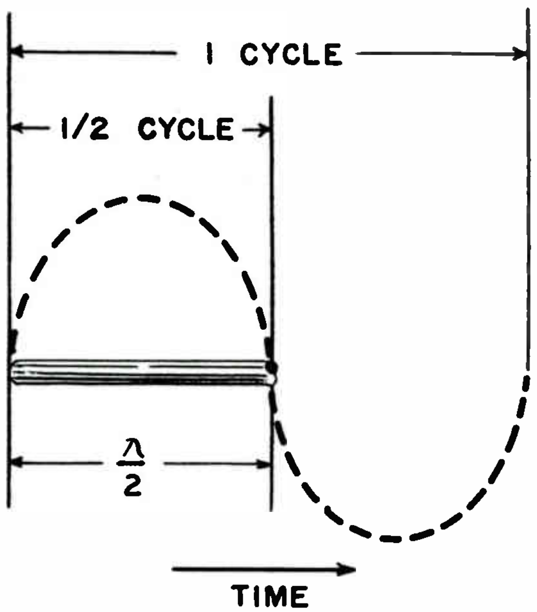


Figure 9-5. Determination of half-wave antenna.

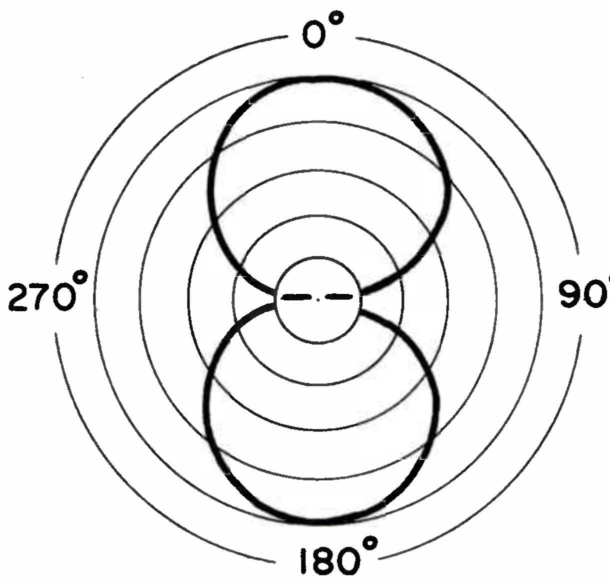


Figure 9-6. Field pattern of dipole.

Since the transmitted television signal is polarized horizontally, television receiving antennas are also placed in this plane, resulting in maximum signal pickup. Vertically polarized propagation is not considered as satisfactory for television service as horizontally polarized waves.

The Half-Wave Antenna

The wavelength of a television signal is determined by the frequency of transmission. Maximum signal pickup is achieved by making the antenna resonant at the operating frequency. Resonance requires that the antenna be made physically equivalent to one-half wavelength at the operating frequency, figure 9-5.

The physical length of the antenna is approximately one-half wavelength at the operating frequency. The physical length of a half-wave antenna is calculated for frequencies above 30 mc by using the following formulas:

Length of a half-wave antenna in feet

$$\text{equals } \frac{462}{\text{freq. in mc.}}$$

Length of a half-wave antenna in inches

$$\text{equals } \frac{5550}{\text{freq. in mc.}}$$

Changes in velocity of the energy when in a conductor over that when in free space, as well as end effects, are taken into account in these formulas.

SECTION 5. HIGH FREQUENCY ANTENNAS

Basic Dipole Antenna

The most common type of high-frequency, half-wave antenna is the elementary dipole, one of the simplest types of resonant antennas. The dipole consists of two quarter-wavelength elements, placed end-to-end, but separated in the center to provide a means of connection at a low impedance point. The dipole impedance is approximately 72 ohms at the resonant frequency.

When resonant, a dipole in free space has a bi-directional (figure-eight) field pattern. The maximum response is broadside, at right angles to the antenna. For example, a signal transmitted from the north or south is best received when the receiving antenna is oriented in an east-west plane. Minimum reception occurs directly off the ends of the antenna.

At frequencies other than the resonant frequency, the field pattern of a dipole, and its characteristic impedance, may be quite different from that shown in figure 9-6. For example, figure 9-7 shows the field patterns of a dipole cut for channel 3. The solid line represents the pattern for channel 3; the dotted line, nearly in registry with the solid line, is the pattern for channel 6; and the four-lobe pattern is the pattern for channel 10. Different patterns are obtainable with other combinations of dipole length and channel frequencies. Also, if the dipole is near the earth or other

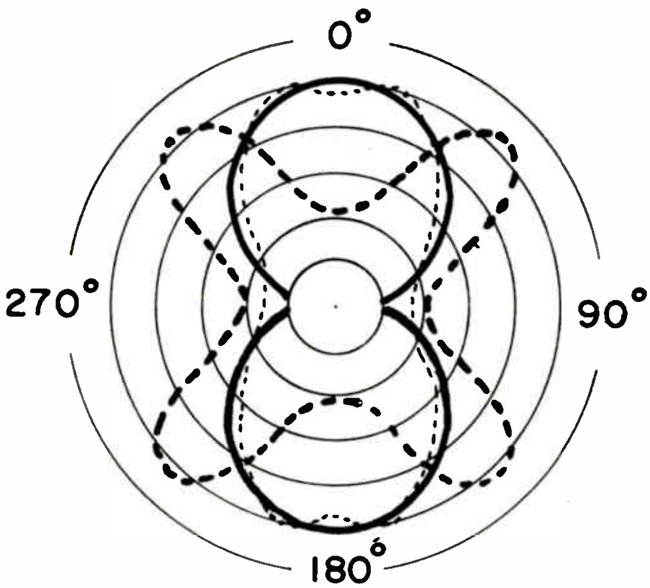


Figure 9-7. Field pattern of channel 3 dipole used for channels 3, 6 and 10.

objects, the field pattern may be affected considerably.

The dipole lends itself to strong-signal area reception. The physical dipole antenna lengths usually employed for the vhf channels are as follows:

Channel	*Length (Feet)*	*Channel*	*Length (Feet)*
2	8.5	8	2.6
3	7.7	9	2.5
4	7.0	10	2.43
5	6.1	11	2.36
6	5.65	12	2.29
7	2.68	13	2.23

Characteristic Impedance of an Antenna

Any antenna at resonance presents a specific impedance at every point along its length. This can be seen in figure 9-8 by comparing the voltage and current values distributed along the antenna. The impedance of an electrical circuit is equal to the voltage divided by the current; the highest impedance occurs where current is lowest, and vice versa. As shown in figure 9-8, the low impedance point at the center is approximately 72 ohms, whereas the high impedance point at the ends is approximately 2400 ohms. The value of 72 ohms is generally accepted as the impedance of a half-wave dipole in free space.

It is important to know the relative antenna impedance when connecting the transmission line to the antenna, because matching of impedances allows optimum signal transfer to the receiver. If the impedance of the antenna is low, a low impedance transmission line should be used, and vice versa.

Folded Dipole Antenna

A better match of the impedance of the antenna to the transmission line at television frequencies is achieved by the use of the folded dipole antenna. Essentially, this antenna may be considered as two half-wave antennas, spaced about three inches apart, parallel to each other, and connected at the ends. One of the elements is center-connected to the transmission line as a half-wave antenna. Assuming that the elements have equal diameters, the impedance at the connection point is four times that of the dipole, or about 288 ohms. This offers a much closer impedance match when using the "twin-lead" transmission line with a characteristic impedance of 300 ohms.

The directivity of this antenna is similar to the dipole. Higher gain and directivity may be achieved from this type by adding a reflector and director as explained in Directive Antennas.

Dual-Band Antennas

Covering the entire vhf television frequency spectrum with a single antenna usually is not practical,

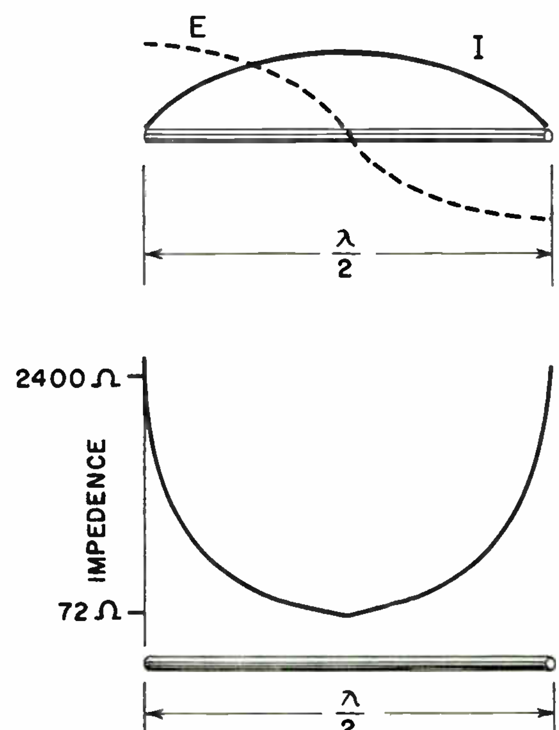


Figure 9-8. Voltage and current distribution and the corresponding impedance curve for a half-wave antenna.

owing to the great change in frequency. However, the basic dipole can be employed satisfactorily to receive dual-range frequencies by mounting two dipoles, one resonant at the center of the upper portion and the other at the center of the lower portion of the vhf spectrum. For instance, if channels in both ranges are used in any given location, one of the two dipoles would be made resonant at about 71 mc, midway between 54 mc to 88 mc. The other would be made resonant at the center frequency between the limits of channels 7 and 13. A weak station may be favored by making one antenna exactly resonant at its frequency. The two dipoles are connected in parallel at the centers by an impedance matching stub or stacking bars, and a common transmission line leads to the receiver.

Directive Antennas

Added directivity may be desirable to eliminate ghosts or improve signal gain. The limited directive property of the basic half-wave antenna may be overcome by adding one or more free elements, called parasitic elements, parallel to the dipole element. The parasitic elements absorb or reflect energy without actual connection to the dipole. First, consider that if two conductors of equal length are placed parallel to each other and if one is excited with r-f energy at its resonant frequency, a current will be induced in the other free conductor which will in turn produce a radiated wave. Thus both conductors radiate energy, and, if separated by more than 0.14 wavelength, the secondary radiated wave from the free parasitic element, acting as a reflector, is in-phase with the energy from the signal-driven dipole. The two waves combine to reinforce each other in the direction of the dipole element.

The effect is as if the parasitic element acted like a mirror on the waves traveling in its direction from the dipole. Conversely, if the elements are separated by less than 0.14 wavelength, the free parasitic element, in this case a director, absorbs the radiated wave and becomes the reinforced element instead of the dipole, resulting in enhanced directional pickup away from the dipole element. When the parasitic element is the same length as the dipole, it is self-resonant, with the spacing from the dipole determining whether it is a director or reflector. The spacing must be more or less than 0.14 wavelength for a reflector or director respectively, or little gain is realized.

If the parasitic element is shorter (tuned to a higher frequency) than the dipole element, and spaced approximately 0.1 wavelength away, it is a director, reinforcing reception from its direction. However, if the parasitic element is longer (tuned to a lower frequency) than the dipole element, and spaced from 0.15 to 0.25 wavelength away, it is a reflector, reinforcing reception away from its direction. The spacing is the chief factor in determining the gain of an antenna-reflector or antenna-director combination, while the lengths of the parasitic elements determine the sharpness of resonance of the multi-element array.

The antenna elements usually are made of tubing ⅜ inch or more in diameter, to broaden the frequency response. Both director and reflector elements are mounted parallel to the dipole if greater directivity is desired, as illustrated in figure 9-9, but addition of elements beyond a reflector-dipole-director combination reduces the frequency response more than color television reception can tolerate.

The directivity of the folded dipole may be materially increased, at slightly lowered antenna impedance of about 250 ohms, by the addition of a reflector and director, to provide a high-gain antenna working over a limited number of channels. The reflector is made five percent longer than the folded section and spaced from it approximately one-quarter wavelength; the director is made five percent shorter and spaced about one-quarter wavelength. The directive folded dipole antenna, arranged for dual-band coverage, presents one of the best solutions of antenna gain, frequency coverage and transmission line matching.

It is often advantageous to rotate the antenna array for proper orientation toward television stations in different directions. This may be achieved by including a motor-driven gear assembly in the antenna mounting.

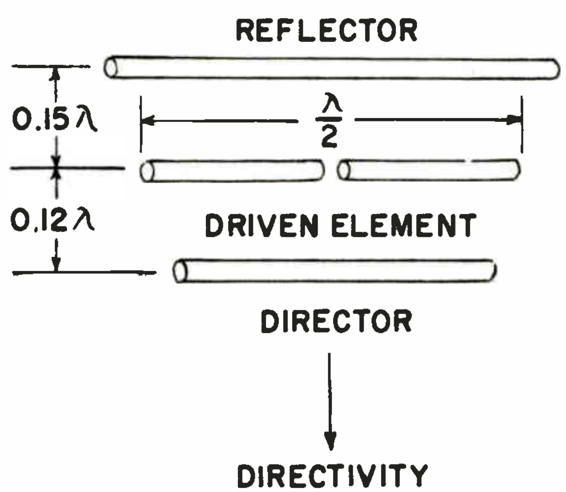


Figure 9-9. Physical arrangement of a three-element parasitic array.

SECTION 6.
TRANSMISSION LINE CONSIDERATIONS

Serious attention should be given to matching the characteristic impedance of the transmission line to the antenna, and the transmission line to the receiver; this will minimize standing waves in the system, with their attendant signal losses and reflections. Such conditions cannot be tolerated when receiving color signals.

The transmission line is the device which transfers the r-f energy from the antenna to the receiver. Transmission line characteristics are very important in color television receiving systems because of the greater bandpass requirements.

In antenna transmission problems, the antenna is considered the generator or source of energy, the connection between the antenna and receiver is considered the transmission line, and the receiver is considered the load or consuming device. All energy collected by the antenna passes through the transmission line if the impedances of the antenna and transmission line are equal (matched) to each other. This results in complete utilization of the transferred energy by the receiver. All energy collected by the source will be absorbed by the load and none will be reflected back on the line if the load impedance is equal to the characteristic impedance of the line.

Characteristic Impedance of a Transmission Line

Every transmission line has a characteristic impedance, which must be understood in practical antenna work. The simplest approach is to recognize the fact that spaced conductors, which constitute the usual transmission line, have resistance, inductance and capacity. The value of impedance of a line containing these distributed constants, as "seen" by a source "looking" into a properly terminated line is referred to as the characteristic impedance of the line. The characteristic impedance of any line is a constant value.

Two methods often employed to determine characteristic impedance for transmission lines are calculation from measurement of inductance and capacitance of a length of open-circuit line, and calculation from the physical constants. Physical determination of impedance value, the more practical method, is given here.

For coaxial lines, $Z_o = \frac{138}{\sqrt{e}} \log_{10} \frac{D}{d}$,

where

Z_o = characteristic impedance

e = dielectric constant

D = inside diameter of outer conductor

d = outside diameter of inner conductor

For example, RG-59/U coaxial cable has an inner conductor of #22 gauge wire (.0253") and its shield has an inner diameter of 0.15". The polyethylene insulator has a dielectric constant of 2.2. The characteristic impedance of this cable is determined as follows:

$$Z_o = \frac{138}{\sqrt{e}} \log_{10} \frac{D}{d}$$

$$Z_o = \frac{138}{\sqrt{2.2}} \log_{10} \frac{.15}{0.0253}$$

$$Z_o = \frac{138}{1.48} \log 5.94$$

$$Z_o = 93.2 \times 0.7738$$

$$Z_o = 72 \text{ ohms}$$

For parallel-conductor lines, where the distance between the centers of the conductors is much greater than the radius of the conductors, which is standard practice:

$$Z_o = \frac{276}{\sqrt{e}} \log_{10} \frac{a}{b}$$

where

a = distance between centers of conductors

b = radius of conductors

e = dielectric constant

The dielectric constant of insulating materials commonly used in coaxial lines varies from the standard of 1 for air, to about 5. For example, polyethylene has a constant of 2.2.

A characteristic of a coaxial line to note is that when the inside diameter of the outer conductor is much greater than the outside diameter of the inside conductor, the transmission line has a high Z_o. Conversely, if the inside diameter of the outer conductor is not much greater than the outside diameter of the inner conductor, the transmission line has a low Z_o. In open-wire, parallel-type lines, when the size of wire is large with respect to the spacing between the wires, the line has a low Z_o; conversely, when the size of wire is small with respect to the spacing between the wires, the line has a high Z_o. In general, the characteristic impedance of a line increases as the spacing between the conductors increases and decreases as the diameter of the conductors increases.

Maximum transfer of energy at the resonant fre-

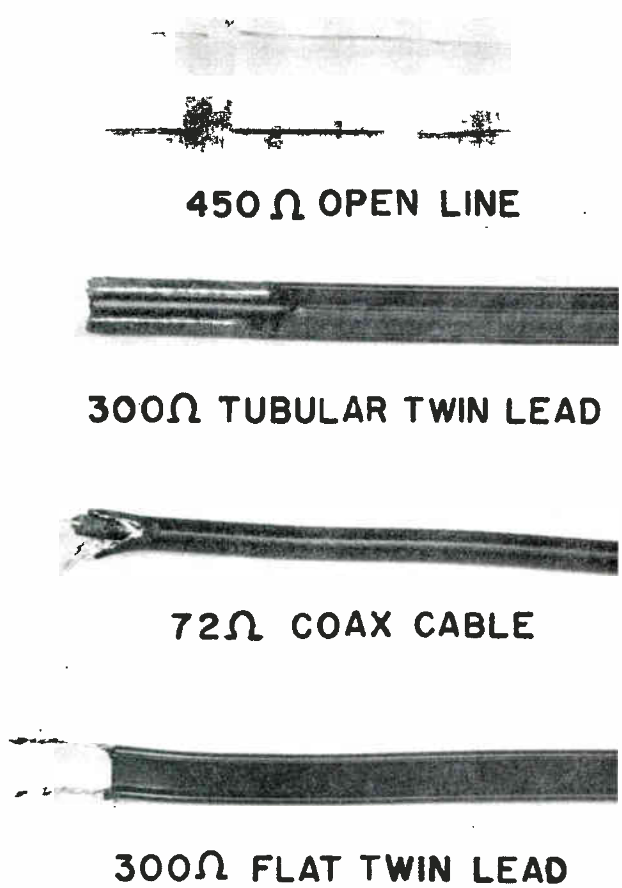


Figure 9-10. Types of transmission lines.

quency occurs when the characteristic impedance of the transmission line matches the input impedance of the receiver and the center impedance of the antenna.

Standing Waves

Mismatch causes a condition known as standing waves, which are voltage and current waves that appear to be stationary along the transmission line, caused by the reflection of some of the signal energy back and forth between the receiver input and the antenna. As the energy moves back and forth, it adds up and cancels at various points along the line. These standing waves represent no useful power; instead, they detract from the usable signal, resulting in a decrease of usable energy at the receiver input.

Extreme mismatch causes the appearance of multiple images (ghosts) on the screen, because each time the energy is reflected to the receiver input, a portion of the energy produces another image which is displaced from the previous one because of the time delay. The longer the line, the greater the displacement of the images. These faults cannot be tolerated in the color receiving system.

In strong-signal areas this effect can be eliminated by the use of attenuators in the form of loading resistors which introduce a loss in the line. The line reflections will be attenuated much more than the original signal because they are forced to pass through the attenuator a greater number of times. In weak-signal areas, however, this method is not advisable, since any attenuation of the signal may be serious. In weak-signal areas the reflections should be reduced by matching the line with line transformers (quarter-wave stubs).

Unless a certain degree of mismatch is desirable for broad-band reception, the characteristic impedance of the transmission line should match the impedance of the antenna for maximum gain at the resonant frequency. If the impedances do not match, a matching device such as a quarter-wave stub may be used. The disadvantage of using a matching stub is that it has a very narrow bandwidth, and therefore narrows the overall response of the antenna system.

A dipole has a center impedance of 72 ohms at its resonant frequency. Therefore, for maximum gain at its resonant frequency, it would have to be matched by a line having a characteristic impedance of 72 ohms. As the frequency for which the dipole is used increases or decreases, however, the center impedance of the dipole increases. Therefore, if a dipole is used for broad-band reception, it is desirable to use a transmission line with a higher characteristic impedance. For this reason a 300-ohm line is more suitable than the 72-ohm line. In most cases, manufacturer's instructions should be followed.

SECTION 7.
TYPES OF TRANSMISSION LINES

Various types of transmission lines are manufactured for television use. The choice depends upon individual installation factors.

Flat Twin Lead

The most popular type of transmission line used is the flat twin lead, figure 9-10. The insulation is usually polyethylene. This line can be obtained in different characteristic impedances, from 75 to 300 ohms, is light in weight, inexpensive and flexible. It has relatively low loss per unit length as compared to other lines. However, the line is unshielded and, in high-noise areas may not be desirable. Flat twin lead is balanced, since neither side is placed at ground potential. Most television receivers use a 300-ohm balanced input, so that this type of line provides a good impedance match.

Tubular Twin Lead

The more-recently introduced 300-ohm tubular twin lead, figure 9-10, is easy to handle, has relatively low db loss, and is not appreciably affected by weather conditions.

Coaxial Cable

Coaxial cable consists of an outer metal braid or shield, which serves as one conductor, a layer of insulation and an inner conductor, figure 9-10. At present it can be obtained with a characteristic impedance of from 10 to 150 ohms. It is not available in higher-impedance values because, in this type of line, the diameter of the outer conductor would be large and of prohibitive cost.

Coaxial cable is the recommended transmission line for installations where noise interference is a primary consideration, since the shield is grounded. The cable is unbalanced, because of the grounded shield. However, most receivers include provisions for the connection of an unbalanced line to the balanced-input coil. Both the cost and signal attenuation of coaxial cable are greater than that of parallel-conductor type lines.

Open Line

The 450-ohm open line, illustrated in figure 9-10, is theoretically the best type of transmission line. It has the lowest db loss and is not too greatly affected by weather conditions. This line provides good reception, but due to its mechanical nature it is a bit difficult to handle when making an installation. With reasonable care and patience, however, this type of transmission line can provide excellent results.

SECTION 8. ANTENNA SYSTEM INSTALLATION

At the high frequencies involved in television service, the half-wavelength antenna is short physically, in comparison with a half-wavelength antenna for a-m broadcast reception. This type of antenna is relatively efficient and simple to manufacture, is easily installed high and away from physical interference, and, being sturdy, withstands weather well.

Selection of Proper Antenna

A number of antennas are available on the commercial market, each designed for some outstanding characteristic or particular circumstance of reception. If signal conditions are such that the color receiver built-in antenna does not provide satisfactory reception for all of the available channels, the external antenna should be selected to provide maximum possible reception.

Where signal fields are strong, the simplest types are preferable. More elaborate installations may be necessary where signal strength is low, where noise interferes or where reflections introduce problems. Care must be exercised when choosing one of these more elaborate types, however, as increased gain and directivity tend to reduce bandwidth of the frequency response. This may materially injure the color picture quality.

Installing the Antenna

The roof area or other location should be surveyed for the antenna location most advantageous to broadside line-of-sight interception from the transmitter site. This usually means mounting the antenna as high as possible, in an unobstructed location. Interference sources and large surfaces causing reflections must also be taken into consideration when locating the antenna. Advance planning will indicate the preferred antenna location from the standpoint of accessibility, supporting methods and shortest, direct lead-in routing. If the supporting mast exceeds 10 feet in height, guying is necessary.

Usually the antenna should be positioned broadside to the transmitting site for maximum signal interception. While this is true, some modification is often necessary to achieve optimum reception. Orientation of the antenna installation should take into account field strength measurements, interference reduction from reflected signals, and noise, or any other factor influencing change from the initial broadside positioning.

Orientation of the antenna can be relatively simple when only one television channel is serving the area. However, it is important that the color television receiving antenna be properly located and oriented on the major reception lobe of the radiated field, as illustrated in figure 9-11. When results cannot be obtained with the antenna in a given roof-top location, adjacent locations should be tried. A shift to a new position, often only a matter of a few feet, can produce a marked difference in reception. Unless these requirements are met, faded or weak color reproduction may occur, although passable black-and-white presentation is obtained. Orientation of a color receiving antenna on the high channels, 7 to 13, is more critical than on the lower channels. Orientation for any channel is greatly facilitated by the use of a field strength meter.

Added control over reflections, interference and

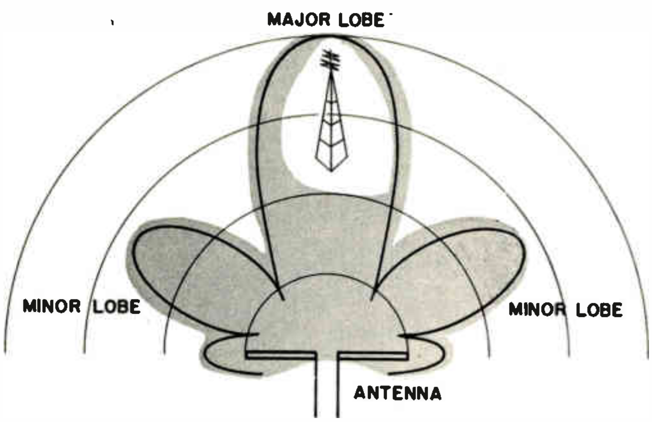


Figure 9-11. Orientation for major lobe reception.

orientation is afforded by the inclusion of an antenna-system rotator. This is usually a motor-driven gear assembly, attached in such a manner that the antenna assembly may be rotated approximately 180 degrees in either direction.

If more than one color television transmitter is located in the area widely separated in frequency, several antennas, stacked on the supporting mast, may be necessary when one antenna cannot provide multiple reception. Each antenna of the array must be oriented so that its major reception lobe intercepts the desired transmitted signal. The importance of this becomes more evident when it is realized that the reception field pattern can change radically with as small a change in frequency as exists between the video carrier and the sound carrier of the same channel.

Such reception pattern changes are even more pronounced with variations in frequency from channel to channel. For example, in figure 9-12A the reception pattern of a specific antenna is illustrated. Both stations "one" and "two" are covered by the pattern, station "one" being covered by a major lobe and station "two" being well covered by a minor lobe. Figure 9-12B shows the same antenna, but the reception pattern is that of another channel frequency. The situation is then radically changed; station "two" is no longer covered by the reception pattern.

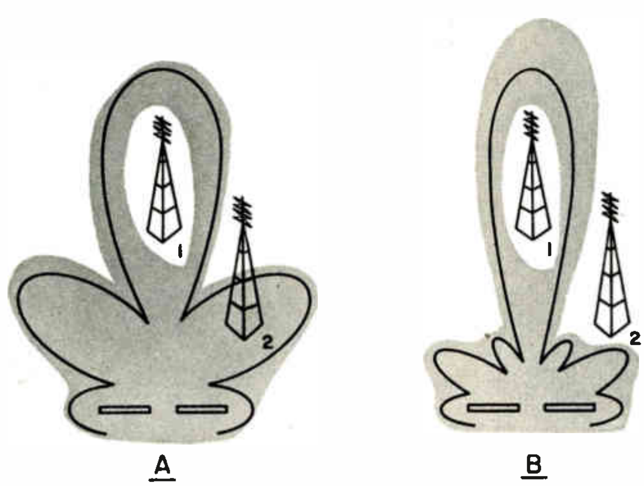


Figure 9-12. Change in reception pattern with change in channel frequency.

Installation of the Transmission Line

As the frequency of the received signal increases, from the vhf range to the uhf range, so also does the possibility of signal losses increase. These losses can occur due to stray capacitance that may exist at high frequencies as a result of poor or careless installation procedures, but which do not matter at lower frequencies.

For instance, suppose that the lead-in lies against a metal drain pipe, and that the capacitance to ground so introduced is only 10 mmfd, a very small amount. At 57 mc the capacitive reactance is approximately 250 ohms, and at the other extreme of 887 mc the reactance drops to approximately 15 ohms. In either case, the signal loss will be considerable. Further, since capacitive effects cause voltage-current phase shift, the signal which does reach the receiver will possess phase distortion. Therefore, care and consideration must be given to the installation of the lead-in, as shown in figure 9-13. The choice of antenna lead-in is governed by circumstances, such as presence of electrical interference, the type of antenna, the lead-in distance and any other factors which affect the lead-in.

Routing of the transmission line to the receiver should be planned for shortest possible distance, consistent with noise and obstruction problems that may exist. Adhere to the precautions of avoiding proximity to power lines and metal objects such as drain pipe and conduit. Avoid signal loss by proper use of spacers and standoff insulators, since any signal loss to ground may affect the chroma signal, with loss in color response.

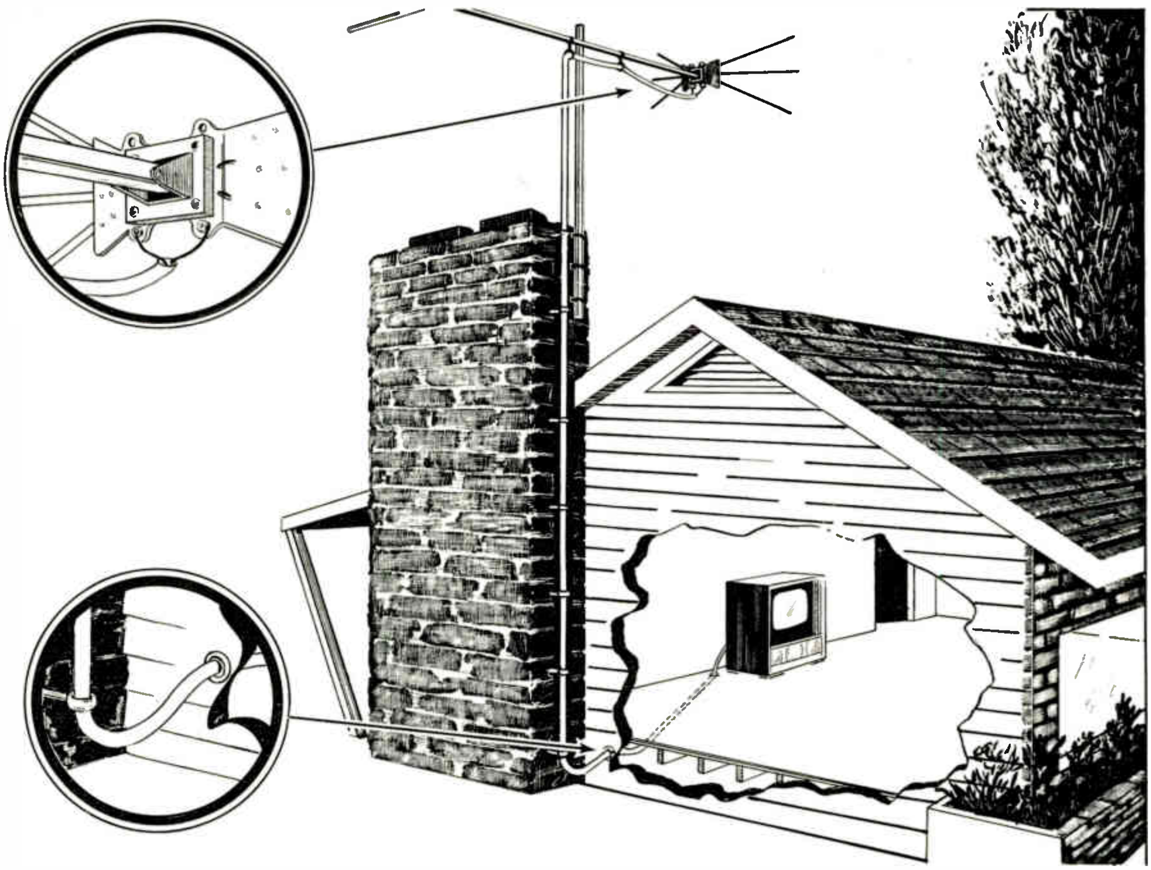


Figure 9-13. Home installation of antenna and lead-in.

When using tubular twin-lead, the lead-in should be formed into a drain elbow and a small drain hole drilled at the bottom of the elbow at the point of entrance into the building. Do not neglect sealing the end connected at the antenna. Objections of the customer to the proposed installation and transmission line routing should be overcome by carefully explaining that the contemplated arrangement is necessary to give the best possible performance and satisfaction.

The installation of color television receiving systems in relation to monochrome installations involves the added precautions of assuring that full high-frequency response is obtained. The importance of care and common sense when planning and making an installation cannot be too strongly stressed. Each time an installation is made, make a mental survey of the situation, taking into account the distance from, and the number of television stations, the noise-to-signal ratio in that area, and ghost or shadow problems. These factors must be considered for an effective installation.

REVIEW EXAMINATION—CHAPTER 1

1. What are the horizontal and vertical sweep frequencies for monochrome television as specified by the F.C.C.?

2. What is the video signal?

3. What are the names and purposes of the synchronizing pulses?

4. What is the purpose of a blanking pulse?

5. How is the 4.5-mc i-f signal obtained in an intercarrier sound system?

6. What is agc and why is it used?

7. What is the main difference between a gated and an ungated agc circuit?

8. How are the sync pulses separated from the composite video signal?

9. Why is a high-voltage pulse developed during fly-back time?

10. Why is a damper tube used in the horizontal deflection circuit?

REVIEW EXAMINATION—CHAPTER 2

1. What is colorimetry?

2. What is light?

3. What is color?

4. What are the three properties of color?

5. What is the chromaticity diagram?

6. What are the three primary colors used in color television as specified by the F.C.C.?

7. In what proportions must the three primary colors be mixed to obtain white light?

8. For what purpose are passive filters used in color television?

9. What is a saturated hue?

10. Does the amount of brightness change the hue of a color?

REVIEW EXAMINATION—CHAPTER 3

1. How does the color television camera convert the reflected light from a scene into the three primary brightness signals?

2. What is the brightness (Y) signal and how is it formed?

3. What are the color-difference signals and how are they formed?

4. What is the color subcarrier and how is it formed?

5. What portion(s) of the composite color television signal is required for normal operation of a monochrome receiver?

6. What is burst and why is it required?

7. What is the frequency of the color subcarrier?

8. What is the purpose of the color subcarrier?

9. Why is a locally-generated carrier required for the demodulator?

10. Draw a quadrature graph and locate the burst and the color-difference signals.

REVIEW EXAMINATION—CHAPTER 4

1. What is a delay line and what is its purpose in the color television receiver?

2. How is the chroma information extracted from the composite color signal?

3. What is acc and why is it used?

4. In the preceding text, which color-difference signals are demodulated and which color-difference signal is obtained by matrixing?

5. What determines the phase angle of demodulation?

6. Why are the phase angles of the demodulators changed from 0° and 90°?

7. How is the burst separated from the chroma signal?

8. How does the burst control the frequency and phase of the locally-generated carrier?

9. What is the color-killer stage and why is it used in the color receiver?

10. Draw a block diagram of the high-level demodulator and the reference oscillator sections.

REVIEW EXAMINATION—CHAPTER 5

1. What are the basic differences between a monochrome picture tube and a color picture tube?

2. What is the shadow mask and why is it used?

3. What control(s) and assembly(ies) are adjusted to obtain color purity?

4. Draw a diagram of one convergence magnet assembly and pole pieces. Indicate movement of electrons between pole pieces.

5. By what means are the electron beams converged along the center vertical and center horizontal axis?

6. Draw the three convergence magnet assemblies in their relative positions and indicate the direction of deflection of each electron stream.

7. What type waveforms are required for dynamic convergence?

8. What is the purpose of the blue lateral magnet?

9. Draw a diagram of the blue lateral magnet in its proper relative position to the three electron streams?

10. What is the purpose of the magnets around the rim of the tri-color cathode ray tube assembly?

REVIEW EXAMINATION—CHAPTER 6

1. Name the external assemblies that control the electron beams in the tri-color cathode ray tube.

2. What is the purpose of the deflection yoke in the tri-color cathode ray tube?

3. What is the purpose of the neutralizing coils?

4. What is the purpose of the horizontal and vertical amplitude controls?

5. What is the purity control and in what circuit is it located?

6. What controls or adjustments are adjusted to converge the three electron beams in the center of the screen?

7. What controls or adjustments are adjusted to converge the three electron beams along the center vertical and center horizontal areas of the screen?

8. What are the G1 and G2 controls and how are they associated with the picture tube?

9. After the color purity ring magnet assembly is adjusted properly, how are color impurities around the edge of the screen eliminated?

10. Why is it necessary to perform the complete convergence procedure twice, i.e., preliminary and final convergence procedures?

REVIEW EXAMINATION—CHAPTER 7

1. Draw a schematic diagram of a variable bias supply using a 67.5-volt battery, a 10K-ohm resistor, a 50K-ohm potentiometer and a switch.

2. Why is a bias supply required during alignment?

3. Why should the traps in the i-f section be aligned before aligning the poles (i-f coils)?

4. Why should the 4.5-mc sound i-f transformer be aligned before aligning the chroma channel?

5. Why must the master phase control be aligned before setting the quadrature adjustment?

6. What method should be used to adjust the oscillator section of the tuner?

7. What portion(s) of the receiver should be realigned if the overall response curve, at the video detector, is not the same for all channels? The sweep-generator signal is applied to the tuner input.

8. Draw the normal color-bar waveform as it should be observed at the control grid of the red electron gun. Label the R-Y bar.

9. Draw the normal color-bar waveform as it should be observed at the control grid of the blue electron gun. Label the B-Y bar.

10. Draw the normal color-bar waveform as it should be observed at the control grid of the green electron gun. Label the G-Y bar.

REVIEW EXAMINATION—CHAPTER 8

1. What section(s) would be suspected of being defective if the raster and sound appear normal and the picture lacks contrast?

2. What section(s) would be suspected of being defective if the picture tube contained only the low-detail color information? Sound is normal.

3. What section(s) would be suspected of being defective if, when receiving a monochrome signal, the picture is ghosty? The antenna installation is not at fault.

4. What section(s) would be suspected of being defective if the picture is moving both vertically and horizontally? Sound is normal.

5. What section(s) would be suspected of being defective with the same symptoms as in 4 above but the waveform at the video detector is normal?

6. What symptoms are noted on the picture tube if the receiver is misconverged while receiving a black and white program?

7. What symptoms are noted on the picture tube if the receiver is misconverged while receiving a color program?

8. What symptoms would appear on the picture tube if the filament of the demodulators (dual tube) is open while receiving a black and white program? While receiving a color program?

9. What symptoms would appear on the picture tube if the 3.58-mc oscillator tube does not oscillate while receiving a black and white program? While receiving a color program?

10. What section(s) may be defective if the raster and sound are missing?

REVIEW EXAMINATION—CHAPTER 9

1. Why should a receiver be checked before delivery to the customer's home?

2. Why are television receiving antennas horizontally polarized?

3. What determines the length of the antenna elements?

4. What is the center impedance of a dipole at its resonant frequency?

5. What is the center impedance of a folded dipole at its resonant frequency?

6. What types of transmission lines are used for television antenna installations?

7. How is the antenna usually positioned, relative to the transmitting antenna, for maximum signal interception?

8. What are the advantages of motor-driven rotor assembly installed in the antenna system?

9. What method is used to prevent the rain that travels along the transmission line from entering the customer's home? Draw a diagram.

10. Why should the transmission line not be installed near drain pipes, conduit or similar grounded metal surfaces?

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