Revised Edition

- Covers Commercial Model Receiver Circuit
- Greatly Expanded Service and Installation Section
- Detailed Description of Latest Color Test Equipment




# PRACTICAL COLOR TELEVISION

*for the service industry*

**RCA SERVICE COMPANY, INC.**

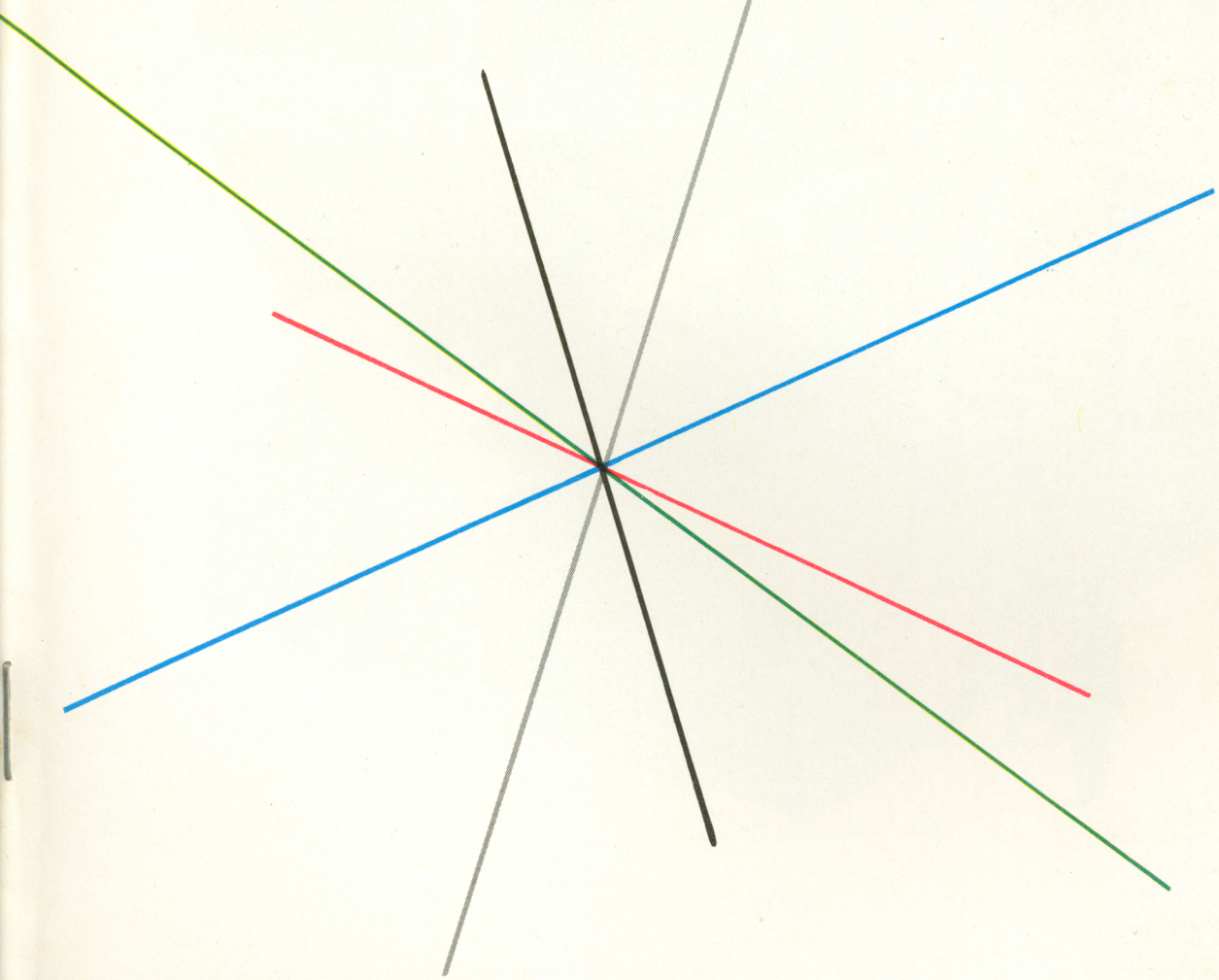
*A RADIO CORPORATION OF AMERICA SUBSIDIARY*

CAMDEN, N. J.

Price $2.00

2011.0011

# PRACTICAL COLOR TELEVISION FOR THE SERVICE INDUSTRY



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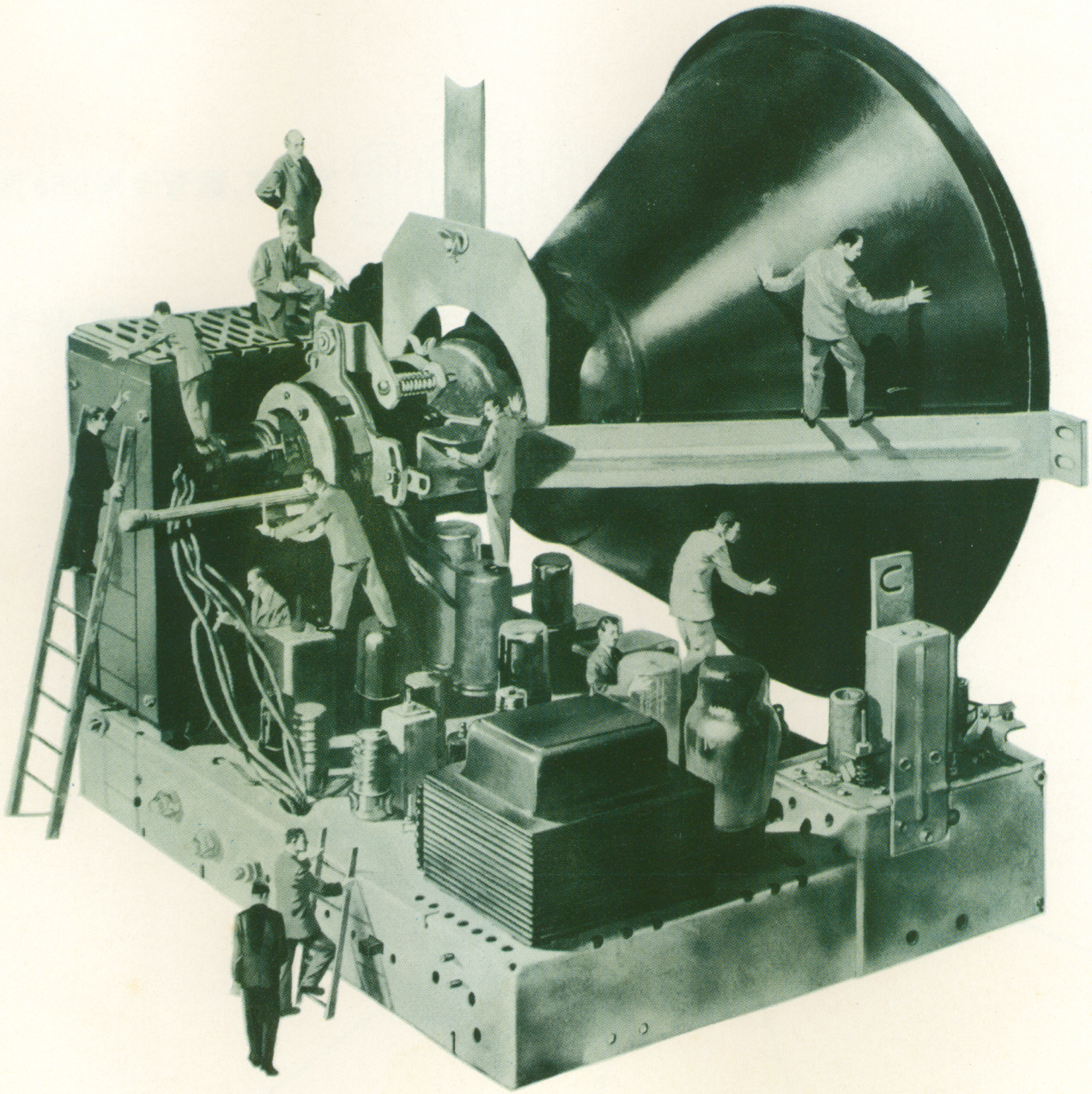

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# THE PICTURE . . .

"Practical Color Television" is dedicated to the Television Service Technicians — the men who make it possible for Mr. and Mrs. America to tune in pictures as well as sound, right in their own living rooms . . . and to *keep on* tuning in and enjoying their favorite programs month after month!

The tremendous task of installing and maintaining more than 25,000,000 television receivers was and is a job requiring expert skill, careful organization and plenty of hard work. It is a real and continuing test of the competence, industry and ingenuity of the nation's electronic service technicians. The splendid way in which these men have measured up to their job is evidence of their ability, and a tribute to their deep sense of responsibility to the American public.

We at the RCA Service Company have faith that these same Technicians will meet the new responsibility of installing and servicing color television receivers for the nation's millions of homes with "flying colors" and in so doing will bring still greater credit and stature to the profession they so ably represent.

This book, then, is dedicated to all who strive to improve the standards of television service; and particularly to the men behind the television picture—the Television Service Technicians.

E. C. Cahill

E. C. CAHILL, *President*

RCA Service Company, Inc.



## ACKNOWLEDGEMENTS

*"Practical Color Television" represents the coordinated efforts of many RCA Service Company Technicians, each an expert in a particular phase of color television.*

*The RCA Service Company is also indebted to the engineers and research scientists of the David Sarnoff Research Center, the Engineering Products Department and the Home Instrument Department of RCA Victor Division, and the Office of Chief Engineer, RCA Victor Division for their helpful suggestions and advice.*

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# SECTION I

## Introduction

Color television is the next big challenge and opportunity in the television service industry. To better prepare yourself for that opportunity, the first step is to learn more about it. This book is written to help you make that first important step.

"Practical Color Television for the Service Industry" is based on the RCA Compatible Color Television System. It was prepared by the RCA Service technicians who have installed and serviced RCA Victor color television receivers since the beginning of the Company's early color tests.

This book is addressed primarily to the service technician who is working with today's black and white television system, and it is assumed that the reader is well versed in the basic operating principles of television. This assumption permits simplification of basic operating descriptions, and the omission of detailed explanation such as the novice would require.

The RCA Victor color television circuit employed as an example is that of a typical compatible color television receiver. While circuit details of color television receivers will certainly change as the art progresses, the fundamental circuit functions undoubtedly will remain. Similarly, future changes in the details of operation, installation set-up adjustments and service procedures will be better understood from a thorough understanding of the basic information here presented.

We believe the service technician, on reading this volume, will understand that, although the installation and service requirements for a color TV receiver are more complex, and more demanding of care and attention to detail, there is really nothing the service technician cannot master. Just remember, though, that this book is *a start* . . . mastery will come only with further study and experience.

While addressed to the individual, "Practical Color Television" was prepared with the broader interests of the television service industry in mind. If it helps television technicians to understand the basic principles of color television . . . if it contributes to higher standards of television service . . . if it helps win for the television service industry an even more respected position in the community . . . its mission will have been accomplished.

# Compatible Color Television – A Natural Step Forward

EVERYONE knows that the human eye in association with the brain picks up the reflected light from a scene and imagines the scene as a brain sensation in full color. Normal vision is color vision. Color vision is realistic vision in that the full psychological and emotional effect of the scene is impressed upon our brain.

Man from his earliest times has had the desire to record the pictures he sees. The cave man made crude charred stick sketches on the walls of limestone caves which were, no doubt, the first black and white pictures. Early man saw color in nature but with his limited tools could not produce pictures in color. As time passed man learned he could make paint pigments of colored materials found in nature, and with his fingers, then with improved tools such as brushes, produce a colored picture of what he saw or thought he saw. Today we call this man an artist or a painter—a producer of color pictures by hand—a slow process at best and his original work finally viewed by only a few. Even the great masters—today and yesterday—have to be satisfied with an *approach* to the perfect picture of a scene or person. For example, every oil painting, upon close inspection, has brush marks and other defects which the eye never sees in nature. How often has the grandeur of our own Grand Canyon view been called "the picture no artist can paint." But still, if we can't see the natural scene in person, we all enjoy viewing a master's work of art—such as a Grand Canyon vista — in oil colors. Can one imagine any such work of art in only black and white with grey shades giving the full color sensation and emotional effect the natural scene would arouse?

## *The development of ink printing*

The development of ink printing by Gutenberg around 1456 soon led to wood block engravings for black and white pictures. A few pioneers saw the natural demand for printed color pictures, and step by step developed color printing processes producing the many fine near-natural color pictures we see every day in many of our magazines, newspapers, books, etc.

As in printing, so in photography. First the crude brown and white "tintypes," then the black and white "snapshots," finally the full color photographs of today. The special appeal of color movies as compared to the same movies in black and white is so well known that the important film stories are most always now made in color.

While it is not believed necessary to further emphasize the appeal of color pictures as compared to black and white some physical evidence may be helpful. Just compare the two pictures in FIGURE 1. Both are the same subject with one in black and white and the other in color. You, no doubt, are looking at the picture in color. The appeal of color is natural and universal.



Figure 1 — The Appeal of Color

As color printed pictures, color photographs, and color movies were natural steps forward in man's progress to record and distribute "color vision" for all, so color television is a natural step to secure finally "color pictures through the air." Color printing and color photography processes are more complex than black and white processes, and it follows that color television is more complex than black and white television.

While color television in itself is a great natural step forward from black and white television, *compatible* color television, as developed by RCA, is a still greater step forward. Webster defines compatibility as "capable of existing together." Compatible color television means that color tele-

vision broadcasts are receivable on the millions of black and white receivers already in the public's hands without any change in the black and white receiver, regardless of manufacturer, model, or year produced. Conversely, compatible color television means that any color television receiver can receive black and white television broadcasts without any modification. The feature of compatibility is important to all. For the broadcaster and sponsor, it means continued service for the audience for whom large monies for programs have been invested, regardless of whether the program is in color or black and white. Even more important, the public's investment of billions of dollars in black and white television receivers, purchased and in use to date, is protected since they can view the color broadcast as a black and white picture without any additional cost.

## Study of Basic Color Principles

In order to grasp the basic principles of the RCA Color Television System it is necessary to understand the essentials of color, or what is meant by "color." The study of color is a complex subject and we only touch on the facts as they apply to the basic principles of the RCA color television system. The study of color is a study of vision—the sense of sight—the physical reception of light by the human eye and the resulting picture as it is registered on the "screen" of the human brain. Since color depends first of all on light, it would be helpful to examine the nature of light itself.

Light is only one of a number of known forms of radiant energy which travel with wave motion. All forms of radiant energy travel at the tremendous speed of 186,000 miles a second, or 300,000,000 meters per second, and differ only in wavelength and frequency in the relationship:—

$$\text{Wavelength In meters } (\lambda) = \frac{300{,}000{,}000 \text{ (meters/sec.)}}{\text{Frequency (f) in cycles/sec.}}$$

Various forms of radiant energy make up the radiant energy spectrum as shown in Figure 2. Toward the center of the spectrum, as can be seen, are located the wave energies of light—the radiant energy that stimulates the human eye. These light waves cover a band of wavelengths from 400 to 700 millimicrons (a billionth of a meter) in length. Light may be defined as that aspect of radiant energy of which a human observer is aware through the visual sensations which arise from the stimulation of the human eye's retina.

When radiant energy of all wavelengths between 400 and 700 milli-microns is presented to the eye in certain nearly equal quantities we receive the sensation of *colorless* or "white" light — similar to the white light from the black and white television picture tube. Under suitable conditions, we can analyze white light into its constituent radiations. In nature, sunshine (white daylight) falling on the curved surfaces of raindrops is broken up into the familiar colors of the rainbow.

The same effect can be shown by passing a narrow beam of light through a glass prism as shown in Figure 3. The resulting band of colored light, as

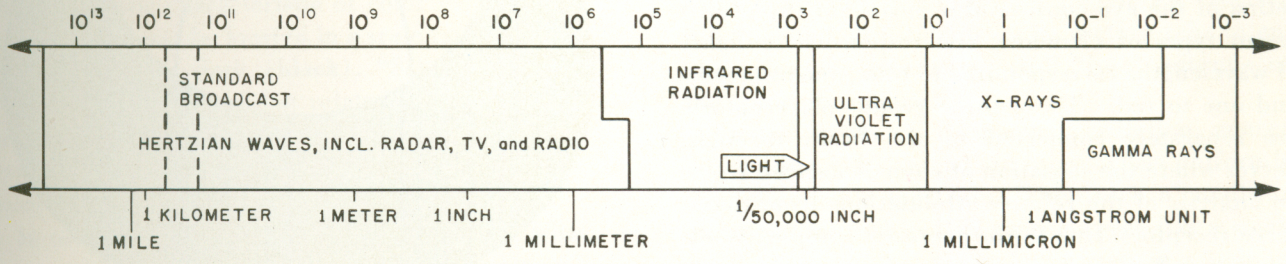



Figure 2 — The Radiant Energy Spectrum in Milli-microns

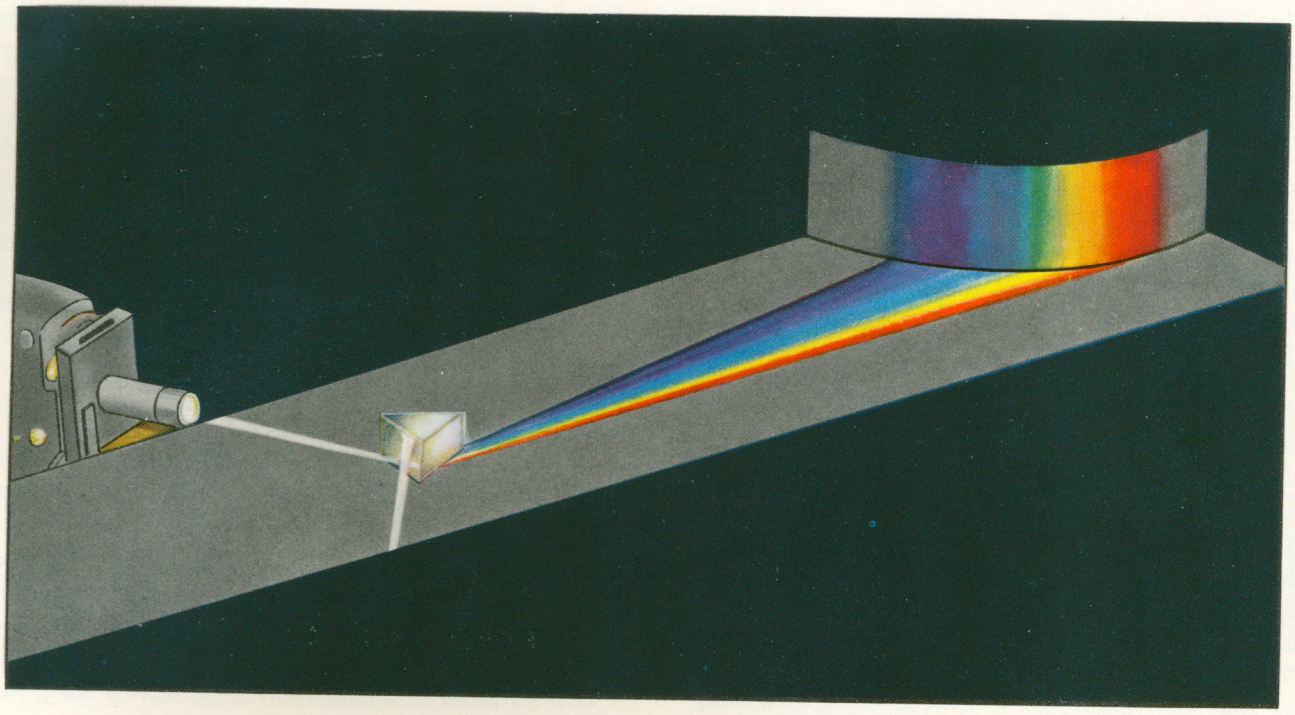


Figure 3—Separation of White Light Through a Prism

shown, is called the *visible spectrum of light* and the principal colors as reproduced are seen to be red, yellow, green, blue-green, and blue.

Actually many more colors are present, and these colors are the purest colors possible, as each is seen in isolation unaffected by mixture with light of other wavelengths.

The exact process by which the human visual system is able to translate light of different wavelengths (and mixtures of wavelengths) into color sensations is still not known. Experiments show that almost the full range of color sensations can be obtained by mixing in various proportions the light from three colored lights, one blue, one green, and one red.

A theory of color vision based on this so-called "trichromatic" color matching property is that the retina of the eye consists of a mosaic of three different types of elements, one responsive to light of wavelengths corresponding to blue, one to green, and one to red. These three groups of receptors are separately connected to the brain through nerves where the sensation of color is derived from an analysis of the relative stimulations from these three receptors. Due to the fantastic complexity of this network of nerves and nerve connections it is easy to understand variations of color vision among individuals. When the network system is seriously out of balance "color blindness" results.

The principal colors obtained by superimposing the different combinations of blue, green, and red sources are shown in FIGURE 4.

Three such colored lights are known as *additive primaries*. Actually, the three additive color primaries are not necessarily restricted to blue, green,

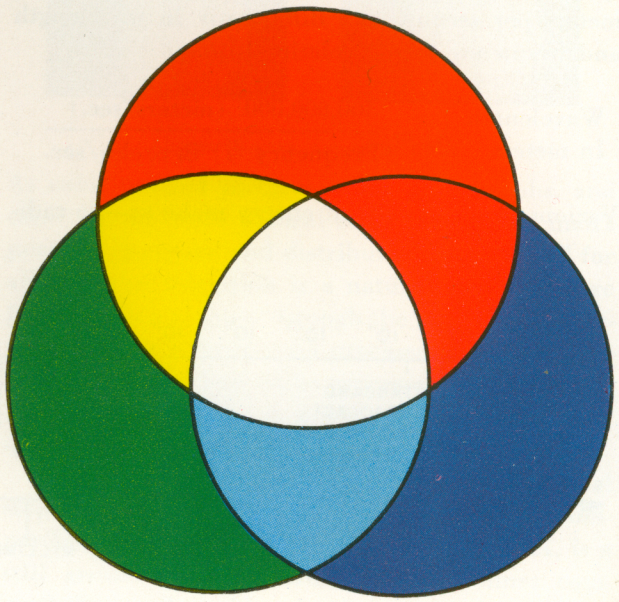


Figure 4 — The Additive Primaries

and red lights; any three colors can be used as primaries as long as no two of the colors can be mixed to match the third. Blue, green and red are chosen as primaries in color television since they permit the matching of the greatest range of common colors.

In the understanding of color primaries, it is essential to distinguish between *additive* and *subtractive* primaries. Additive primaries, the only type of direct interest in color television, are so called because they are actually sources of light which are added together to yield a desired color. Subtractive primaries, on the other hand, are absorbers of light which are used in series (layers) to create color by removing selected wavelengths from a white source. Subtractive primaries in the form of dyes and pigments are used in modern photographic and printing color processes.

A study of color as applied to color television principles would be relatively simple if all we had to consider were the various colors of light obtainable by mixing various intensities (amounts or portions) of red, green, and blue primary lights. These primary colors, and their many companions resulting from their mixture such as yellow, orange, magenta, cyan, violet, etc., in the known facts of *color sensation*, are but one of three basic characteristics of color sensation and are called "hues."

Besides the basic color sensation of hue there are two other characteristics of color that must be considered; namely "saturation" and "brightness."

Saturation is a term which describes the amount of white light mixed with the hue. The artist calls it the "tint." The degree of saturation in a red hue is well understood if we remember pink is a fundamental red hue diluted or mixed with considerable white. A zero saturation of red hue represents white light while 100% or full saturation of red hue is the full and true vivid red with no white light. In other words, the pale or pastel shades of hue are less saturated than the vivid shades of hue.

"Brightness" is a term familiar to TV servicemen. It is that basic characteristic of color by means of which colors may be located in a scale ranging from light (white) to dark (black). "Saturation" and "brightness" are somewhat related because we can say that saturation refers to the degree by which a color departs from gray or "neutral hue" of the same brightness.

In order to illustrate more technically just what we mean by "brightness," "hue" and "saturation," it will be helpful to consider our common knowledge that light and radio waves are both electromagnetic waves, and that light waves are detectable by the human eye. In other words, the average human eye and the associated brain is a picture receiver having a fixed *selectivity* characteristic and a variable *sensitivity* characteristic. Roughly, the eye's "RF circuits" respond to light having a wavelength range of some 400 to 700 millimicrons (0.0000004 to 0.0000007 meters—rather short waves!). As shown in FIGURE 5, the eye's brightness response is not uniform.

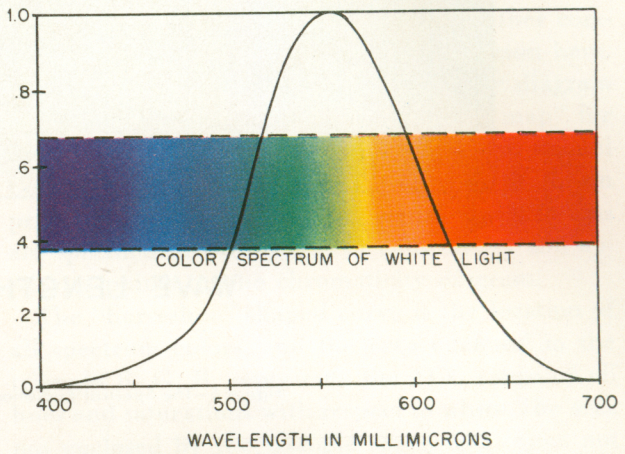



Figure 5 — Luminosity Response of the Human Eye

This curve describes the spectral characteristics of the *brightness sensation* only. Note that the curve peaks near the wavelength of green. The curve shows then that a given amount of light energy may appear *much brighter* at some wavelengths than at others. The curve shown is the standard CIE (International Commission of Illumination) *luminosity* (brightness) curve.

The other two variables of color — "hue" and "saturation"— are controlled by the *relative spectral* distribution of light energy. "Hue" is determined by *radiant purity*, or freedom from white. (Note the word "purity," a common term used in color television. For example, a color TV receiver has "purity" adjustments on its picture tube to enable complete saturation — full "hue" output — of the color phosphors.)

FIGURE 6 shows a spectral radiation energy curve (line A-A) spread out more or less uniformly over the visible spectrum. When such a condition exists we see "white." If such a curve has a small peak (line A-B-A), the color is seen as a pale or pastel shade — in this case pink — a low saturation of the dominant wavelength "hue" of red. If the

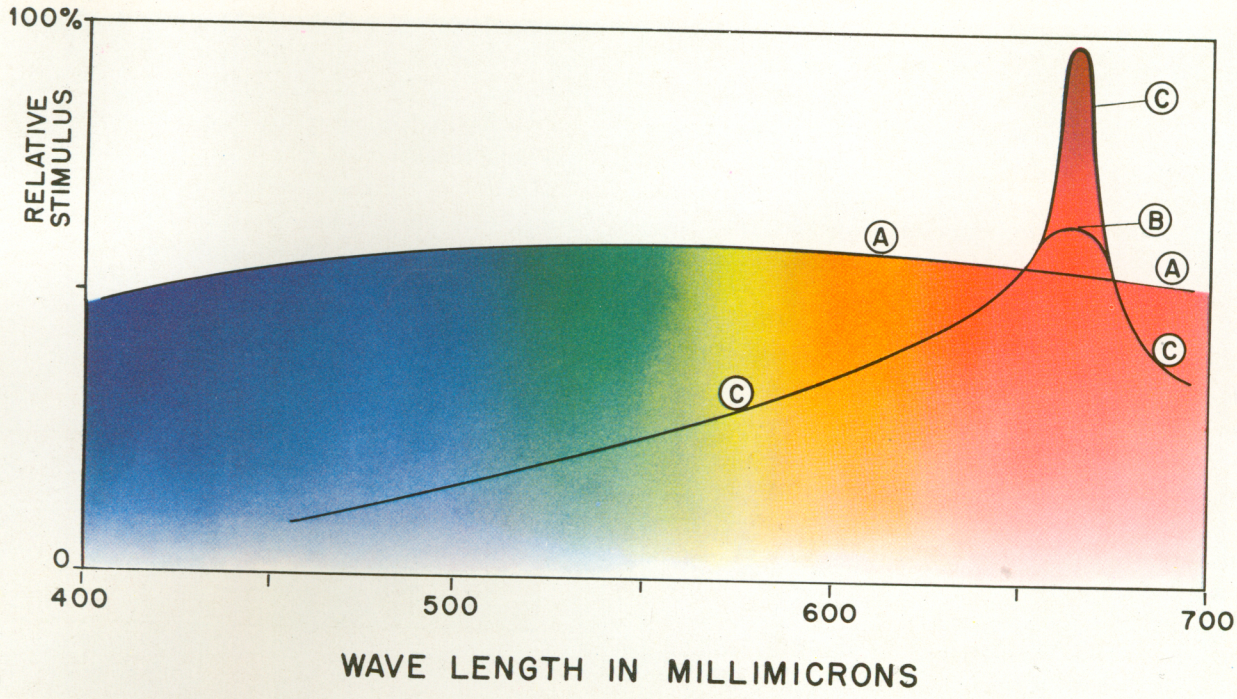



Figure 6—The Spectral Radiation Curve of White, Pink and Red Objects

curve of spectral energy was like that shown as line C the color is seen as a high saturation of the dominant wavelength hue of red.

In order to better illustrate the color characteristics of "hue," "saturation," and "brightness," FIGURE 7 shows their relationship. The upper third of this figure shows a strip of white, the middle

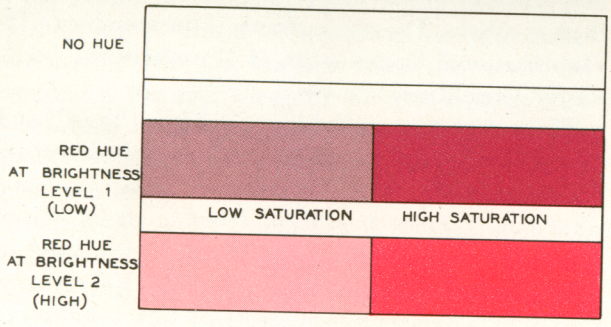



Figure 7 — Relationship of Brightness and Saturation

third a strip divided by a "red hue" at low saturation and high saturation for "brightness level 1" and the lower third a strip with the same "red hue" at the same saturations but for a higher "brightness level 2." Notice that your eye can detect a difference — in other words, all four colors are red but different because we have changed the strip step by step from original white (no hue but the same bright white of black and white television) by the three basic characteristics of color. First we added "hue" to white, then changed amount of "hue" to secure a "saturation" change, and finally raised the same "saturation" values of a given "hue" in "brightness."

A basic tool for the study of color is the "color solid" which is shown in FIGURE 8. The hue variations are indicated by the position of a radius of the cylinder at some point on the circumference of the cylinder. The length of this radius determines the saturation of the hue, while brightness is determined by the position of the radius along the central axis of the cylinder.

In black and white television, our system (assuming everything else is equal or similar, such as picture detail or resolution, field and frame frequency, etc.) only has to supply one signal variable, namely a means of controlling the "brightness" range of a given picture element on the receiver picture tube. In the present color television system, we must add two more signal variables; i.e.: the hue and saturation, using three primary colors in order to secure satisfactory color—so the home viewer's color television picture looks as near natural as possible—just as if he were viewing the original scene *in person.*

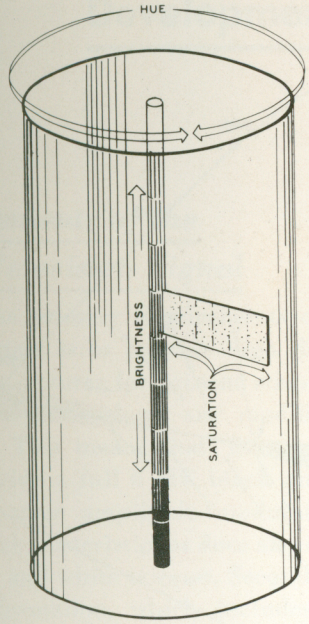



Figure 8 — Relationship of Brightness, Hue and Saturation

Another basic tool in the study of color is the chromaticity diagram. "Chromaticity" is that characteristic of a color representing hue and saturation together (i.e., chromaticity describes everything about a color except its brightness). The word "chroma" usually refers to the saturation of colors; the color control (sometimes referred to as the chroma control) on a color receiver affects the vividness of the colors in the picture but not their hues. The most commonly used chromaticity diagram is the one shown in FIGURE 10, which is based on the "color mixture curves" shown in Figure 9. These color mixture curves show the amounts of three hypothetical primaries, X, Y, and Z, needed to match unit energy at each wavelength in the spectrum. The derivation of the chromaticity diagram from the color mixture curves is rather complex, and is not necessary for our discussion here. Let it suffice to say that the chromaticity diagram of FIGURE 10 is the standardized "color map" for the system of colorimetry used by the International Commission on Illumination. The color television primaries listed in the FCC signal specifications are specified in this system of colorimetry and appear as points on the chromaticity diagram.

The "horseshoe" shaped curve is the location of all spectrum colors, and the area enclosed in the triangle R, G, B, represents the FCC range of all hues and saturations with respect to white. The area not enclosed by the triangle represents colors not

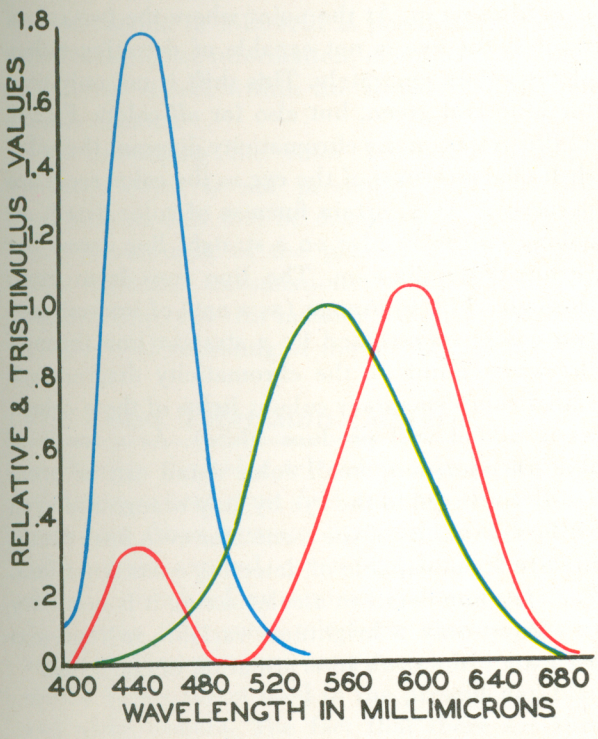



Figure 9 — Fundamental Color Mixture Curves

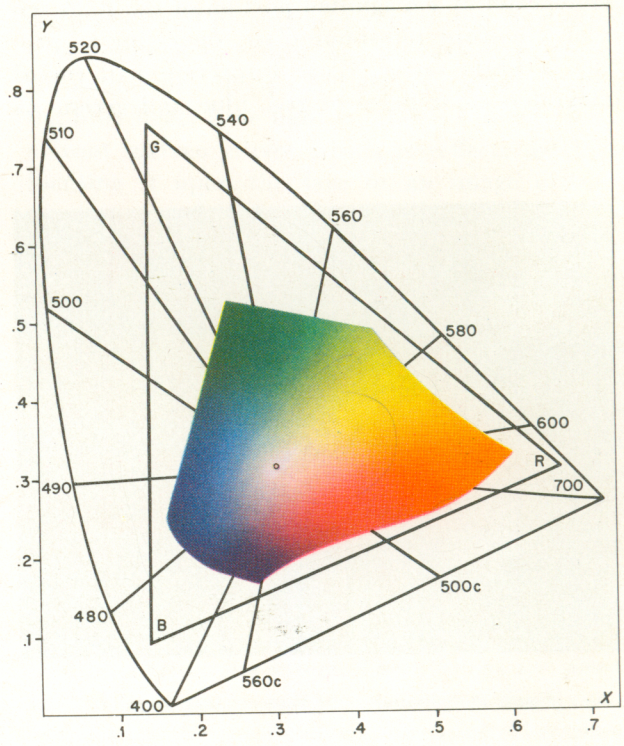



Figure 10 — The Gamut of Printing Inks and Color Television on the Chromaticity Diagram

reproducible by the color television system, but, since these are mostly the heavily saturated greens and blues that rarely occur in nature, the compromise of omission has been relatively unimportant. FIGURE 10 shows actual color hue areas in the chromaticity diagram. As an example of superiority over any other modern color reproduction process, the color area of FIGURE 10 represents the chromaticity "gamut" (range) of color printing inks and is seen to be *smaller* in area than that bounded by the triangle R, G, B, the FCC chromaticity specification for the hue and saturation range for color television.

The preceding pages discussing the basic principles of color have dealt with color as interpreted by the human eye. Only fundamentals can be touched upon in these few pages; however, in order to interpret more clearly the color television signal and how it is developed, there is a more specialized phenomenon of color that warrants discussing here.

It has been found by experimentation and research that the normal human eye tends to become color blind to a varying degree as color areas in a color scene become smaller. All colors appear to the eye to change from the original as the color area becomes smaller. FIGURE 11 demonstrates this color shift for green and blue. The illustration is a photograph of a magnified portion of the RCA tricolor kinescope phosphor plate, operating to produce a white raster. Close inspection will reveal integrated color fields of red, blue and green. As

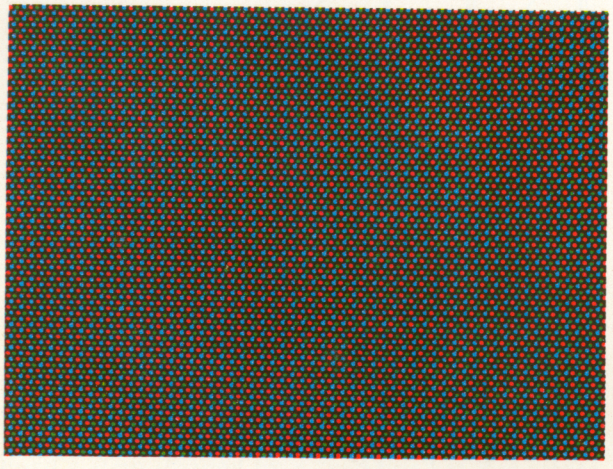


Figure 11 — Illustration of Normal Color Blindness

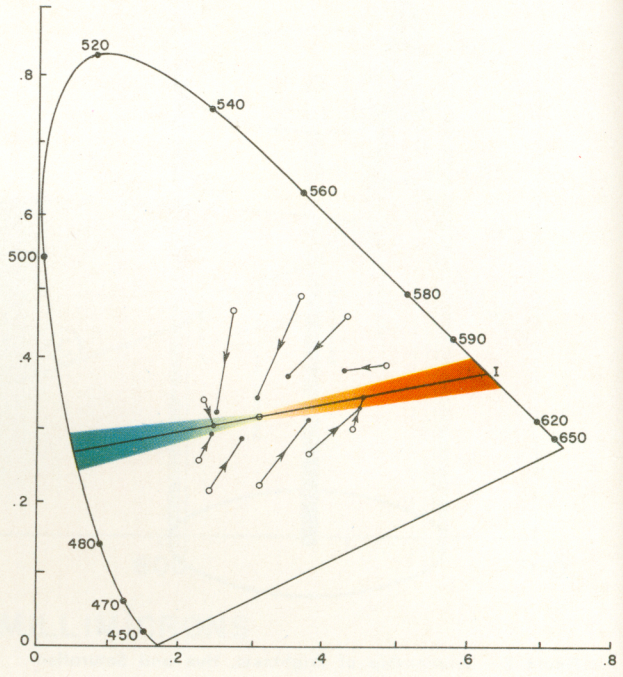



Figure 12 — Resolving of Color Detail to the Orange — Cyan Line

the page is moved away from the eye, at some distance the blue and green dots will resolve to a pale blue-green. At the point where the two colors resolve, the eye is not capable of detecting either of the colors separately. This shift is not only true for blue and green, but also for *all* colors. FIGURE 12 illustrates on the chromaticity diagram, the color shift characteristic of the eye as the color areas are decreased. At a certain fineness of color detail, all colors tend to resolve on a straight line across the chromaticity diagram. The line runs from cyan, through white to orange (as a note of interest, any two colors represented by a straight line through the white point on the chromaticity diagram are called *complementary* colors; lights of these colors, when added will produce white). As a result of this phenomenon, small color detail can be accurately conveyed to the eye by only orange and cyan as the true colors of the scene. For even finer detail, the eye is not capable of detecting color sensations. For very fine detail in a color scene, it is necessary to convey only a brightness variable to represent accurately the eye's interpretation of the scene.

# Development of the Transmitted Color Signal

## *Requirements of the Color Television Signal*

One of the primary requirements of a color television system is to provide high definition black and white pictures for present standard black and white receivers without any modifications to the receivers. This means that, first, a color telecast must provide a full 6 MC black and white signal with the same amplitude modulation, sync and blanking characteristics as does any ordinary standard black and white telecast. Secondly, the chrominance information, which includes the hue and saturation variables of color, must be transmitted within the standard 6 MC television channel and thirdly, the transmitted chrominance information must not in any way cause objectionable interference with the black and white signal (the brightness variable of color).

At first glance, this seems to be a difficult task to accomplish, since the 6 MC channel is apparently already well filled. However, as will be learned in the discussion to follow, it is possible to transmit the chrominance information, along with the black and white signal, within the standard 6 MC television channel.

In developing the color television signal, a method which is not presently used for color transmission will first be discussed. This will lead into development of the present system of high color definition transmissions. It is felt that treating the subject in this manner will give the reader a better understanding of the techniques involved.

## *The Color Television Camera*

To develop the color television signal, the color television camera must first split up the televised scene into three separate light images. The three light images are red, green and blue. FIGURE 13 shows a sketch of an optical system used in an RCA three tube color television camera. On the left is an objective lens on a turret which is very similar to the turret used in the present day black and white camera. The fact that there are three lenses on the turret does not indicate that they split up the light into three primary colors. Actual-

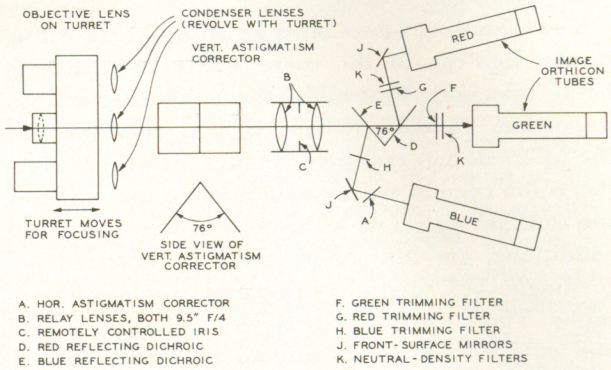



Figure 13 — The Optical System Used in an RCA Three Tube Color Television Camera

ly, all light enters the center lens which is the objective lens. Neglecting the vertical astigmatism corrector and the iris for the moment, follow the light path back to the letter E, which is a blue reflecting dichroic mirror. A dichroic mirror has the property of passing all light but the light which it is designed to reflect. In the case at E, the dichroic mirror will pass red and green light, reflecting blue light. Blue light is reflected to the face of a front surface mirror which re-reflects the light, focusing it upon the face of an image orthicon camera tube designated to operate from only the blue light of the televised scene. The red and green light passes through the blue reflecting dichroic mirror to another dichroic mirror D; in this case, a red reflecting dichroic mirror. Green light continues to pass through this mirror and is focused on the face of the green camera tube. The red light is reflected by the red reflecting dichroic mirror and is re-reflected by another front surface mirror indicated at J, to the face of the red camera tube.

The three camera tubes are adjusted to have equal output when the televised scene is white or neutral. Notice that F, G and H are red, green and blue trimming filters. These filters are placed in the light paths in order to adjust the spectral response of the color camera. The spectral response of the combined camera tubes should be equal to that of the black and white camera. This spectral response in the black and white camera is very

similar to the spectral response of the human eye, shown in FIGURE 5. Since the dichroic mirrors have rather broad spectral responses, the trimming filters placed in the three light paths are selected so that the total or combined spectral response equals that of the human eye, or that of the black and white television system.

The trimming filters must be adjusted according to the lighting in the room where the scene is being televised. The color of the lighting is very important. Indoors, it can be kept constant and the filters do not require changing. However, when the color camera is moved outdoors, the color of the sunlight varies with the time of day and cloud conditions, and the filters must be changed accordingly. This might be compared to color photography. There are different types of film for indoor and outdoor use. If an outdoor type film is used indoors, a special filter must be placed in front of the camera lens to compensate for the change in lighting color from artificial to natural sunlight. The same thing holds true for the color camera. Every time the color of lighting is changed, the trimming filters must be changed accordingly.

At letters K in the red and green light paths there are two neutral density filters. Since the three camera tubes are adjusted to have equal output when televising a white or neutral scene, neutral density filters must be placed in the red and green light paths to compensate for the eye's unequal response to the individual hues comprising white light. From FIGURE 5, it can be seen that the eye responds differently to the different colors contained in white light. Actually, blue light has a brightness characteristic which is only 11% of white, and red and green are 30% and 59% respectively, so a neutral density filter is necessary in the red and green light paths to balance the amount of light focused on the three camera tubes. A final adjustment of the output voltage of these camera tubes may be made electrically.

A vertical astigmatism corrector is required in the main light path because horizontal astigmatism is introduced when light passes through dichroic mirrors. The blue light does not pass through any dichroic mirror but is merely reflected from the surface of the blue reflecting dichroic. Therefore, at A, a horizontal astigmatism corrector is incorporated to balance all three light paths astigmatically.

At C, there is located a remotely controlled iris. This iris is controlled by the operator in the master control room. As the light at the televised scene varies in brightness, the operator may vary the amount of light passing through the color television camera. This is similar to the iris on most cameras.

In summarizing the color television camera, the light of the original scene is separated into three primary colors – red, green and blue. Three individual signal or voltage elements are provided by means of the image orthicon camera tubes to represent the information of three primary colors. When a white or neutral scene is scanned, the three cameras are adjusted for equal voltage outputs.

## Compatibility

As was originally pointed out, color television programs must be so transmitted that they can be faithfully reproduced by present black and white receivers without any modifications. This feature is known as compatibility and is illustrated in FIGURE 14. The red, green and blue blocks indicate

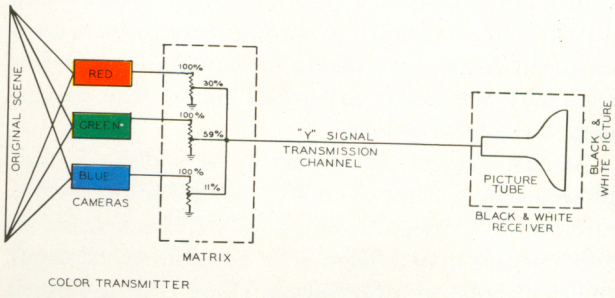



Figure 14 — Color to Black and White Compatibility

the red, green and blue camera tubes. To maintain compatibility, the color camera must produce a black and white signal (referred to as the "Y" signal for simplicity). This is accomplished by using a so called "matrix" or mixing technique where the total output of the red camera tube is attenuated to 30%, the total output of the green camera tube is attenuated to 59% and the total output of the blue camera tube is attenuated to 11%. This provides a match of the spectral characteristics of the color cameras to those of the human eye, as shown in FIGURE 5 and approximates the output of a black and white camera. Connecting this signal from the color camera directly to a black and white picture tube would then reproduce an original color scene in black and white.

## Reverse Compatibility

Black and white on the color receiver, or "reverse

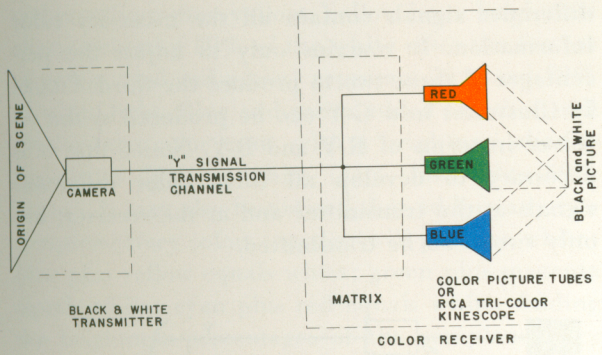



Figure 15 — Black and White to Color Compatibility

compatibility", is illustrated in FIGURE 15. A black and white signal being transmitted by a black and white television system is split equally three ways and is applied to the red, green and blue guns of the tri-color kinescope. Before this signal is applied to its electron guns, the tri-color kinescope is adjusted to produce a white raster. Just how the kinescope provides this white raster before signal is applied will be discussed in a later section of the book. After a white raster is obtained, then an equal signal is applied to all three guns and the black and white signal being transmitted will then produce a black and white picture on the tri-color kinescope. In the process of producing a white screen, the kinescope automatically separates the brightness signal into the ratio of 30:59:11 as the signal is applied equally to the electron guns.

## *Basic Color System*

If a color picture is desired, the color television camera could be connected directly to the tri-color kinescope, as shown in FIGURE 16. The total output of the red camera tube could be directly connected to the red gun of the receiver kinescope, the total green output connected to the green gun, and the total blue camera output directly connected to the blue gun. This will provide a color picture as it appears in the original scene. Notice that the total output of each camera tube is used, although these outputs may not be equal; the output of each camera being dependent upon the color content of the scene being reproduced.

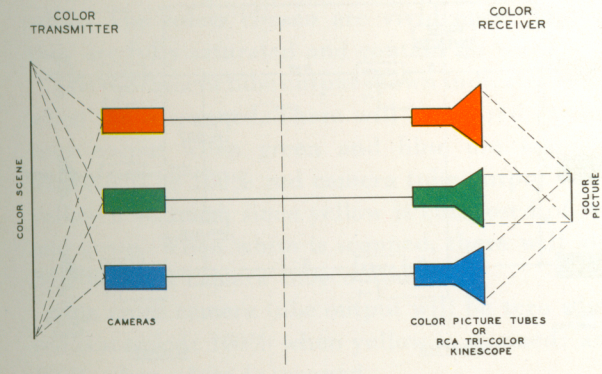



Figure 16 — Reproducing Color on the Color Kinescope

## *Chrominance Signal Development*

In actual practice, the output of the color camera cannot be directly connected to the input of the tri-color kinescope. To maintain compatibility specifications, the three camera signals cannot be transmitted as a television signal, since black and white receivers would be incapable of detecting them. Therefore, the color television system must first produce a standard black and white television signal. Chrominance information must then be combined with this signal in such a way that it will not interfere with black and white reception, but still be capable of detection by color receivers.

It has been shown previously that a black and white signal can be developed from the color camera output by adjusting the three video output signals in the ratio of 30:59:11 and combining them. One method of producing chrominance signals is to develop *color difference* signals from the Y or brightness signal and the three camera tube outputs. The color difference signals can then be regulated as to bandwidth and combined with the Y signal in such a way as to not interfere with black and white reception. A color receiver on the other hand, will be capable of detecting the color difference signals and can recombine them with the Y signal. This will produce three video signals equivalent to the signals at the camera pick-up tubes.

Color difference signals can be produced by subtracting the Y signal from each color camera signal. To do this, the Y signal is inverted so that all values are negative (—30R —59G —11B). This is algebraically added to each camera tube output in turn, thus producing three chrominance signals, R-Y, G-Y and B-Y. As an example of how one of these signals would operate in a television system using this principle, assume that the red camera tube is producing some arbitrary output, with the green and blue tubes inactive.

| | |
|---|---|
| Then: Red Signal | 100 R |
| Inverted Y Signal for red | —30 R |
| R-Y signal for red | +70 R |

Receiver video circuits designed to utilize such a system will appear as in FIGURE 17. Here, the adder at the red kinescope gun will combine the Y signal for this red picture element with the equivalent R-Y signal. The complete Y signal will be 30R + 0G + 0B, since only the red camera tube is active. Adding this to the R-Y signal (70R + 0G + 0B) will produce 100R at the red kinescope grid, which is the original signal at the red camera tube output.

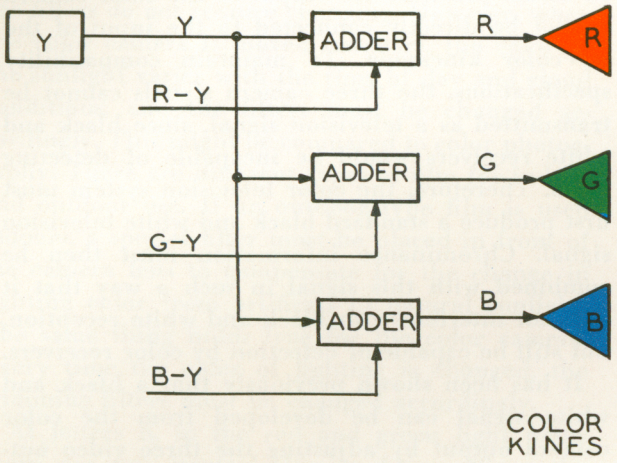



Figure 17 — Receiver Matrix

From this simple example and the hinted implications, it can be seen that four signals are transmitted to produce color (R-Y, G-Y, B-Y and Y). It has been found that only two color difference signals plus the Y signal need be transmitted to reproduce the color elements of any televised scene. One of the color difference signals may be developed in the receiver, since any two of the color difference signals contain all the necessary color information. It remains only to adjust the percentages of these two to produce the third. FIGURE 18 illustrates how G-Y can be produced at the receiver in terms of R-Y and B-Y. Notice that it is necessary to develop all three color difference signals at the transmitter and at the receiver, but only two need be transmitted.

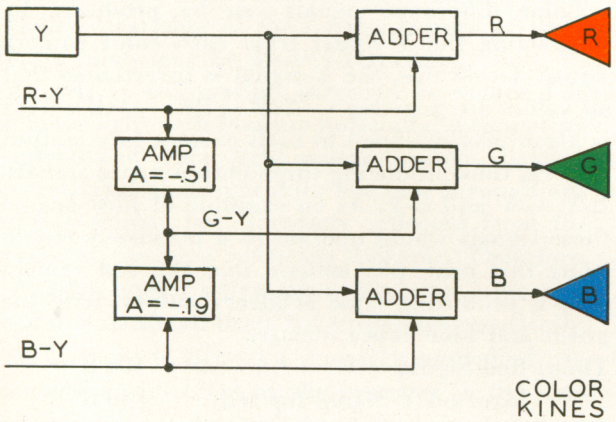



Figure 18 — Receiver Matrix Producing G-Y

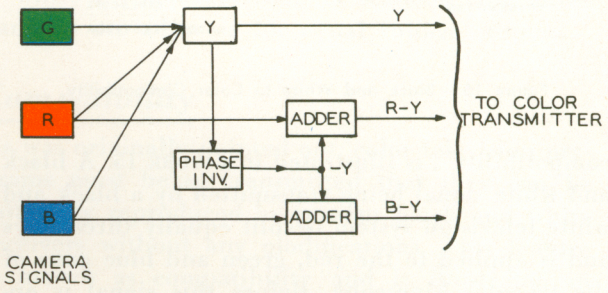



Figure 19 — Transmitter Matrix

Before developing the actual signal in a color television system, it will be well to review FIGURE 4, discussed in the "Study of Basic Color Principles." The primary colors used in the color television system are red, green and blue. Adding three separate over-lapping light sources of these three colors will produce white light. For this to be true, blue must have a brightness characteristic of 11%, red a brightness characteristic of 30% and green 59%. When these percentages of light are added together, they will total 100% brightness output of white light. If red and blue only are added together, they will produce the color magenta. Since blue and red have brightness characteristics of 11% and 30% of white light, the product (magenta) will be 41% as bright as white. Red and green added to-

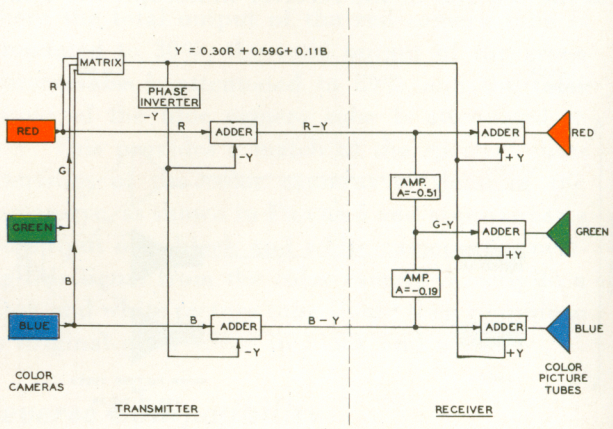



Figure 20 — Transmitting Color by Three Cables

gether will produce yellow. Yellow has a brightness characteristic of 89% of the white since the factors of yellow (red and green) represent 30% and 59% of white light. Blue and green added together will produce the color cyan, with a brightness characteristic of 70% of white (11% blue plus 59% green). It may also be noticed that adding any two *complementary* colors together will produce white: blue plus yellow equals white; green plus magenta equals white; cyan plus red equals white. Adding the brightness percentages of the complementary colors will bear this out. Notice that these complementary colors consist of one primary and another color representing the other two primaries; hence the product white from only two colors.

Where the original scene is vivid yellow, containing no white, by substituting camera tubes for separate light sources, only the red and green camera tubes will have output, and these camera tubes signals will be equal in amplitude. Then 30% of the red camera tube output and 59% of the green camera tube output combine to produce a signal representing yellow, 89% as bright as white.

If the scene that is being televised is blue, containing no white, there will be no output from the green or red camera tubes. At this instant a signal will be produced representing only 11% of the total brightness of the scene and will appear on a black and white receiver as very close to black (black being zero output from the camera tubes). This matches the spectral sensitivity of the eye, since this fully saturated blue will appear in color to the eye as very near black in brightness level.

## *Televising Vivid Colors*

By applying these same principles, an analysis of a color signal can be made. FIGURE 21 demonstrates the waveform analysis of a typical color scene. The waveforms indicated are for one horizontal line scanning through red, green, blue, yellow and white. The colors chosen are vivid ones: that is, they are fully saturated and contain no white.

The red camera tube output shown indicates 100% when red is scanned. There will be no red camera tube output when green and blue are scanned. There will be 100% red camera tube output when yellow is scanned, since yellow is composed of red and green. When white is scanned, there will also be 100% red camera tube output.

The green camera tube output will be zero when red is scanned; 100% when yellow is scanned; and 100% when white is scanned.

The blue camera tube output will be zero on

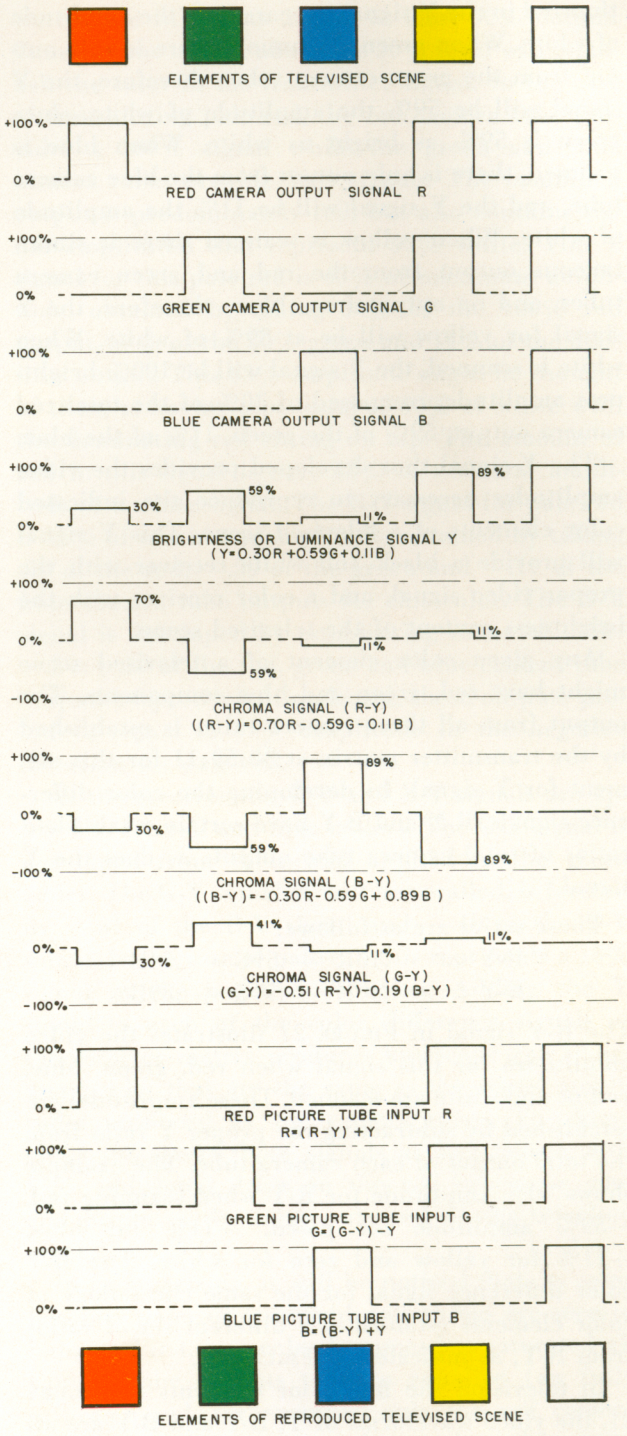



Figure 21 — Signal Evolution Employing R-Y and B-Y

red, green and yellow and 100% when blue and white are scanned.

The three outputs of the camera are fed into the matrix where the black and white signal is developed. When red is scanned, there is only output from the red camera tube. The Y signal utilizes only 30% of the output from the red camera tube;

thus red in the Y signal appears 30% the amplitude of white. When green is scanned, there is only output from the green camera tube; therefore, the Y signal will be 59% the amplitude of white, since green is 59% as bright as white. When blue is scanned, there is only output from the blue camera tube, and the Y signal will be 11% the amplitude of white. When yellow is scanned there is simultaneous output from the red and green camera tubes, and no output from blue; therefore, the Y signal for yellow will be at 89% of white. When white is scanned, the Y signal will be 100% brightness amplitude, composed of 30% of the total red camera output, 59% of the green, 11% of the blue.

The Y signal thus developed provides the video amplitudes necessary to reproduce the indicated color elements of a televised scene. This Y signal will provide a black and white receiver with the proper video signal, and a color receiver with the brightness content of the televised scene.

Any given color element of a televised scene might have red, green and blue components. The output from all three camera tubes is established by the transmitter matrix at 30:59:11 for this element for Y signal. In developing the color difference signals, R-Y and B-Y have certain established ratios of total camera tube outputs as does the Y signal.

These ratios are as follows:

$$\text{R-Y} = .70\text{R} - .59\text{G} - .11\text{B}$$
$$\text{B-Y} = -.30\text{R} - .59\text{G} + .89\text{B}$$

The R-Y signal in FIGURE 21 illustrates the video amplitudes for this signal when red, green, blue, yellow and white are scanned. These amplitudes are established by subtracting the proper Y ratio from the total output of each camera tube. The example shows 70% amplitude for R-Y when scanning red, —59% amplitude for green, —11% for blue, +11% for yellow and zero for white. The B-Y color difference signal for the same chronology of color elements establishes a different set of ratios from R-Y, as indicated in FIGURE 21.

In television the five color elements of FIGURE 21, the video waveforms of Y, R-Y and B-Y are all that need be transmitted for the color receiver to reproduce the same color elements.

It will be recalled from FIGURE 20 that G-Y is established at the receiver by combining —.51 of R-Y with —.19 of B-Y. Some quick arithmetic will bear out the amplitudes of the G-Y waveform in FIGURE 21. At the receiver, the R-Y signal is applied to the red adder stage, G-Y to the green adder and B-Y to the blue adder. The Y signal is applied to all three adders equally. To see how the receiver reproduces the five color elements in FIGURE 21, add the Y signal to each of the three color difference signals for one picture element: for the red element, as an example, Y plus R-Y (30% + 70%) equals 100% input to the red kinescope grid. Y plus B-Y (30% — 30%) indicates no input to the blue kinescope for red. Y plus G-Y (30% — 30%) also indicates no input to the green kinescope grid. So, for the red element, only the red kinescope grid is activated.

Analyzing the yellow element, as a second example, Y plus R-Y (89% + 11%) equals 100% input to the red kinescope grid; Y plus B-Y (89% —89%) equals zero input to the blue kinescope grid, and Y plus G-Y (89% + 11%) equals 100% input to the green kinescope grid. For yellow, then, the red and green kinescope grids are activated to full input. It will be recalled that the tricolor kinescope automatically adjusts to the ratio of 30:59:11 for red, green and blue signals respectively. Therefore for the yellow picture element, the kinescope provides 30% brightness from the red gun and 59% brightness from the green gun — the blue gun being inactive. Thus the kinescope reproduces a yellow element, 89% as bright as a high brightness white element, the same as was picked up by the color camera.

## *Televising Pale Colors*

FIGURE 21 illustrated the development of color signals for fully saturated, vivid colors. In order to understand more thoroughly how these signals operate within saturation limits, assume the same color element chronology (red, green, blue, yellow and white) but with a fifty per cent reduction in saturation for each color. Red will become pink, green a pale green, etc., and white a medium gray. It must be pointed out that, pale or vivid, the amplitudes in these elements represent *saturation* or *contrast*, with no regard to the *brightness* of the scene.

Referring to FIGURE 22, the red, green and blue camera tube outputs that produce gray are at the 50% level instead of 100%, as was the case for full white. Gray in the Y signal is represented by a signal amplitude that is 50% of the total white contrast scale. This is obtained by the Y transmitter matrix ratios of 30:59:11 for the three camera signals: 30% of the 50% red amplitude, 59% of the 50% green amplitude and 11% of the 50% blue amplitude will provide 15%, 29½% and 5½%

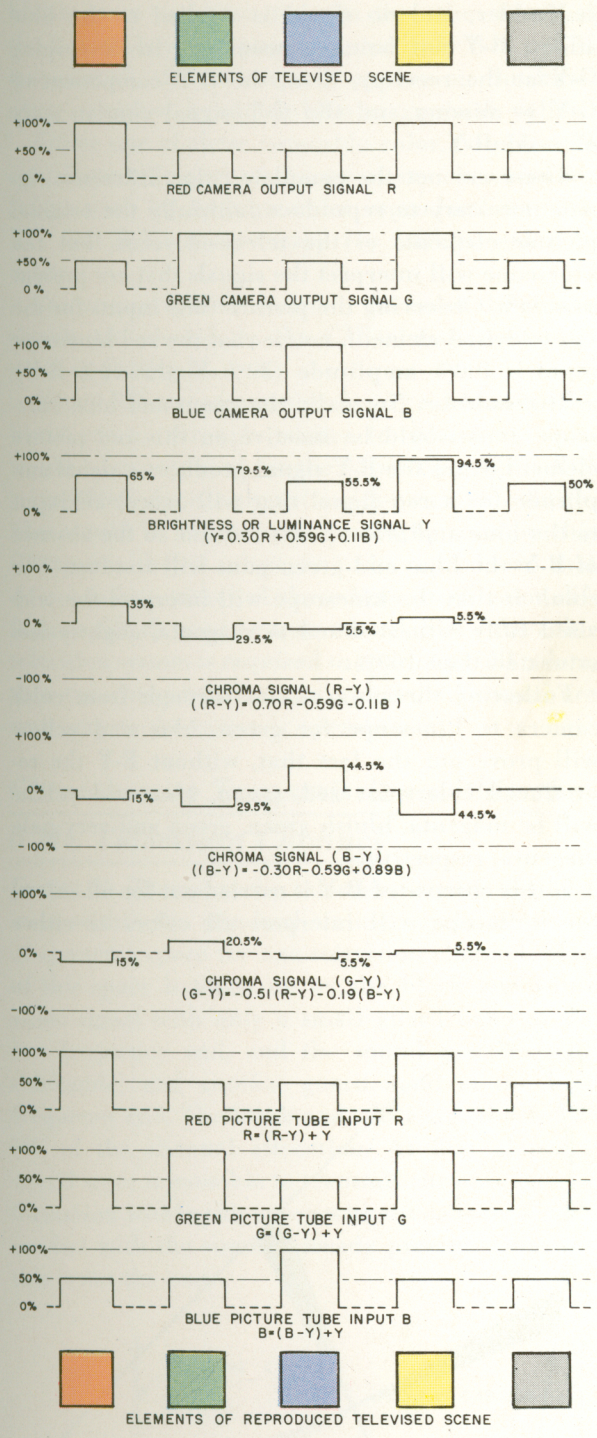



Figure 22 — Signal Evolution of Pale Colors

signals respectively. Adding these three percentages together will equal 50% output in the Y signal for white, and will produce a medium contrast white (or gray) at the receiver. In the case of reproducing pale colors, each camera tube in each illustrated case in FIGURE 22 has at least 50% output. Camera tube output *above* the 50% level will establish the color in the transmitter signal. In the case of transmitting pale red, the red camera tube provides a 100% signal while the green and blue camera tubes provide 50% signals. The combined output is predominately red, but also contains signal amplitudes that represent 50% white. The Y signal for this pale red is 65% of maximum amplitude, obtained by taking 30% of the 100% red output, 59% of the 50% green and 11% of the 50% blue output. This 65% amplitude might be thought of then, as having a pedestal of 50% of white with the dominating red sitting on top. The amount of red in this signal is only 15% of the total amplitude of a white signal. The R-Y signal for pale red is 35% of maximum amplitude, obtained by taking .70 of the red, —.59 of the green and —.11 of the blue camera tube outputs for this color. The B-Y signal is developed by establishing ratios of —30: —.59:+.89 of the red, green and blue camera tube outputs respectively. Combined, these outputs provide a signal of 15% amplitude in the *negative direction* for pale red.

At the receiver the R-Y and B-Y signals are applied to the red and blue adders. The G-Y signal is developed from these and applied to the green adder. The G-Y signal, it will be recalled, is formed by —.51 of the R-Y signal and —.19 of the B-Y signal. In the case of pale red this represents a 15% signal in the negative direction. Adding the Y signal to each of the color difference signals at the receiver matrix produces kinescope gun signal amplitudes that are the same as the signal amplitudes produced by the camera tubes. The kinescope interprets those signals as 50% white with 15% additional drive on the red kinescope gun, and produces the same pale red of the televised scene.

In summarizing, it will be noticed that, as color becomes paler or less vivid, two things are seen to happen. First, as a color becomes less saturated all camera tube outputs tend to equalize (on fully saturated red, for example, only the red camera tube is providing output — then as the red becomes paler, the blue and green camera tubes increase their output; as the pale red approaches white the blue and green tube outputs approach 100%). Secondly, as vivid colors become less and less vivid, zero saturation is eventually reached. At that time there are no color difference signals transmitted.

At this point, assume that one of the cables in FIGURE 20 carrying the color difference signals has

been disconnected, and that only the R-Y and Y signals are being transmitted. In following these signals from televised scenes to kinescope, consider four fully saturated color elements of a televised scene as shown in FIGURE 23. These elements are red, green, blue and yellow.

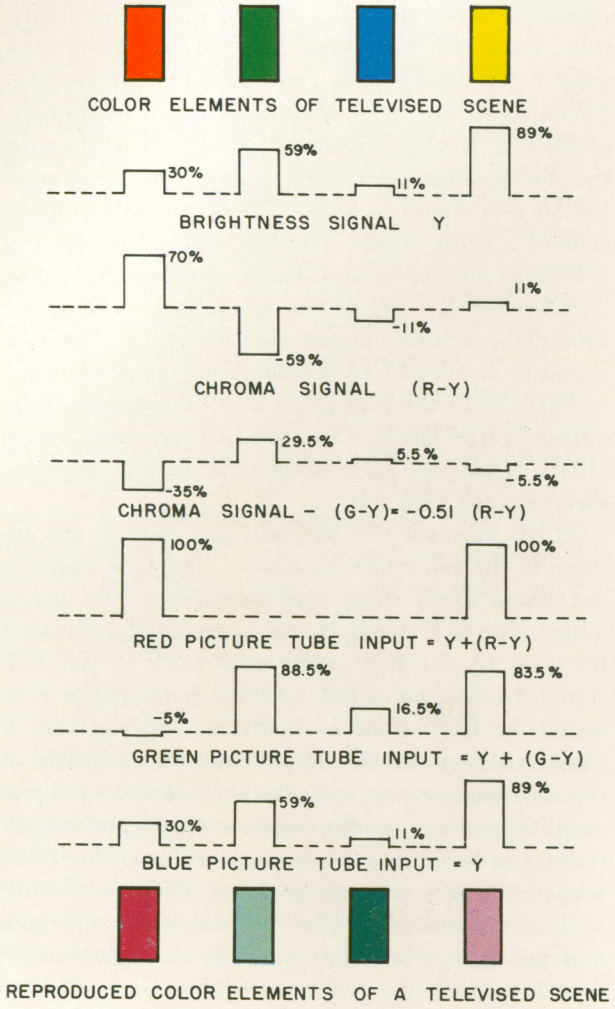



Figure 23 — The Effect When One Color Difference Signal is Missing

The Y signal for these picture elements after transmitter matrix will be 30% amplitude for red, 59% for green, 11% for blue and 89% for yellow. The R-Y signal is established by the R-Y matrix ratios of +.70R —.59G —.11B. The amplitudes for R-Y for this four element scene therefore are 70% amplitude for red, —59% for green, —11% for blue and +11% for yellow (70% of the 100% red signal plus —59% of the 100% green camera signal).

At the receiver the R-Y signal is applied to the red adder, and *no* signal is applied to the blue adder, B-Y not being transmitted. In developing G-Y at the receiver, then, the B-Y component of G-Y is missing and the G-Y signal consists only of —.51 R-Y.

These are not the complete color difference signals necessary to reproduce faithfully the original picture elements of the televised scene, but the kinescope will interpret the signals that *are* present as colors. Observing the picture tube inputs for the red televised element, notice that the red kinescope input is 100% amplitude (30% Y plus 70% R-Y) as it should be. Normally the green and blue kinescope guns would be inactive on this red picture element, since the B-Y signal produces a signal amplitude for a red signal that will cancel all input to the blue and green guns; but due to the absence of B-Y the blue and green guns will conduct. The result is that the kinescope will interpret the televised fully saturated red as magenta, slightly less saturated than 100%.

Following these waveforms through from color camera to kinescope for green, blue and yellow will prove out the fact that, without B-Y the reproduced colors for red, green, blue and yellow will be magenta, bluish green, green and very pale magenta, respectively.

If this absence of B-Y is carried out for all colors, the kinescope will interpret all colors as either

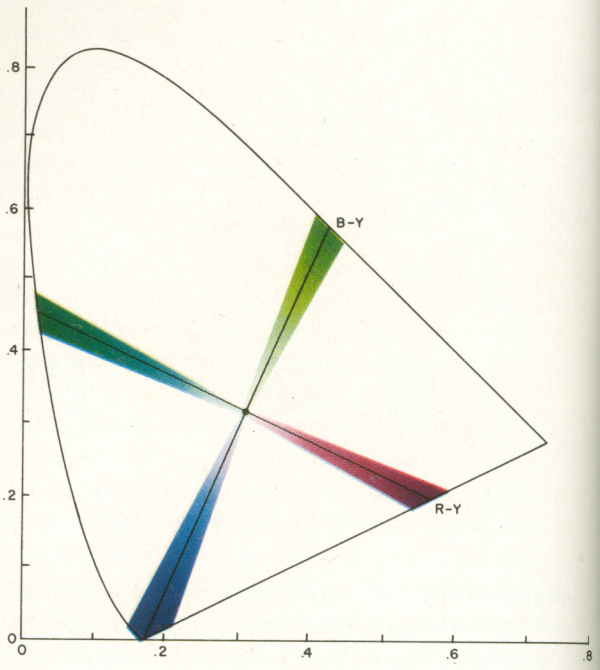



Figure 24 — R-Y and B-Y Chromaticity Coordinates

bluish green or bluish red. On the other hand, if the R-Y cable were opened up and only B-Y and Y transmitted, all colors would appear on the kinescope as either a reddish blue or greenish yellow.

Either one of these two-cable color systems will contribute only part of the necessary chrominance information for accurate color reproduction: both R-Y and B-Y are necessary for faithful color fidelity.

For purposes of illustration, the color difference signals are plotted on the CIE chromaticity diagram in FIGURE 24.

If only R-Y were transmitted, only colors along the bluish-green, through white, to bluish-red line would be reproduced on the kinescope. With B-Y transmitted alone, only yellowish-green or reddish-blue would be reproduced. It can be seen by this illustration that if colors are to be reproduced that do *not* fall on either of these lines, *both* color difference signals must be transmitted. Since the color television system is required to reproduce all colors, then two chrominance signals plus the Y signal are necessary to the system's operation.

## *Chrominance Transmission within the 6 MC Television Channel*

FIGURE 25 illustrates the television signal displacement within the standard six megacycle allotment of spectrum space for one television channel. Most of this space is taken up by the black and white video signal with only a small guard band at the low frequency end, and the sound carrier (with sidebands) and another guard band at the high frequency end. The black and white signal fills 5.35 MC of the channel allocation. At first glance it would seem impossible to transmit chrominance information within this space without causing serious conflict with the signals already present. However, this is not the case.

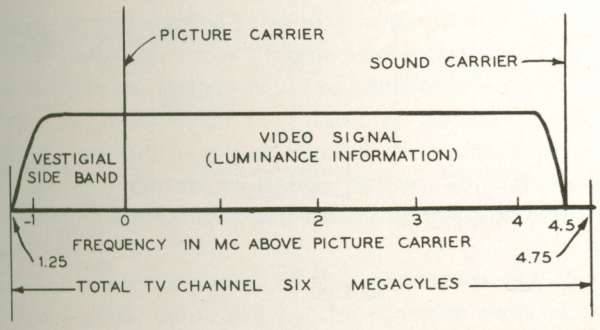



Figure 25 — Frequency Allocation of a Television Channel

The reason that channel space is available for signals other than the Y or brightness signal is that when a black and white picture is scanned, the signals resulting are found to cluster around the harmonics of the frame scanning frequency (30 cps) and the line scanning frequency (15,750 cps). Nearly half the space between the frame and line scanning frequency harmonics up to video band pass cutoff (4.1 MC) is relatively devoid of video information. By selecting a chrominance signal carrier frequency that is an odd multiple of one half the scanning frequencies, the chrominance signal can be made to fit into the voids between clusters of Y video signal. The chrominance signals will also cluster about the harmonics of its base frequency (½ the scanning rate), and the two signals will fit together without conflict.

It has been found by experimentation that if the chrominance signal carrier is placed in the upper sideband 3.58 MC from the picture carrier, the maximum bandwith of chrominance signals can be utilized without causing interference with the accompanying brightness signal. This 3.58 MC chrominance carrier is called a *subcarrier*, since it is inserted into the standard video sideband before the video signal is applied to the picture RF carrier. The sideband information of the subcarrier is not related to the sideband information of main picture carrier, although it occupies the same spectrum space; hence the term *subcarrier*.

In practice, the 3.58 MC carrier is suppressed, since in the case of color television, this subcarrier only wastes transmitter energy. The subcarrier is necessary for the purpose of detection in the receiver, but can be readily reinserted at the receiver with appropriate synchronizing signals.

Previously it was proved that two chrominance signals are necessary to reproduce all colors. Naturally, both of these signals must have bandwidth. The more color definition the wider the bandwidth of chrominance signals. There is a limited amount of space in the Y video sideband to place these signals. For this reason a special method of combining the chrominance signals "in quadrature" is employed. The two chrominance signals are amplitude modulated at the same 3.58 MC subcarrier frequency, *but the two signals are phase displaced by ninety degrees.*

The two amplitude modulated signals are combined, forming a single modulation envelope that is the resultant of the combination of the two differently phased signals. If detected by a *phase sensitive* device, the original signals can be sepa-

rated from the resultant signal. There is nothing mysterious about this, since conventionally two signals are maintained separately by transmitting them at different frequencies. A frequency sensitive device (such as an RF unit of a television receiver) will detect these as individual signals. Using the converse of this conventional method, two signals of the *same frequency* but of *different phase* can be detected by a phase sensitive device.

FIGURE 26 is a block diagram of a system utilizing the principle of transmitting the chrominance signals in quadrature. The output of the three camera tubes (through the matrix) are made to produce R-Y, B-Y and Y signals. The two color difference signals are amplitude modulated on a common 3.58 MC carrier, but the B-Y signal is shifted 90° in phase from the R-Y signal. These two signals are combined at the output of their respective modulators and added to the Y sidebands at the adder. At the receiver, chrominance information is separated from the Y signal and applied to two "synchronous detectors" that are simply phase sensitive detectors. The output of the synchronous detectors are the original R-Y and B-Y signals developed at the transmitter.

At the transmitter, the 3.58 MC chrominance subcarrier is suppressed before the signal is transmitted. In order to detect the chrominance information at the receiver, the subcarrier must be reinserted. To provide for carrier reinsertion, the receiver employs a 3.58 MC oscillator that generates a signal which is divided into two components 90° displaced in phase. These, in turn, are compared with the chrominance signal and detection takes place. This in itself is not sufficient for accurate detection of the color difference signals. It remains for the receiver 3.58 MC oscillator to be kept in synchronization with the 3.58 MC oscillator at the transmitter, so that both transmitter and receiver have the same phase reference. In order to accomplish this, a color synchronizing signal is transmitted to maintain synchronization of the oscillators.

## *Two Phase Modulation Techniques*

It was mentioned in the previous paragraphs that the two color difference signals are modulated upon a subcarrier at the same frequency but 90° displaced from each other in phase, and that these two signals are combined to form a single chrominance signal that is eventually transmitted. It was also mentioned that the two color difference signals can be recovered from this single envelope by a process known as synchronous detection. Since this cycle of transmission and detection is one of the

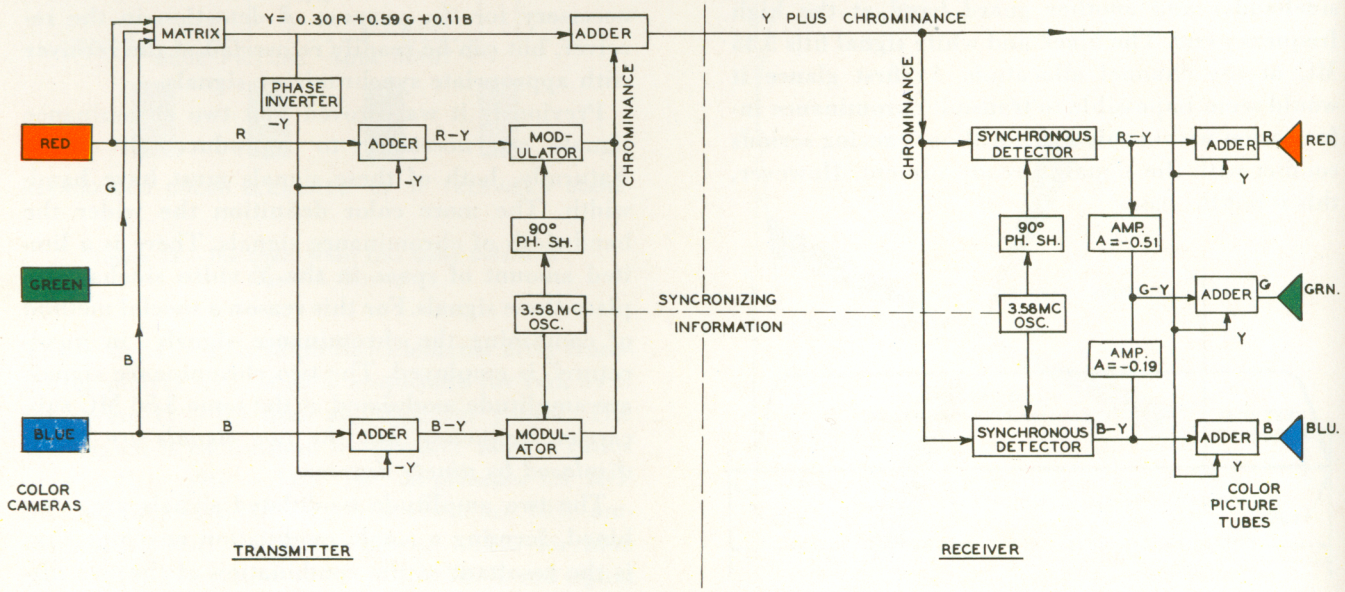



Figure 26 — Block Diagram of an R-Y B-Y Transmitter and Receiver

truly new processes in color television beyond those circuits already well known in black and white television, it may be well to digress at this point into some detail on the involved circuitry.

## *Doubly Balanced Modulation*

The transmitter device that develops the chrominance sidebands is called a "doubly balanced modulator." Two of these are used in the transmitter, one for each of the chrominance signals.

The doubly balanced modulator combines chrominance information with a CW carrier to produce sidebands that contain neither of the input signals. The output sidebands vary in amplitude as the input video amplitude varies, and the *phase* of the sidebands reverses as the *polarity* of the input video reverses.

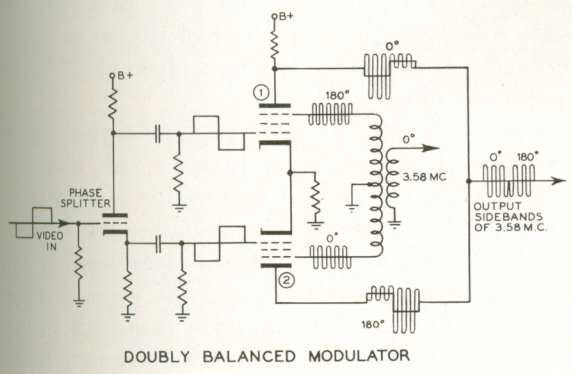



Figure 27 — Basic Diagram of a Doubly Balanced Modulator

FIGURE 27 is a simplified diagram of a doubly balanced modulator. The input stage is a phase splitter that is adjusted to supply equal amplitudes of signal output at the plate and cathode. The signal at the plate is 180° out of phase with the signal at the grid input. The signal at the cathode is the same phase as the grid input.

The two signals from the phase splitter are applied to the control grids of two modulator tubes. The modulator tubes therefore have signals on the control grids that are equal in amplitude but opposite in phase. Since the plates of the modulator tubes are tied together through a common plate load, and the modulators function linearly, the control grid voltages will cancel at the modulator output.

The suppressor grids of the modulators are also signal grids, being fed by the opposite ends of a transformer that is driven by a 3.58 MC CW signal. Since the extremes of any transformer winding present a 180° phase difference in the activating AC signal, the suppressor grids of the modulators are fed by signals that are 180° out of phase. These signals are also equal in amplitude. Considering the suppressor grid signals alone, these too will cancel at the modulator output. However, when both video and the 3.58 MC CW carrier are applied, the modulators will produce a signal output.

Consider the control grid waveforms for a moment. When the control voltage of modulator #1 is moving in a positive direction, the control voltage on modulator #2 is negative going. With a less negative control grid voltage on modulator #1, plate current in this tube will become greater as the control grid signal moves positive, while modulator #2 plate current becomes less as control grid signal goes more negative. Tube amplification is a function of plate current. Consequently, modulator #1 will amplify the suppressor grid signal to a greater amplitude than will modulator #2. This being the case, there will only be a partial cancellation of output signal at the modulator plates. In this case modulator #2 only cancels part of the modulator #1 plate signal. The *average* plate current waveform indicates that the output of the doubly balanced modulator will have an amplitude that is the function of the video input signal amplitude, having a phase opposite that of the suppressor grid phase (because of the 180° phase shift through the tube).

As the video input signal polarity reverses, all conditions just described will reverse, and the doubly balanced modulator output phase will shift 180°, with the amplitude of the output sidebands increasing as input video increases.

It was mentioned that there are two doubly balanced modulators at the transmitter; one amplitude modulated by R-Y, the other amplitude modulated by B-Y. The two modulators are adjusted so that there is 90° phase difference between them. The output of the B-Y modulator is either 0° or 180°, depending upon the polarity of the B-Y video input. The R-Y modulator, on the other hand, produces an output that is either 90° or 270°.

If, at any instant, the B-Y modulator output is 0° in phase and the R-Y modulator output is 90° in phase, the signal resulting as a combination of the two will fall somewhere between 0° and 90°, depending upon the amplitude relationships of the two original signals. As an example, if the B-Y modulator output amplitude is high as compared to the R-Y modulator output, the phase of the combined signal will fall somewhere close to 0°.

From the following chart it can be seen that when the polarities of the color difference video signals change, the phase of the combined chrominance sidebands can vary from 0° to 360°. The amplitude of the resultant sideband is a direct function of the video input amplitudes.

| When B-Y Phase is: | and | R-Y Phase is | The Result will fall between |
|---|---|---|---|
| 0° | | 90° | 0°— 90° |
| 180° | | 90° | 90°—180° |
| 180° | | 270° | 180°—270° |
| 0° | | 270° | 270°—360° |

## *Development of the Color Subcarrier*

The chrominance signal, as transmitted, varies in amplitude and phase. To further understand this relationship, FIGURE 28 is a waveform analysis of the chrominance signal for a few sample colors.

The B-Y and R-Y amplitudes have been attenuated by certain percentages in FIGURE 28 for purposes that are unimportant here. It suffices to say that this is done so that the chrominance signals will not over-modulate the picture carrier when the composite color television signal is transmitted. This will be dealt with in more complete detail in the next section.

The three colors chosen for the example in FIGURE 28 are red, blue and green. The B-Y video signal for red is negative, and of a relatively small amplitude. The output of the B-Y doubly balanced modulator for this red signal is consequently a relatively small amplitude, and has a phase of 0°, established by the negative polarity of B-Y. For this same red, the R-Y signal is positive, and is relatively high in amplitude. The R-Y doubly balanced modulator output has a correspondingly high amplitude at a phase of 90°. The color subcarrier signal that results from a combination of the two modulator outputs has a phase that falls between 0° and 90°. Since the R-Y modulator has the greater output amplitude, the color subcarrier phase will fall close to 90°. The amplitude of the color subcarrier for red will be that portion of the R-Y modulator output not cancelled by the B-Y modulator output. The chrominance subcarrier signal for this particular red, then, can be determined to have, vectorially, a phase of 76.5° at an amplitude of 0.63. This is shown in FIGURE 29.

The blue and green color subcarrier signals can be similarly developed from color difference signals, with blue having a phase of 192° at an amplitude of 0.45 and green having a phase of 299° at an amplitude of 0.59.

These red, blue and green color subcarrier signals represent fully saturated hues of red, blue and green. They are plotted vectorially in relation to the color difference signal modulator phases in FIGURE 29. Notice that each colored vector has R-Y and B-Y amplitudes and polarities the same as those indicated in the color difference signals in FIGURE 28. Notice too, that all phases are measured in degrees from a "reference subcarrier." This is the phase of the transmitter 3.58 MC oscillator that feeds the suppressor grids of the two doubly bal-

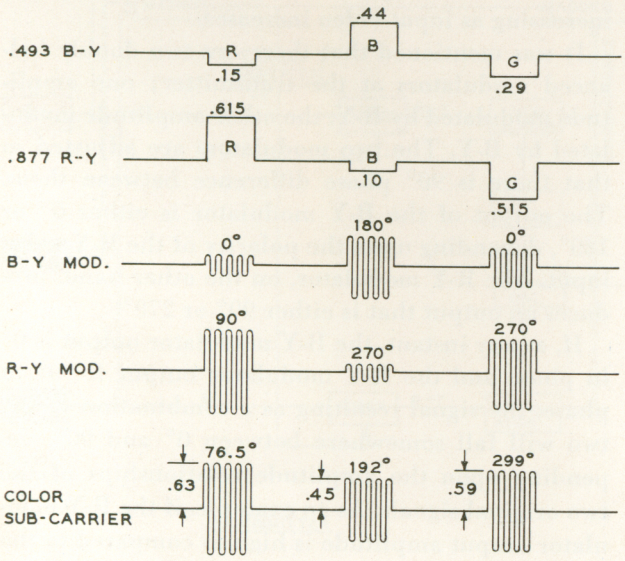



Figure 28 — Development of the Chrominance Signal

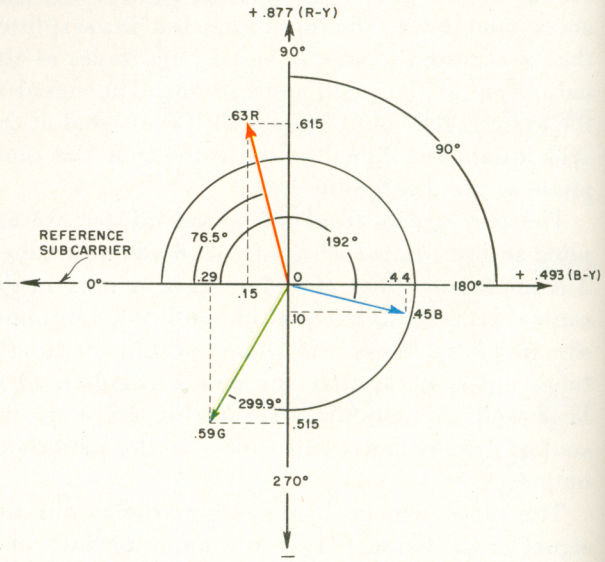



Figure 29 — Vector Diagram of the R-Y, B-Y Color Coordinates

anced modulators. All phases refer to this oscillator phase.

To further consolidate the vector relationship in FIGURE 29, the R-Y and B-Y coordinates are the same as those shown in FIGURE 24. The +(R-Y) vector is the bluish-red line in FIGURE 24. The "reference subcarrier" is the yellowish-green line. It is interesting to note that the color of +(R-Y) is mostly red, with only a small amount of blue. Consequently, it takes only a small amount of yellowish-green (which is composed of green and some red) to offset the blue in +(R-Y) in order to produce true red. Relating this to the vector diagram, the red vector is rotated from the +(R-Y) vector by only 13.5°.

## *Detection of the Chrominance Signal*

The color subcarrier, as transmitted, has all of the components of the two color difference signals. It remains for the receiver to detect this chrominance subcarrier and produce the original R-Y and B-Y color difference signals. The device that is capable of this in the receiver is commonly known as a "synchronous detector." There are two such synchronous detectors in the receiver, and they function to perform the exact opposite operations of the doubly balanced modulators at the transmitter. For this reason the synchronous detectors are called *demodulators* in discussing receiver circuitry.

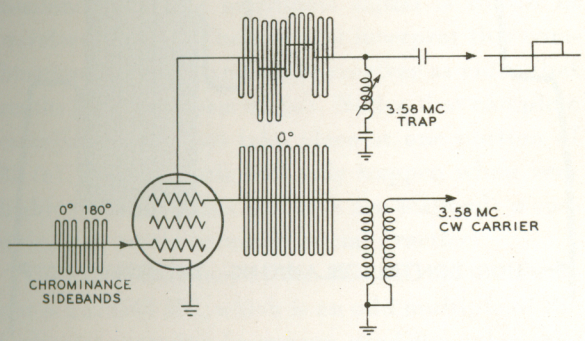



Figure 30 — Receiver Demodulator Operation

Consider the operation of a single demodulator for the moment, as illustrated in FIGURE 30. The control grid signal voltage is the chrominance sideband signal; in this case, two opposite phases of 3.58 MC carrier are represented. The suppressor grid signal is a 3.58 MC CW signal having a 0° phase relationship. With only suppressor grid signal applied, and no control grid signal present, the plate voltage output will appear as the first two cycles of the plate voltage waveform are shown. The first three cycles of control grid voltage are the same phase as the suppressor grid voltage. As the control grid voltage swings in a positive direction there is less bias on the control grid, and consequently plate current will increase. This will afford a greater amplification of the positive half cycles of the suppressor grid signal. When the control grid signal swings negative, bias becomes more negative and the tube will amplify the negative portion of the suppressor grid signal less. Because of the 180° phase reversal of voltage from grid to plate through the tube, the greater amplification of grid signal is indicated in a negative direction in the plate voltage. The *average* plate voltage *decreases* when control grid and suppressor grid signals are *in phase.*

When the control grid signal phase shifts to 180°, the negative going portions of the suppressor grid signal will be amplified more than the positive half cycles, and the resulting effect is an increase in the average plate voltage. The demodulator average plate voltage, then, will vary in amplitude as the phase of the control grid signal input changes. By filtering out the carrier component of the plate voltage, a waveform will remain that will follow the average plate voltage.

As a second condition of demodulator operation, consider that the suppressor grid signal is at 90° instead of 0°. With the control grid signal at the same frequency and at 0° phase, the average plate current will remain at a constant level for all polarities of signal input. The reason is as follows: on the first half cycle of control grid signal, plate current is increasing but no suppressor grid signal is applied. As the control grid signal swings in the negative direction, suppressor grid signal starts going positive. The effect of the two input signals moving in opposite directions is cancellation of any average plate voltage change. The same will occur if the control grid voltage is at 180°: the two grid signals are still 90° out of phase, and the same cancellation will take place. The plate voltage will still vary at the carrier frequency and will also vary in phase, but the average plate voltage will remain constant. Since the carrier frequency is filtered out, the demodulator will have no output.

It was mentioned previously that there are two demodulators in the receiver. The suppressor grids of the demodulators have 3.58 MC CW signals that are 90° displaced from each other. The same control grid signal (the chrominance sidebands) is applied to each demodulator.

If the chrominance sideband signal applied to the demodulator control grids is the same as that shown in FIGURE 30, then one demodulator will produce video output while the other will have none. Rarely, if ever, will the chrominance sidebands have phase relationships exactly as shown in FIGURE 30. Suppose that the chrominance sidebands have a phase relationship of 76.5° to the reference subcarrier frequency. Both demodulators will produce output voltages in the order of the amplitudes and polarities of the video signals that produced the chrominance sidebands at the transmitter modulators. For example, one of the demodulators is phase sensitive to the reference subcarrier (0°). With a control grid signal applied at 76.5°, only partial cancellation of grid signals will take place. The average plate voltage output will vary, to the extent that it will represent the video signal input to the transmitter doubly balanced modulator producing the chrominance sideband phase shift from 90° to 76.5°. The demodulator that is sensitive to 0° phase is called the B-Y demodulator. In the example just described, the B-Y demodulator has produced the B-Y signal component of the chrominance sidebands. The R-Y demodulator is sensitive to signal phases that are 90° (or 270°) from the reference subcarrier, and this will also produce an output signal when the 76.5° chrominance sideband signal is applied to the control grid. This output will duplicate the R-Y video signal fed to the R-Y double balanced modulator at the transmitter in producing a chrominance sideband signal having 76.5° phase.

In summation, it can be said that doubly balanced modulators are necessary to remove the color subcarrier from the transmitter video signal and receiver demodulators are necessary to reinsert it at the receiver for proper detection. This provides a means of transmitting and receiving two independent signals while utilizing the spectrum space necessary for only one signal.

There are other distinct advantages in suppressing the color subcarrier from the transmitted signal. If transmitted, the color subcarrier will produce an objectionable interference pattern on the face of the kinescope during a color transmission. Interference patterns between signal carriers are common to black and white television, in the form of the 4.5 MC beat produced between the sound and picture carriers. Since this beat frequency is outside the video response of the receiver, it can be easily trapped out. But in the case of the color subcarrier, a beat will occur between it and the sound carrier at 920 KC (4.5 MC minus 3.58 MC). Since this falls well within the video response of the receiver, it cannot be trapped out. By not transmitting the color subcarrier, the carrier interference problem has been minimized.

## *Color Synchronizing Signals*

Detection of the color subcarrier sidebands would not be possible if exact phase relationships were not maintained between the 3.58 MC subcarrier oscillators at the transmitter and the receiver. In order to maintain these two oscillators in phase, a short "burst" of the transmitter 3.58 MC oscillator voltage is transmitted at the beginning of each horizontal scanning line. This burst is frequent enough, and of sufficient duration to insure that the receiver 3.58 MC oscillator is in exact phase relationship with the equivalent transmitter oscillator.

The burst consists of approximately eight cycles of 3.58 MC signal, and is placed on the "back porch" of the horizontal blanking pedestal next to the horizontal sync pulse, as shown in FIGURE 31.

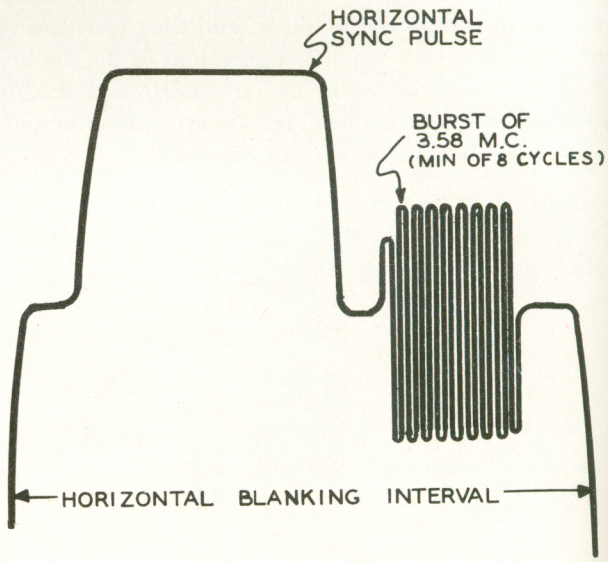



Figure 31 — The Color Synchronizing Signal

The color burst does not interfere with horizontal synchronization because it is lower in amplitude than the sync pulse, and only the amplitude of the leading edge of the sync pulse is important in maintaining horizontal sync. The burst functions in a similar manner as scanning sync. Applied to the proper circuits, it produces a correction voltage in the form of bias that maintains the receiver 3.58 MC oscillator at the proper phase.

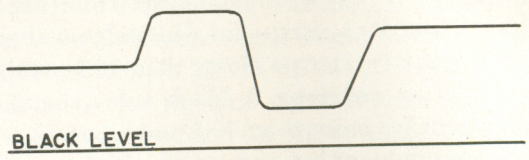
## *Frequency Interlace Technique*

It has been mentioned throughout the preceding pages, without giving a reason, that the color subcarrier frequency is selected as 3.58 MC. This is done so that the chrominance information will average out when a color telecast is being received on a black and white receiver. To accomplish this, the color subcarrier frequency was chosen to be odd multiple of one-half the horizontal scanning line frequency. Chrominance signal amplitudes do not necessarily follow the amplitudes of the brightness signal, and if not eliminated, would appear on a black and white kinescope as a spurious dot pattern. By selecting the color subcarrier frequency as an odd multiple of one-half the horizontal scanning line frequency, chrominance information on any given scanning line will be 180° out of phase on successive scans of that line. FIGURE 32 illustrates this principle.

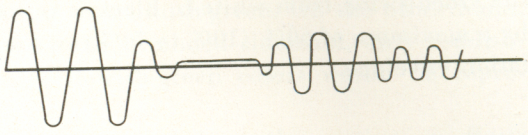
Waveform 32 (a) represents a hypothetical luminance, or brightness, video signal for one scanning line. Waveform 32 (b) represents the chrominance signal for the same brightness intelligence. When the same line is scanned twice, the chrominance signal on the second scan will be 180° out of phase with the chrominance signal on the first scan. These two signals superimposed as shown in FIGURE 32 (c) will then appear to the eye to cancel out. The cancellation effect of the chrominance signal when combined with the brightness signal is shown in waveform 32 (d). The eye will interpret this combination on a black and white receiver as video that results from waveform 32 (e). Notice that complete cancellation does not take place at one portion of 32 (e). However, this will only happen when very highly saturated blues and reds are scanned; a condition that rarely occurs in actual practice.

The exact frequency of the 3.58 MC color subcarrier is 3.579545 MC, which is an odd multiple of the horizontal scanning frequency used for color television, 15,734.264 cps. This scanning frequency is roughly 16 cps lower in frequency than the standard for black and white television, and is within 1% of standards for black and white transmission. This slight deviation is within the AFC pull-in range of present black and white television receivers.

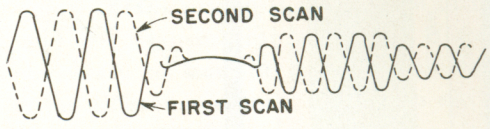
Changing the horizontal scanning frequency means that the vertical scanning rate must also be changed. The vertical scanning rate for a color telecast has been lowered from 60 cps to 59.94 cps.



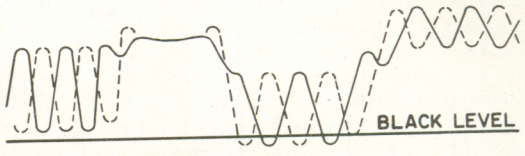

(a) LUMINANCE BLACK AND WHITE SIGNAL



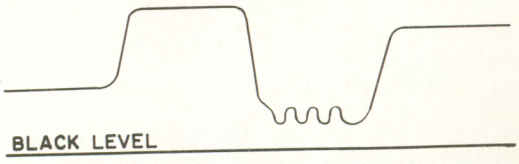
(b) CHROMINANCE SIGNAL, FIRST SCAN




(c) CHROMINANCE SIGNAL, COMBINED FIRST AND SECOND SCANS




(d) SUMMATION OF (a) AND (c)




(e) AVERAGE LIGHT OUTPUT AFTER TWO SCANS

Figure 32 — The Frequency Interlace Principle

## *Adjustment of Chrominance Amplitudes*

It was mentioned previously, under the discussion of FIGURE 28, that the R-Y and B-Y signals are somewhat attenuated before they are combined with the Y signal for transmission. This is done for several reasons, the most important of which will be covered here.

Transmission standards define certain modulation limitations for video and synchronizing signals. For video, maximum white signal specification

is 12½% (±2½%), modulation from the carrier level. That is, a maximum white signal should approach the carrier no closer than 10% of the total modulation envelope. A black video signal should represent no more than 70% modulation, with the horizontal blanking pedestal at 75% modulation. The horizontal sync pulse maximum amplitude represents 100% modulation. It will be noticed that the video swing from white to black is represented by a maximum of 60% (10% to 70%) of the modulation envelope.

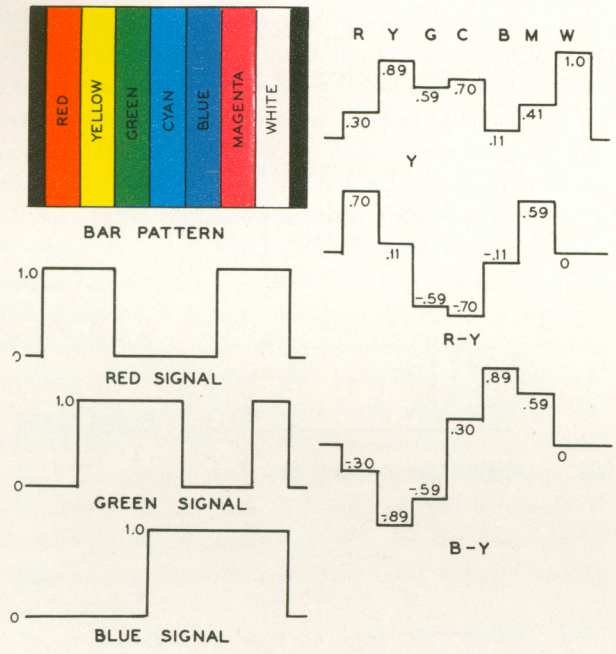



Figure 33 — Color Signal Waveforms for a Bar Pattern

FIGURE 33 illustrates the red, green and blue camera signals for the illustrated bar pattern, and the video signals for Y, R-Y and B-Y developed from these camera signals.

FIGURE 34 at (c) indicates the composite video signal as a result of the combination of the Y signal (a) and the combined R-Y B-Y signal (b).

If transmitted in this manner, notice that the chrominance signal and the brightness signal will add, resulting in all colors overshooting the white level (white being the bar next to the blanking pedestal represented by 1.00), and also the black level. The yellow and blue bars are the greatest offenders, each overshooting its respective level by 79%. It has been found by experience that overshoots of 33% by video signals can be tolerated

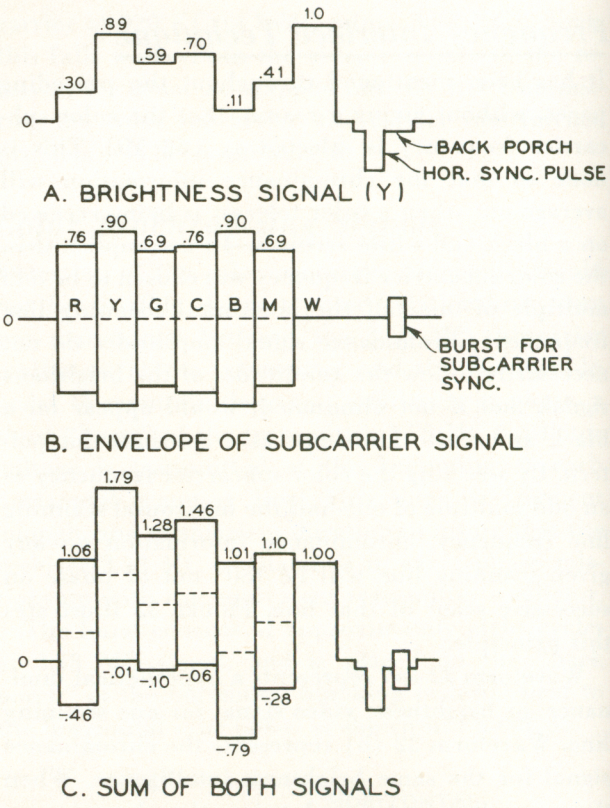



Figure 34 — The Video Envelope for Unadjusted Chrominance Signals

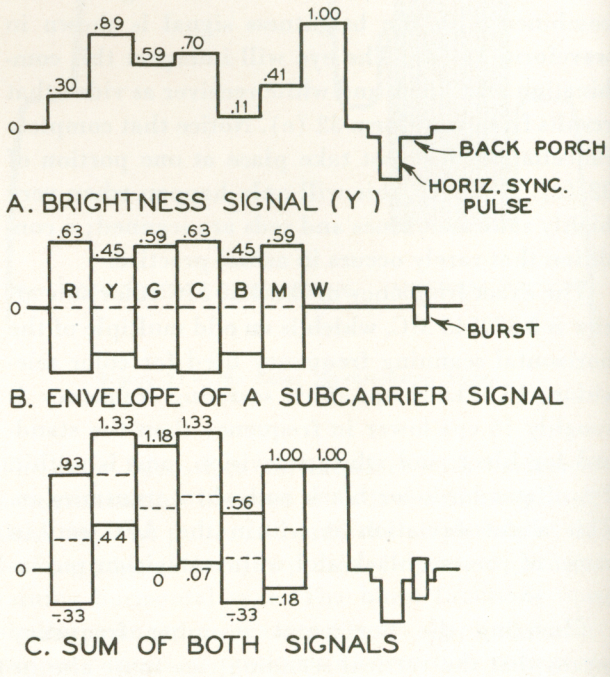



Figure 35 — Re-adjusted Chrominance Values

without causing overmodulation or compression of any color. However, FIGURE 34 indicates that even these limitations are surpassed.

FIGURE 35 illustrates re-adjusted values of R-Y and B-Y in order to maintain all colors within practical limitations of modulation. By reducing R-Y to .877 of its original value and B-Y to .493 of its original value, maximum saturations of yellow and cyan overshoot 33% and color compression or overmodulation will not occur.

Notice that red and blue overshoot the black level by 33%. These signals will go beyond kinescope cutoff, and a dot pattern, caused by the waveform illustrated in FIGURE 32 (e), will appear on the black and white kinescope. It is seldom, however, that *fully* saturated blues or reds are televised, and this dot pattern will rarely occur.

## *Bandwidth Limitations*

To this point, no mention has been made of the amount of color detail that can be televised. Since picture detail is a function of the transmitted signal bandwidth, and there is a limited amount of bandwidth allowed for chrominance information, this is an important point to consider.

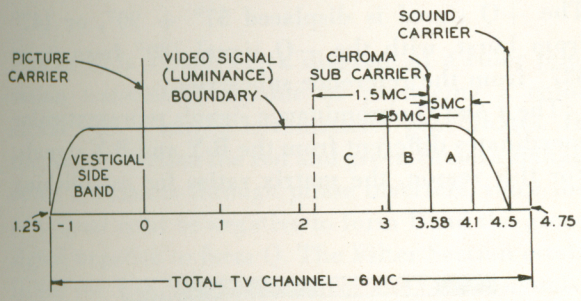



Figure 36 — Brightness and Chrominance Sidebands within the 6 MC TV Channel Allocation

Referring to FIGURE 36, the highest useable video brightness signal frequency is 4.1 MC, with the chrominance subcarrier at 3.58 MC. Transmitting symmetrical or double sidebands of chrominance would mean that color definition would be limited to 0.5 MC and color would be absent in all fine detail in the picture. It is possible, however, to transmit the chrominance sidebands vestigially; that is, with one sideband suppressed, the same as the black and white signal. Although this would extend the color definition to possibly 1.5 MC, it is practical to transmit only one of the chrominance signals vestigially. One of the color difference signals would then extend from 0 MC to 1.5 MC while the other color difference signal would be limited to picture detail from 0 MC to 0.5 MC. If this were the case, colors for the fine detail represented by sideband frequencies from 0.5 MC to 1.5 MC would appear inaccurate. Referring back to FIGURE 24 will remind the reader that if R-Y were the extended sideband, fine detail would appear as either a bluish-red or a bluish-green. On the other hand, if B-Y were the extended sideband, only reddish-green or yellowish-green colors would be reproduced.

It will be recalled from the section on *Basic Color Principles* that fine color detail can be represented accurately to the eye by orange, or cyan, for any color. If this principle were to be utilized by R-Y and B-Y transmission standards, it would still be necessary to transmit extended sidebands of *both* color difference signals, since both are necessary to reproduce either orange or cyan. It appears, then, that color definition using the color difference signals must be limited to one-half megacycle of sideband extension, and therefore cannot, by their inherent colors, represent full color fidelity of the televised scene.

Recalling FIGURE 12 and its accompanying text, it will be remembered that the eye is not capable of detecting all colors accurately for all sizes of picture detail. Color areas, beyond a certain fineness of detail, can be accurately represented to the eye by either orange, or cyan, since the eye cannot distinguish any color other than one of these. For extreme fineness of detail the eye is not capable of detecting *any* color sensation, and only a brightness variable is necessary to represent the object as having color. Logically, then, if the axes of the chrominance subcarrier signals were shifted in phase from the reference subcarrier so that one of the axes would represent orange and cyan, with the other axis at right angles to it, then many transmission problems would be solved. The orange-cyan axis could then be extended to 1.5 MC and since the fine detail conveyed by this extended bandwidth need only be either orange or cyan to represent accurate color reproduction to the eye, full color fidelity would be accurately reproduced in picture detail up to 1.5 MC of picture definition.

By re-adjusting the phase of the chrominance signals and transmitting one signal vestigially with extended bandwidth, all colors are faithfully reproduced in picture detail from 0 MC to 0.5 MC. Beyond this point one of the chrominance signals drops out. With the orange-cyan signal still present

to 1.5 MC, effectively the eye still sees all color though only orange and cyan are transmitted. The eye is not capable of distinguishing color in picture detail represented by video frequencies beyond 1.5 MC. With no chrominance signals transmitted beyond this point, the brightness signal will accurately convey the illusion of color in video detail from 1.5 MC to 4.1 MC.

The re-adjustment of chrominance signal phases is called *high definition color transmission* and is the system of color transmission used today. Since the chrominance axes in this system are not the same as R-Y and B-Y, they have been given new titles. One is called the "I" signal since it is nearest in phase with "burst," or the reference subcarrier, and the other is called the "Q" signal since it is in quadrature with the "I" signal. The colors represented by the I and Q signals are plotted on the chromaticity diagram shown in FIGURE 37. The I axis is the orange-cyan line and the Q axis is the green-magenta line.

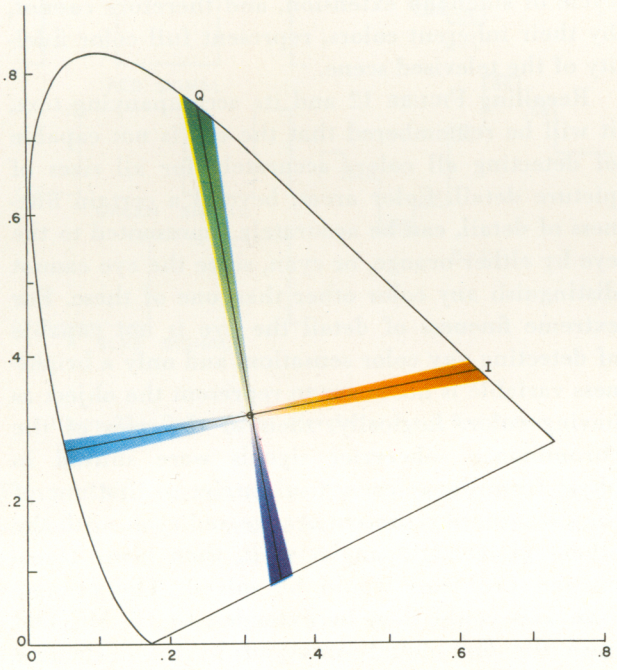



Figure 37 — I and Q Axes on the Chromaticity Diagram

Making this shift at the transmitter requires adjustment of the phases of the doubly-balanced modulators. It will be recalled that the B-Y signal was produced with the B-Y doubly-balanced modulator in-phase (or 180° out-of-phase) with the reference subcarrier. The R-Y doubly-balanced modulator was in quadrature (90° or 270°) from the reference subcarrier. The I and Q signals are produced maintaining their phase coordinates 90° from each other, but the +I signal is 57° from the reference subcarrier, with —I at 237° (180° from +I).

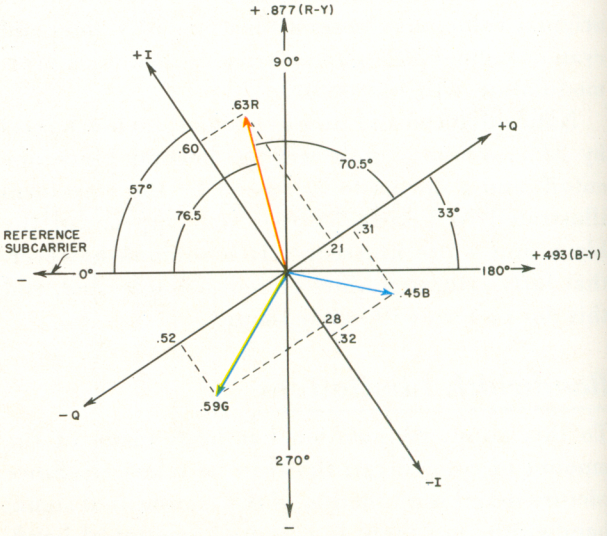



Figure 38 — Vector Diagram of the I and Q Color Coordinates

The +Q signal is displaced 57° + 90°, or 147° from burst, with the —Q signal 180° from it, at 327° from the reference subcarrier.

The I and Q chrominance signals represent color coordinates different from the R-Y and B-Y signals. For this reason, the matrix ratios for establishing

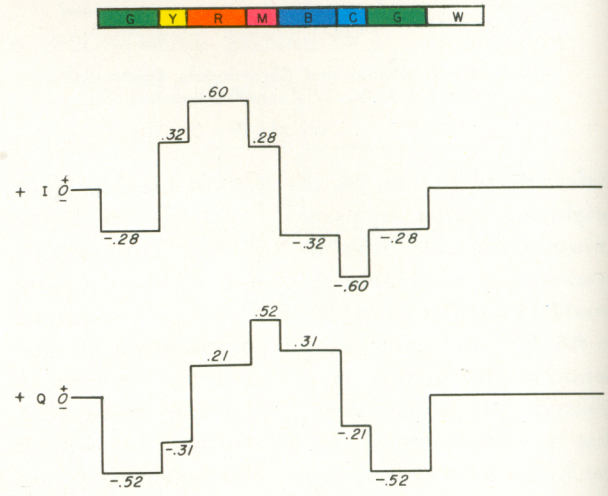



Figure 39 — I and Q Signals of Fully Saturated Primary and Secondary Colors

chrominance amplitudes for various colors are different. FIGURE 39 illustrates the I and Q signals for the indicated bar pattern.

The Y signal maintains the ratio 30:59:11 for red, green and blue camera signal output, since the I and Q system of transmission must remain compatible with black and white standards.

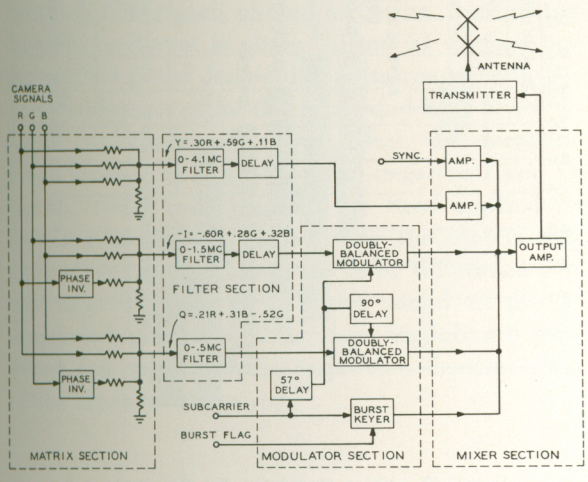



Figure 40 — Color Television Transmitter Block Diagram

FIGURE 40 is a basic block diagram of a color television transmitter capable of producing a color signal with I and Q chromaticity coordinates. In the Matrix Section the red and green camera signals enter the matrix through phase inverters, since the red signal must be negative to form I and the green signal negative to form Q. The Filter Section establishes the bandpass for each of the video signals: 4.1 MC for Y, 1.5 MC for I and 0.5 MC for Q. Since these signals are of different bandwidths, and their envelopes must have a specific placement with regard to each other, the I and Y signals are sent through delay networks so that all three signals will have the proper time placement when applied to the Mixer Section. The I and Q video signals are applied to the Modulator Section, where they produce the chrominance signal. Notice that the reference subcarrier frequency is phase shifted 57° before being applied in quadrature to the doubly-balanced modulators. The three video signals, plus burst and sync, are combined in the Mixer Section to produce the composite color video signal, and sent on to the transmitter.

At this point it might be well to derive the I and Q signals and the composite color signal for ele-

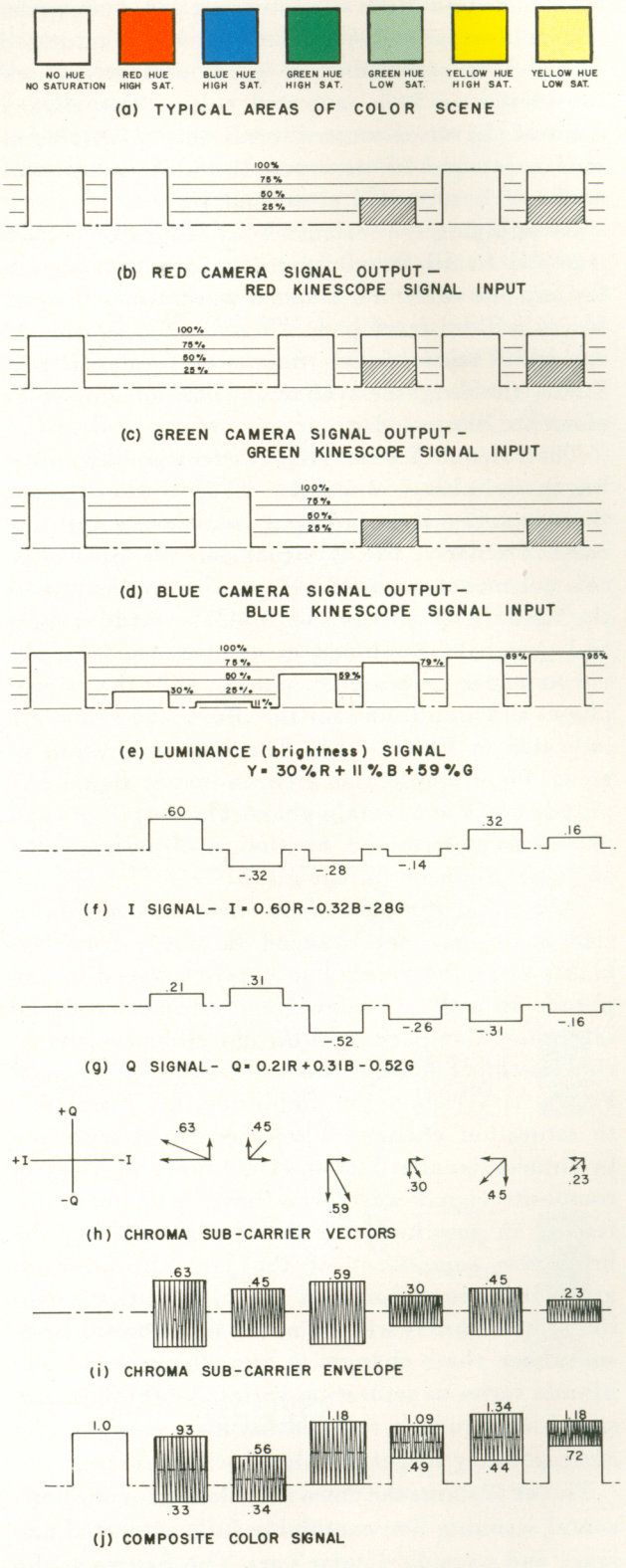



Figure 41 — Evolution of the Composite Color Signal

ments of a televised color scene. FIGURE 41 illustrates the signal development for the indicated color elements. High saturations of red, blue, green and yellow are considered to be 100% saturated colors. Low saturations of green and yellow are considered as 50% saturated colors. The shaded areas of the three camera signal output waveforms at (b), (c) and (d) represent the white component of the 50% saturated green and yellow.

By applying the formula Y = +30%R +11%B +59%G to all three camera tube output signals for any one color, the Y signal waveform at FIGURE 41 (e) will be developed. When applied to a black-and-white receiver, this video waveform will represent the brightness characteristic of the color elements illustrated.

The I signal (FIGURE 41-f) is developed by applying the formula I = 0.60R —0.32B —0.28G to the three camera signal output waveforms for any color. Similarly, the Q signal for the illustrated color elements can be developed by application of the formula, Q + 0.21R + 0.31B — 0.52G. The I and Q signals, combined in quadrature, form the chrominance subcarrier signal, and the signal phases and amplitudes for the illustrated colors are indicated at FIGURE 41-h. The high saturation of green, for example, has a chrominance signal amplitude of .59 at a certain phase. The amplitude and phase are determined by the amplitudes of —I and —Q produced for the green.

Notice that the pale green chrominance subcarrier vector has not changed in phase from the highly saturated green, but merely reduced in amplitude in order to convey the effect of reduced saturation. Comparison of the chrominance subcarrier envelopes for the two saturations of green at FIGURE 41 (i) show the amplitude differences due to saturation change. When combined with the brightness signal at FIGURE 41 (j) however, the two composite signal waveforms have little *total* difference in amplitude for the two greens, but the brightness component of the low saturation of green is greater than that for high saturation of the same color. It will be noted that chrominance subcarrier phase changes as hue changes, and amplitude varies as saturation varies. As chrominance signal amplitude is reduced for the same hue, the corresponding brightness signal will increase.

FIGURE 42 shows the video modulation for one horizontal scanning line containing fully saturated primary and secondary color bars. The figures at the left of the chart indicate percentages of modulation. The brightness signal for each bar is the AC axis

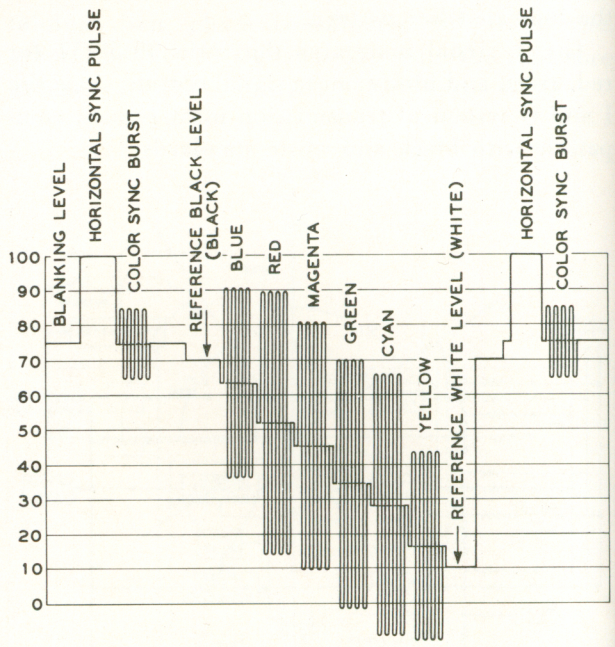



Figure 42 — Video Modulation for One Horizontal Scanning Line

of each chrominance signal, forming the "stair-step" pattern from black to white. The video swing from black to white is shown at its maximum tolerance, with white at 10% modulation. This provides a contrast range from 70% modulation to 10%, or 60% of the total modulation envelope. Black, then, represents 0% of this 60% range. The brightness signal for the colors, from left to right, represents the following percentages of this 60% range of contrast: blue, 11%; red, 30%; magenta, 41%; green, 59%; cyan, 70%; yellow, 89%; white, 100%. The green, cyan and yellow chrominance signals overshoot zero modulation, with yellow representing maximum (9%) modulation overshoot. If transmitted, these highly saturated colors would cause the RF carrier to be interrupted each time the color was scanned, and with intercarrier type receivers, would possibly cause a "buzz" in the sound. Since fully saturated colors are rarely telecast, however, this condition is unlikely to occur.

The preceding pages have thus far outlined the transmitter pre-requisites for developing and transmitting a color television signal using I and Q chromaticity coordinates. It might be well, then, to outline the receiver requirements for converting this color signal into a full color kinescope representation.

Referring to FIGURE 43, the transmitter section requires little discussion here, since this is basically the same diagram as FIGURE 40. For simplicity the receiver block diagram indicates only the video and color portions of the receiver. From the antenna, then, the video Y signal is applied to the three matrix blocks. A filter separates the chrominance signal and applies it to the I and Q demodulators.

Burst is applied to the 3.58 MC oscillator. The resulting CW signal, phased with the transmitter 3.58 MC oscillator, is phase shifted 57° before being applied to the demodulators in quadrature. By the combination of locally generated 3.58 MC CW signals and the chrominance signal, the demodulators produce both positive and negative I and Q signals. The I and Q signals are then applied in certain amounts and polarities to the matrix circuits, where they produce the color difference signals R-Y, G-Y and B-Y. When added to the Y signal, red, green and blue video signals are produced and applied to the respective electron guns of the tri-color kinescope.

It will be well to note that the I and Q signals must produce color difference signals which, when added to Y, will duplicate the output signals of the three camera tubes. FIGURE 43 also points out that the receiver exactly reverses the transmitter signal development.

FIGURE 44 shows the video waveforms of color difference signals, for the indicated bar pattern, that result from I and Q matrix. These signals, when added to Y, will produce the required kinescope grid signals for operation of the tri-color kinescope. As an example, the Y signal for the green bar has an amplitude of 0.59. When added to the B-Y signal there is no video signal produced for the blue kinescope gun for the green bar. The combination of Y and R-Y produces zero signal for the red kinescope gun; however, 0.59 Y added to the .41 G-Y signal produces 100% amplitude signal to the green gun to represent the green bar on the kinescope.

I and Q demodulators for the receiver are the same in principle as discussed under FIGURE 30. With refinements necessary for the I and Q system,

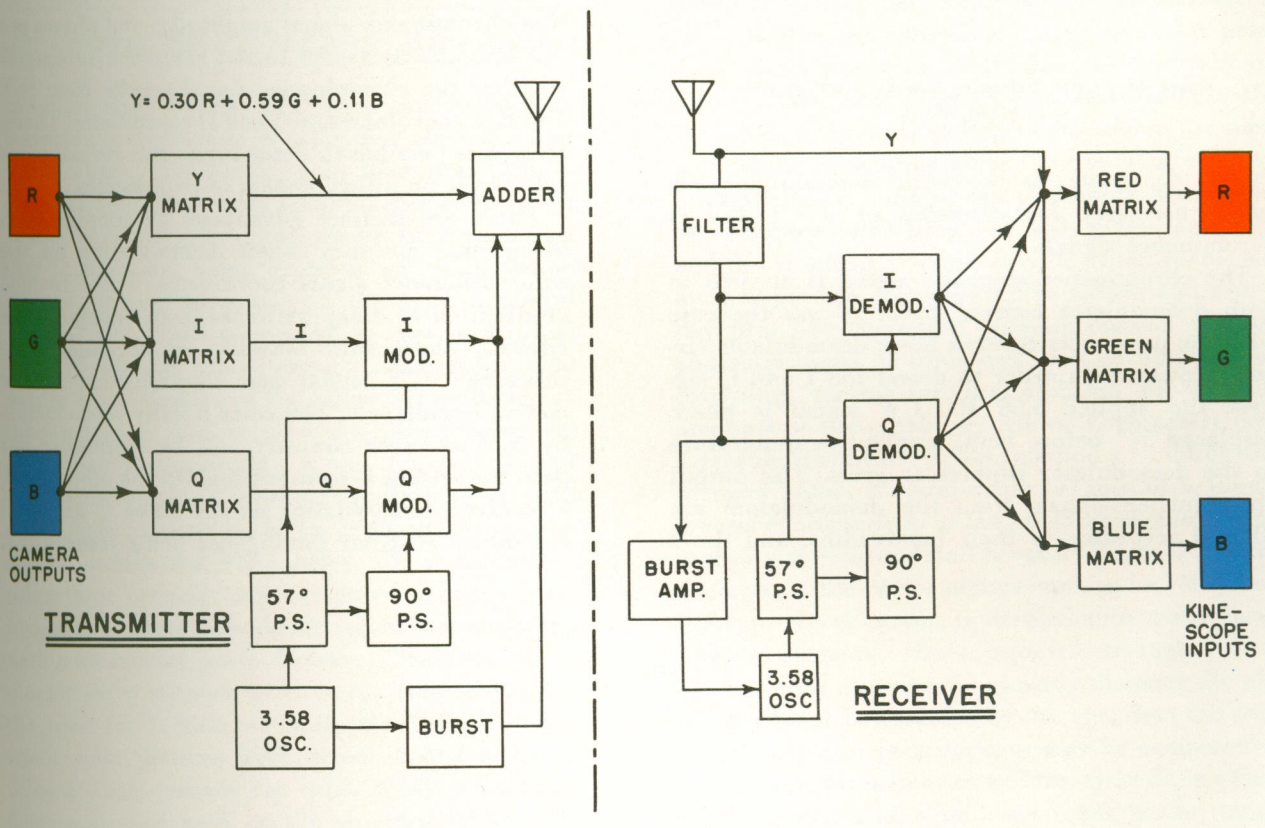



Figure 43 — Block Diagram of a Color Transmitter and Receiver

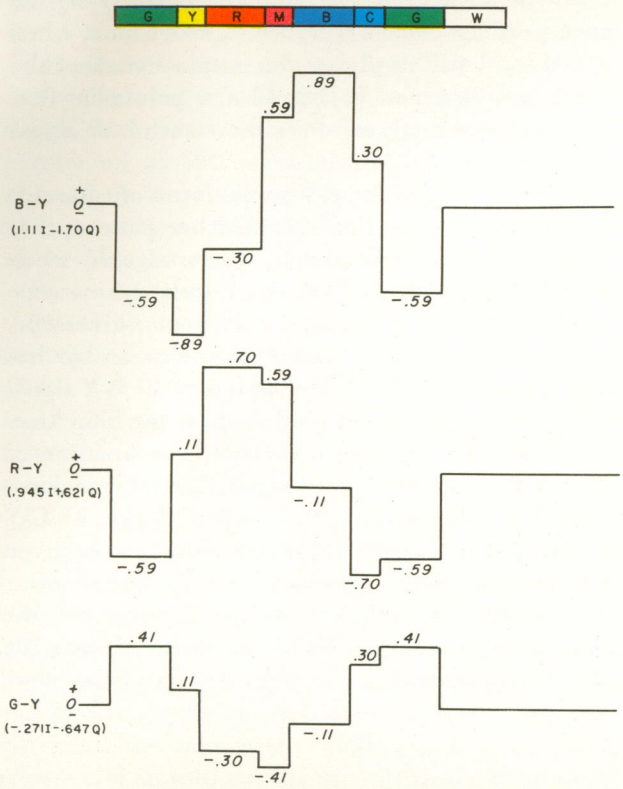



Figure 44 — Color Difference Signals Resulting from I and Q Matrix

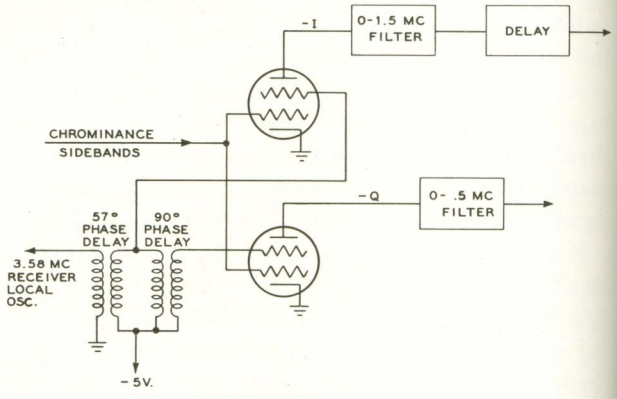



Figure 45 — Basic Demodulator Circuitry

FIGURE 45 illustrates the basic demodulator circuitry necessary for detection of the I and Q chrominance signals.

The chrominance sideband signal is applied to both demodulator control grids, as was the case with the previously covered basic demodulator circuit. However, in order to detect the I and Q signals, the applied 3.58 MC CW signal is phase displaced 57° before being applied in quadrature to the demodulator suppressor grids. The output chrominance signals from the demodulators are filtered according to their bandwidths, and the I signal is delayed to coincide with the center frequency of the Q signal bandpass.

Transmitting the chrominance sidebands which result from I and Q modulation coordinates means that full color definition is transmitted. However, it is not necessary that a receiver be designed for I and Q detection in order to reproduce color. A brief review of FIGURES 29 and 38 will point out that chrominance signal amplitudes and phases are the same *with respect to the reference subcarrier* whether the chrominance signal results from R-Y and B-Y coordinates, or I and Q coordinates. Therefore, it is possible to demodulate the chrominance subcarrier on either system of coordinates.

There are distinct advantages in simplification of receiver circuitry when demodulating on the color difference signal coordinates. These include elimination of delay networks in the demodulator circuits, phase shift networks in developing the subcarrier CW signal and simplification of the matrix circuits, etc. The color fidelity reproducible by such receiver circuitry will be something less than the system is transmitting. On the other hand, a receiver demodulating on the I and Q axes will reproduce all color intelligence being transmitted.

# The RCA Tri-Color Kinescope

One of the major contributing accomplishments in developing the RCA color television system to its present acceptable and practical status was the RCA Tri-Color Kinescope. The descriptions in the previous section outlined the necessary circuits of the receiver so as to provide the necessary red, green, and blue picture signals for operation of the respective red, green, and blue electron guns of the Tri-Color Kinescope.

This section will give a brief outline of the general background development leading to RCA's search for a practical color picture tube and a detailed description, including operating principles of the present RCA Tri-Color Kinescope. Its circuit application, power supply requirements, etc., follow in later sections.

## *Background Development Leading to the Present RCA Tri-Color Kinescope*

Inventors and scientists have been concerned with television *reproduction* in color ever since the late 1920's when a number of color television demonstrations were given using scanning-disc techniques. While there was evidence in patent literature, etc., that thought was being given to an *all-electronic* method for color reproduction, the most successful work of the 1930's continued to use mechanical (usually scanning disc or drum) methods. By 1940 (while a combination of the electronic cathode ray tube–scanning disc method simplified color reproduction mechanically) it was recognized that there still remained inherent limitations in such color reproduction. Back in 1940, RCA demonstrated, before the FCC, color TV reproduction using three optically super-imposed primary color images from three cathode ray tubes, thereby eliminating all moving parts. However, the bulk of requiring three separate cathode ray tubes indicated the need for further research. By 1942, all electronic color pictures were demonstrated by RCA using a single cathode ray tube. While RCA engineers continued work on the objective of a single cathode ray color picture tube, the advent of World War II stopped all such progress. The problem was again attacked with much vigor in the post-war years with such factors as improved high voltage and deflecting systems resulting from post-war black and white television developments, as well as metal kinescopes and aluminized phosphors, providing the key to some of the problems. As a result of the progress made, early in 1950 RCA was able to demonstrate that a single cathode ray, three color, reproducer tube for the home color TV receiver was practicable.

## *General Requirements of a Color Reproducer*

It will be recalled from Figure 10 that the entire range of colors (hues at various saturations as compared to white) observable by the normal eye is found within the horseshoe-shaped figure. A practical color reproducer should therefore use primary colors which would lie so that lines joining the three selected points of Figure 10 enclose the most part of the horse-shoe area. Development of suitable cathode-ray tube screen phosphors determined the primary color points of red, green, and blue and the resulting triangle R-G-B, which covers the most important colors found in nature and everyday life. The maximum possible number of hues and saturations of color can then be obtained by providing means for the addition of variable amounts of these primary colors. Fortunately considerable flexibility in the method of adding the primary colors is permissible because of a *fundamental characteristic of the human eye*, namely the inability to resolve detail beyond a finite limit. For example, if the entire picture area to be viewed on the reproducer screen is divided into many small picture elements (lines, squares, triangles, dots, etc.) so that at a normal viewing distance the elements cannot be resolved by the eye, then the various elements in juxtaposition may be composed of groups of color primaries and the eye will, in effect, add these primaries and see them as the *single color* represented by the added primaries.

There are also, of course, other general requirements for an acceptable and practical color repro-

ducer, which briefly are:—

1. Picture area should be as large as practicable.
2. Picture brightness should be comparable to that of present day black and white television to permit the screen to be viewed under average room illumination.
3. Picture contrast range should be even better, if possible, than that of present day black and white television because ambient white light (such as average room illumination), which reduces contrast in black and white pictures, has the additional effect of reducing saturation in color reproduction.
4. Picture resolution capabilities should permit reproducing a fineness of detail somewhat better than that which the television system is capable of conveying.
5. Mechanical and electrical design should permit eventual mass production, application to realizable receiver circuits, leading to economies and wide public acceptance.

## *Description of the RCA Tri-Color Kinescope*

Before discussing the operating principles, the principal parts of the Tri-Color Kinescope should be listed and described.

The principal parts are:—

1. Phosphor Dot Viewing Screen
2. Shadow Mask
3. Three Electron Gun Assembly
4. Envelope

### *Phosphor Dot Viewing Screen*

Among the fundamental differences which distinguish the Tri-Color picture tube from black and white kinescopes is, first and foremost, its phosphor viewing screen. In contrast to the uniformly coated phosphor mixture used in a black and white kinescope, the color tube screen is composed of an orderly array of small closely spaced phosphor dots arranged in triangular groups, or trios, accurately deposited in inter-laced positions on a supporting glass surface. Each trio represents one of each of the three primary color phosphors; a green emitting dot, a red emitting dot, and a blue emitting dot. The phosphor dots emitting these colors are kept separate without wasted space and yet without overlapping. The early Tri-Color Kinescopes demonstrated in March and April of 1950 had approximately 117,000 dot trios, or 351,000 dots. The present day Tri-Color picture tube has been improved in picture resolution represented by 585,000 dots or 195,000 dot trios. This is an improvement of nearly 55% and represents picture detail greater than that conveyable by the over-all color TV system. The dots are metalized after application to increase light output as well as preventing an ion spot blemish. While the earlier RCA Tri-Color Kinescope had to have a color filter in front of the phosphor screen to improve red color response due to the limiting red orange color phosphor available at that time, the present Tri-Color Kinescope, through the efforts of RCA research, now has the proper color red phosphor thus eliminating the color filter. By eliminating the latter, a substantial increase in light output resulted. An improved blue color phosphor in the present Tri-Color Kinescope eliminated the trailing blue color fringes because of a longer decay characteristic. The present phosphor screen now has acceptable color balance in all phosphors.

The present RCA Tri-Color Kinescope has been improved in contrast over the older 1950 model by using a neutral filter glass (often referred to as "black glass") for the clear glass phosphor screen plate, as well as by improved metalizing to obtain the best balance for controlling contrast ratio and light output.

Contrast ratio is equal to that obtainable in black and white tubes of comparable sizes used, and the highlight brightness between 30 or 40 foot lamberts is entirely satisfactory in a room with average illumination.

### *Shadow Mask*

A second difference between this Tri-Color kine-

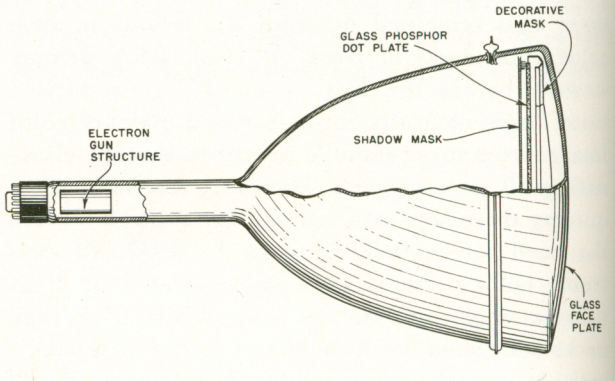



Figure 46 — The RCA Tri-Color Kinescope

scope and the conventional black and white kinescope is the addition of a shadow mask. From the position of the tube viewer, the mask is located parallel to and just back of the phosphor dot plate. FIGURE 46 shows its position in relation to the overall envelope.

The metal shadow mask contains round holes equal in number to the dot trios, or 195,000 holes.

The shadow mask provides color separation by shadowing two of the three arrays of phosphor dots from two of the three electron beams while exposing the proper array to bombardment by each beam. In order to obtain precise alignment, which is absolutely necessary, between the holes in the mask and the phosphor dots, the mask and phosphor dot screen are mounted together in an assembly. This assembly is then placed in the tube and held in proper relationship to the electron guns.

### *The Three Electron Gun Assembly*

In the RCA Tri-Color Kinescope three parallel, closely spaced electron guns, built as a unit, provide separate beams for excitation of the three different phosphor arrays. Thus it becomes possible to control the brightness of each of the three colors independently of the other two. FIGURE 47 shows the details of a typical gun assembly.

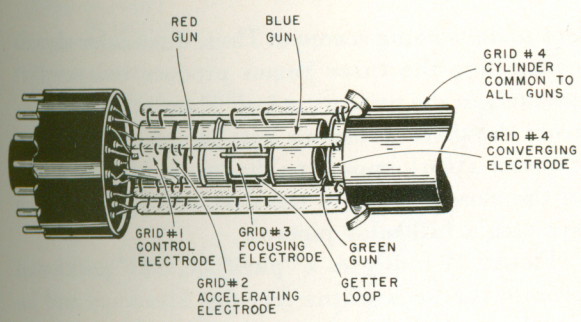



Figure 47 — A Typical Electron Gun Assembly

### *Envelope*

The first RCA Tri-Color Kinescopes will use fifteen inch round glass envelopes that will permit a picture size of 11½" by 8⅝" with rounded sides. A decorative mask that determines the picture size is included within the tube envelope.

## *Operating Principles of the RCA Tri-Color Kinescope*

It must be kept in mind that the Tri-Color Kinescope, as used in the RCA color television receiver, is a *simultaneous* color display device. Structurally, the tube consists of three electron guns mounted with their axes parallel to the central axis of the envelope, and spaced 120 degrees with respect to each other. Each gun has a focus electrode, whose potential is adjusted to cause the electron beams to focus at the phosphor-dot plate. All three beams pass through an electro-static lens system, whose potential is adjusted to cause the three beams to converge in the plane of the aperture mask. The three converged beams are electro-magnetically deflected in the usual way, horizontally and vertically, by a common yoke. FIGURE 48 shows a representation of the operating components of the Tri-Color Kinescope. The relationship of the three electron scanning beams, shadow mask and phosphor-dot plate is shown by the illustrated details.

The three beams can be made to converge at point (A) as a unit by adjustment of grid #4 (converging electrode) voltage, which changes the voltage

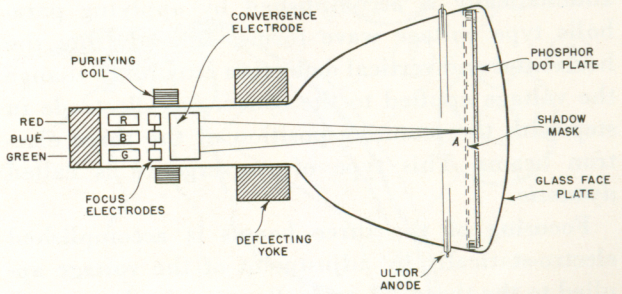



Figure 48 — Operating Components of the Tri-Color Kinescope

difference between grid #4 and grid #5 (neck coating). Since some variation in the convergence position of each beam will exist because of electron gun manufacturing tolerances and the effect of stray fields, individual positioning of each beam to accomplish proper convergence requires the use of three external permanent magnets called "beam positioning magnets," located directly over each electron gun and mounted in the neck shield assembly, as shown in FIGURE 51. This is called *static* convergence and is one of the first adjustments the

color TV receiver service man will have to perform.

Because the shadow mask and the phosphor-dot screen are flat, it can be seen from FIGURE 49 that convergence would take place at (B) when the

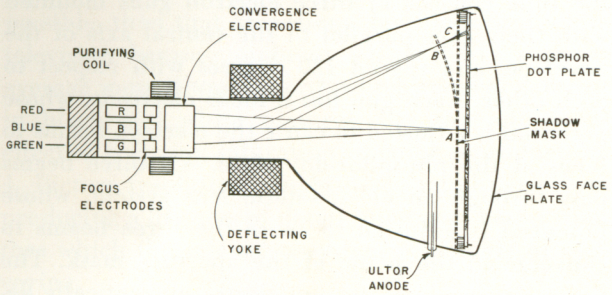



Figure 49 — The Need for Convergence Voltage

three beams were moved by the deflecting yoke. Obviously, convergence must take place such as at point (C) in FIGURE 49 when the beams are deflected to the top and bottom as well as to the left or right hand side. It is necessary therefore that the *converging lens* be made to vary as a function of the deflecting angle. Varying the converging lens automatically is accomplished by applying parabolic type voltage wave forms, derived from the horizontal and vertical deflection circuits, to change the voltage applied to the converging electrode in step with the scanning position of the three electron beams. This type of convergence is called *dynamic.*

Focusing of the three beams is accomplished electro-statically by adjustment of the voltage applied to the three #3 grids. Because the *beam path length* from the focusing lenses to the flat screen assembly is also a function of the position of the screen area being scanned, and because these lenses are affected by the dynamic converging voltage applied to grid #4, it is desirable that the grid #3 voltage be varied as a function of the position of the trio being scanned. This *dynamic focusing* is accomplished by applying appropriate voltage wave-form from the horizontal and vertical deflection circuits so as to properly vary the potential applied to the focusing electrodes, grids #3.

As can be seen from FIGURE 50 the different angles at which the three electron beams, from the three electron guns, controlled by the red, green and blue color signals feeding the respective signal control grids (Grids #1 in FIGURE 47) reach the shadow mask determine the particular color phosphor dot which is energized by each beam. Thus, one gun is associated with each of the primary colors so that control of beam current from that gun *controls the amount* of the primary color developed. FIGURE 50 shows the effect of approach angle of the three beams. The shadow mask is positioned so that with correct approach angle, electrons from one of the three beams can strike phosphor dots of *only a single color* no matter which part of the phosphor

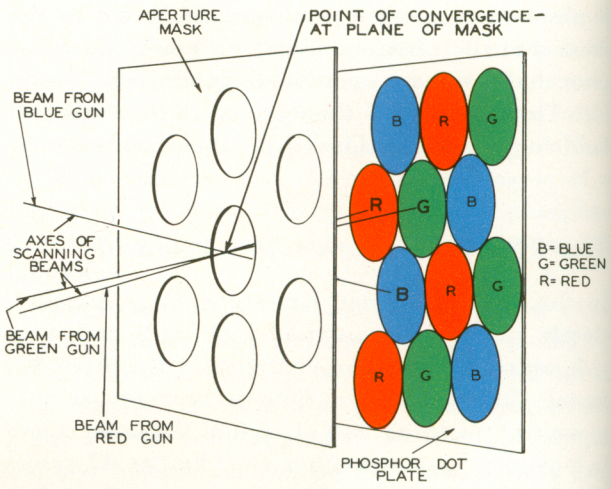



Figure 50 — Convergence Relationship to the Shadow Mask

dot plate is being scanned. Thus, three color signals controlling the three beams produce independent pictures in the primary colors. These primary colors from the three phosphor dots comprising a picture element (trio) appear to the eye to blend because of the close spacing of the dots, and as a result the eye sees a full-color picture.

FIGURE 51 indicates a "purifying coil" positioned around the neck of the tri-color kinescope and located over the three gun assembly. The coil is activated by DC and creates a field of electromagnetic force that acts equally on all three electron beams. Its effect is to correct for production tolerances in kinescope manufacture that would cause the gun assembly to be turned slightly in the tube neck with respect to the phosphor dot plate. This normally would constitute a "purity error," in that the three beams will strike only the edges of the correct dots, and also the edges of adjacent dots. With this condition existing, the tube will not be capable of producing pure primary fields. Such a purity error

can be corrected by varying the DC through the purifying coil, or by physically rotating the coil.

The yoke for the RCA tri-color kinescope is similar in design and operation to the yokes for black and white receivers, with one major exception: the end turns of the yoke coils are lifted away from the neck of the tube to prevent their interfering with normal deflection. This of course is done to an extent with black and white tube yokes, but not to the extent necessary in color kinescopes. The end turns of the yoke constitute an electromagnetic field at right angles to the deflecting field. Its effect on black and white deflection is not noticeable, but these end turn fields each have a varying effect on the three beams in a tri-color kinescope, and would make purity difficult to achieve. For this reason the yoke end turns are removed as far as possible from the neck of the tri-color kinescope.

Stray magnetic fields entering any portion of the tri-color kinescope will have an effect on purity and convergence. This kinescope, therefore, must be completely shielded to insure optimum operation. The neck and the major portion of the glass bell are protected from magnetic fields by mu-metal shields. Mu-metal has a high permeability, and thus acts as a short circuit to external magnetic fields. These shields are shown in their normal positions in FIGURE 51. Notice that the bell shield does not extend fully to the face plate of the tube. The shield must be cut back to allow for the second anode connection (the metal sealing ring around the entire circumference of the glass bell) and its protective plastic insulating shield. The resulting exposed portion of the glass bell plus the face plate is protected from stray magnetic fields by a *field neutralizing coil.* This coil (not shown) is fixed to the inside wall of the cabinet, completely encircling the bell of the kinescope at the face plate. The coil is activated by a DC that, when adjusted, establishes a field of force over the unprotected portions of the kinescope, preventing external magnetic fields from affecting tube operation.

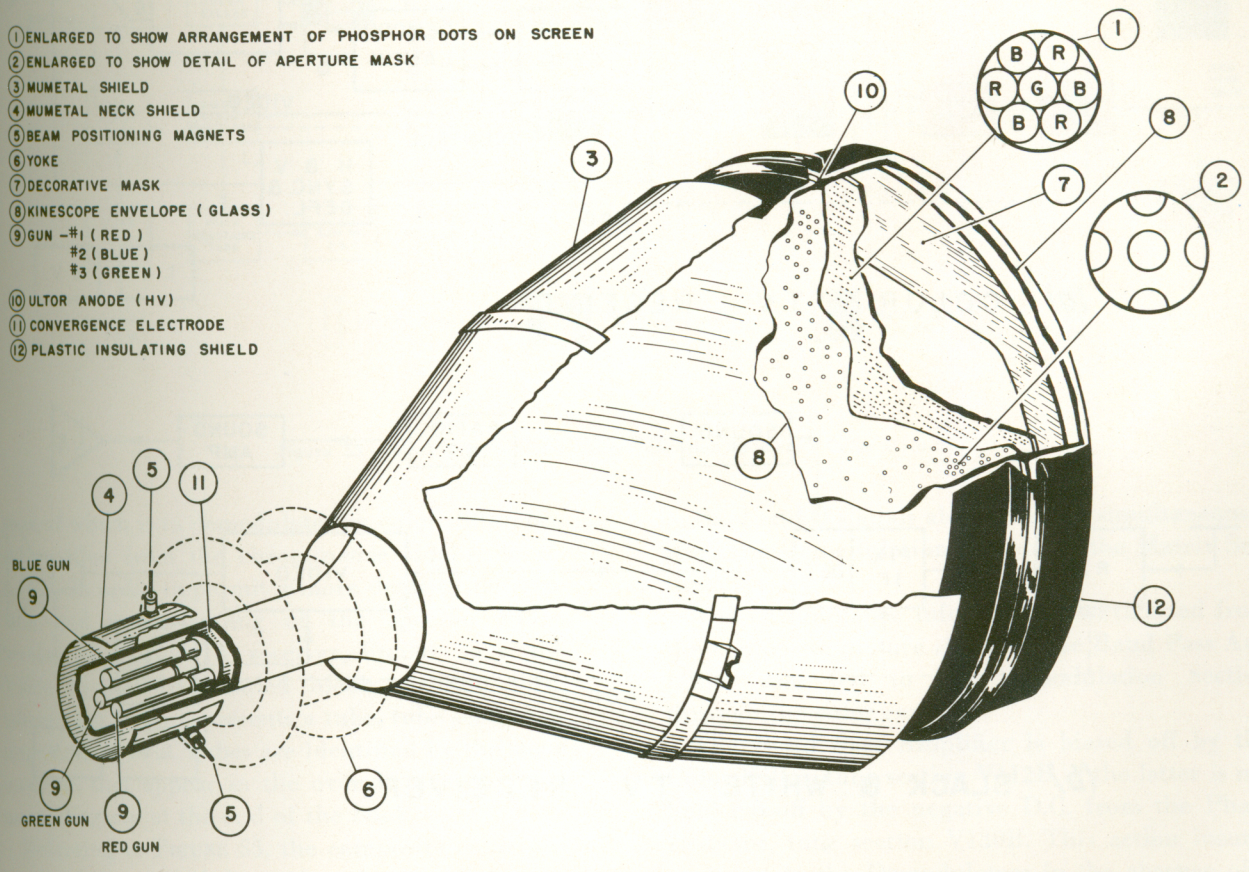



Figure 51 — The RCA Tri-Color Kinescope and its Associated Components

# SECTION II

## Basic Circuit Description of a Typical RCA Color TV Receiver

In order to present the basic circuits of a typical color television receiver, circuits are first shown in signal flow – block diagram form rather than the actual schematic diagram, wherein all parts, tubes, etc., are shown electrically connected. To further simplify this discussion, only the differences that exist between a black and white and a color receiver will be discussed.

FIGURE 52 is a block diagram which at (a) illustrates the basic portions of a color TV receiver as compared to the basic portions of a black and white TV receiver as at (b). As can be seen, the

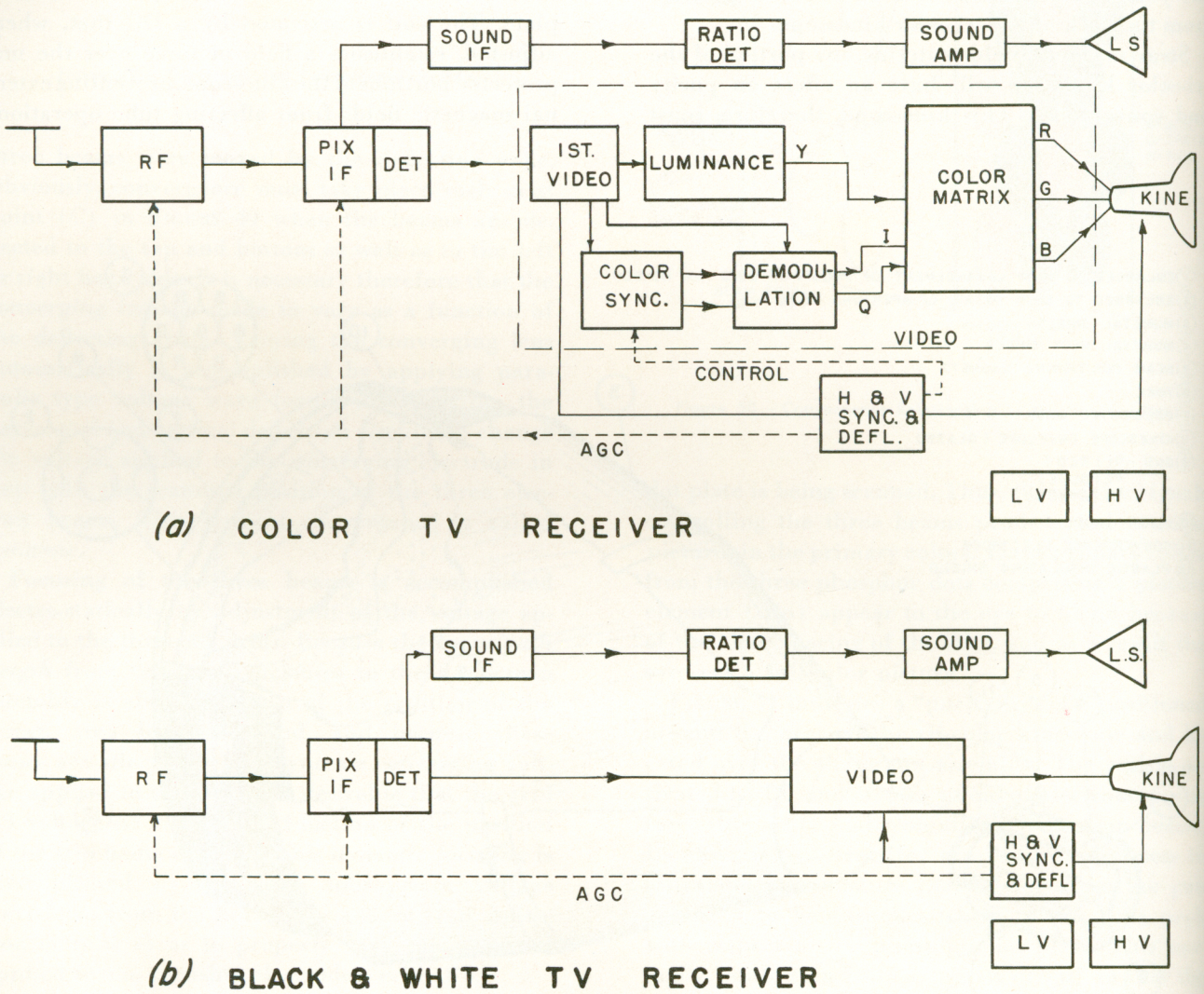



Figure 52 — Color and Black and White Receiver Block Diagram Comparison

color receiver differs from the black and white receiver only by the addition of three new sections, labeled Color Synchronizing, Demodulation (Chrominance) Section and Matrix Section. The Luminance Channel corresponds to the Video Channel section of the black and white receiver and therefore is new in name only. The function of the Luminance Channel is to amplify the luminance information at the video second detector to a value suitable for application to the matrix (mixing) circuits. Also, as can be seen, there must be a Demodulation, or Chrominance Channel, the purpose of which is to demodulate the color difference information from the chrominance sidebands received. In order to permit a more detailed description and understanding of the specific Video Section of a color TV receiver, FIGURE 53 is the Video Section in detailed block diagram form where each block represents a tube, tube section or important circuit. Tubes are identified by the same numbers that appear in the overall receiver schematic diagram at the end of the book.

Referring to FIGURE 53, the composite color picture signal rectified from the picture IF by the Second Detector passes through a pentode tube section (V114) which provides positive polarity signal at the plate for horizontal and vertical synchronizing, AGC and "burst" color synchronizing signal.

A potentiometer in the cathode circuit of V114, ganged with the potentiometer located in the grid circuit of V115A acts as the contrast control and provides wide band video voltage for the chrominance channels.

From the plate circuit of V114 the video "Y" signal is passed through a delay line terminated by the contrast control to tube section V115A. This keeps the luminance signal equalized in time delay to the I and Q signals also being fed simultaneously from the Demodulation Section to the Matrix Section.

The chrominance information is extracted from the composite picture signal in the Band Pass Amplifier and fed to the Demodulation Section through the color control.

The Band Pass Amplifier is biased off by the Color Killer, tube section V112B, if the latter is not held cut-off by the negative D.C. from the Phase Detector, tube section V130B. This action insures no input to the Demodulators in the absence of a "burst"; i.e., with black and white transmissions.

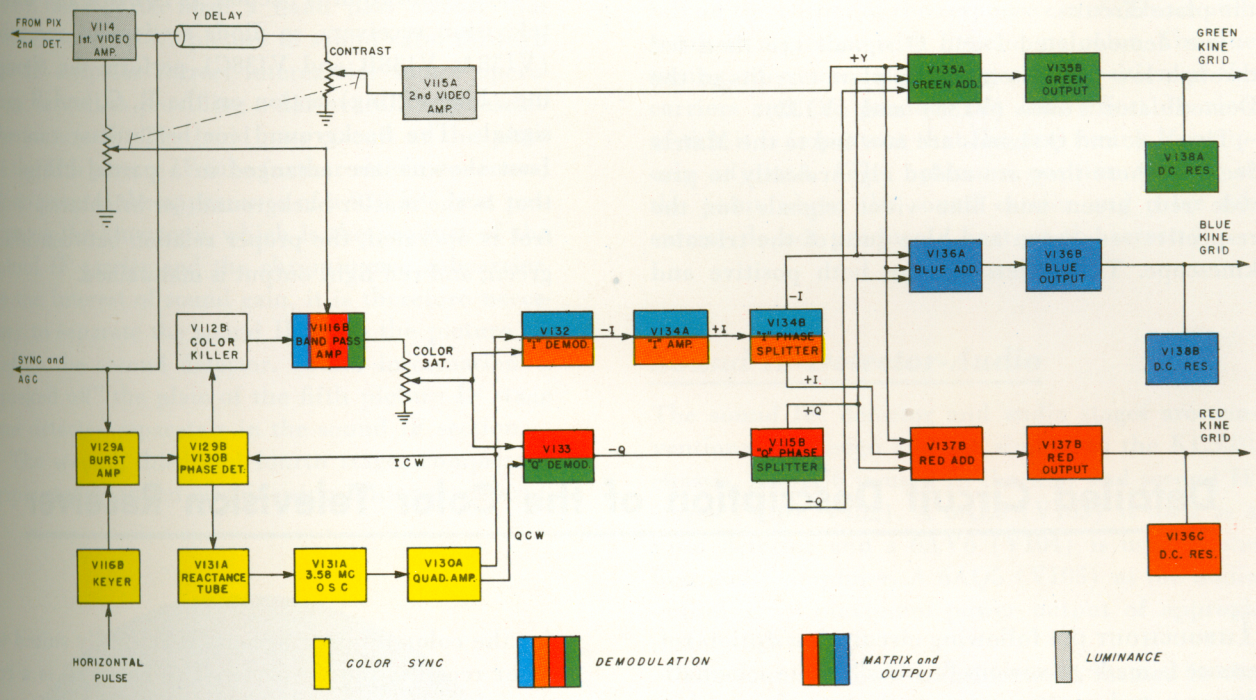



Figure 53 — Block Diagram of a Color Television Receiver's Color Circuits

The output of the Burst Amplifier (V129A) supplies a burst reference voltage at 3.58MC to the Balanced Phase Detector, (V129B-V130B). Here the reference burst signal is compared to a local 3.58MC signal (from V131B via V130A) and an error voltage fed to the Reactance Tube (V131A) keeps the Crystal Oscillator (V131B) in phase with the burst reference.

Color subcarrier CW signal from the Color Sync Section is fed at proper phase to the suppressor grids of tubes (V133) and (V132) of the Demodulation Section while the chrominance signal is applied to the control grids. Synchronous detection occurs and the detected I and Q signals appear in the plate circuits.

The demodulated I and Q signals are then fed through low pass filters in the plate circuits of the Demodulator Tubes (V133) and (V132).

The Y, I, and Q signals are now fed to the Matrix Section where they are added algebraically to provide red, green and blue video signals for the respective red, green and blue guns of the tri-color kinescope. The adders require both positive and negative quantities of both I and Q signals, so two phase-splitters (V115B and V134B) are used. Suitable amounts of positive or negative I and Q and the Y signal are added through resistors in the grid circuits of the adder stages, tubes V135A, V136A, and V137A. This combination yields the three *simultaneous* R, G and B signals required at the control grids of the tri-color kinescope. It should be noted that negative I (cyan) is applied to the green and blue adders and positive I (orange) is applied to the red adder. Also negative Q (green) is applied to the green adder, and positive Q (magenta) is applied to the red and blue adders.

D.C. restoration is needed, as in black and white television receivers, so diode sections of one tube (V138A, V138B and V138C) perform the clamping (bias setting) action on the R, G, and B gun signals. The background (or brightness) controls (not shown) are arranged in a partial bridge so that as the master background (or brightness) control is operated, the proper relation between blue, green, and red light output is maintained.

## Detailed Circuit Description of the Color Television Receiver

THROUGHOUT the following circuit description reference is made to various "blocks" of the schematic diagram and component parts by specific number. The reader will find these references to the pull-out schematic diagram at the end of the book. For convenience in reading the circuit description, all parts of the schematic except the RF unit will appear outside the book when fully extended.

The complete schematic of the color receiver is shown in block diagram form. This presentation not only shows the circuits in schematic form but also indicates the function of each section of the receiver and its relation to other sections. Signal paths are shown as heavy lines with arrows indicating the direction of signal path.

### *RF Unit—KRK12C*

This tuner has given excellent service in RCA deluxe black and white receivers and was selected for the color receiver because it is ideally suited to color receiver requirements. The KRK12C is a rotary drum type tuner with provision for sixteen inserts that may be individually aligned to any combination of 16 VHF or UHF channels.

The RF amplifier (V1) uses a 6BQ7A tube in a low noise, cascode type amplifier. The RF oscillator (V2) is a 6AF4, high frequency triode. The mixer circuit uses a K3E silicon crystal to produce the IF signal which is further amplified by V3 (6U8) to obtain added gain before being fed to the IF amplifiers on the main chassis. The feature of individual channel inserts is especially important for reception of color TV, since they not only are calibrated for any individual channel, but can also be aligned individually so that each channel will have an ideal RF response curve. This is all-important in color television as color information as well as picture and sound carriers must be amplified without attenuation or phase displacement.

## *Picture IF*

The picture IF stages are designed for a picture carrier of 45.75 MC and a sound carrier of 41.25 MC. Although there is an IF stage on the KRK12C unit (V3) the first 6DC6 tube will be called the first picture IF amplifier. This is followed by four additional IF stages; two 6DC6's, a pentode section of a 6AN8, and a 6CL6. Comparing this IF strip with the IF stages in the RCA KCS-81 (21D300 series) black and white receiver, a definite similarity can be seen. Three bandpass circuits are used – in the grid and plate of the first picture IF stage and also in the plate of the fifth stage. 1T107 and 1T108 form a band pass circuit that establishes the 15:1 picture to sound ratio through the IF strip for correct intercarrier sound operation, as well as providing a flat overall response to the picture IF. The band pass circuit at the plate of the fifth picture IF tube further attenuates sound IF to prevent the appearance of a 920 KC beat pattern on the kinescope, which is the product of the sound IF carrier and the chrominance subcarrier. In the interest of sound gain, it is therefore necessary to separate the sound IF from the picture IF *before* the second detector. Sound information is "picked off" the plate of the fifth picture IF stage and detected separately in the sound IF section.

The second, third and fourth stages comprise a triple stagger-tuned circuit using bifilar transformers similar to those in the KCS-81. The second stage is tuned to the high frequency side of the band pass, the third to the low side, and the fourth to approximately the center of the band.

In summarizing, it may be said that this picture IF strip is similar to black and white IF amplifiers except that it provides more bandwidth and a flatter response. Another notable exception is the downward shift of the picture carrier with low bias (weak signal). A look at the IF response curve as shown in FIGURE 54 will reveal the reason for this. It can be seen that if the picture carrier should rise on a weak signal (as it does with many present black and white sets) the color subcarrier would fall off the corner of the response curve. This would result in a picture with little or no color. The fine tuning, of course, also changes the position of the carriers and can produce the same effect. In view of this it is important that the fine tuning be properly adjusted. (The optimum position will be at the point where the sound carrier and color sub carrier do not produce a beat on the screen.)

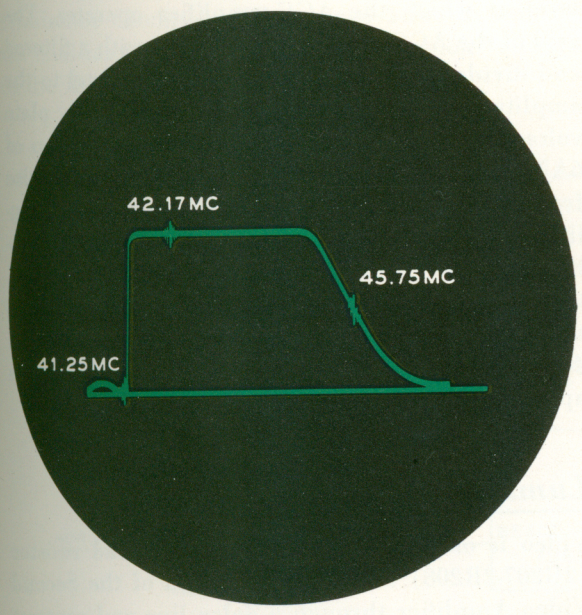



Figure 54 — Color Receiver IF Response

## *Sound IF-Detector-Audio*

The sound IF, detector and audio stages are conventional in design and are similar to the KCS-81 chassis. A 6AU6 is used in the first and second IF stages (V101, V102). A 6AL5 (V103) is used as a ratio detector and a 6AV6 (V104) is used as the first audio amplifier. A 6AQ5 (V105) as the audio output gives maximum power output of approximately 3.0 watts.

The sound take-off transformer is located in the plate circuit of the fifth picture IF stage *before* the picture detector. In the color receiver the color subcarrier (3.58 MC) will produce a beat of 920 KC with the sound carrier (Sound IF = 41.25 MC, color subcarrier = 42.17 MC) that would be apparent on the screen if sound were not attenuated at the picture detector. This is accomplished by the 41.25 MC sound trap contained in fifth picture IF transformer.

In order to produce a 4.5 MC sound IF it is necessary to feed the output of the sound take-off into a detector. A 1N60 crystal is used for this purpose and the 4.5 MC IF output is amplified by the following two stages. These are coupled by a double tuned 4.5 MC IF transformer. The amplified 4.5 MC IF is detected by a conventional ratio detector, similar in circuitry to many present day black and white receivers.

## *Picture Detector — Composite Video Amplifier*

The composite video information from the picture detector is amplified by a 6CL6, first video amplifier (V114). This information is used in several different ways. Video of positive polarity is supplied to the sync circuits for sync separation and AGC purposes. Video is supplied to the Burst Amplifier for extraction of the 3.58 MC burst. This is accomplished in the tuned circuit (2L141, 2R200, 2C186) in the plate of the video amplifier which is tuned to 3.58 MC. The resulting signal is fed to the grid of the burst amplifier.

Composite video of negative polarity is removed from the cathode of the video amplifier by means of the contrast control 2R204 and fed to the Band Pass Amplifier. A 4.5 MC trap is included at the Video Amplifier to insure that this signal component does not enter the chrominance channel. The Band Pass Amplifier, using the pentode section of a 6AN8, amplifies a band of frequencies with a bandwidth of approximately 2.4 to 5.0 MC as shown in FIGURE 55.

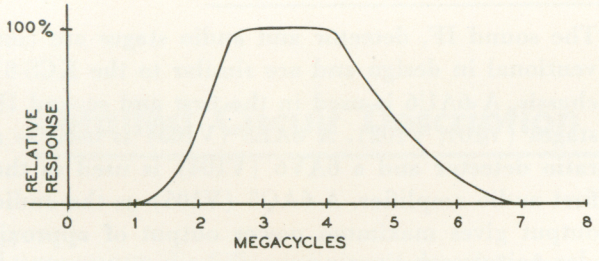



Figure 55 — Band Pass for the Chrominance Channel

It will be noticed that the screen of this amplifier (V116A) is tied back to a coil of the horizontal output transformer, introducing a negative pulse that prevents amplification during horizontal blanking time. Since the burst occurs during blanking time, it will not appear at the output of the Band Pass Amplifier. The need for this "keying out" of the burst from the chrominance channel is to prevent the possibility of color occuring in the picture during retrace time.

The output of the Band Pass Amplifier is terminated in a color control. This is a front panel control that governs the amount of color information passed on to the Demodulators.

## *Sync — AGC*

The sync line from the first video amplifier is capacity coupled to the Vertical Sync Separator (triode section of a 12AT7, V118B) and directly coupled to the grid of the Horizontal Sync Separator (triode section of a 6AN8, V117B). By using separate circuits for horizontal and vertical sync, each circuit is designed for its particular requirements which results in best performance. Noise immunity is improved in the Vertical Separator by coupling the screen of the fifth picture IF tube to the grid of the separator. Noise pulses arriving by way of the sync line are effectively cancelled by the same noise pulses of opposite polarity arriving from the fifth picture IF stage.

Sync from the horizontal and vertical separators are combined at the grid of a Sync Amplifier stage (triode section of a 6AT7, V118A). Another noise limiting circuit is featured here in the grid circuit. A 1.2 megohm resistor connected at the grid is tied to the plate return of the third picture IF tube. The plate voltage on the third picture IF tube varies slightly with changes in signal due to AGC action; this voltage applied to the grid of the Sync Amplifier tube varies the operation of the tube depending on signal amplitude. Sync tips are thus maintained at cut-off and noise pulses, greater than sync, are beyond cut-off and are effectively removed.

Returning to the Horizontal Sync Separator, it can be seen that the cathode contains a variable resistor, labeled AGC control. This control sets the level at which the AGC amplifier operates. The grid of the AGC amplifier is supplied with a filtered and divided DC voltage that is proportional to the amplitude of horizontal sync pulses. The plate voltage of the AGC Amplifier (pentode section of 6AN8, 117A) is supplied by a large positive pulse from the horizontal output transformer. The charging capacitor, 2C133, discharges to ground producing a negative voltage for biasing the first three picture IF stages and the RF amplifier. The degenerative feedback circuit from plate to grid of the AGC Amplifier is to prevent vertical sync pulses from appearing in the IF bias.

## *Luminance Amplifier*

Video is obtained from a split plate-load resistor (2R207-2R208) and fed to the grid of the Second Video Amplifier through a delay line and contrast control. The delay line is a small piece of coaxial cable giving the effect of a time constant with a

time delay of approximately one microsecond. The time delays in the receiver are necessary since three signals of different bandwidths take separate paths to the kinescope, and if no corrective action were taken, they would arrive at different times. This, of course, is not permissible, as it would cause misregistration of the various signals at the kinescope.

The delay line in the luminance channel is terminated in a contrast control that is ganged with the contrast control in the cathode of the First Video Amplifier. Ganging these controls will insure that the amount of video for the chrominance channel will be in the correct proportion to the video for the luminance channel.

The Second Video Amplifier (pentode section of 6AN8, V115A) amplifies the video to a level suitable for mixing with the chrominance signals in the matrix section. Series peaking is employed together with cathode compensation to obtain optimum bandwidth.

## *Chrominance Synchronization*

In this block two continuous wave signals are required at a frequency of 3.58MC. Although they are of the same frequency they differ in phase by 90 degrees. The purpose of these CW signals is covered in the description of the demodulators. The chief purpose of the Chrominance Synchronization block is to maintain the 3.58 MC Crystal Oscillator in the receiver in phase with a reference obtained from the few cycles of burst transmitted by the TV station. This is accomplished by using a Phase Discriminator Circuit and Reactance Tube in a manner similiar to the horizontal "Synchrolok" circuit in the RCA 630 TS receiver.

The tuned circuit in the plate of the First Video Amplifier supplies a frequency of 3.58 MC (the burst accompanying horizontal sync) to be amplified by the Burst Amplifier and used for reference purposes. In order that only the burst frequency be amplified, the Burst Amplifier (V129A) conducts only during horizontal blanking time. The Burst Amplifier is held at cutoff, during trace time, by the cathode voltage on the keyer tube (V116B). By applying a negative pulse obtained from a small winding on the horizontal flyback transformer, to the keyer grid, the keyer will be cut off. The voltage on the cathode will remain constant since the by-pass capacitor is 2 MF. However, a sharp increase in the keyer plate voltage is coupled by means of 2C250 to the grid of the Burst Amplifier. This will allow the Burst Amplifier to conduct, amplifying the burst information.

The burst plate transformer (1T122) has a high impedance primary tuned to 3.58 MC with a bi-filar secondary tightly coupled to the primary. Opposite ends of the secondary are connected to the triode sections of separate 6AN8 tubes (V129B, V130B). These triodes are actually diodes since the plates and grids are tied together. This is a phase detector that compares the phase of the incoming burst signal with the phase of the locally generated CW signal. This signal originates with a 3.58 MC Crystal Oscillator (V131B) and is applied to the phase detectors through a Quadrature Amplifier (V130A). The output of the detector is a DC correction voltage representing any phase error between the locally generated signal and the burst reference signal. The Burst Amplifier contains a phase control that permits manual adjustment of

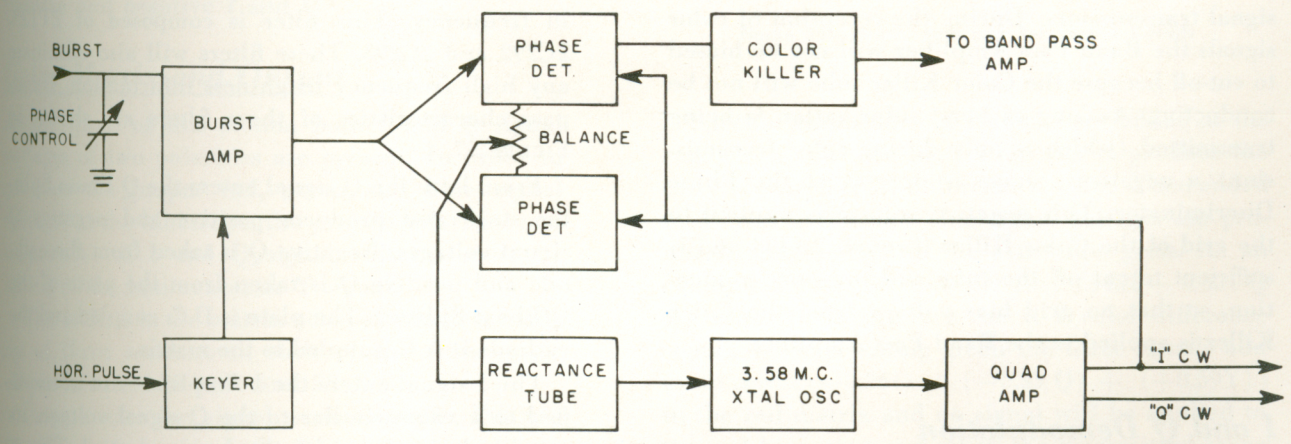



Figure 56 — Block Diagram of the Chrominance Sync Circuits

the phase of the 3.58 MC oscillator. This is a front panel adjustment that serves to produce the desired color tone of the picture. Any phase change here changes the color of the picture; for example, red becomes blue, blue becomes green, etc.

The DC correction voltage from the Phase Detector Circuit is applied to a capacitive type Reactance Tube circuit, pulling the 3.58 MC oscillator until zero correction voltage appears out of the phase detector. This maintains the oscillator at proper phase with burst reference.

The output of the 3.58 MC oscillator is cathode coupled to the quadrature amplifier V130A. In order to establish the CW signals 90° separated in phase, a quadrature transformer (2T125) is located in the plate circuit of the Quadrature Amplifier. This transformer supplies the proper ICW and QCW signals for demodulating the chrominance signals. The ICW signal is also used as the comparison signal in the phase detector circuit in order to maintain correct oscillator phase.

One circuit included in this block but not yet mentioned is the Color Killer (V112B). The purpose of this circuit is to prevent video information from passing through the Band Pass Amplifier and subsequent circuits when the receiver is receiving black and white transmissions. This circuit operates in the same manner as a pulsed AGC amplifier. A pulse from a special winding on the horizontal output transformer is applied to the plate of the Color Killer tube by incorporating this winding in series with the plate lead. When the positive pulse drives the tube into conduction, capacitor 2C259 is charged. In discharging to ground through 2R310 a negative voltage is produced. This is applied to the grid of the Band Pass Amplifier effectively "killing" this amplifier during black and white signal transmissions. During the reception of color signals the Band Pass Amplifier will not be biased to cut-off because the Color Killer tube will not be conducting. As long as burst information is being transmitted (which is only during color transmission) a negative voltage is present at the Phase Discriminator. This negative voltage is applied to the grid of the Color Killer through 2R308 and is sufficient to cut off the tube and prevents conduction, so that no grid bias voltage from the Color Killer is applied to the Band Pass Amplifier.

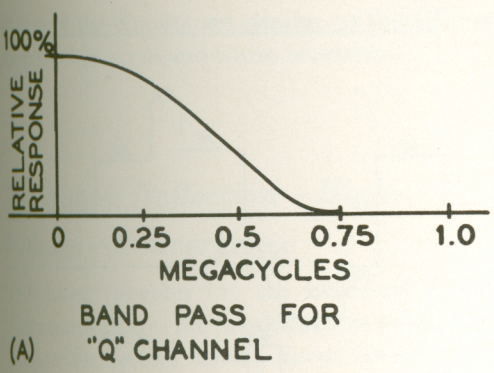
## *I and Q Demodulation*

The purpose of the demodulator is to separate the chrominance information into I and Q signal voltages. To accomplish this demodulation or "detection," the two continuous wave 3.58 MC voltages (I CW and Q CW from the Color Sync Stage) must be added vectorially to the chrominance signal. This is done by using two 6BY6 tubes, (one labeled the "I Demodulator," the other the "Q Demodulator"). By applying the chrominance signal to both demodulator control grids, applying the I (in phase) CW signal to the suppressor of the I Demodulator, and applying the Q (quadrature phase) CW signal to the suppressor of the Q Demodulator, "synchronous detection" occurs. The chrominance and I CW signal will add vectorially in the I Demodulator so that the vector addition of chrominance and I CW will cause the Q sidebands to cancel and no Q signal voltage will appear at the output of the I Demodulator. Similarly in the Q Demodulator, the Q sidebands and Q CW will add vectorially producing the Q signal; the I sidebands and Q CW will add vectorially cancelling the 0 to .5 MC I sidebands. The I sideband from .5 to 1.5 MC will not cancel out since only one sideband is transmitted. This portion will be filtered out before reaching the Q phase splitter. The I signal voltage is now present at the output of the I Demodulator and the Q signal voltage plus the .5 to 1.5 MC portion of the I signal voltage is present at the output of the Q Demodulator. An I gain control is located in the cathode of the I Demodulator so that the output level of I may be varied.

The polarities of I and Q are negative at the output of the demodulators. These signals now pass through two filters. The Q filter passes signals from 0 to .5 MC in frequency, eliminating the .5 to 1.5 MC I signal present at the Q Demodulator output. This filter is composed of 2L122, 2L123, 2C266 and 2R321. The I filter passes signals from 0 to 1.5 MC in frequency. This filter is composed of 2T123, 2C292 and 2C293. These filters will also eliminate any high frequency brightness information. Bandpass characteristics of these filters are shown in FIGURE 57.

From here the Q signal enters the Q Phase Splitter stage and produces positive and negative Q signal voltages. Negative Q is taken from the cathode and positive Q is taken from the plate of the Q Phase Splitter. The plate is D.C. coupled and the cathode is A.C. coupled to the matrix.

The I signal enters the I Amplifier and is amplified to a value similar to the Q signal voltage. Its amplitude is varied by the I gain control. This is necessary since only one sideband of I between .5 to 1.5 MC is transmitted as compared to Q with two



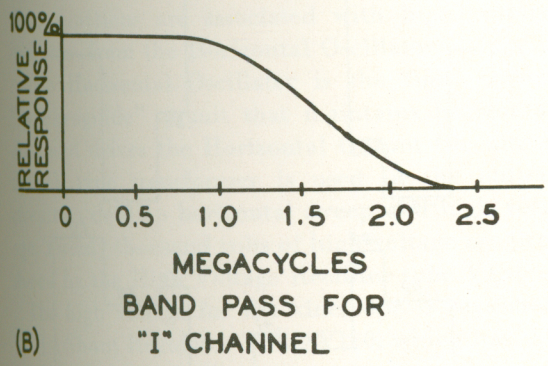




Figure 57 — Band Pass for the I and Q Channels

sidebands. The Q sidebands add, producing twice the amplitude of I. The I signal leaves the I Amplifier and enters the I Phase Splitter stage. This stage produces both the positive and negative I signal voltages. Negative I is AC coupled to the matrix from the plate of the I Phase Splitter Stage. Positive I is DC coupled to the matrix from the cathode of the I Phase Splitter Stage. There are four signal voltages produced at the output of this block; both positive and negative I and Q.

## *Color Matrix and Output*

At the input of this section both I and Q signal voltages of two polarities are present. In order to produce the proper red, green and blue signal voltages at the kinescope, the proper polarities and amplitudes of I and Q signal voltages must be added to the luminance, or Y signal.

This is done in the matrix network which is made up of three resistors in each of the three color channels, as shown in FIGURE 58.

Using a color bar signal as an example, FIGURES 59, 60 and 61 show how the Y, I and Q signal voltages are combined to provide red, green and blue output voltages.

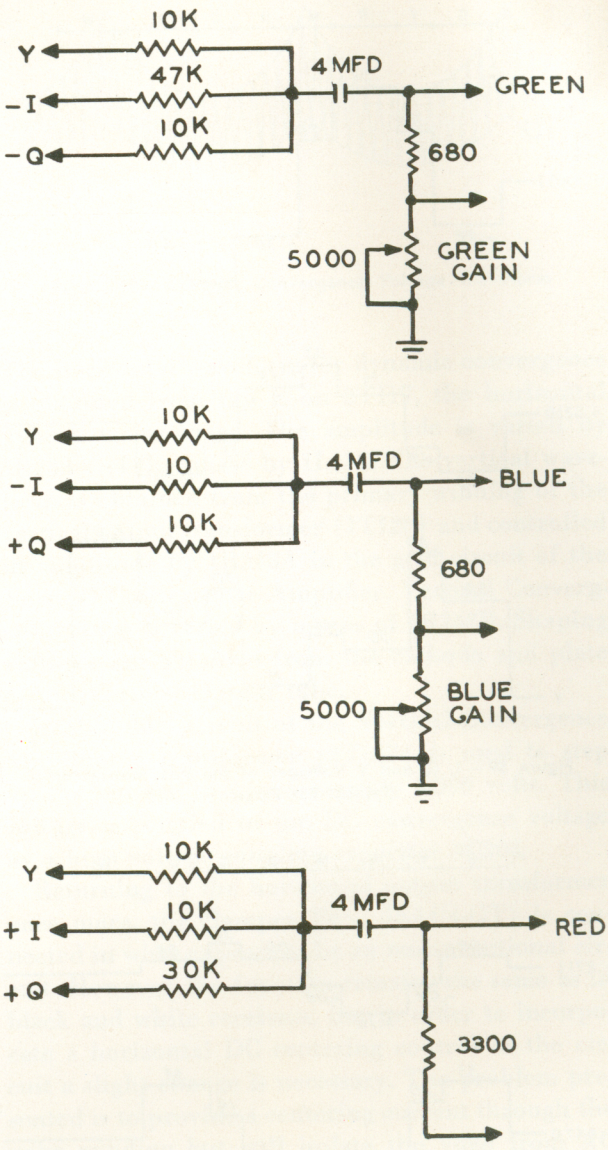



Figure 58 — Green, Blue and Red Matrix Circuits

Specific amplitudes of I and Q are added at the red, green and blue matrix circuits to produce the three required color difference signals. When added to Y, red, green and blue signal voltages are produced and applied to the kinescope grids. As an example, FIGURE 59 indicates that 0.945I + 0.621 Q are required to produce the R-Y color difference signal. When scanning green the three signals add up to zero ((—0.26I) + (—0.33 Q) + (+0.59Y)) in the red matrix and no signal will be applied to the red kinescope gun when the transmitted scene is fully saturated green. At the green matrix (FIGURE 60), however, the three signals add up to pro-

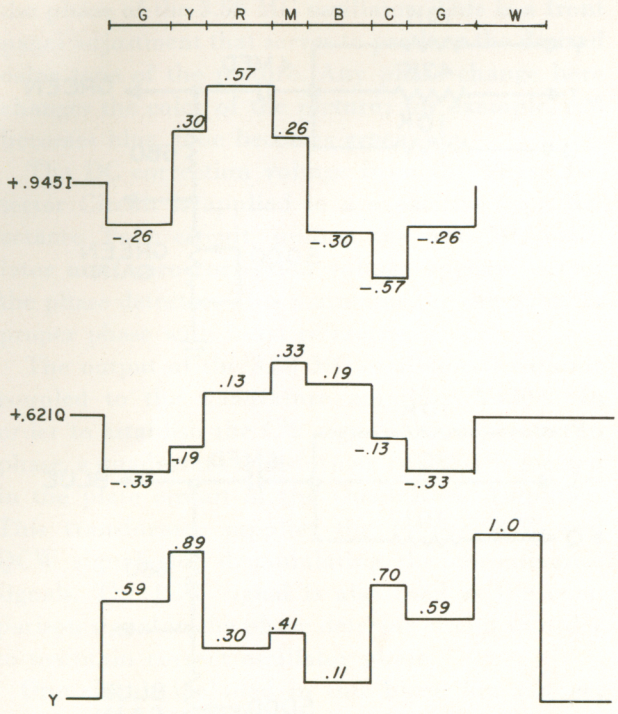



Figure 59 — I, Q and Y Voltages at the Red Matrix for a Typical Bar Pattern

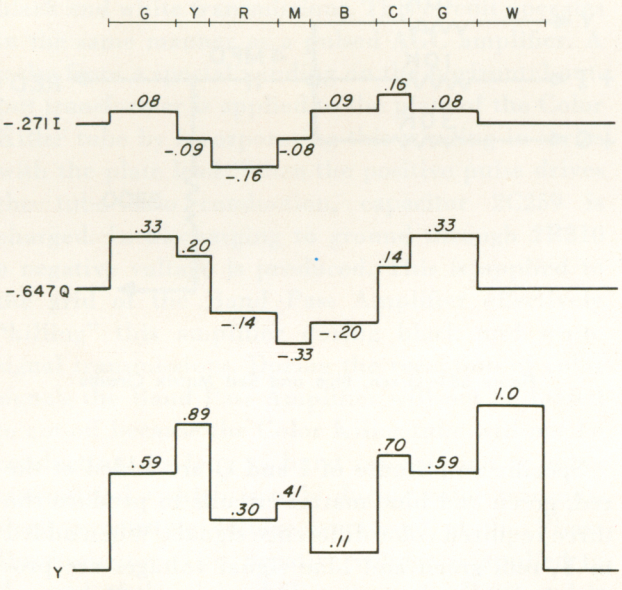



Figure 60 — I, Q and Y Voltages at the Green Matrix for a Typical Bar Pattern

duce 100% input to the green gun when scanning the same green. At the blue matrix (FIGURE 61) complete signal cancellation takes place during the saturated green scene and there is no signal applied to the blue gun of the kinescope.

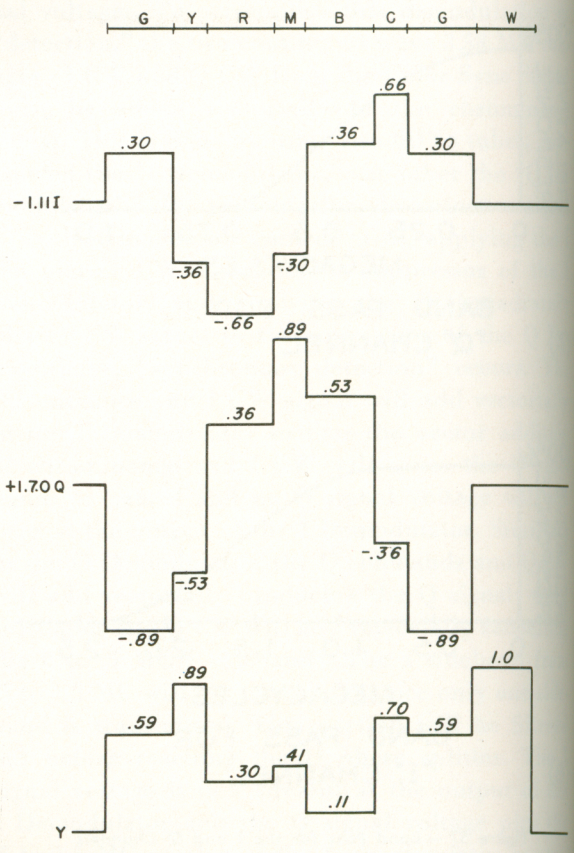



Figure 61 — I, Q and Y Voltages at the Blue Matrix for a Typical Bar Pattern

A gain control is incorporated in the green and blue amplifiers. This is necessary since it takes more signal voltage to drive the red phosphor than the green and blue phosphors, to produce the same light output. The red amplifier is driven at maximum gain and the green and blue amplifiers are driven by lesser, controllable amounts of signal voltage so that the proper amount of light output is obtained from each color phosphor in the kinescope.

Since video information is being amplified through the Color Matrix and Output stages, it is necessary to incorporate high frequency compensation. This is accomplished in the cathode circuit of the output tubes. The cathode resistance of each tube is split and part of the resistance is bypassed to ground by a 470 mmfd capacitor. The high frequencies will be bypassed to ground and the low frequencies will cause some degeneration of the signal in the grid circuit. Some low frequency degenerative voltage is fed back to the Adder grids through resistors (4R229, 5R331 and 6R370). A 6BC7 tri-diode tube is incorporated for DC restora-

tion and the circuits are similar to the DC restoration used in black and white receivers.

## *Horizontal Deflection — High Voltage — Convergence*

This block provides (1) the necessary horizontal deflection voltages for the deflection yoke; (2) high voltage for second anode, focus anode and convergence anode; (3) dynamic convergence waveforms for the kinescope convergence anode. All of these functions are associated with high voltage and stem from the Horizontal Oscillator.

The Horizontal Oscillator is the time proven "Synchroguide" circuit that maintains horizontal sync and drives the Horizontal Output Circuit. A flyback type transformer is used in the output circuit to develop horizontal sweep and high voltage. Twenty thousand volts of high voltage are produced by the High Voltage Rectifier tube V121.

The high voltage for the kinescope is regulated by the Shunt Regulator Tube, V120, which has the effect of maintaining a constant load on the high voltage supply. During an all black picture (no electron beam current) the regulator absorbs the entire load. Conversely, during all white picture, the kinescope takes most of the load and the regulator very little. A voltage divider network taps down on the high voltage supply to produce a voltage for DC convergence (about 10,000 volts). Another tap on the divider provides an adjustment so that the second anode voltage may be properly set.

Referring once more to the horizontal output transformer, a tap is connected to the Focus Rectifier tube, V124. This tube rectifies the high voltage pulses, and the high voltage capacitor (3C218) filters the rectified voltage so that it may be applied to the kinescope focusing anode. A five megohm potentiometer controls the voltage applied to the focusing anode and thereby controls the size of the spot formed by each of the three electron beams. The Vertical Convergence Amplifier is included in this block since its output modulates the 10,000 volt convergence voltage. The purpose of the Vertical Convergence Amplifier (12AU7, V119) is to create a varying voltage that modulates the 10,000 volts applied to the convergence anode in the kinescope. The waveshape of the modulating voltage, if viewed on an oscilloscope, would appear as a series of arcs, parabolic in shape, as shown in FIGURE 62.

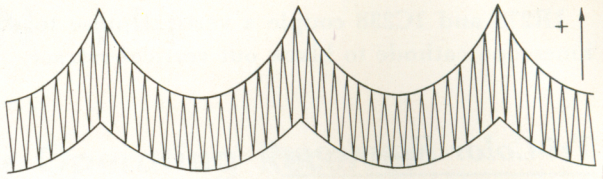



Figure 62 — Dynamic Convergence Voltage Waveform

The horizontal waveform for dynamic convergence is obtained from tap E on 3T117, the horizontal flyback transformer. The amplitude is varied by 1R238 and the phase by 1L138. The vertical waveform is obtained from the primary winding of the vertical output transformer (1T120) and controlled in amplitude by 1R248A in the grid circuit of the Vertical Convergence Amplifier. Vertical Convergence shape is varied by means of 1R248B. Shaping voltages are obtained from the cathode and plate of the Vertical Output tube.

In the plate circuit of the Vertical Convergence Amplifier a transformer (3T127) is used to step up the voltage to approximately 1,500 volts. This voltage is coupled to the DC convergence voltage by a high voltage coupling capacitor 3C204.

Returning to the horizontal output transformer once more, the Damper Tube (6AU4-GT) is connected in what appears to be an unconventional circuit. However, the function remains the same as in black and white receivers, but in order to incorporate a horizontal DC centering control in the circuit a slight change is necessary. The problem presented is to provide a centering current through the yoke winding but still isolate the yoke from AC ground. As B plus is AC ground, a high impedance must be inserted between the yoke and the centering control. To accomplish this, 3L145 and the width coil 3L120 are placed in series across the yoke.

## *Vertical Amplifier*

One tube, a 12BH7 dual triode (V128), is used in the vertical section. One of the triodes is used as a blocking oscillator and the other section as the Vertical Output Stage. Both circuits are conventional to black and white receiver design.

Electrical instead of magnetic centering is used for vertical positioning of the raster. The vertical yoke is also placed above AC ground by means of the vertical centering choke (2T129) in the low voltage power supply.

1R278 and 1C238 couple a vertical pulse to the kinescope cathode to blank out vertical retrace.

## *Tri-Color Kinescope*

The outputs of the Red, Green, and Blue Adders are capacity coupled to the respective grids of the tri-color kinescope. Because the DC level cannot be applied to the kinescope through a capacitor, it is necessary to restore the DC level with a circuit such as is used in many black and white receivers. A triple diode tube, 6BC7, is used here, each diode being a DC Restorer for the red, green and blue outputs.

It will be noticed that three controls are connected to the plates of the DC Restorer tubes. The adjustment of these controls is a part of the field set-up of the color receiver and should be thoroughly understood.

Referring to the simplified schematic in FIGURE 63 it can be seen that the master background control is a brilliance control, since it controls the voltage on the kinescope grid, making it less positive than the cathode.

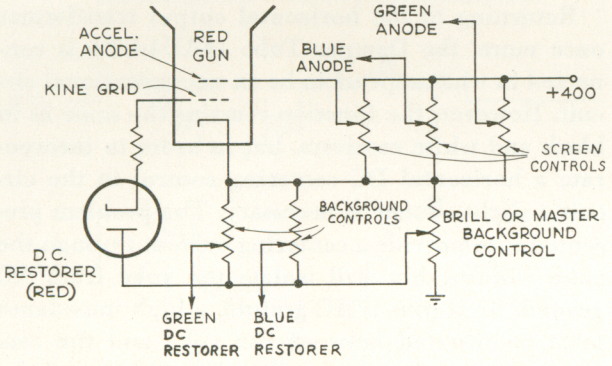



Figure 63 — Simplified Schematic Diagram of the Kinescope Controls

If the green and blue background controls were at the extreme counterclockwise position, the bias on each kinescope grid would be the same. This would result in unequal brightness from the color phosphors resulting in a white raster tinged with some color. If the raster were blue, a slight adjustment of the blue background control would increase the bias on the blue gun and the effect would be to produce a white raster, as all three colors would have equal brightness.

The red, green, and blue screen adjustments can be used to produce a raster of one color by making the accelerating voltage high on one gun and low on the other two. This is usually done while adjusting for a white screen of the proper "white color."

## *Low Voltage Power Supply*

The Low Voltage Power Supply is similar to current black and white receivers using selenium rectifiers in a voltage doubler circuit.

A top B plus of 400 volts, which is slightly higher than most black and white receivers, is obtained from the voltage doubler. The power transformer supplying the AC voltage to the selenium rectifiers is therefore correspondingly larger. Two filament windings are provided — one for all tubes except the AGC Amplifier (V117A) and the Shunt Regulator (V120). These tubes have B plus on the cathode and require an ungrounded filament winding to prevent the possibility of a cathode-filament short within the tubes. A 285 volt bus is supplied to the various blocks of the receiver except the picture and sound IFs. These two blocks are supplied by a separate 285 volt bus.

The low voltage block also supplies centering control and purity control currents. A negative thirty volts created in the ground return of the doubler supplies a needed voltage for the control grid of the Horizontal Sweep Output tube.

# SECTION III

## Instructions to Customer for Operating Receiver

THE FOLLOWING is a procedure for teaching a customer the proper technique for adjusting a typical color television receiver. The procedure merely gives the proper *sequence* of adjustments, and is not intended as a word for word instructional piece to tell the customer. The service technician should use his own judgment in his selection of words, and should repeat the procedure with the customer until the customer is capable and confident enough to perform the receiver adjustment alone.

### *Receiving Color Programs*

Turn OFF-VOLUME right to turn set "on" (allow about 30 seconds warm-up) and advance halfway for medium volume (adjust volume later as desired). Make sure CONTRAST control (beneath cover between main tuning controls) is advanced (to right) at least one-quarter turn.

Select CHANNEL on which a color program is being broadcast. Should sound bars, or no color appear on UHF channels, turn FINE TUNING to most counterclockwise position (on VHF channels, to most clockwise position) until picture starts to disappear. Then turn back slowly to the point where sound bars have just disappeared and color is in the picture.

If still no color, advance COLOR control at least one-quarter turn.

Adjust HUE (redness, blueness) quality of the picture for most pleasing flesh tones or color of some familiar object.

Adjust COLOR for desired saturation or strength.

Alternately adjust the color controls to obtain most pleasing color rendition.

IF color fringes appear on large objects, when receiving a black-and-white picture, adjust CONVERGENCE (side of cabinet) control for minimum fringes in the center of the picture.

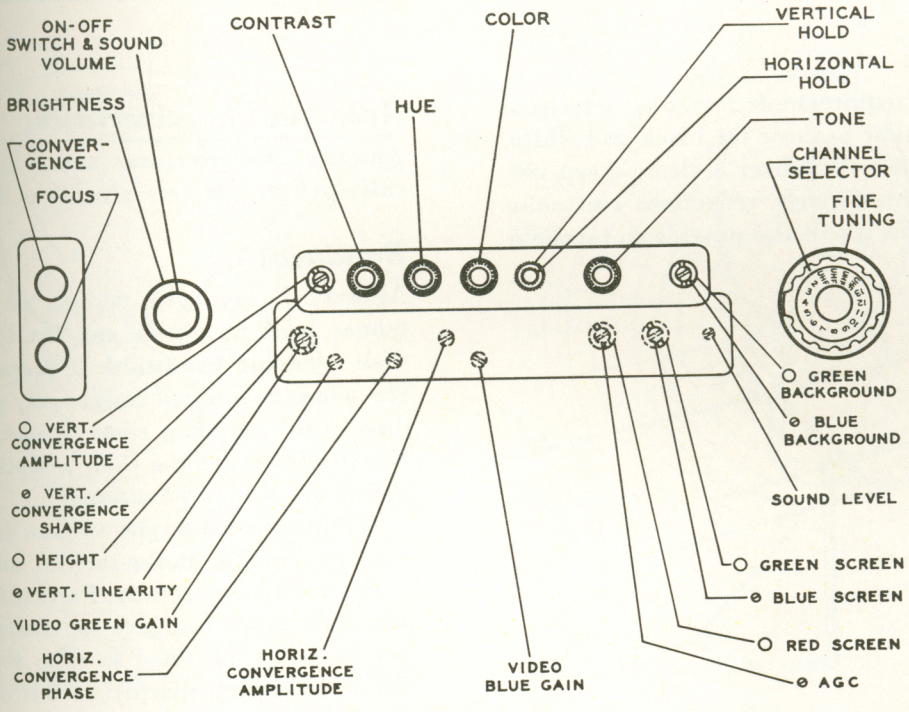



Figure 64 — Front Panel Controls

If picture is blurred, adjust FOCUS (side of cabinet) for clearest detail.

Select TONE preference — emphasize bass, normal or treble tones as TONE control is turned to the right.

NOTE: *On a color telecast, a 920 KC interference pattern may be noticed across the entire screen. Adjustment of the FINE TUNING will correct this situation.*

In switching from one color telecast to another it may be necessary to re-adjust FINE TUNING, COLOR control and the HUE control for best picture on each channel.

To assume finest COLOR program reception — it is *essential* that black-and-white picture be properly tuned-in, with TUNING control positioned, as explained, to receive color signals.

NOTE: *During customer instruction, explain all the similarities between the adjustment of the color receiver and a black and white receiver. Make quite sure that the customer understands the functions of the two additional color controls.*

### *Correctly Tuning-In Black & White Pictures*

Turn OFF-VOLUME right to turn set "on" (allow about 30 seconds warm-up) and advance halfway for medium volume (adjust volume later as desired). Make sure CONTRAST control (beneath cover between main tuning controls) is advanced (to right) at least one-quarter turn.

Turn CHANNEL control until desired UHF station or VHF channel numbers appear in the lighted window.

Turn BRIGHTNESS fully left then slowly right until picture appears. At this point, if picture is moving up or down, diagonally, sideways, or is split into segments, correct by adjusting the horizontal or vertical hold controls.

For UHF—Turn FINE TUNING to most counter-clockwise position; for VHF turn to most clockwise position, until picture starts to disappear. Then turn back *slowly* to the point where sound bars have just disappeared. After picture is on a few minutes, further FINE TUNING adjustments may be required.

## Antenna Considerations for Color Television Reception

IN GENERAL the requirements for color television reception are similar to those for black and white. When the antenna will deliver a clear, sharp picture, free from interference, reflections and noise for black and white, it will also provide an excellent color picture.

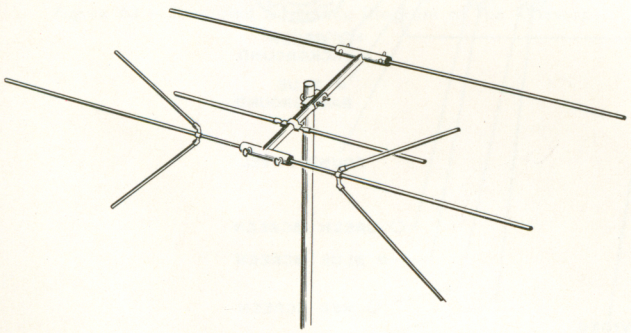


Figure 65 — A Typical Antenna Suitable for Color Reception

### *Antenna Characteristics*

Antenna characteristics and their effect on the color picture can be evaluated as follows:

#### *Bandwidth:*

Almost all standard designs of broadband antennas, such as dipole and fan types, have more than adequate bandwidth if properly installed. A few non-conventional designs may show some sharp dips in the response curve at certain frequencies. When this occurs, the color reception on the channel involved may be altered.

The narrow-band type, such as the multi-element yagi or tunable in-the-cabinet antenna must be examined more carefully. Particularly on channels 2-6, these types can give too sharp a response or can be easily mistuned so as to reject one side of the channel very sharply. If this occurs, the color subcarrier information could be reduced in amplitude resulting in degraded color information.

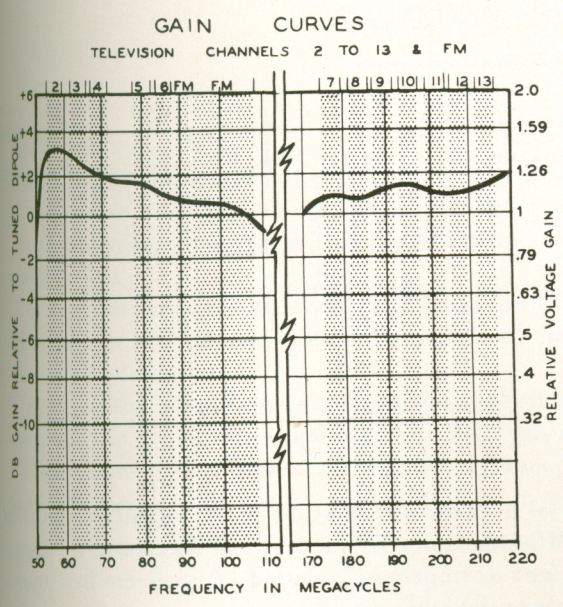



Figure 66 — Gain Curves for the Antenna Shown in Figure 65

### *Directivity:*

This requirement is the same as for black and white reception. Narrow beam-width helps discriminate against reflections, which may appear in various hues and shades in the color picture. Reflections may cause partial or complete cancellation of the color subcarrier "burst" if the reflected path is an odd multiple of a half wavelength at the transmitted subcarrier frequency (i.e. 70.83 MC for channel 4).

Interference pickup, which appears as in black and white reception (but in various colors), may sometimes be reduced by good directivity.

### *Gain:*

As in black and white reception, gain is important only to the point of producing a noise free picture.

### *Voltage Standing Wave Ratio:*

Impedance matching as it affects *vswr* between the transmission line and antenna does not seem too important. A *vswr* of over 5 to 1 has been demonstrated to have no adverse effect on the color picture. The match between transmission line and receiver is somewhat more important. This is mostly the result of RF unit design. Currently available units with a *vswr* of 2- or 3-to-1 seem satisfactory. The service technician can confine himself to insuring proper adjustment of the input tuned circuits, and using a transmission line to match the design impedance of the RF unit input. A deliberate mis-match, such as attaching a 50 ohm cable directly to a 300 ohm input without matching

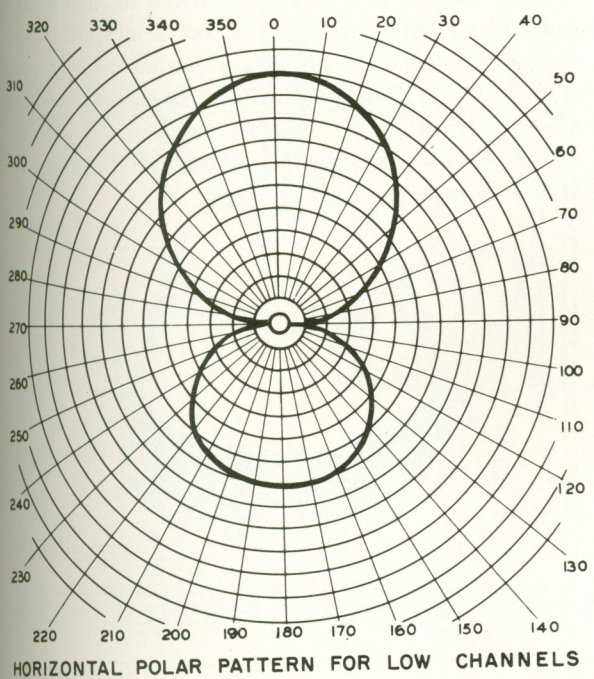



Figure 67 — A Polar Pattern for the Antenna Shown in Figure 65

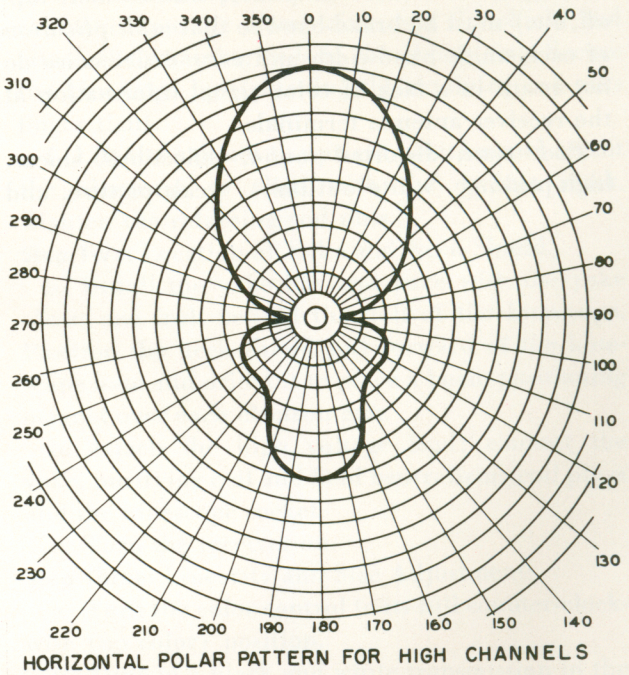



Figure 68 — A Polar Pattern for the Antenna Shown in Figure 65

transformers or pads can cause the same indications mentioned for reflections, particularly if the line is an odd multiple of a quarter wavelength long at the transmitted subcarrier frequency.

## *The Use of RF Booster Amplifiers*

General receiver RF Unit design has progressed to the point where a properly adjusted unit will have a noise figure of very low value. However, should a particular receiver lack gain (or an extremely long transmission line be used) and a booster is required, the bandwidth and *vswr* requirements listed under "Antenna Characteristics" also apply.

The suitability of any booster or RF amplifier for color work depends again on its design. The average single-tuned circuit type may attenuate the color subcarrier "burst" by 3 to 6 db and still be satisfactory if it is not used with an antenna that also discriminates against color information. In this case, either unit may be satisfactory alone, but the *addition* of losses, when the units are used together, may cause a lack of color information.

## *Antenna Distribution Systems*

Multiple outlet distribution systems, with or without amplifiers, have the same requirements as above, however, it should be remembered that each individual unit (i.e. — amplifier, transformer, tap-off, etc.) must be broad-band so that *multiplication* of each unit's bandwidth and *vswr* deficiencies do not result in a lack of color signal information at the receiver antenna terminals.

Poor sync, distorted sound, reflections, smear, high-peaking (white outlines), weak picture, and

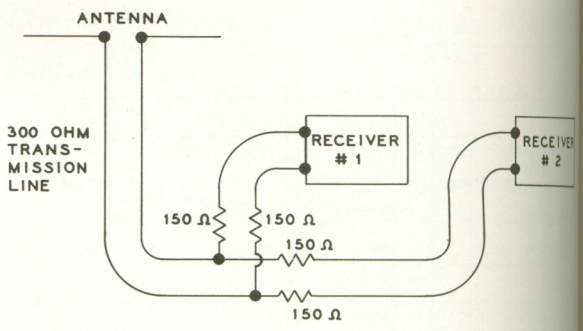



Figure 69 — Coupling Two Receivers to One Antenna

loss of color information in the vicinity of the 3.58 MC subcarrier frequency, can be caused by insufficient or improper isolation of receivers in a multiple outlet system.

Most receivers (and RF amplifiers) have input circuits which match the transmission line *only* on the channel to which they are tuned. On any other channel they may reflect back into the transmission line anything from an open to a short circuit. To prevent this, each receiver should have *at least* 6 db of resistive isolation from the transmission line.

Many color television receivers will be installed in place of, or in addition to, present black-and-white receivers and may be attached to the existing antenna system. FIGURE 69 shows a method of isolating two receivers which are connected to a common 300 ohm transmission line. In instances where 72 ohm transmission line is installed, 39 ohm resistors should be substituted for the 150 ohm resistors shown.

# Receiver "Set-Up" Procedure

**Step One:** Installation of Kinescope.

a. Remove the cabinet top, the cabinet rear panel, the yoke support bar and the kinescope top clamp.

b. Lay the receiver cabinet face down on the floor with a quilted pad under the top front just above the safety glass.

c. Place the kinescope face down on a cloth or pad. The top of the kinescope is in line with pin 17 on the kinescope socket. Viewing the kinescope from the rear, install the second anode clip on the anode ring slightly to the right of the top of the kinescope.

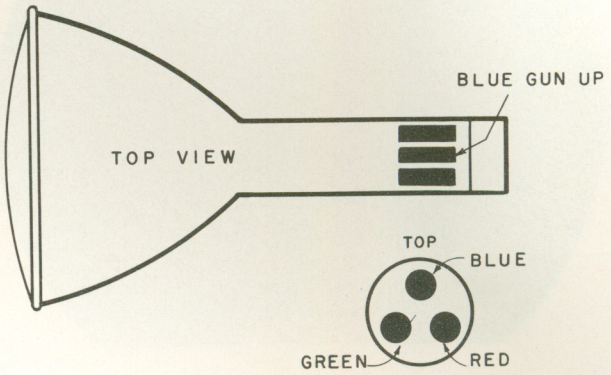



Figure 71 — Correct Installation Position of the Kinescope

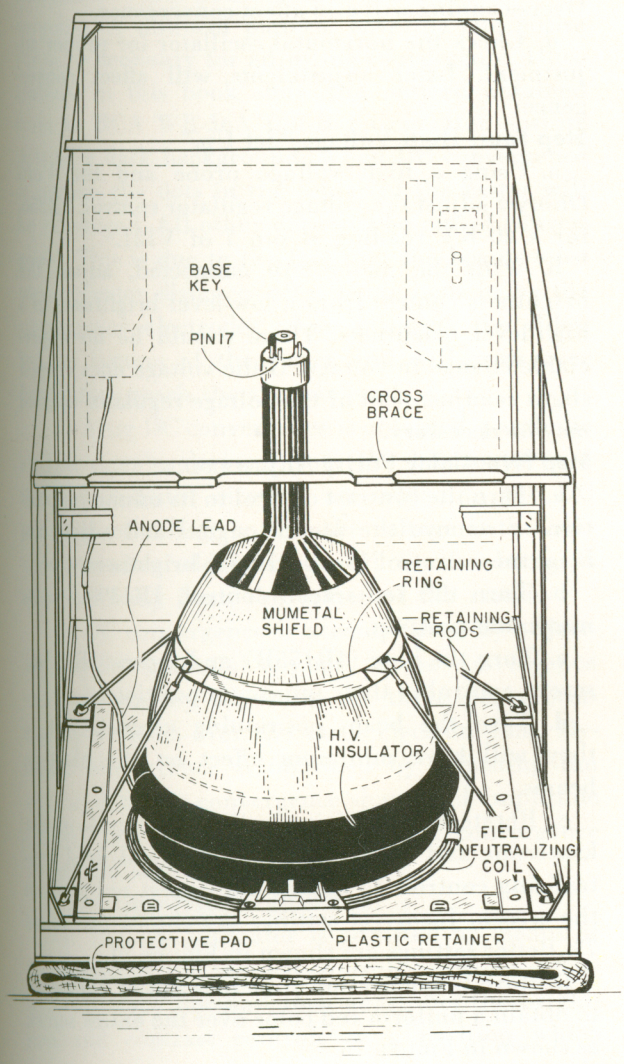



Figure 70 — Tri-Color Kinescope Installation

d. Place the kinescope insulator over the anode ring, with the overlap arranged to allow the second anode lead to come through at the right side of the kinescope. Place the mu-metal shield over the insulator making sure the grounding spring contacts the aquadag coating of the kinescope.

e. Install the kinescope in the cabinet with pin 17 on the kinescope socket toward the top of the cabinet. Place the clamp ring over the shield and attach the retaining rods to the clamp ring. Secure the kinescope by tightening the retaining rod nuts finger tight.

f. Lift the cabinet to upright position and orient the kinescope to align with the cabinet mask. Tighten the retaining rod nuts.

**Step Two:** Location of Yoke and Neck Shield.

a. Install the yoke bar and yoke with the yoke about one inch behind the bell of the kinescope. Position the neck shield just forward of the kinescope base and orient it to place a beam positioning magnet over each electron gun.

b. Attach the high voltage lead; connect the yoke, purifying coil and field neutralizing coil plugs and the kinescope socket.

c. Turn the receiver on.

**Step Three:** Linearity and Size Adjustments.

a. Turn the color control to its full counter-clockwise (no color) position.

b. Tune in a black and white transmission in the normal manner.

c. Make sure that the linearity of the picture is

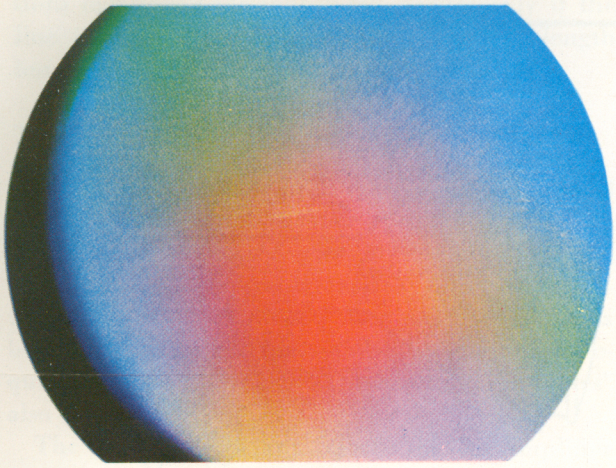


Figure 73 — Incorrect Purity Adjustment



Figure 74 — Better Purity Adjustment

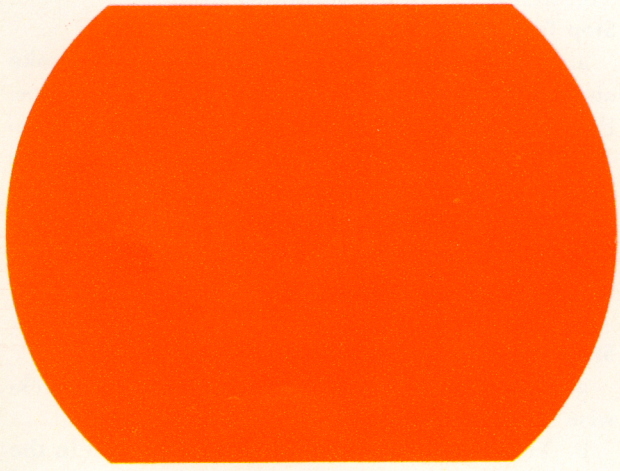


Figure 75 — Correct Purity Adjustment for the Red Screen

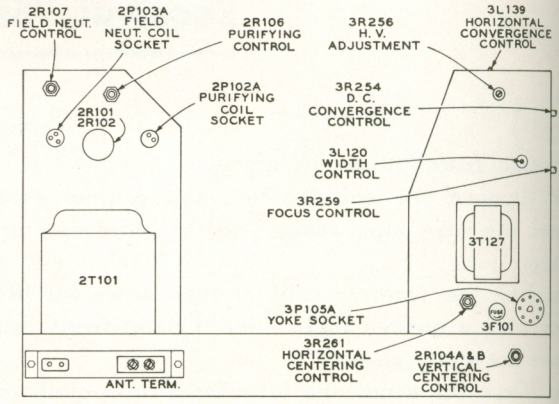



Figure 72 — Chassis Rear View Showing Adjustments

correct, as any readjustment of linearity and size controls will affect dynamic convergence voltages. Over-scanning will also affect convergence.

d. Check the horizontal oscillator for proper adjustment. Later adjustments will affect convergence.

**Step Four:** High Voltage "Set Up."

a. Using a high voltage probe and the *Volt-Ohmyst* adjust the voltage regulator control, 3R256, for a 20 KV reading at pin 7 of V121.

b. With the meter still connected, adjust the brightness control from a low-level brightness to a high-level brightness. There should be no appreciable change in voltage. If the voltage does vary, a slight readjustment of the voltage regulator control may be necessary.

**Step Five:** Color Purity Adjustments.

a. Turn the contrast control to its minimum position to remove the picture signal and adjust the brightness control for maximum brightness.

b. Turn the red screen control, 1R139A, to its maximum position.

c. Turn the blue (1R155B) and green (1R155A) screen control to their minimum positions.

d. Turn the beam positioning magnets out so they will have minimum effect on the electron beams.

e. Rotate the purifying coil on the neck of the kinescope and adjust the purifying and field neutralizing controls to obtain the largest red area on the screen. Incorrect settings are shown in FIGURE 73. Better settings are shown in FIGURE 74.

f. Move the deflection yoke forward or backward to obtain a uniform red color over the entire screen as shown in FIGURE 75.

g. If a pure red field is still not obtained readjust the purifying and field neutralizing controls.

h. Next, check the blue purity by turning down the red screen control and turning up the blue screen control. Green purity should be checked by turning down the red and blue screen controls and turning up the green screen control. If some contamination remains, it may be necessary to make a compromise adjustment for best results on all three fields. Correct purity adjustments for the green and blue screens is shown in FIGURES 76 and 77, respectively.

**Step Six:** Setting the Kinescope to White.

a. With the color and contrast controls set to minimum, turn the brightness control to maximum.

b. Adjust the red, blue and green screen controls for a low brightness white as in FIGURE 78.

**Step Seven:** Convergence Adjustments.

a. General Considerations.

1. Convergence adjustments are divided into two classes — DC Convergence and Dynamic Convergence. A uniform pattern, covering the entire raster, is necessary for adjusting convergence. Illustrations in this book show the pattern obtained from an RCA WR-36A Dot-Bar Generator — white dots on a dark background. When DC convergence is proper, the dots in the center of the raster will be converged. All other dots will be out of convergence. This is due to the fact that the beams must travel greater distances after being bent in by the convergence electrodes when scanning the sides, top, or bottom of the raster and will cross over before they reach the shadow mask.

2. After DC convergence is obtained, parabolic shaped signals, derived from the horizontal and vertical oscillator circuits, are added to the DC convergence voltage so that the voltage at the convergence electrode is increased as the beam is deflected away from the center of the raster.

3. DC convergence is accomplished by adjusting the DC potential applied to the convergence electrode and by adjusting the three beam positioning magnets over the three electron guns. Dynamic convergence is obtained by adjusting the vertical dynamic convergence shape and amplitude controls and the horizontal dynamic convergence phase and amplitude controls.

b. Dot Generator Adjustment

1. The dot generator is adjusted by means of its horizontal and vertical controls to produce dots approximately one-half inch apart. Set the brightness and contrast controls to a position which prevents "blooming" of the dot pattern. A properly converged dot pattern is shown in FIGURE 79.

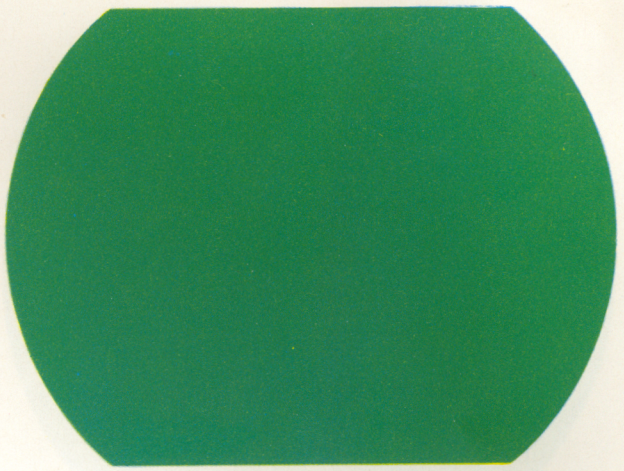


Figure 76 — Correct Purity Adjustment for the Green Screen

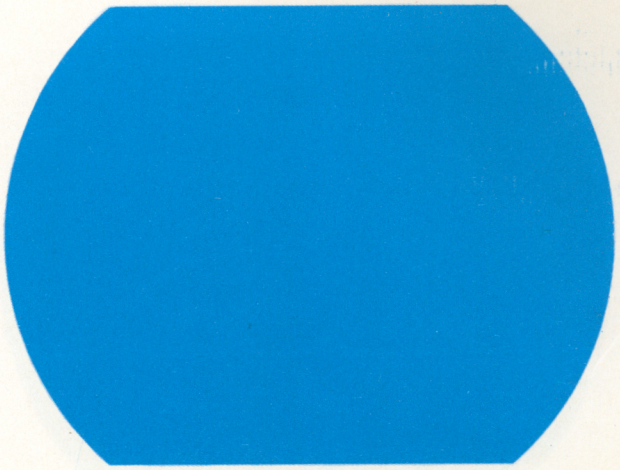


Figure 77 — Correct Purity Adjustment for the Blue Screen

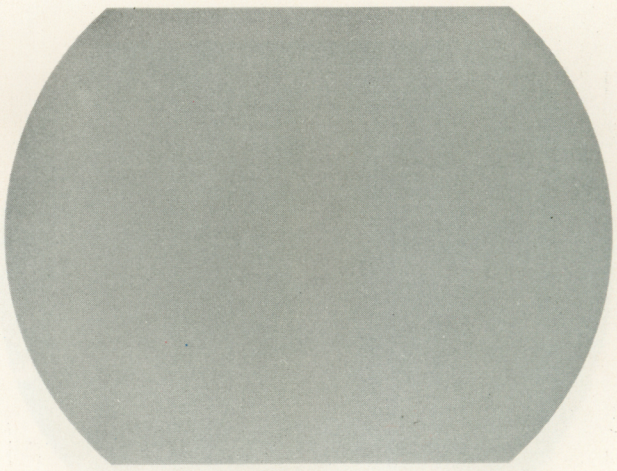


Figure 78 — Proper White Balance Between Red, Green and Blue Screens

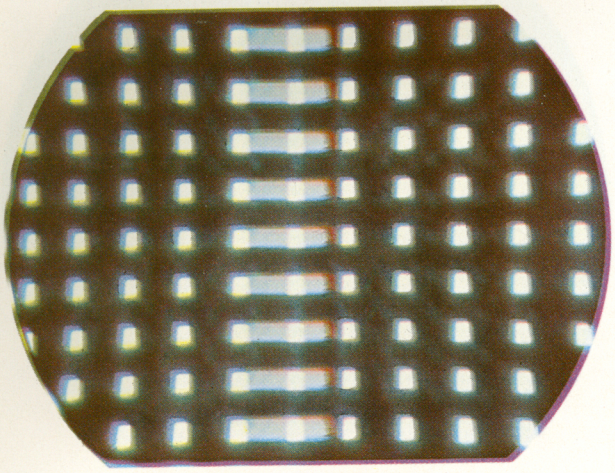


Figure 79 — Properly Converged Dot Pattern

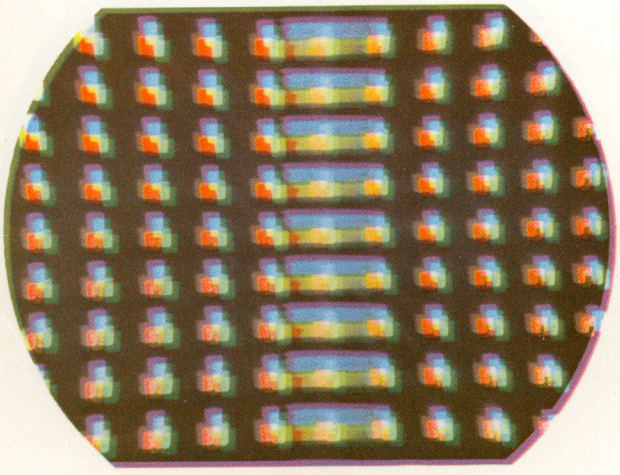


Figure 80 — DC Convergence Voltage Too High

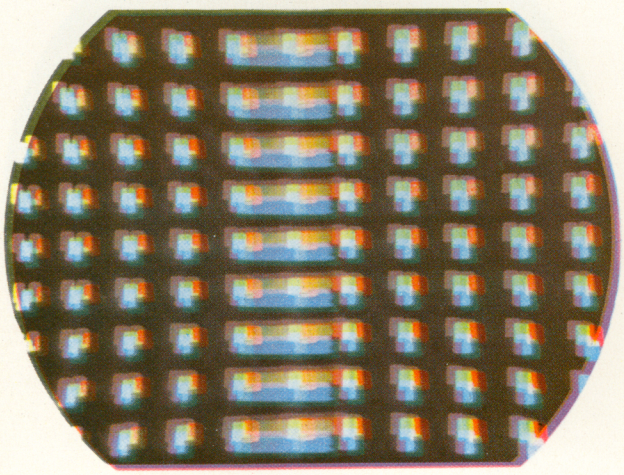


Figure 81 — DC Convergence Voltage Too Low

c. Initial Receiver Adjustment

1. Turn the horizontal dynamic amplitude control 1R238 to minimum. Turn the vertical dynamic amplitude control 1R248B and shape control 1R248A to minimum.

2. Turn the beam positioning magnets out to the edge of the neck shield. Turn the DC convergence control 2R254 to obtain best convergence of the dots in the center of the raster. FIGURE 80 illustrates under-convergence (too high a value of DC convergence voltage). FIGURE 81 illustrates over-convergence (too low a value of DC convergence voltage).

3. With the DC convergence control set to obtain optimum white in the center dots, adjust the beam positioning magnets, as necessary, to obtain perfect convergence in the center of the raster.

4. These magnets may be turned out of the shield and the opposite end inserted, if necessary, to obtain greater adjustment range. A dot pattern with proper center convergence is shown in FIGURE 82.

d. Dynamic Convergence Adjustment

The dynamic convergence adjustments should now be made. Vertical and horizontal dynamic convergence adjustments provide correct dot overlap of the dot generator pattern at the top, bottom, and sides of the raster. Horizontal and vertical dynamic controls are inter-acting and the adjustment of one may affect the adjustment of the others. It has been found best to begin with the adjustment of vertical dynamic convergence.

e. Vertical Dynamic Convergence

Adjust the vertical dynamic shape control

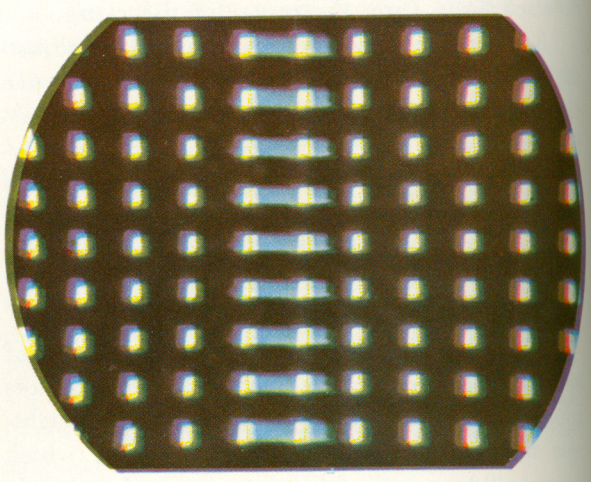


Figure 82 — DC Convergence Correct

1R248B until the extreme top and bottom dots show equal displacement error. FIGURE 83 illustrates improper vertical shape control adjustment. Adjust the vertical dynamic convergence amplitude control 1R248A until all dots along a vertical line through the center of the raster show equal displacement error. (See FIGURE 84.) When this condition is obtained, adjusting the DC convergence control will converge the dots that are on this vertical line.

f. Horizontal Dynamic Convergence

Adjust the horizontal dynamic phase control 1L138 until the extreme left and right center dots are equally displaced. FIGURE 85 illustrates an improper setting of the phase control while FIGURE 86 illustrates the correct setting of this control. Adjust the horizontal amplitude control 1R238 until all dots along a horizontal line through the center of the raster show equal displacement. Adjust the DC convergence control to converge dots on the horizontal center line. FIGURE 79 shows proper over-all convergence.

NOTE: *It has been found that in some tubes purity is improved if the tube is converged before purity adjustments are made. After adjusting purity in this manner, convergence must again be set.*

**Step Eight:** White Adjustment.

(Remove the dot generator.)

a. Turn the color control and contrast control to minimum.

b. Turn brightness control to maximum.

c. Adjust the red screen control 1R139A, blue screen 1R155B, and green screen control 1R155A to

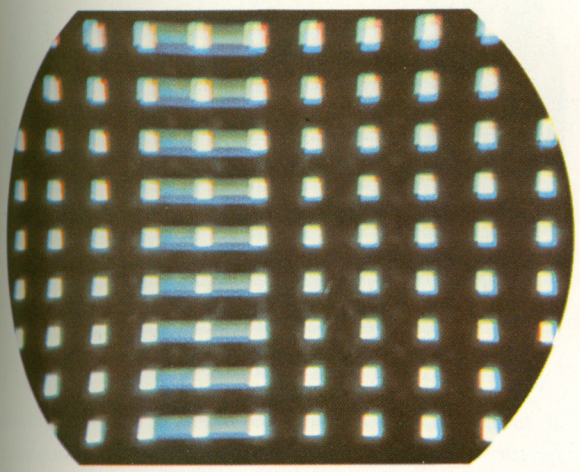


Figure 83 — Vertical Shape Control Misadjusted

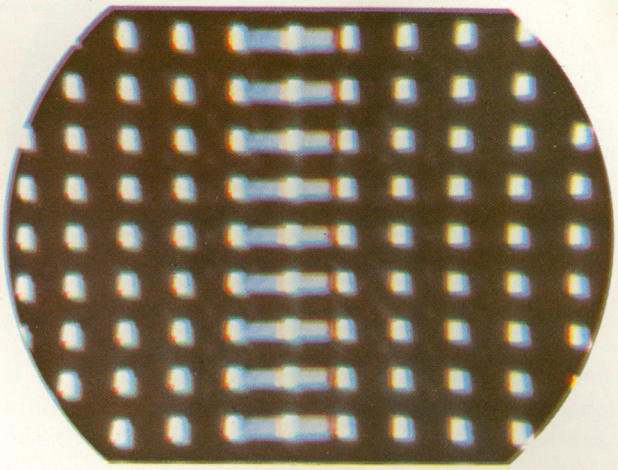


Figure 84 — Vertical Shape and Amplitude Controls Correct

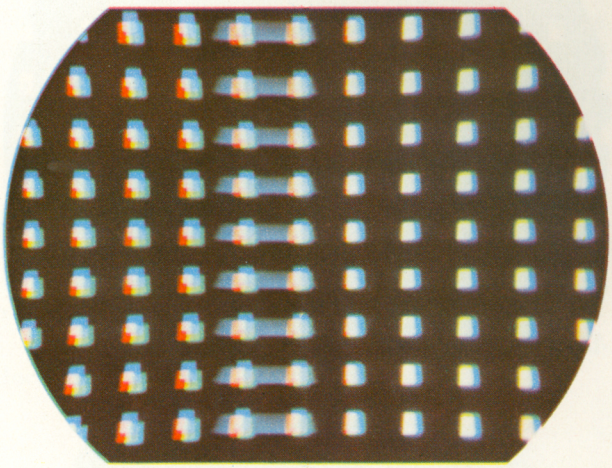


Figure 85 — Horizontal Dynamic Phase Incorrect

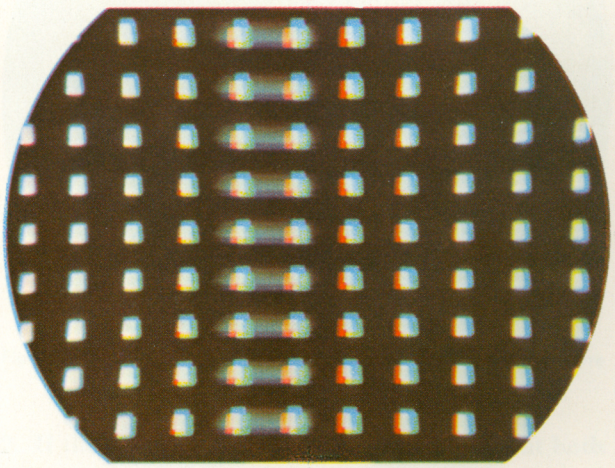


Figure 86 — Horizontal Dynamic Phase Correct

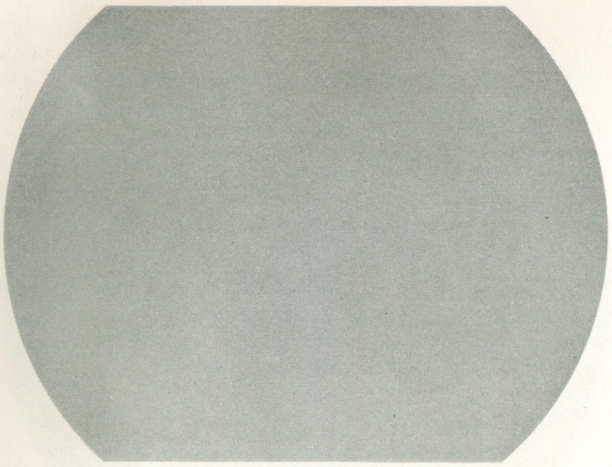


Figure 87 — Correct White Adjustment

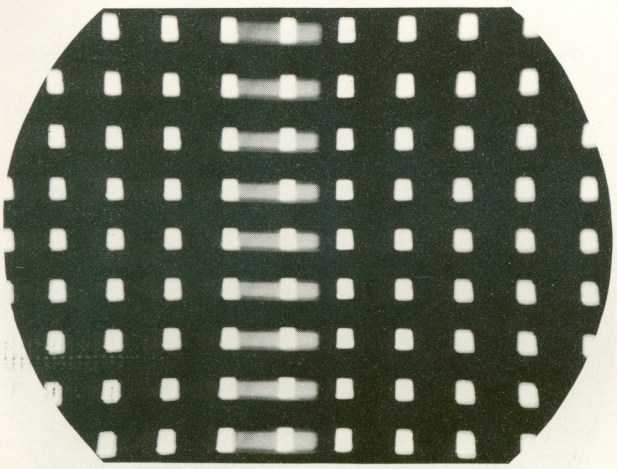


Figure 88 — Correct White Highlight Adjustment

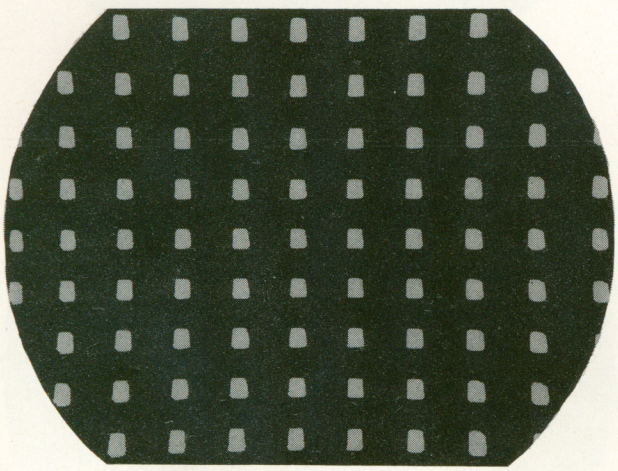


Figure 89 — Correct White Lowlight Adjustment

a low brightness white. The "color" of the white should be about the white produced by a low brightness setting on a standard black and white kinescope as shown in FIGURE 87.

**Step Nine:** Highlight Adjustment.

a. With the brightness control still fully clockwise, turn the contrast control to some mid-position.

b. Tune in a black and white picture or the Dot-Bar Generator pattern.

c. Adjust the blue gain control 5R330 and the green gain control 4R228 until a white (same reference white as in step eight) appears on the high brightness highlights in the picture. FIGURE 88 illustrates correct white highlight adjustment.

**Step Ten:** Lowlight Adjustment.

a. With the contrast control still at mid-position, turn the brightness control down to a reduced value. Adjust the blue (1R162B) and green (1R162A) background controls to reach an equal white on the lowlights in the picture (See FIGURE 89). FIGURE 90 illustrates insufficient blue and green background control. Steps Nine and Ten should be repeated until the "white" is made to track from highlights to lowlights using the contrast control.

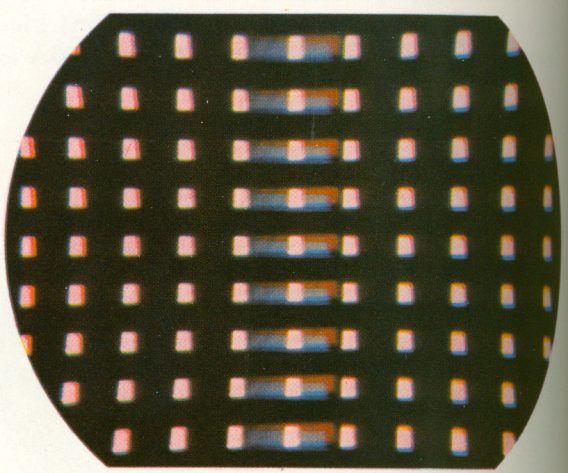


Figure 90 — Insufficient Blue and Green Background Control

# Servicing the Color Television Receiver

After studying the schematic diagram of the color TV receiver the servicing problems would seem to be much greater than those in black and white receivers. Although some new and unfamiliar circuits are encountered, servicing need not be exceptionally difficult if a logical pattern of good trouble-shooting techniques is followed. The expert technician follows the system of block diagram analysis to quickly isolate troubles. The system divides the receiver into sections or blocks according to functions. However, the purpose and theory of operation of each block of the receiver must be thoroughly understood by the technician in order for him to become proficient in the diagnosis and location of troubles. The schematic diagram of this RCA color television receiver has been divided into functional blocks, not only for the purpose of understanding the operation of the receiver, but also as an aid to developing a servicing technique.

In isolating troubles in a color receiver it is well to remember that the receiver is basically a reproducer of black and white pictures, and that certain additional circuits are devoted entirely to color. It is logical to assume, then, that the first step to locate receiver malfunction would be to observe the reception of a black and white transmission.

## *Checking Black and White Reception*

Operating the color receiver as a black and white receiver will reveal:

1. Faults in circuits common to color receivers *and* black and white receivers. (See *Basic Circuit Description of a Typical RCA Color TV Receiver.*)
2. Faults in producing pure primary color fields (kinescope block).
3. Faults in convergence and focus (Kinescope, Vertical Deflection and Convergence blocks).
4. Faults that prevent the forming of uniform white or gray scale. (Kinescope and Color Matrix blocks.)

## *Pure Primary Color Field Troubles*

Receiver faults in this category have the effect of producing a primary color shading over the entire field of an otherwise normal black and white picture. This type of malfunction is confined to the kinescope block and can be located by following the procedure for obtaining color purity, as described in *Receiver Set Up Procedure.*

## *Convergence and Focus Troubles*

If proper convergence over the entire face of the kinescope cannot be obtained by following the setup procedure outlined in the previous section, the following steps should be taken:

1. If the kinescope cannot be made to converge in the center of the raster it may be necessary to check the convergence voltage. The DC convergence circuits are designated so that at one end of the range of the DC convergence control the blue dot should appear at the top and at the other end of the range, the blue dot should appear at the bottom. This is illustrated in Figures 80 and 81. If the blue dot remains on top at all settings of the DC convergence control, the convergence voltage is too high. Check the setting of the phase control and check the dynamic convergence circuits with the aid of an oscilloscope.

Figure 91 shows how improper convergence affects a black and white picture.

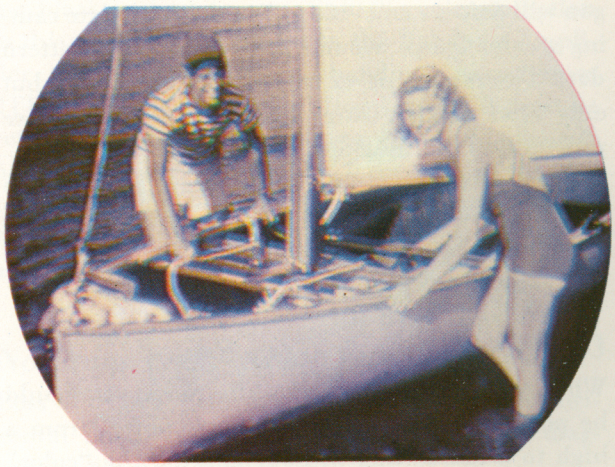


Figure 91 — Improper Convergence on a Black and White Picture

2. If the raster will converge in the center but both sides are out of convergence, check the horizontal dynamic voltages by rotating the horizontal ampli-

tude control and noting the difference. If convergence voltage is present but has insufficient amplitude, check the peaking of the convergence amplifier circuits. Remember also that any malfunction in the Horizontal Deflection or Horizontal Oscillator circuits will affect the convergence voltage.

3. If the raster comes into convergence on one side of the screen before the other, a re-check of the horizontal phasing adjustments should be made. Check the Convergence Amplifier tube and the Horizontal Output Amplifier tube in addition to the phase coil adjustment.

4. If the raster will converge on the sides but not at top and bottom of the screen, a check of the vertical dynamic amplitude and shape should be made. FIGURE 83 illustrates this condition, which should be checked with a scope. A fault in the Vertical Output stage can cause this voltage to vary.

5. If the convergence voltages are correct and the raster cannot be made to converge through the range of the DC convergence control, the kinescope and/or yoke should be replaced.

6. An effect of improper convergence may be noted when there is a fault in the Color Matrix block resulting in poor frequency response of one video stage only. This can be seen on the kinescope as a fringe of one color around the white dots of a convergence pattern. Check for peaking and proper response in the Color Adder section involved.

7. An effect similar to the trouble outlined in step 6 may be caused by low emission from one of the guns of the kinescope. The beam from the defective gun will defocus and "bloom" at the face plate causing a color fringe around the convergence pattern dots. The remedy is to replace the kinescope, but only after making sure that proper voltages are present on the kinescope.

8. If an abrupt shift in convergence is noted make sure that the high voltage regulator circuit is operating properly. A shift in high voltage will shift convergence voltages also.

## *Uniform White or Gray Scale*

While viewing a black and white picture it should be possible to vary the brightness control from a high to a low setting without altering the "color" of white or gray. In other words, after the correct white is obtained on a raster there should be no color contamination of the highlights or lowlights in a black and white picture. If such a condition does not exist, then "tracking" adjustments must be made as follows:

### *Highlight Adjustment*

a. With the brightness control turned clockwise, turn the contrast control to mid-position.

b. Tune in a black and white picture, or a *Dot-Bar Generator* pattern.

c. Adjust the blue gain control 5R330 and the green gain control 4R228 until a white of the same "color" as the raster appears on the high brightness highlights in the picture

If the preceding adjustments cannot be obtained, the trouble is in the adder circuit which controls the complementary hue of the color shading on the face of the kinescope. For example, if the kinescope field is magenta, the green adder circuit is defective, green being the complement of magenta. Before troubleshooting the adder circuits, make sure the raster is normal without video drive being applied to the kinescope grids.

### *Lowlight Adjustment*

a. With the contrast control still at mid-position, turn the brightness control down to a reduced value. Adjust the blue (1R162B) and green (1R162A) background controls to reach a match on the low lights in the picture. It may be necessary to repeat the highlight and lowlight adjustments until "tracking" is obtained.

## *Checking Color Reception*

If no troubles are apparent on a black and white picture, reception of color transmissions should next be checked. If any picture fault is seen, it is logical to assume that the fault is located in the

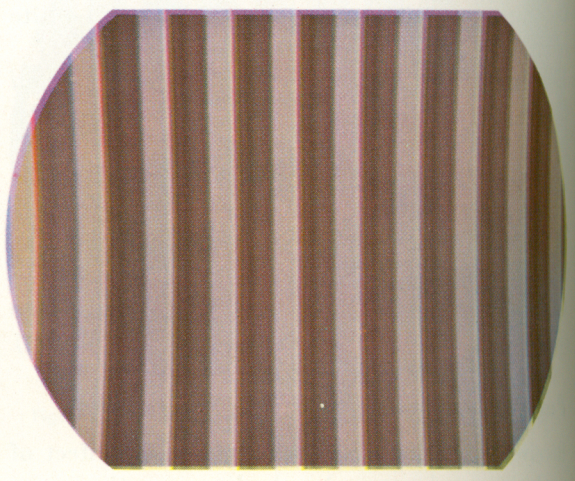


Figure 92 — RCA Color Bar Generator Pattern — Color Missing

Color Sync block or Demodulation—Phase Inversion block. In these two blocks trouble can occur that will not affect the reproduction of a black and white picture.

FIGURE 92 illustrates the bar pattern provided by the *RCA Color Bar Generator* with color missing. There are three types of trouble that can originate in one or both of these blocks:

1. No color reproduction
2. No color lock (synchronization)
3. Improper color rendition

In the following descriptions, two illustrations are used to demonstrate the same circuit trouble, in many cases. One is a typical televised scene and the other is the bar pattern for that trouble obtained from the *RCA Color Bar Generator* described in *Test Equipment for Color Television Receiver Servicing*. Referring to FIGURE 93, the normal bar pattern consists of ten color bars. From left to right the bars are as follows: (1) dull yellowish-orange; (2) orange (+I); (3) bright red + (R-Y); (4) bluish-red; (5) magenta (+Q); (6) blue + (B-Y); (7) greenish-blue; (8) cyan (—I); (9) bright bluish-green — (R-Y); and (10) dark green. These bars are formed by chrominance signals with thirty degrees phase displacement between each bar. The first visible bar represents 30° from burst, the second 60°, etc. Although I is 57° from burst, the three degree difference between this and the second bar is not important since the eye is incapable of detecting the difference in color. Although ten color bars are visible on the screen, twelve bars are produced by the *RCA Color Bar Generator*, providing chrominance signal phase rotation of 360°, in increments of 30°. The two bars not seen occur during the horizontal blanking interval. The eleventh bar represents a chrominance phase of 330°, while the twelfth is in phase with burst, or 0°. The colors and phases of each color bar will be further consolidated by plotting the bars on the vector diagram in FIGURE 37.

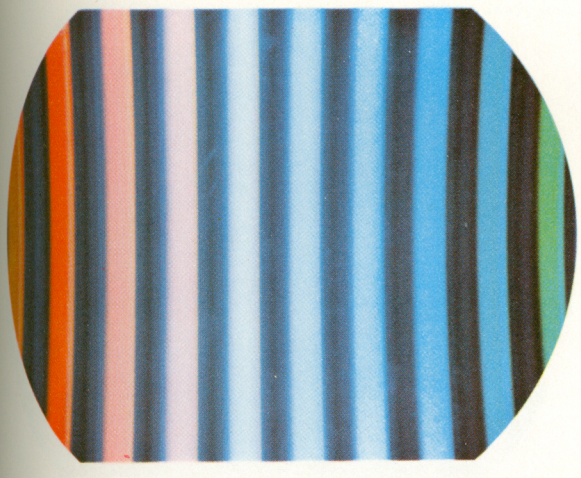


Figure 93 — Normal Color Bar Generator Pattern

## *Faults Resulting in No Color*

Before looking for tube or component failures a check should be made to see that the set is properly adjusted to receive color and that the channel selected is transmitting a color program. The color control should be advanced and the fine tuning properly set. Also check the following:

1. Check the operation of the 3.58 MC crystal oscillator. A good method is to measure the voltage at the cathode of the oscillator tube using the *Volt-Ohmyst* with a calibrated RF probe. If the oscillator is functioning properly, the peak-to-peak reading should be approximately 5 volts. If this reading is unobtainable, the crystal or the oscillator tube may be defective. Also, check the oscillator circuit components as the oscillator may be greatly off frequency.
2. Check the Bandpass Amplifier tube and components up to the grids of the I and Q Demodulators. Although the Bandpass Amplifier is not in one of the blocks under discussion, troubles in this circuit can most definitely cause color faults not affecting black and white reception. No color reception in this circuit could be due to the Bandpass Amplifier tube (V116A), the bandpass transformer 2T126, or associated circuit components. It must be remembered that the Bandpass Amplifier tube can be driven to cut-off by a bias from the Color Killer tube; the killer tube will supply this cut-off bias if the grid bias to the Color Killer is lost due to the absence of burst.

## *No Color Lock (Sync)*

Loss of color synchronization will show up as horizontal bands of color moving vertically or diagonally. See FIGURE 94.

If the color bands are very few in number, it indicates that the 3.58 MC oscillator is only slightly off frequency. Loss of color sync can be caused by:

1. Failure in the Color Phase Discriminator circuit
2. Failure in the Reactance Tube circuit
3. 3.58 MC oscillator slightly off frequency

## *Improper Color Rendition*

Any fault that causes a change in the phase relationship between I and Q will produce improper colors:

1. Hue control misadjusted

Before trouble shooting for this fault it is advisable to check the hue control on the front panel of the receiver. An example of this is shown in FIGURE 95, as opposed to a normal scene in FIGURE 96.

2. Quadrature Transformer Phase Off

The Quadrature Transformer is responsible for the 90 degree shift in phase of the Q CW signal to the I CW signal. Therefore, troubles here could be expected to cause improper color rendition.

Quadrature may be checked using the *Color Bar Generator*. Remove the Q demodulator tube and adjust the hue control to obtain the colors shown in FIGURE 97. Notice that the fifth bar has no color. Replace the Q demodulator tube and remove the I demodulator tube. The colors should be similar to those shown in FIGURE 98, with the second and eighth bars devoid of color. With this pattern indicated, the I and Q channels are in quadrature. The *RCA Color Bar Generator* may also be used to check quadrature in a receiver demodulating on R-Y and B-Y coordinates. In this receiver, remove the B-Y demodulator tube and adjust the hue control for no color in the sixth bar. Replace the B-Y demodulator and remove the R-Y demodulator tube. If the circuits are in quadrature, the third and ninth bars will be devoid of color.

It will be noticed from FIGURES 97 and 98 that removal of the Q demodulator tube made little difference in the televised outdoor scene, while removal of the I demodulator made a major difference in the scene. This is true because the scene shown contains little Q signal information—most colors being reproducible by the I signal alone. Notice, however, that the *RCA Color Bar Generator* readily indicates the absence of Q signal, since the generator is not dependent on transmitted signal content for operation.



Figure 94 — Loss of Color Sync

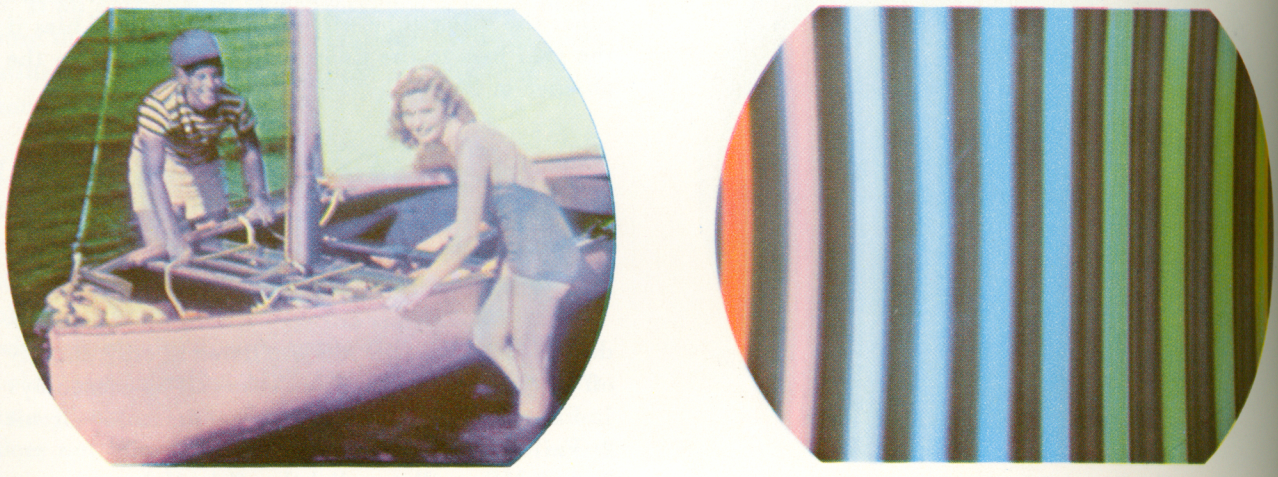


Figure 95 — Incorrect Hue Control Adjustment



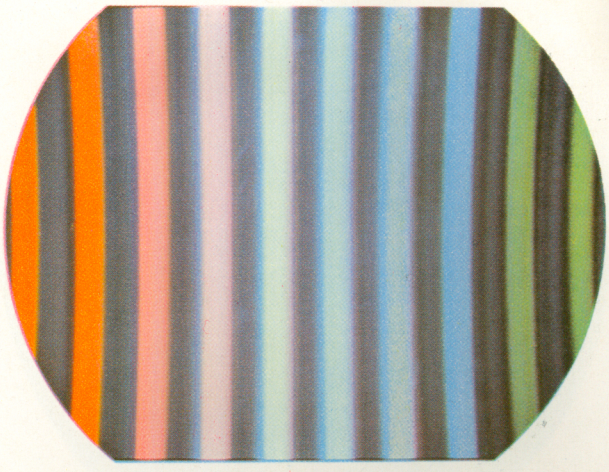


Figure 96 — Normal Picture



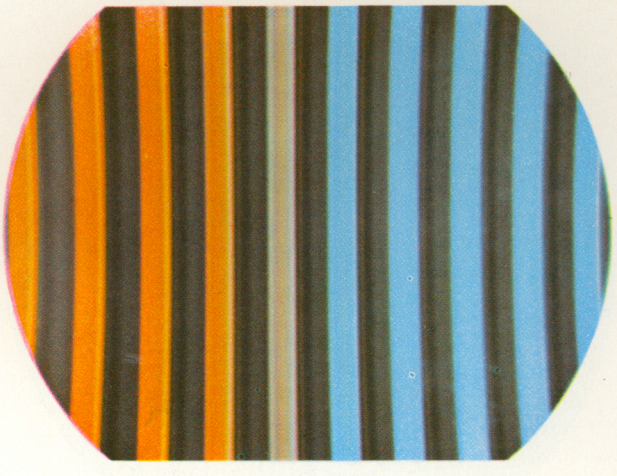


Figure 97 — Color Picture Minus the Q Signal



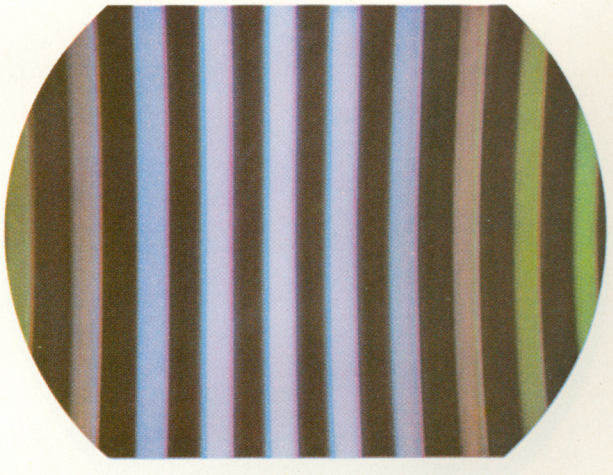


Figure 98 — Color Picture Minus the I Signal



Figure 99 — Color Bar Pattern with Picture Carrier High

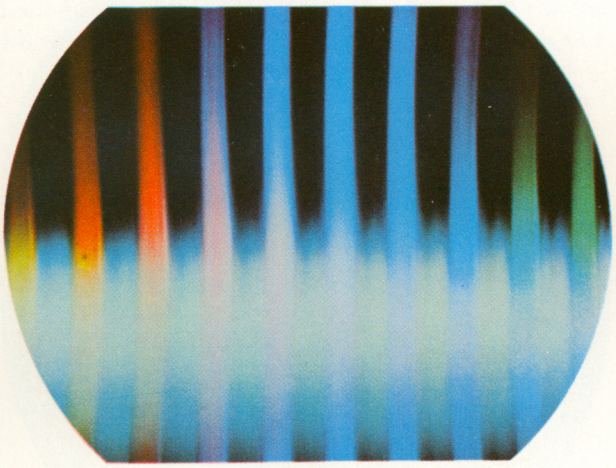


Figure 100 — Color Bar Pattern Showing IF Limiting

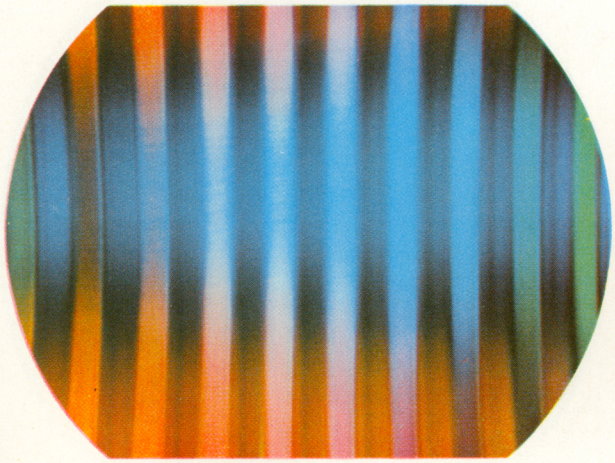


Figure 101 — Hum in the I Channel

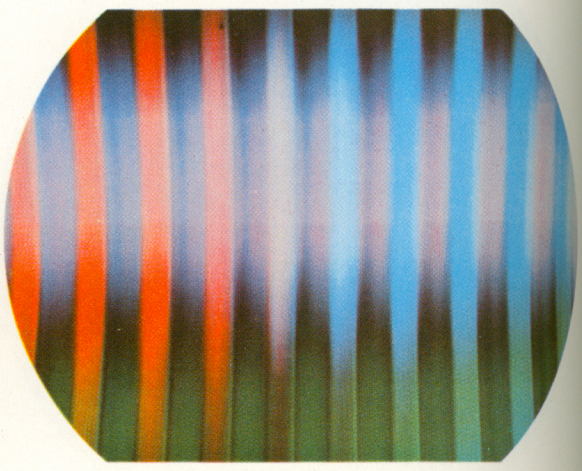


Figure 102 — Hum in the Q Channel

### 3. IF Distortion

Although malfunction of the Color Sync and Demodulation sections are most frequent causes of improper color rendition, this does not mean that color cannot suffer from faults in other parts of the receiver. Improper alignment of the RF and IF amplifiers can cause attenuation or loss of color information. Adjacent vertical edges of a sharp color transition, shown in FIGURE 99, appear as narrow bands of incorrect color if the high video frequencies are lost or attenuated. This loss of high video frequencies could go unnoticed on a black and white transmission. Clipping in the picture IF or video sections could remove the burst reference, resulting in color sync trouble.

FIGURE 100 illustrates limiting the IF stages. This can be checked by inserting a 60 cycle hum into the bar pattern. Using the *Color Bar Generator*, depress the "Mod." button. With the *Color Bar Generator* properly adjusted the color in the bars should not change or wash out. If they do, the signal is being clipped.

In a black and white transmission, it is well known that reflections can cause poor picture synchronization. In a color receiver, the *color sync* information may be cancelled by reflections and result in no *color* synchronization.

A fault that will affect color can occur in the delay line in the Luminance Amplifier Section. Approximately one microsecond of delay represents an appreciable misregistration of chrominance information with Y signal. This fault, of course, would not be apparent on a black and white transmission.

Faults in the power supply, such as hum in the raster, present no additional problems in a color receiver. However, filament - cathode leakage in tubes in the video amplifier channels will produce color hum bars. To aid in diagnosis it would be well for service technicians to know the predominant color of the I and Q signals. Hum appears as green and magenta bars in the Q channel and as orange and cyan bars in the I channel. FIGURES 101 and 102 illustrate hum in the I and Q channels.

4. Matrix and Output Malfunctions

Improper color rendition can also be caused by a defect in the matrix. This can be checked by shorting any two kinescope grids to ground and observing the bar pattern on the face of the kinescope. The red, green and blue matrix checks are shown in FIGURES 103, 104 and 105. The third and ninth bars of the blue matrix shown in FIGURE 105 should have approximately the same brightness. The I gain control may be adjusted until they are correct. Checking the red matrix shown in FIGURE 103, the sixth bar should have the same brightness as the background. Checking the green matrix shown in FIGURE 104, the first and seventh bars should have the same brightness as the background. When these visual conditions are met, the matrix section is functioning normally.

As well as affecting color reception, an improperly operating adder or output stage, will also affect black-and-white reception. Using the pattern from the Color Bar Generator as a reference, FIGURES 106, 107 and 108 illustrate respectively improperly operating red, green and blue adder stages.

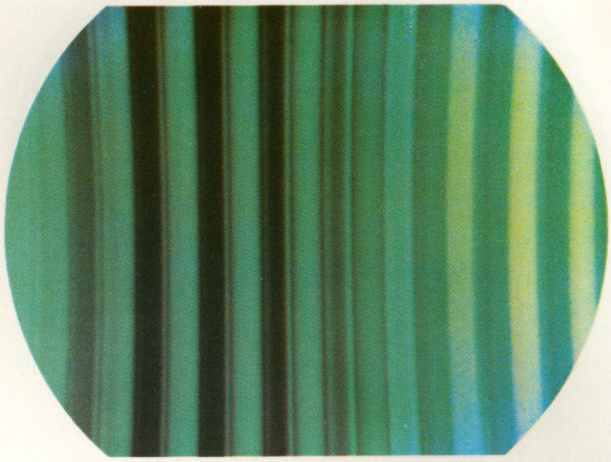


Figure 104 — Green Matrix — Blue and Red Guns Shorted

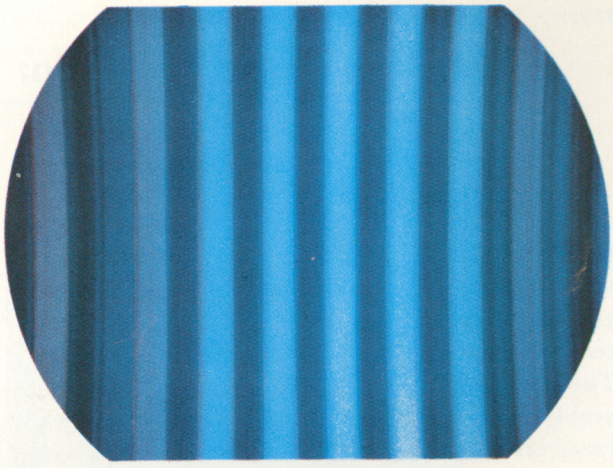


Figure 105 — Blue Matrix — Red and Green Guns Shorted

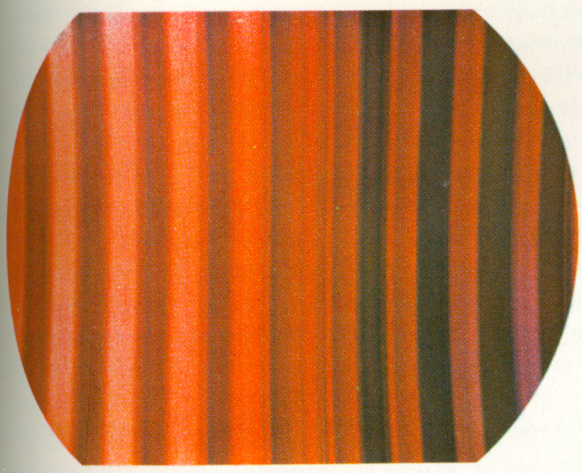


Figure 103 — Red Matrix — Blue and Green Guns Shorted

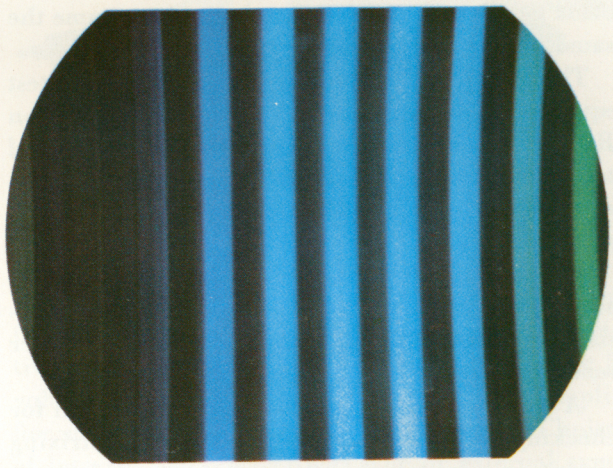


Figure 106 — Red Missing

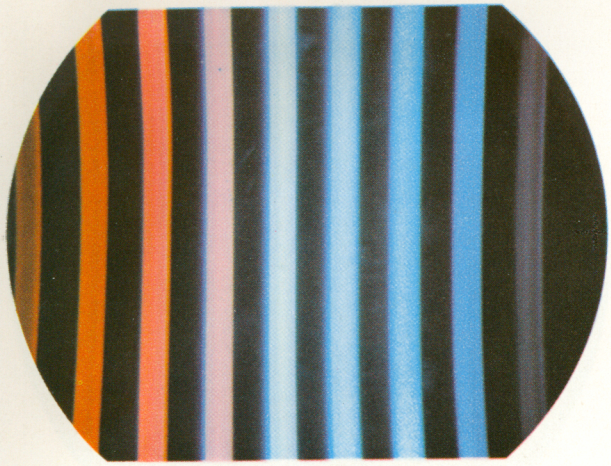


Figure 107 — Green Missing

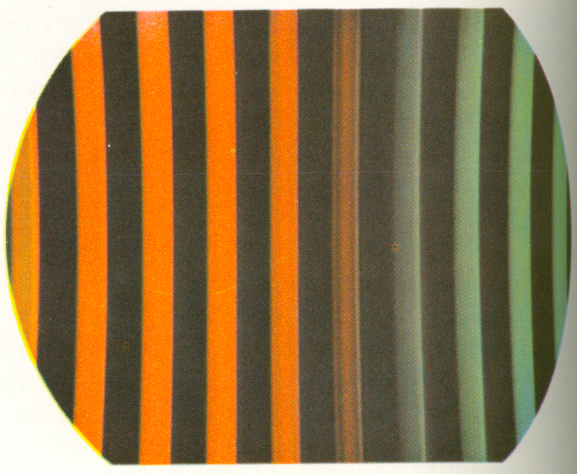


Figure 108 — Blue Missing

# Test Equipment for Color Television Receiver Servicing

In the previous pages of this book dealing with receiver circuitry and receiver adjustment, the reader will have undoubtedly assumed that extra and specialized test equipment will be necessary for color receiver servicing. To a certain extent this is true. The first commercial color receivers will be considerably more complex than current black and white receivers and, within certain limitations, more complex than color receivers that will be marketed a year or two after the first commercial designs. This has been the television industry's experience in black and white receivers. It is logical to assume the same will follow in color television.

The following is the present thinking on test equipment requirements for the initial production RCA color television receivers: two new pieces of test equipment are essential for servicing color receivers; (1) a color-bar generator, and (2) a dot generator.

One additional instrument, a wide-band oscilloscope with flat frequency response to 4.5 mc., is desirable for certain applications in color receiver servicing.

A color-bar test pattern is virtually essential for checking and adjusting the phasing and matrixing circuits in color television receivers, since it is probable that color-bar test patterns may not be telecast at the time the color television receiver is being installed or serviced.

With the advent of FCC approval of compatible color television standards the need for a portable lightweight, relatively inexpensive color-bar generator became evident. Faced with this problem, the RCA Service Company originated and developed a radically new type of color-bar generator that is compact, light, portable and relatively inexpensive. The generator is designed to provide a positive check on the operation and adjustment of color receivers. Color phasing in the new device is inherently accurate. The color subcarrier, picture carrier, sound carrier, horizontal sync and bar frequency are crystal controlled to insure utmost accuracy and stability.

RCA has used this design in a new piece of test equipment, the *RCA WR-61A Color-Bar Generator*. RCA has also introduced the new *WR-36A Dot-Bar Generator*, and the new *WO-78A Wide-Band Oscilloscope*. The major features of these three new units are described briefly below.

## *RCA WR-61A Color-Bar Generator*

The *RCA WR-61A Color-Bar Generator* is a compact, lightweight, portable instrument for use in

checking the overall operation of color receivers, and for adjusting color phasing and matrixing. The instrument produces 10 bars of different colors, accurately spaced at 30° phase intervals, which correspond to the R-Y, B-Y, I and Q axes.




Figure 109 — RCA WR-61A Color-Bar Generator

The WR-61A provides crystal-controlled picture-carrier, color-subcarrier, and sound-carrier frequencies on Channel 3. The bar frequency and horizontal sync pulses are also crystal controlled. The sound carrier (unmodulated) is provided to insure precise tuning of the receiver, to check sound rejection, and to check for presence of beat interference between the color subcarrier and the sound carrier. A push button permits temporary elimination of the sound carrier for quick identification of sound interference.

Luminance signals are provided at the edges of the color bars to check the "fit" or registration of the luminance and chrominance signals. A brightness signal, push-button controlled, produces a horizontal area of increased brightness to check for possible shift of hue in the bright areas or highlights. The amplitude of the color subcarrier and burst is adjustable by means of a front-panel control to provide a positive check on color sync lock in the receiver.

Color video signals of positive or negative polarity are provided for both low-impedance (75 ohm) and high-impedance (3-5000 ohms) video circuits. The high-impedance output signals are valuable in localizing certain trouble as being ahead of, or after, the second detector.

A built-in rectifier circuit, for use with an external *VoltOhmyst,* facilitates measurement and adjustment of sync and subcarrier amplitudes.

## *RCA WR-36A Dot-Bar Generator*

This new instrument is designed to provide a pattern of optimum-size rectangular dots for making all convergence adjustments in color receivers. It also provides choice of horizontal bars, vertical bars, or cross-hatch pattern for linearity adjustments in color and black-and-white receivers. The number of bars is adjustable: 8 to 15 horizontal bars; 11 to 13 vertical bars.

The WR-36A provides white dots on a black background. The dots are approximately 3/16″ x ⅜″, as viewed on a 15″ tube. Experience has shown that, under normal room lighting conditions, the use of smaller dots creates a strong tendency to run the brightness too high, thereby causing blooming, which is definitely undesirable for correct convergence adjustments.

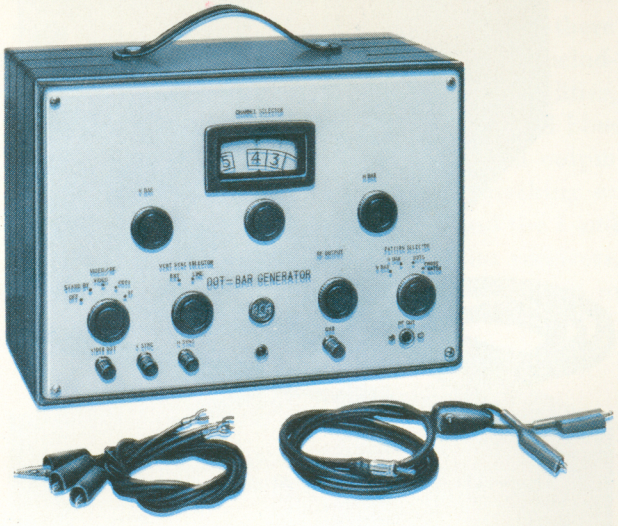



Figure 110 — RCA WR-36A Dot-Bar Generator

Both modulated-RF and video output are provided. The RF output is continuously tunable over Channels 2 to 6, with adjustable amplitude. Positive or negative video output of approximately 5 volts is provided for feeding into the video amplifier of color or black-and-white receivers. Choice of internal 60-cycle vertical sync or external sync is provided.

## *RCA WO-78A Wide-Band Oscilloscope*

The RCA WO-78A 5-inch oscilloscope has dual bandwidth and dual sensitivity, as follows:

*Wide Band:* The frequency response is flat within 3 db, from 3 cycles to 4.5 MC, with direct sensitivity of 0.1 volt peak-to-peak per inch (0.035 volts RMS per inch).

*Narrow Band:* The frequency response is flat, within 3 db from 3 cycles to 500 KC, with direct sensitivity of 0.01 volt peak-to-peak per inch (0.0035 volts RMS per inch).



Figure 111 — RCA WO-78A Wide-Band Oscilloscope

Phase characteristics are excellent throughout the entire frequency range. Rise time is 0.1 microsecond or less, and overshoot is less than 5% for a square-wave signal having .05 microsecond rise time.

The vertical attenuator has 14 positions, corresponding to the following sensitivities in peak-to-peak volts per inch: Narrow band, .01, .03, .1, .3, 1.0, and 10. Wideband, 0.1, 0.3, 1.0, 3, 10, 30, and 100.

The horizontal amplifier is flat, within —6 db. from 3 cycles to 1.0 MC, with sensitivity of 0.2 volts peak-to-peak per inch (0.07 volts RMS per inch). Horizontal trace expansion is three times screen diameter.

The horizontal sweep has four ranges from 10 cycles to 100 KC. Positive and negative internal sync, AC line sync, and external sync.

A low-capacitance probe (9.5 MMF, 10 megohms) provides low loading of the circuit under test. A four-foot vertical input cable is provided to facilitate working on color receivers in cabinets.

The WO-78A is equipped with an RCA 5ABP1 flat-face CRO tube. This tube has post-deflection acceleration for increased sensitivity. An ultor potential of approximately 3000 volts ensures a bright, sharply-focused trace.

Additional information on the WO-78A is given later in this section under the heading "Oscilloscopes".

In addition to requiring new types of test equipment, color television calls for stiffer requirements in alignment equipment, high-voltage probes, and oscilloscopes, as described below.

## *Sweep Generator and Crystal Calibrator*

In black-and-white receivers, it is desirable that the RF-IF amplifiers should have uniform gain for modulating frequencies up to 4 MC, as shown at "A" in FIGURE 112. In some black-and-white receivers the overall RF-IF response falls off above 2 or 3 MC, as shown at "B". This loss of gain above 2 or 3 MC causes a softening of sharp vertical edges, and a loss of small detail in the picture.

In color receivers, all of the color information is contained in the region from about 2 MC to 4.1 MC on the overall RF-IF response curve, as shown at "C". Any loss of gain in this region will weaken the color signals. If the loss is appreciable, it may result in poor color sync, poor color "fit" (incorrect registration of color and brightness information on the kinescope), cross-talk or color contamination between I and Q channels, etc.

It should be noted in "C" that a space of 0.5 MC is specified between the color subcarrier and the "shoulder" of the overall RF-IF response curve. This space is necessary to accommodate the 0.5 MC I and Q color-signal sidebands on this side of the subcarrier. If the response curve is narrowed on this end by as little as 0.1 MC, it amounts to a 20% reduction in the width of these sidebands, with resulting loss of color detail, and introduction

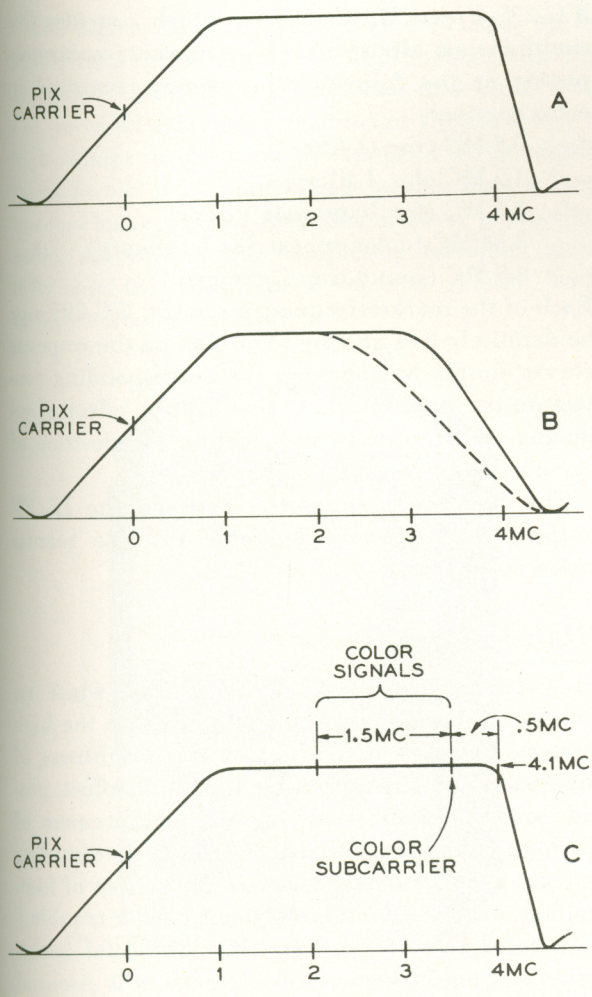



Figure 112 — Overall RF-IF Response Curves

of phase shift that causes cross-talk between I and Q channels.

Unlike black-and-white receivers, there is virtually no leeway in the alignment of the RF-IF amplifiers in color receivers. The amplifier must be aligned correctly to provide flat response for modulating frequencies up to 4.1 MC, as shown in "C".

In checking or aligning the RF-IF amplifiers in color receivers, it is essential to use a reliable sweep generator and an accurate crystal calibrator. The sweep generator should provide fundamental frequencies in the RF ranges, flat voltage output, minimum standing waves on the output cable, a wide-range attenuator, minimum leakage, and good linearity. The *RCA WR-59C Sweep Generator* is ideally suited for color work because it has all of the above features, plus the video-frequency range that is required in servicing all color receivers.

In black-and-white receivers, the video-frequency



Figure 113 — RCA WR-59C Sweep Generator

section is relatively simple, consisting of a one-stage or two-stage amplifier with no tunable peaking adjustments. For this reason there is seldom any need for checking the response of the video amplifier in black-and-white receivers, except as a quick check for narrowing down troubles that cause poor picture quality. But in color receivers, there are a number of video-frequency sections, including the video amplifier, the band-pass amplifier, the I and Q channels, and the green, red and blue matrix networks including the adders and output stages. A video sweep is essential in checking or aligning the tunable band-pass filter and the I and Q filters. Hence, unlike black-and-white receivers, there is a very definite need for a video sweep in servicing color receivers.



Figure 114 — WR-89A Crystal Calibrator

The video sweep should cover the frequency range from about 50 KC to 6 MC. Some brands and makes of sweep generators do not include a video range, or do not cover video frequencies below 3.0 MC. Current production of the *RCA WR-59C Sweep Generator* covers the video range down to 50 KC. (Earlier WR-59C, and WR-59B can be modified to extend their low-frequency limit, of 300 KC, to 50 KC. Instructions for this modification can be obtained from Commercial Engineering Section, RCA Tube Division, Harrison, N. J.)

The *RCA WR-39C* and *WR-89A Crystal Calibrators* are also ideally suited for color service, because they insure the accuracy that is required in locating the "shoulder" of the overall RF-IF response curve, the position of the picture carrier, and the exact frequencies for the IF traps.

## *Video Multi-Marker*

In using the video-frequency range of a sweep generator to check the response of a video amplifier, or to align the chrominance band-pass filter, or to check the I and Q channels, it is necessary to provide markers to identify specific frequencies on the response curves.

It is possible to use a CW oscillator as a marker, but this method is not recommended for video frequencies because the harmonics of the oscillator usually create a number of unwanted markers on the response curve, thus making it difficult to identify the desired point. For video-frequency work, it is preferable to use an absorption-type marker, consisting of a tuned circuit loosely coupled to the output of the sweep generator. The tuned circuit absorbs a small amount of the sweep signal, thus producing a dip or notch in the response curve at a point corresponding to the resonant frequency of the tuned circuit.

For convenience, accuracy, and speed in marking the video response curves, RCA has designed the *WG-295 Video Multi-Marker*, which provides five simultaneous absorption-type markers accurately pre-set at the following frequencies required in color receivers:

0.5 MC (for Q filter)
1.5 MC (for I filter)
2.5 MC (for band-pass filter)
3.58 MC (color subcarrier frequency)
4.5 MC (sound-trap frequency)

Each of the marker frequencies in the WG-295 may be definitely and quickly identified on the response curves simply by touching the corresponding contact on the multi-marker; this has the effect of reducing the amplitude and shifting the position of the particular marker notch.

The WG-295 is connected between the IF/VF output on the sweep generator and the regular video output cable.

## *High Voltage Probe*

In installing and servicing black-and-white receivers, it is seldom necessary to measure the high voltage, because in most cases the brightness of the raster, and any noticeable blooming effect, provide sufficient indication. (Actual measurement of the high voltage is of course helpful in determining quickly whether a dim raster is due to loss of high voltage, or to worn-out kinescope, or other trouble.)

In color receivers, at the time of initial installation and on subsequent service calls, it is essential to adjust the high voltage to the specified value and also check the action of the high-voltage regulation. An incorrect value of high voltage, or change in voltage, affects convergence, focus, color purity, highlight — lowlight tracking, etc. It is therefore essential to use an accurate voltmeter, such as the RCA *VoltOhmyst*, and an accurate high-voltage probe, such as the RCA WG-289 or WG-290. "Spark" type and gas-type high-voltage indicators are not recommended for color servicing.

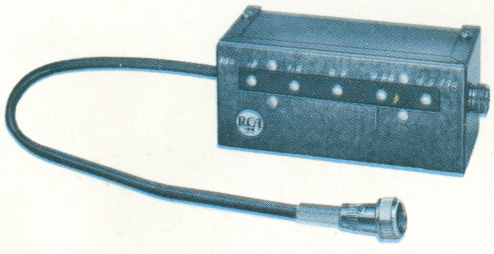


Figure 115 — RCA WG-295 Video Multi-Marker

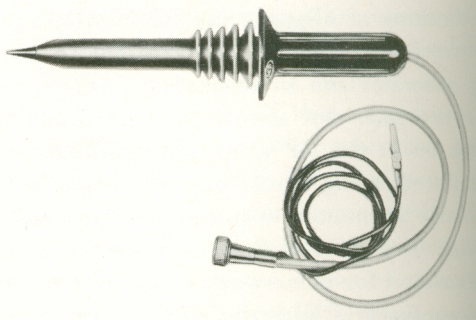


Figure 116 — RCA WG-289 High-Voltage Probe

The high voltage in color receivers ranges up to 30,000 volts or more, and the high-voltage supplies are much "huskier" than in black-and-white sets. For personal safety, the technician should select a high-voltage probe that is designed with ample safety factor. RCA high-voltage probes have a long low-loss leakage path, grounded arc-over protection baffle, anti-corona tip, completely insulated grip, fully shielded cable, and a separate ground lead, to insure maximum safety.




Figure 117 — RCA WV-97A VoltOhmyst

For use with RCA *VoltOhmyst,* models WV-75A, WV-65A, WV-77A, WV-87A, WV-95A, WV-97A, WV-165, WV-165A, use *RCA High-Voltage Probes WG-289,* and WG-206 multiplier resistor. For 20,000 ohm-per-volt meters that have phone-tip connectors and a 5000 volt range, use *RCA High Voltage Probe WG-290,* and WG-210 multiplier resistor. This combination provides a 50,000 volt range.

## *Oscilloscope*

The vertical amplifier in an oscilloscope should have essentially flat response from the lowest to the highest frequency components in the observed waveforms. In black-and-white servicing, the highest frequencies are represented by horizontal sync pulses; the lowest frequencies are represented by a 60 cycle sweep alignment curve with blanking on alternate half cycles (equivalent to a 60 cycle square wave). If the vertical amplifier, including the isolating probe and cable, has flat response to 100 KC, and is within —3 db at 500 KC, trailing off to 1.0 MC or higher, it will reproduce the horizontal sync pulses with adequate fidelity. If the vertical amplifier has flat response down to DC (zero frequency), or to a few cycles, it will faithfully reproduce the sweep alignment curves. The phase response of the vertical amplifier must of course be satisfactory. Poor low-frequency response can cause serious errors in sweep alignment, due to tilting of the response curve.

In color receivers, the highest frequency that the oscilloscope must reproduce is the 3.58 MC color sync burst, and the 3.58 MC oscillator signals in the receiver.

The RCA WO-88A, WO-56A, and WO-57B are essentially flat to 500 KC. These oscilloscopes are more than satisfactory for the majority of applications in servicing color receivers, including alignment, trouble shooting in sync and deflection circuits, trouble shooting in dynamic convergence circuits, etc. But for certain other applications, such as measurement of the 3.58 MC signals, a wide-band oscilloscope with flat response to 4.5 MC is required.

To be of any value in television servicing the oscilloscope must have provision for measuring the actual value of the input voltage, because it is just as important to know whether the voltage is correct as it is to know whether the shape is correct. RCA Oscilloscopes have a built-in calibrating voltage and a calibrated vertical step attenuator; the voltage of the input signal is read directly on the ruled screen in terms of volts per inch.

In order to measure the voltage of input signals, and to observe the correct relative amplitudes of high and low-frequency signals, the oscilloscope must have *flat* response up to the highest frequency involved. This means that for color servicing the response must be flat to 4.5 MC. Oscilloscopes that have unspecified "response" at 4.5 MC produce error in measurement of input voltages, and in observation of relative amplitudes of high and low-frequency signals.

The RCA WO-78A Oscilloscope has dual bandwidth. In the wide-band position, the response is flat, within —1 db, from 3 cycles to 4.5 MC, with direct sensitivity of 0.1 volt peak-to-peak per inch. In the narrow-band position, the response is flat, within 3 db, from 3 cycles to 500 KC, with sensitivity of .01 volt peak-to-peak per inch.

With the WO-78A, it is as easy to measure the voltage of any desired portion of any waveform as

it is to measure DC with an ordinary voltmeter. The ease and accuracy of voltage measurements is the result of several design features:

(1) In calibrating the WO-78A, it is not necessary to disconnect the input cable from the circuit under test, or to set the vertical attenuator on a specified range: the "calibrate" pushbutton automatically disconnects the input cable and the attenuator, and applies a fixed internal calibrating voltage to the vertical amplifier. To calibrate, it is necessary only to push the button and set the vertical vernier for two inches of vertical deflection.

(2) The vertical attenuator has numerous small steps which provide generous over-lapping of ranges. The correct pattern height, neither too small nor too large, is selected by turning the attenuator knob only.

(3) A limiter tube in the sync circuit eliminates any need for adjusting sync amplitude. The pattern stays locked in sync over wide ranges of input voltage, and over a considerable range of input frequency. There is no sync amplitude knob on the WO-78A.

(4) The measurement and visual comparison of low and high-frequency components of composite waveforms are accurate because the WO-78A has flat response from 3 cycles to 4.5 MC.

(5) The removable graph screen is ruled in inches and tenths of inches for ease in measuring signal voltages.

The characteristics of the RCA WO-78A make it especially suited for servicing color receivers.

# Alignment of the Color Television Receiver Circuits

ALIGNMENT of the circuits of a color TV receiver involves not only more circuits than a black and white receiver, but also requires more care and precision. Any response curves other than ideal are not acceptable. Circuits requiring alignment are:

RF Unit Section
Picture IF Section
Sound IF Section
Video Amplifier—Detection Section
Chrominance Synchronization Section

Equipment required for alignment will, for the most part, be the same as that used in alignment of black and white receivers. In making the overall picture IF alignment a sweep generator is used. The sweep generator should produce a sweep that is linear and assures the reproduction of a response curve that can be made linear. The sweep generator should also produce accurate sound and picture carrier markers for sound alignment.

## *Alignment Procedure*

Equipment required —

1 Sweep Generator RCA WR-59C or equivalent
1 Crystal Calibrator RCA WR-39C or equivalent
1 Oscilloscope, with low capacity and diode probes. (Oscilloscope should have flat frequency response to 4.5 MC) RCA WO-78A or equivalent
1 Video marker
1 Vacuum tube voltmeter RCA WV-79A *Volt-Ohmyst* or equivalent
1 Calibrated RF probe.

Align the tuner for the VHF or UHF stations being received, according to the procedure for the tuner being used in the receiver.

## *Picture IF Alignment*

1. Ground the grid, pin 8 of V112A, with a short lead.
2. Connect the scope to the 2nd detector test point 1TP101.
3. Connect the IF sweep to pin 2 of V113. Adjust the output of the sweep generator for a 6V peak-to-peak trace on the scope.
4. Couple the calibrator loosely to obtain markers.
5. Adjust the top core of 1T113 for minimum response at 41.25 MC.
6. Adjust the sound reject control 1R276 for minimum response at 41.25 MC.
7. Adjust the top core of 1T112 for minimum response at 47.25 MC.
8. Adjust the bottom cores of 1T112 and 1T113 for maximum gain and response as shown in FIGURE 118.
9. Remove all equipment connections previously made. Continue the grounding of pin 8, V112A.
10. Connect the 300 ohm balanced output of the sweep through a 6 db "H" pad to the antenna terminals of the tuner. Set the fine tuning control to the proper point.
11. Connect the scope diode probe to pin 5, V109, and connect a 330 ohm resistor from pin 5, V109, to the junction of 1R169 and 1R170.
12. Couple the calibrator loosely to obtain markers.

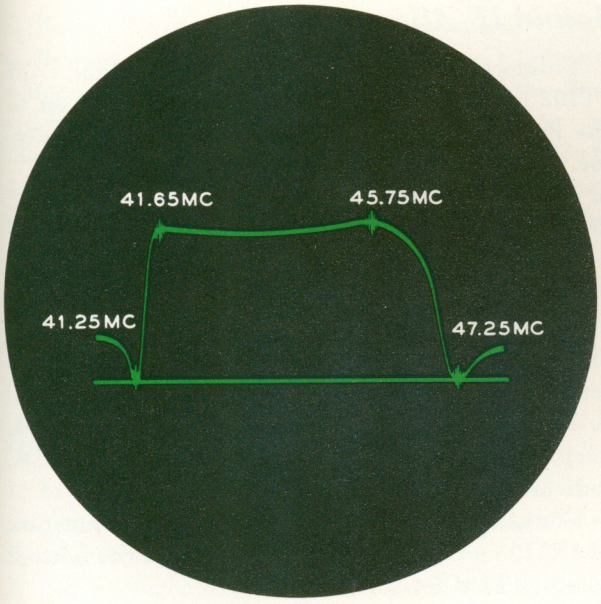



Figure 118 — Fifth Picture IF Response

13. Ground the junction of 2R135 and 2R134 to remove developed AGC.

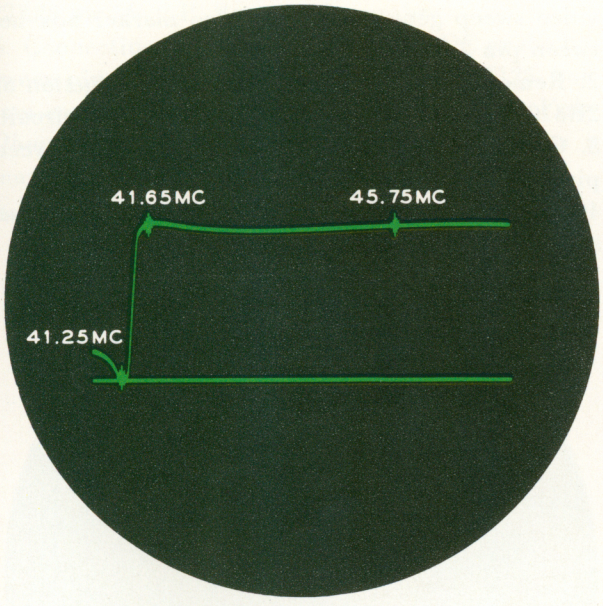



Figure 119 — Converter-Picture IF Response (Overcoupled Stage)

14. Connect to the picture IF AGC bus, —6 volts of bias (junction of 1L102 and 1O152).
15. Adjust the top core of 1T106 and the sound level control 1R166 for minimum response at 41.25 MC.
16. Adjust T10 and T2 on the tuner unit and 1T106, bottom core, on the chassis, for maximum gain and response as shown in FIGURE 119.
17. Remove the 6 db pad in the antenna circuit and insert a 30 db attenuator pad. Adjust the sweep output and measure the indication on the scope at the 43 MC point on the trace.
18. Remove the 30 db attenuator and connect the sweep directly to the input terminals. Adjust 1R166 sound level control until the distance between the base line and the bottom of the 41.25 MC trap notch is the same as the measured indication obtained in Step 17.
19. Re-check Steps 10 through 16 for any change in response which may have occurred due to adjustment of the sound level control.
20. Leave equipment connected as in Steps 10, 12, 13 and 14.
21. Remove the scope diode probe from V109 and connect to pin 5, V110. Connect a 180 ohm resistor from pin 5 to pin 6, V110.
22. Adjust top cores of 1T107 and 1T108 for minimum response at 40.7 MC and 47.25 MC, respectively.

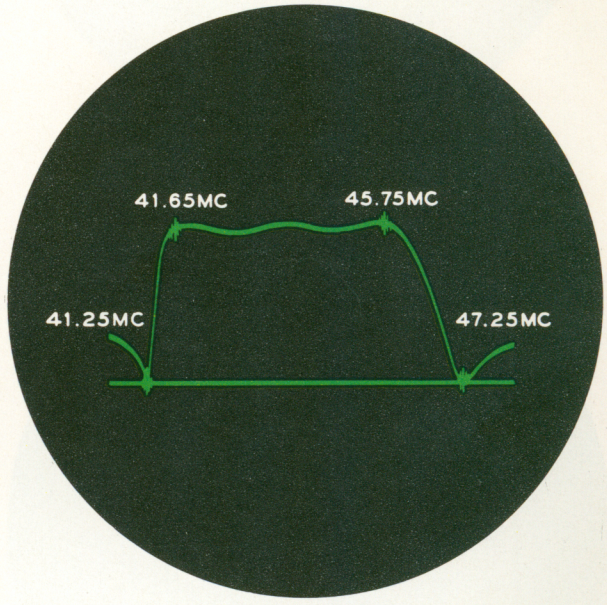



Figure 120 — First Picture IF Response

23. Adjust bottom cores of 1T107 and 1T108 for maximum gain and response as shown in FIGURE 120. Reduce sweep output as necessary to prevent overload.
24. Remove the scope diode probe and 180 ohm loading resistor from pin 5, V110 and change the bias to —9 volts.

25. Remove the ground from pin 8, V112A.
26. Connect the scope to the 2nd detector test point 1TP101 and adjust the sweep output so that the scope trace measures 6V P-P.
27. Adjust the cores of 1T109, 1T110 and 1T111 for maximum gain and response as shown in FIGURE 121.

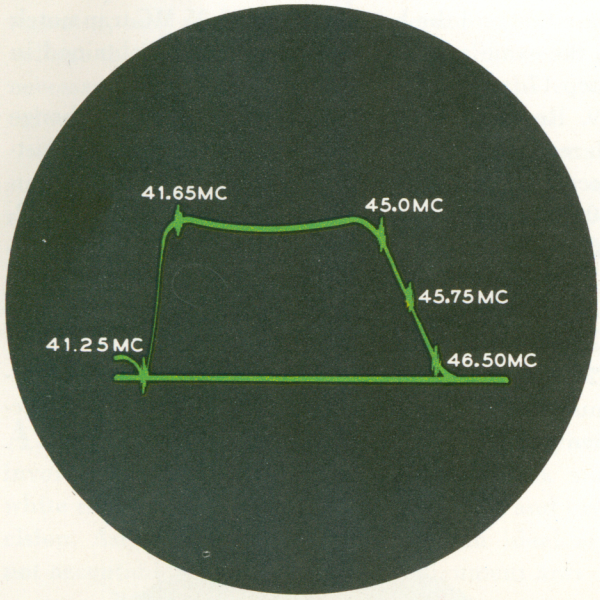



Figure 121 — Overall Picture IF Response

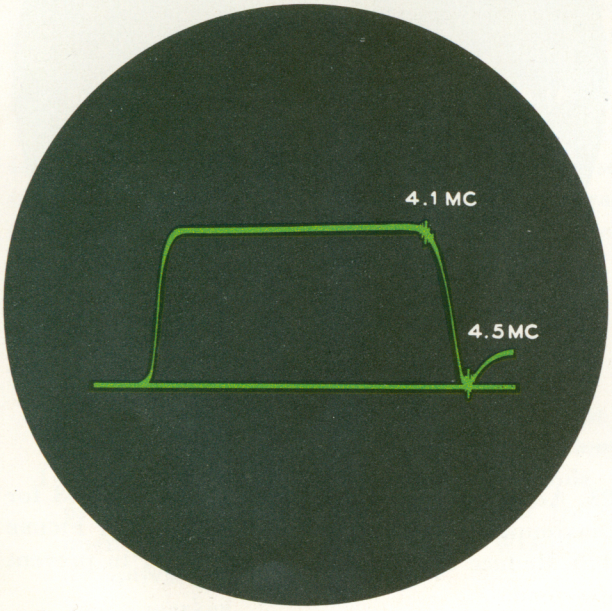



Figure 122 — First Video Amplifier Response

## *Sound IF Alignment*

1. Connect the calibrator between terminal C of 1T102 and ground and connect the *VoltOhmyst* to the junction of 1R118 and 1C123 in the ratio detector.
2. Adjust the output of the calibrator to 4.5 MC and adjust 1T102, 1T103 and top core of 1T104 for a maximum DC indication.
3. Reduce the output of the calibrator so that the *VoltOhmyst* reads 12V DC and re-peak 1T103, alternately loading the secondary with a 1500 ohm resistor while adjusting the primary, and vice versa.
4. Re-peak 1T102 and adjust top core of 1T104, keeping calibrator output reduced so that final DC indication on the *VoltOhmyst* is 12V.
5. Connect the *VoltOhmyst* between the junction of 1R119 and 1C120 and ground. Adjust the bottom core of 1T104 for zero DC.

## *Video and Bandpass Amplifier Alignment*

1. Disconnect the grid of the video amplifier, pin 2, V114, from terminal "F", 1T113, and connect the video sweep generator with video marker box between pin 2 of V114 and ground.
2. Remove fuse 3F101 and ground the junction of 2R310 and 2C259 in the Color Killer plate circuit.
3. Connect the scope, with diode probe, between pin 1, V114 and ground.
4. Adjust 2L108, the 4.5 MC trap, for response as shown in FIGURE 122.

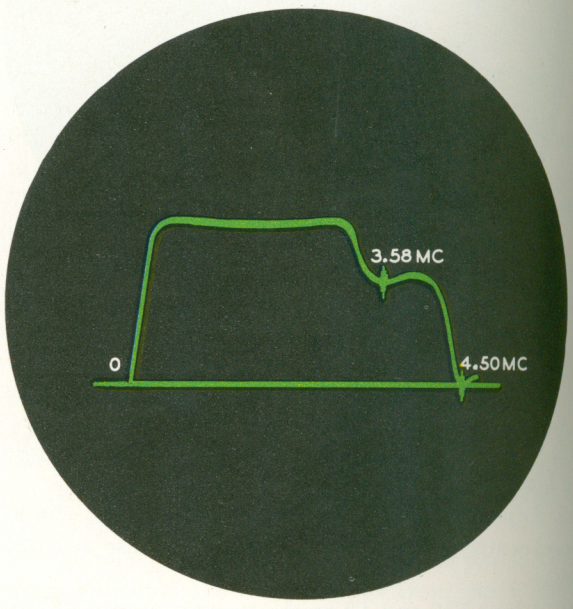



Figure 123 — Video Response After Burst Take-off

5. Rotate the contrast control to maximum.
6. Remove the scope diode probe from V114 and connect to pin 9, V115A, the cathode of the 2nd video amplifier. Adjust 2L140 for response as shown in FIGURE 123, being careful not to overload.
7. Connect the scope diode probe to the cathode of the "Q" demodulator, pin 2, V133, and turn the color saturation control to maximum.
8. Adjust 2T126 and 2L121 for maximum gain and response as shown in FIGURE 124.

## *Color Synchronization and Matrix Adjustment*

1. Adjust the receiver fine tuning control for proper reception of the signal from the *RCA Color Bar Generator*, or similar equipment.
2. Adjust the contrast and color saturation controls until a color bar pattern is seen on the screen, being careful not to overload the receiver.
3. Ground the grid of the burst amplifier, pin 8, V129A, with a short clip lead.
4. Using a calibrated RF probe on a *VoltOhmyst* connected between pin 8, V130A and ground, adjust 2T128 for 5V P-P. Remove the probe.
5. Connecting the *VoltOhmyst* with a DC probe between pin 1, V130A, and ground, adjust 2T125, bottom core, for a maximum indication on the *VoltOhmyst*. Then adjust the top core, 2T125, for a maximum dip in this indication.
6. Remove the clip lead grounding pin 8, V129A, and set the hue control to a mid-range position.
7. Adjust 2L141 and 2T122 for a maximum indication on the *VoltOhmyst*.
8. Ground the junction of 2R384, 2C275, and 2L130 at the reactance tube grid, with a short clip lead.
9. Adjust 2T124 for a slow swing of the meter needle on the *VoltOhmyst*. This may also be observed on the kinescope by a color coming to a standstill.

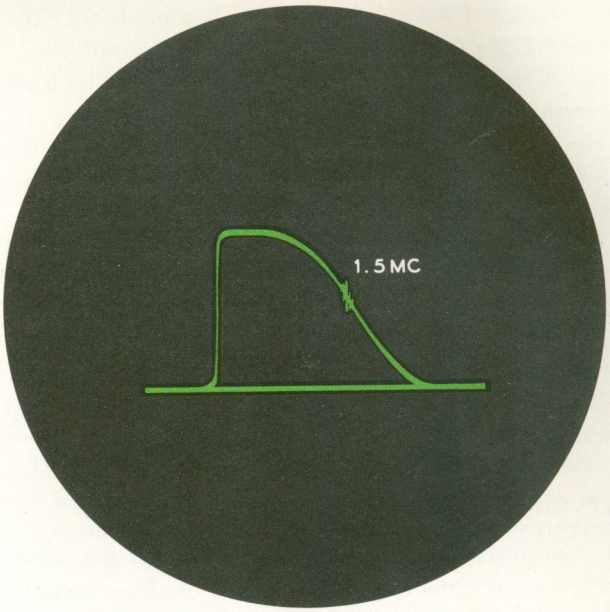



Figure 125 — I Response

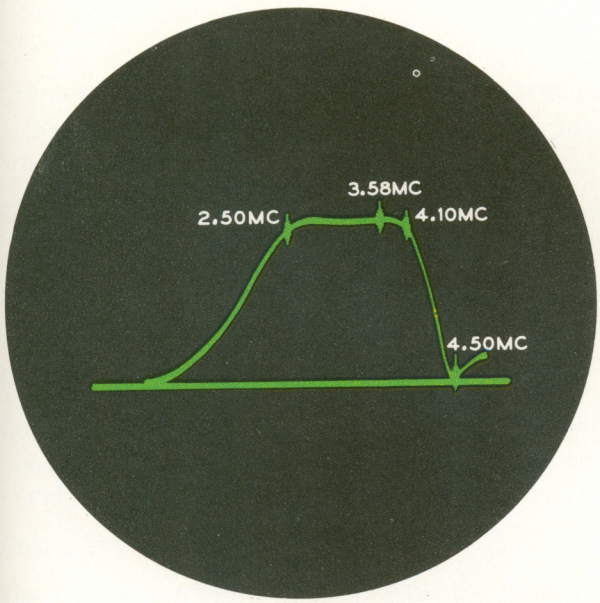



Figure 124 — Bandpass Amplifier Response

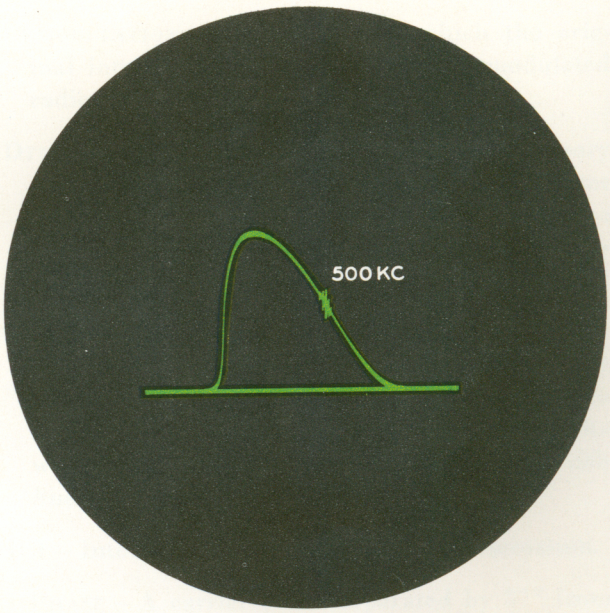



Figure 126 — Q Response

10. Remove the clip lead at the junction of 2R384, 2C275, and 2L130 and connect the *VoltOhmyst* with a DC probe between this point and ground.
11. Shunt the 3.58 MC crystal, 2Y101, with a 10 MMF capacitor to change the crystal frequency.
12. Adjust the AFC balance control 2R306 for zero DC indication on the *VoltOhmyst*.
13. Remove the 10 MMF capacitor and observe the reading. If it changes from zero, re-adjust 2T124 for a zero DC reading.
14. Connect the scope to the "I" test point, 2TP103, and trigger the scope sweep with horizontal sync.
15. Adjust the hue control for response on the oscilloscope as shown in FIGURE 125.
16. Connect the scope to the "Q" test point, 2TP102, and adjust the top core of 2T125, for response as shown in FIGURE 126.
17. Connect the oscilloscope to the "blue" grid of the kinescope and adjust the color saturation control until the 6th bar observed on the reviewing screen is of equal amplitude, but of opposite polarity, to the sync pulse.
18. Adjust the "I" gain control, 2R361, for zero amplitude of the 3rd and 9th bars.

## *Dynamic Convergence Alignment*

1. Coupling the scope probe loosely to the kinescope convergence lead (pin 13 on the kine socket) trigger the scope with horizontal pulses from the yoke lead, also loosely coupled.

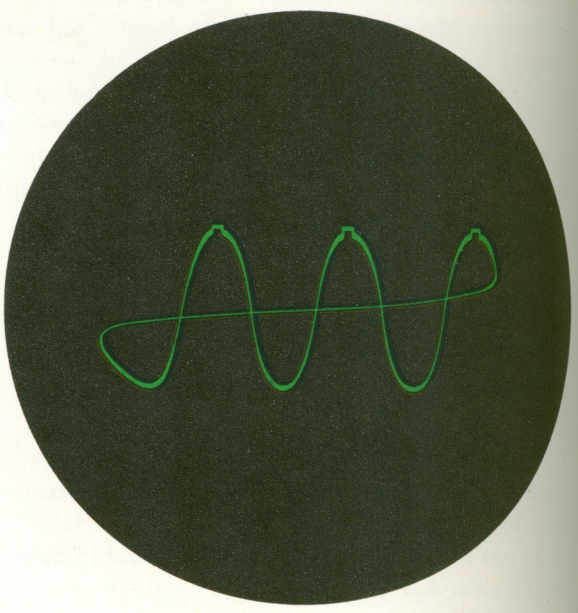


Figure 127 — Dynamic Convergence Waveform

2. Set the vertical dynamic convergence control to minimum and the horizontal dynamic convergence control to maximum.
3. Adjust horizontal convergence phase control 1L138 and horizontal convergence amplitude control 1R238 in H.V. compartment for maximum parabola and phasing as shown in FIGURE 127.

# GLOSSARY Of Color Television Terms

APERTURE PLATE — Refer to Shadow Mask.

BRIGHTNESS — The attribute of visual perception in accordance with which an area appears to emit more or less light, ranging from black to maximum white.

BRIGHTNESS SIGNAL — That part of the composite color signal wave which has the major control of the luminance of the color picture, and which controls the luminance of the picture produced by a conventional black and white receiver.

BURST — A synchronizing signal composed of eight (8) cycles of color subcarrier frequency (added to the horizontal blanking pedestal) for synchronizing the color carrier oscillator in the color receiver with the color carrier oscillator at the transmitter.

CHROMA — The characterization of a color quality without reference to its brilliance or hue (saturation only)

CHROMINANCE — Reference to color quality without reference to its brilliance (hue and saturation)

CHROMINANCE SIGNAL — The sidebands of the modulated color subcarrier which are added to the black and white signal to convey color information.

CIE — Committee Internationale d'Eclairage (French: International Commission of Illumination)

COLOR EDGING — Spurious color at the boundaries of differently colored areas in the picture.

COLOR GAMUT — A restricted range of hues and saturations in the color spectrum.

COLORIMETRY — The study of color.

COLOR SUBCARRIER — The carrier whose modulation sidebands are added to the black and white signal to convey color information.

COLOR SYNC SIGNAL — See Burst.

COLOR TRANSMISSION — In television the transmission of a signal wave for controlling both the luminance and chrominance values in a picture.

COMPATIBILITY — The nature of a color television system which permits normal black and white reception of the color transmission by typical unaltered black and white receivers designed for standard black and white reception.

COMPOSITE COLOR SIGNAL — The color signal, including blanking, luminance and chrominance intelligence, and all synchronizing signals.

CONSTANT LUMINANCE TRANSMISSION — A method of color transmission in which the chrominance signal controls the chromaticity of the produced image without affecting the luminance, the luminance being controlled by the brightness signal.

CONVERGENCE — The meeting and crossover of the three electron beams of the tri-color kinescope at a common point on the shadow mask.

CROSSTALK — Distortion of a desired signal caused by the presence of an undesired signal. In color television this might be caused by reaction between the chrominance signal and the high frequency brightness signal.

D.C. CONVERGENCE — The correction necessary to adjust the paths of the three electron beams in a tri-color kinescope so that they meet at a common point at the center of the shadow mask.

DEMODULATION — The process by which the original intelligence is obtained from a modulated radio wave.

DYNAMIC CONVERGENCE — The correction necessary to adjust the paths of the three electron beams in a tri-color kinescope so that they meet at a common point as they are deflected over the entire area of the shadow mask.

HUE — May be defined as *Dominant Wavelength.* The attribute of colors that permits them to be separated into groups designated by such terms as red, green, blue, yellow, purple, and etc. The word *color* is often considered synonymous with *hue.*

ICI — International Commission of Illumination.

I PHASE — A carrier phase separated by 57° from the color subcarrier (sometimes referred to as the in-phase carrier).

ICW – A 3.58 MC continuous wave signal having I phase. Generally restricted to reference to the receiver local oscillator (3.58 MC) and associated circuits.

I Signal – The sidebands produced by modulating the I phase carrier. The modulating signal is defined by NTSC standards as: I = 0.60R – 0.28G – 0.32B.

Luminance – Standardized brightness.

Luminance Signal – Refer to Brightness Signal.

Matrix – A device consisting of an array of components whose values are so chosen that selected percentages of input signals are combined to form the desired output signal.

Mu-Metal Shield – A high permeability metal shield placed around the bell of the tri-color kinescope to prevent stray magnetic fields from disrupting the paths of the electrons beams.

NTSC – National Television System Committee.

Phosphor Screen – An integral part of the tri-color kinescope: a glass plate having deposited upon one surface an orderly array of small phosphor dots which, upon electron bombardment in correct sequence and intensity, will produce the visible effects of television.

Phosphor Trio – Closely spaced phosphor dots, arranged in triangular groups accurately deposited in interlaced positions on the phosphor screen of the tri-color kinescope. Each trio consists of a green-emitting dot, a red-emitting dot and a blue-emitting dot.

Purity – Complete saturation, freedom from white.

Q Phase – A color television signal carrier phase separated by 147° from the color subcarrier (sometimes referred to as the quadrature carrier).

Q Signal – The sidebands produced by modulating the Q phase carrier. The modulating signal is defined by NTSC standards as: Q = 0.21R – 0.52G + 0.31 B.

QCW – A 3.58 MC continuous wave signal having Q phase. Generally restricted to reference to the receiver local oscillator (3.58 MC) and associated circuits.

Reactance Tube – Generally a pentode type – in principle, a variable reactance may be produced at the plate of the tube by varying DC bias on the grid. The type of reactance (inductive or capacitive) produced at the plate is dependent upon the signal bias applied from grid to cathode (capacitive voltage at the cathode produces inductive reactance at the plate).

Saturation – The "vividness" of a color described by such terms as pale, deep, pastel, vivid and etc. May be defined as *chromatic purity.*

Shadow Mask – A metal mask directly behind the phosphor screen in a tri-color kinescope having openings through which the phosphor trios of the screen are bombarded by electron beams.

Synchronous Detection – A phase sensitive process of detecting amplitude variations of a single phase from a multi-phase modulated carrier.

V.S.W.R. – Voltage Standing Wave Ratio.

Y Signal – Refer to Brightness Signal.

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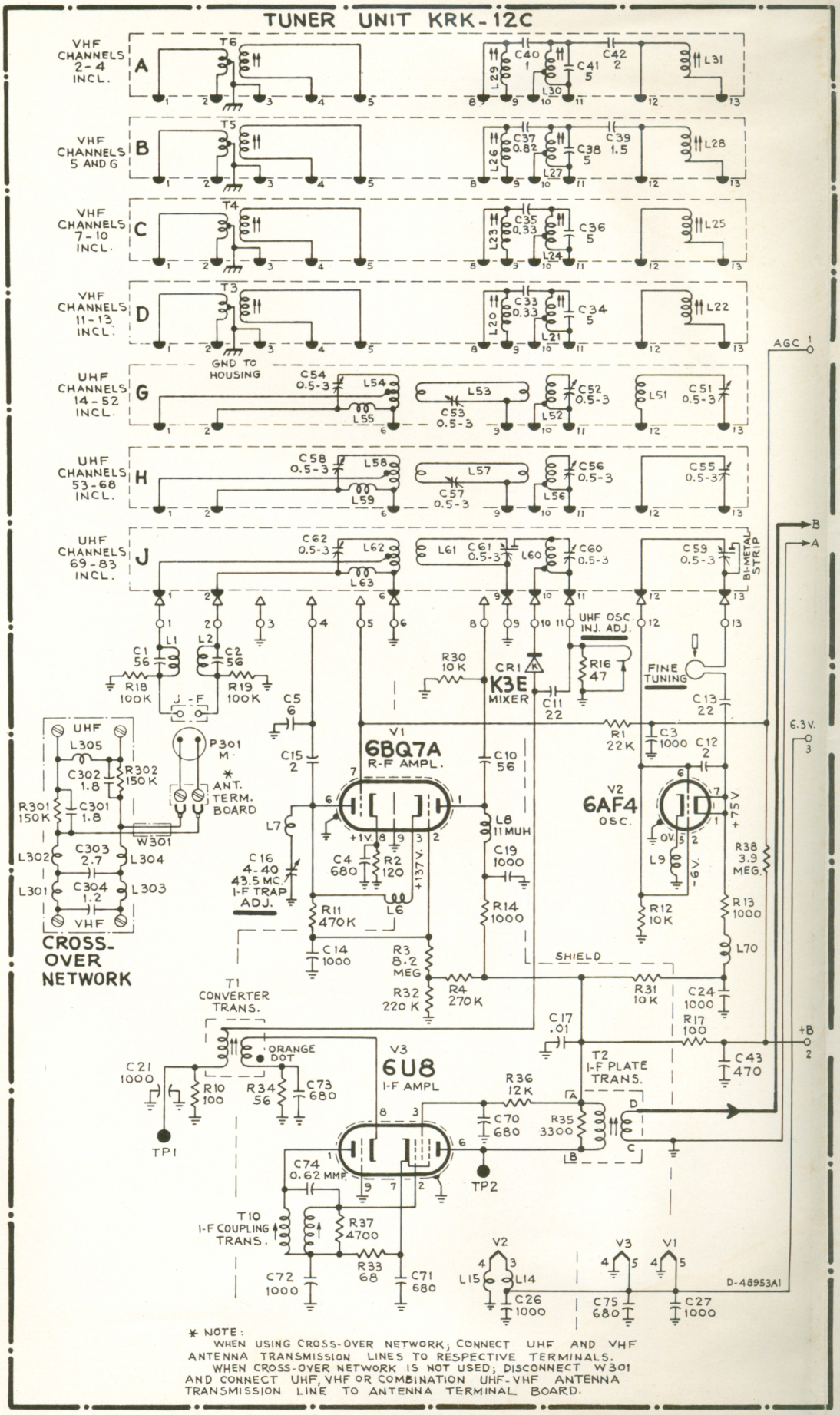
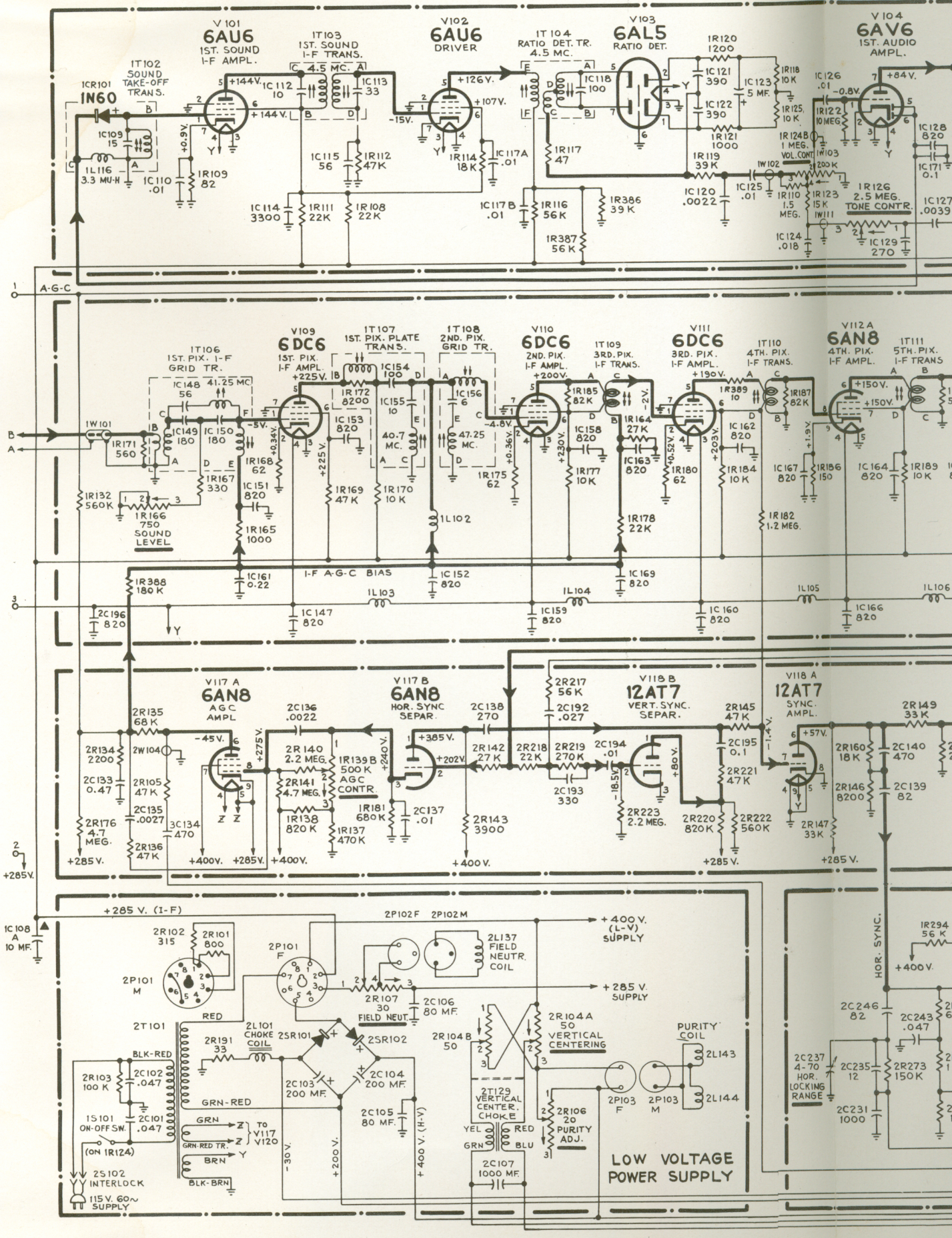

TUNER UNIT KRK-12C
VHF CHANNELS 2-4 INCL.
A
T6
C40 1
C41 5
C42 2
L29
L30
L31
VHF CHANNELS 5 AND 6
B
T5
C37 0.82
C38 5
C39 1.5
L26
L27
L28
VHF CHANNELS 7-10 INCL.
C
T4
C35 0.33
C36 5
L23
L24
L25
VHF CHANNELS 11-13 INCL.
D
T3
C33 0.33
C34 5
L20
L21
L22
GND TO HOUSING
UHF CHANNELS 14-52 INCL.
G
C54 0.5-3
L54
L55
C53 0.5-3
L53
L52
C52 0.5-3
L51
C51 0.5-3
UHF CHANNELS 53-68 INCL.
H
C58 0.5-3
L58
L59
C57 0.5-3
L57
L56
C56 0.5-3
C55 0.5-3
UHF CHANNELS 69-83 INCL.
J
C62 0.5-3
L62
L63
L61
C61 0.5-3
L60
C60 0.5-3
C59 0.5-3
BI-METAL STRIP
AGC
B
A
6.3 V.
+B
UHF OSC. INJ. ADJ.
FINE TUNING
C1 56
L1
R18 100K
L2
C2 56
R19 100K
L-F
R30 10K
CR1
K3E
MIXER
R16 47
C11 22
C13 22
C5 6
V1
6BQ7A
R-F AMPL.
C15 2
C10 56
R1 22K
C3 1000
C12 2
V2
6AF4
OSC.
+75V
0V
-6V.
L9
R38 3.9 MEG.
UHF
L305
C302 1.8
R302 150K
R301 150K
C301 1.8
P301
*
ANT. TERM. BOARD
W301
L302
C303 2.7
L304
L301
C304 1.2
L303
VHF
CROSS-OVER NETWORK
L7
+1V.
C4 680
R2 120
+137V.
C16 4-40 43.5 MC. I-F TRAP ADJ.
L8 11 MUH
C19 1000
R14 1000
R11 470K
L6
C14 1000
R3 8.2 MEG
R32 220 K
R4 270K
R12 10K
R13 1000
L70
SHIELD
R31 10K
C24 1000
T1 CONVERTER TRANS.
C17 .01
R17 100
C43 470
T2 I-F PLATE TRANS.
ORANGE DOT
V3
6U8
I-F AMPL
C21 1000
R10 100
R34 56
C73 680
R36 12K
C70 680
R35 3300
TP1
TP2
C74 0.62 MMF.
T10 I-F COUPLING TRANS.
R37 4700
R33 68
C72 1000
C71 680
L15
L14
C26 1000
C75 680
C27 1000
D-48953A1
* NOTE:
WHEN USING CROSS-OVER NETWORK, CONNECT UHF AND VHF ANTENNA TRANSMISSION LINES TO RESPECTIVE TERMINALS.
WHEN CROSS-OVER NETWORK IS NOT USED; DISCONNECT W301 AND CONNECT UHF, VHF OR COMBINATION UHF-VHF ANTENNA TRANSMISSION LINE TO ANTENNA TERMINAL BOARD.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V102 6AU6 DRIVER
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V103 6AL5 RATIO DET.
V104 6AV6 1ST. AUDIO AMPL.
1T102 SOUND TAKE-OFF TRANS.
1CR101 IN60
1L116 3.3 MU-H
1R120 1200
1R119 39K
1R117 47
1R386 39K
1R387 56K
1R116 56K
1R126 2.5 MEG. TONE CONTR.
A-G-C
V109 6DC6 1ST. PIX. I-F AMPL.
1T106 1ST. PIX. I-F GRID TR.
41.25 MC
1T107 1ST. PIX. PLATE TRANS.
1T108 2ND. PIX. GRID TR.
40.7 MC.
47.25 MC.
V110 6DC6 2ND. PIX. I-F AMPL.
1T109 3RD. PIX. I-F TRANS.
V111 6DC6 3RD. PIX. I-F AMPL.
1T110 4TH. PIX. I-F TRANS.
V112A 6AN8 4TH. PIX. I-F AMPL.
1T111 5TH. PIX. I-F TRANS
1W101
1R166 750 SOUND LEVEL
1R132 560K
1R165 1000
1L102
1L103
1L104
1L105
1L106
I-F A-G-C BIAS
1R388 180 K
2C196 820
V117 A 6AN8 AGC AMPL
V117 B 6AN8 HOR. SYNC SEPAR.
V118 B 12AT7 VERT. SYNC. SEPAR.
V118 A 12AT7 SYNC. AMPL.
1R139 B 500 K AGC CONTR
1R181 680K
2R135 68K
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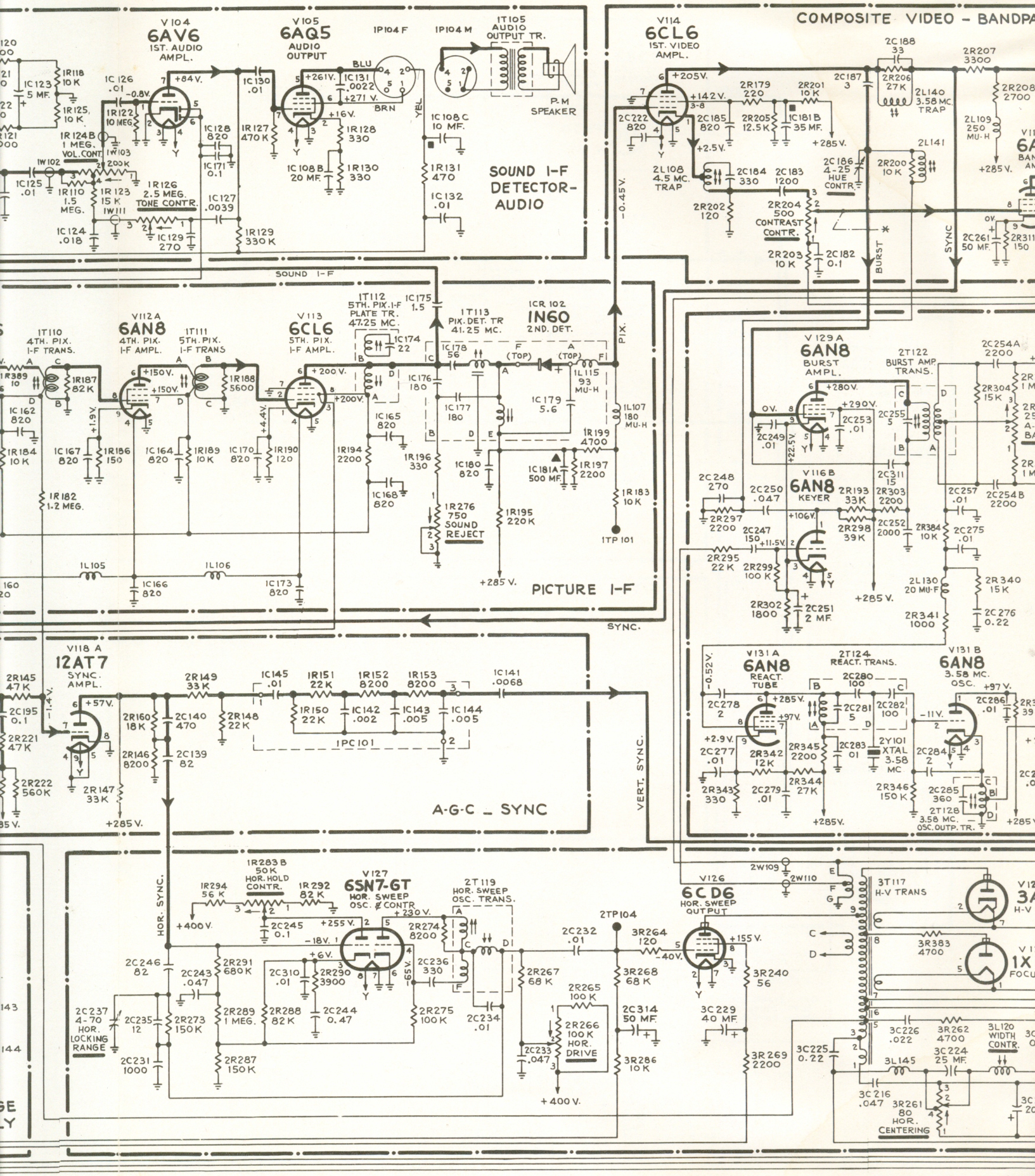
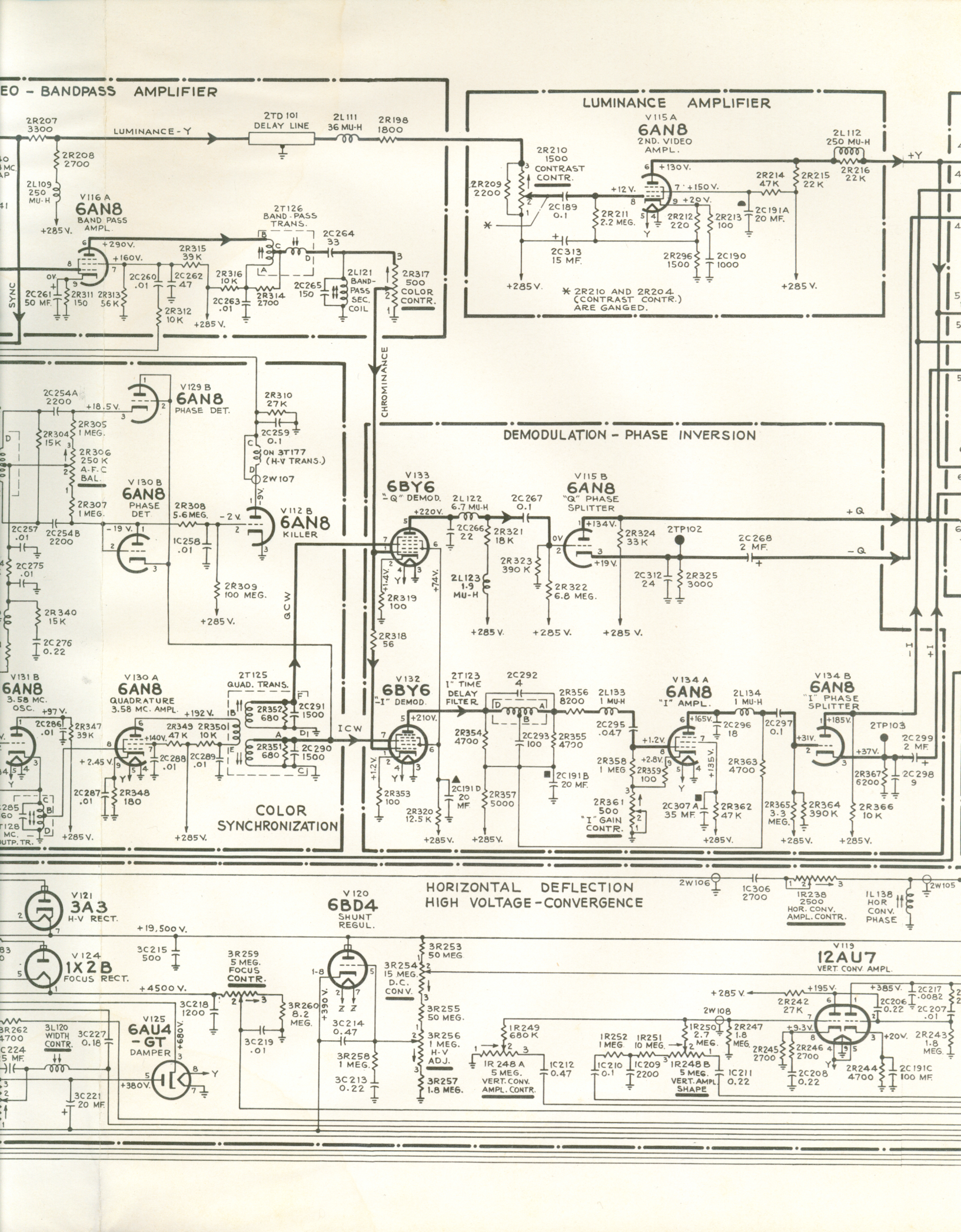
+400 V.
+285 V. (I-F)
2P102F
2P102M
+400 V. (L-V) SUPPLY
+285 V. SUPPLY
2L137 FIELD NEUTR. COIL
2R107 30 FIELD NEUT.
2C106 80 MF.
2T101
2L101 CHOKE COIL
2SR101
2SR102
2C103 200 MF.
2C104 200 MF.
2C105 80 MF.
2R104A 50 VERTICAL CENTERING
2R104B 50
2T129 VERTICAL CENTER. CHOKE
2R106 20 PURITY ADJ.
PURITY COIL
2L143
2L144
2P103 F
2P103 M
1S101 ON-OFF SW.
2S102 INTERLOCK
115 V. 60~ SUPPLY
HOR. SYNC.
LOW VOLTAGE POWER SUPPLY



COMPOSITE VIDEO - BANDPA
V104 6AV6 1ST. AUDIO AMPL.
V105 6AQ5 AUDIO OUTPUT
1P104 F
1P104 M
1T105 AUDIO OUTPUT TR.
P-M SPEAKER
SOUND I-F DETECTOR-AUDIO
V114 6CL6 1ST. VIDEO AMPL.
2L140 3.58 MC. TRAP
2L108 4.5 MC. TRAP
2C186 4-25 HUE CONTR.
2R204 500 CONTRAST CONTR.
SOUND I-F
V112A 6AN8 4TH. PIX. I-F AMPL.
1T110 4TH. PIX. I-F TRANS.
1T111 5TH. PIX. I-F TRANS
V113 6CL6 5TH. PIX. I-F AMPL.
1T112 5TH. PIX. I-F PLATE TR. 47.25 MC.
1T113 PIX. DET. TR 41.25 MC.
1CR 102 1N60 2ND. DET.
1R276 750 SOUND REJECT
1TP 101
PICTURE I-F
V129A 6AN8 BURST AMPL.
2T122 BURST AMP. TRANS.
V116B 6AN8 KEYER
V131A 6AN8 REACT. TUBE
2T124 REACT. TRANS.
V131B 6AN8 3.58 MC. OSC.
2Y101 XTAL 3.58 MC
2T128 3.58 MC. OSC. OUTP. TR.
V118 A 12AT7 SYNC. AMPL.
1PC101
A-G-C _ SYNC
VERT. SYNC.
HOR. SYNC.
1R283B 50K HOR. HOLD CONTR.
V127 6SN7-GT HOR. SWEEP OSC. & CONTR
2T119 HOR. SWEEP OSC. TRANS.
2TP104
V126 6CD6 HOR. SWEEP OUTPUT
3T117 H-V TRANS
2C237 4-70 HOR. LOCKING RANGE
2R266 100K HOR. DRIVE
3R261 80 HOR. CENTERING
3L120 WIDTH CONTR.


EO - BANDPASS AMPLIFIER
LUMINANCE AMPLIFIER
DEMODULATION - PHASE INVERSION
COLOR SYNCHRONIZATION
HORIZONTAL DEFLECTION
HIGH VOLTAGE-CONVERGENCE
LUMINANCE - Y
2TD 101 DELAY LINE
2L111 36 MU-H
2R198 1800
2R207 3300
2R208 2700
2L109 250 MU-H
V116 A 6AN8 BAND PASS AMPL.
2T126 BAND-PASS TRANS.
2C264 33
2R315 39K
2R316 10K
2R314 2700
2C265 150
2L121 BAND-PASS SEC. COIL
2R317 500 COLOR CONTR.
2C260 .01
2C262 .47
2C263 .01
2R312 10K
2C261 50 MF.
2R311 150
2R313 56K
SYNC
V115 A 6AN8 2ND. VIDEO AMPL.
2R210 1500 CONTRAST CONTR.
2R209 2200
2C189 0.1
2R211 2.2 MEG.
2C313 15 MF.
2R212 220
2R213 100
2C191A 20 MF.
2R296 1500
2C190 1000
2R214 47K
2R215 22K
2L112 250 MU-H
2R216 22K
+Y
* 2R210 AND 2R204 (CONTRAST CONTR.) ARE GANGED.
CHROMINANCE
V129 B 6AN8 PHASE DET.
2C254A 2200
2R304 15K
2R305 1 MEG.
2R306 250 K A.F.C BAL.
2R307 1 MEG.
2R310 27K
2C259 0.1
ON 3T177 (H-V TRANS.)
2W107
V130 B 6AN8 PHASE DET.
2C254B 2200
2R308 5.6MEG.
V112 B 6AN8 KILLER
1C258 .01
2R309 100 MEG.
2C257 .01
2C275 .01
2R340 15K
2C276 0.22
GCW
V133 6BY6 1ST "Q" DEMOD.
2L122 6.7 MU-H
2C266 22
2R321 18K
2C267 0.1
2R323 390 K
2R322 6.8 MEG.
2L123 1.9 MU-H
2R319 100
2R318 56
V115 B 6AN8 "Q" PHASE SPLITTER
2R324 33K
2TP102
2C268 2 MF.
2C312 24
2R325 3000
+Q
-Q
V131 B 6AN8 3.58 MC. OSC.
2C286 .01
2R347 39K
2C287 .01
2R348 180
2C288 .01
2C289 .01
V130 A 6AN8 QUADRATURE 3.58 MC. AMPL.
2R349 47K
2R350 10K
2T125 QUAD. TRANS.
2R352 680
2C291 1500
2R351 680
2C290 1500
ICW
V132 6BY6 1ST "I" DEMOD.
2T123 1ST TIME DELAY FILTER
2C292 4
2R354 4700
2C293 100
2R353 100
2C191D 20 MF.
2R320 12.5 K
2R357 5000
2R356 8200
2R355 4700
2C191B 20 MF.
2L133 1 MU-H
2C295 .047
2R358 1 MEG
2R359 100
2R361 500 "I" GAIN CONTR.
V134 A 6AN8 "I" AMPL.
2L134 1 MU-H
2C296 18
2C307 A 35 MF.
2R362 47K
2R363 4700
V134 B 6AN8 "I" PHASE SPLITTER
2C297 0.1
2TP103
2C299 2 MF.
2C298 9
2R367 6200
2R365 3.3 MEG.
2R364 390K
2R366 10K
+I
-I
V121 3A3 H-V RECT.
V124 1X2B FOCUS RECT.
V125 6AU4-GT DAMPER
V120 6BD4 SHUNT REGUL.
+19,500 V.
3C215 500
3R259 5 MEG. FOCUS CONTR.
3R260 8.2 MEG.
3C218 1200
3C219 .01
3C214 0.47
3R258 1 MEG.
3C213 0.22
3R253 50 MEG.
3R254 15 MEG. D.C. CONV.
3R255 50 MEG.
3R256 1 MEG. H-V ADJ.
3R257 1.8 MEG.
3L120 WIDTH CONTR.
3C227 0.18
3C221 20 MF.
2W106
1C306 2700
1R238 2500 HOR. CONV. AMPL. CONTR.
1L138 HOR CONV. PHASE
2W105
V119 12AU7 VERT. CONV. AMPL.
1R249 680 K
1R248 A 5 MEG. VERT. CONV. AMPL. CONTR.
1C212 0.47
1R252 1 MEG.
1R251 10 MEG.
1R250 2.7 MEG.
2W108
2R247 1.8 MEG.
1R248 B 5 MEG. VERT. AMPL. SHAPE
1C210 0.1
1C209 2200
1C211 0.22
2R242 27K
2C206 0.22
2C217 .0082
2C207 .01
2R245 2700
2R246 2700
2C208 0.22
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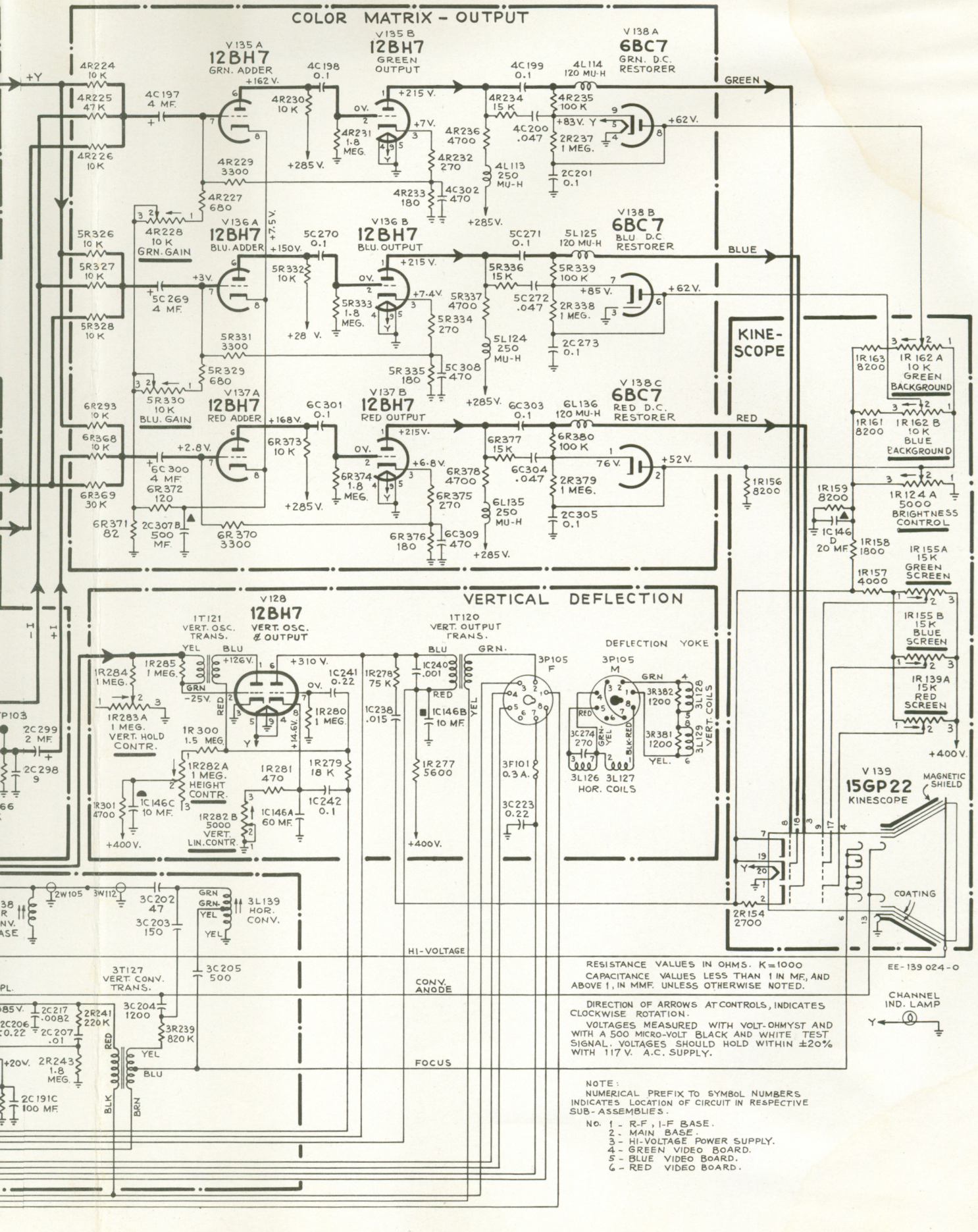
2R243 1.8 MEG.


COLOR MATRIX - OUTPUT
V135A 12BH7 GRN. ADDER
V135B 12BH7 GREEN OUTPUT
V138A 6BC7 GRN. D.C. RESTORER
V136A 12BH7 BLU. ADDER
V136B 12BH7 BLU. OUTPUT
V138B 6BC7 BLU D.C RESTORER
V137A 12BH7 RED ADDER
V137B 12BH7 RED OUTPUT
V138C 6BC7 RED D.C. RESTORER
KINE-SCOPE
VERTICAL DEFLECTION
V128 12BH7 VERT. OSC. & OUTPUT
V139 15GP22 KINESCOPE
MAGNETIC SHIELD
COATING
DEFLECTION YOKE
1T121 VERT. OSC. TRANS.
1T120 VERT. OUTPUT TRANS.
3L126 3L127 HOR. COILS
3L128 3L129 VERT. COILS
3L139 HOR. CONV.
3T127 VERT. CONV. TRANS.
HI-VOLTAGE
CONV. ANODE
FOCUS
CHANNEL IND. LAMP
GREEN
BLUE
RED
+Y
-Y
+I
-I
+285 V.
+400V.
+62V.
+52V.
+215 V.
+310 V.
+126V.
+168V.
+150V.
+162 V.
+7.5V.
+7V.
+7.4V.
+6.8V.
+2.8V.
+3V.
+20V.
+83V. Y
+85 V.
76 V.
-25V.
+14.6V.
+28 V.
4R224 10 K
4R225 47 K
4R226 10K
4C197 4 MF.
4R230 10 K
4C198 0.1
4R231 1.8 MEG.
4R232 270
4R233 180
4C302 470
4R229 3300
4R227 680
4R228 10 K GRN. GAIN
4C199 0.1
4L114 120 MU-H
4R234 15 K
4R235 100 K
4C200 .047
2R237 1 MEG.
2C201 0.1
4R236 4700
4L113 250 MU-H
5R326 10 K
5R327 10 K
5R328 10 K
5C269 4 MF.
5C270 0.1
5R332 10 K
5R333 1.8 MEG.
5R334 270
5R335 180
5C308 470
5R331 3300
5R329 680
5R330 10 K BLU. GAIN
5C271 0.1
5L125 120 MU-H
5R336 15 K
5R339 100 K
5C272 .047
2R338 1 MEG.
2C273 0.1
5R337 4700
5L124 250 MU-H
6R293 10 K
6R368 10 K
6R369 30 K
6C300 4 MF.
6R372 120
6C301 0.1
6R373 10 K
6R374 1.8 MEG.
6R375 270
6R376 180
6C309 470
6R370 3300
6R371 82
2C307B 500 MF.
6C303 0.1
6L136 120 MU-H
6R377 15 K
6R380 100 K
6C304 .047
2R379 1 MEG.
2C305 0.1
6R378 4700
6L135 250 MU-H
1R156 8200
1R159 8200
1C146 D 20 MF.
1R158 1800
1R157 4000
1R163 8200
1R161 8200
1R 162 A 10 K GREEN BACKGROUND
1R 162 B 10 K BLUE BACKGROUND
1R124 A 5000 BRIGHTNESS CONTROL
1R155 A 15K GREEN SCREEN
1R155 B 15K BLUE SCREEN
1R139 A 15K RED SCREEN
1R284 1 MEG.
1R285 1 MEG.
1R283 A 1 MEG. VERT. HOLD CONTR.
1R300 1.5 MEG.
1R282 A 1 MEG. HEIGHT CONTR.
1R282 B 5000 VERT. LIN. CONTR.
1R280 1 MEG.
1R281 470
1R279 18 K
1C241 0.22
1C242 0.1
1C146C 10 MF.
1C146A 60 MF.
1R278 75 K
1C238 .015
1C240 .001
1C146B 10 MF.
1R277 5600
3P105 F
3P105 M
3F101 0.3 A.
3C223 0.22
3R382 1200
3R381 1200
3C274 270
2C299 2 MF.
2C298 9
2W105
3W112
3C202 47
3C203 150
3C205 500
3C204 1200
3R239 820 K
2C217 .0082
2C207 .01
2R241 220 K
2R243 1.8 MEG.
2C191C 100 MF.
2R154 2700
RESISTANCE VALUES IN OHMS. K=1000
CAPACITANCE VALUES LESS THAN 1 IN MF, AND ABOVE 1, IN MMF. UNLESS OTHERWISE NOTED.
DIRECTION OF ARROWS AT CONTROLS, INDICATES CLOCKWISE ROTATION.
VOLTAGES MEASURED WITH VOLT-OHMYST AND WITH A 500 MICRO-VOLT BLACK AND WHITE TEST SIGNAL. VOLTAGES SHOULD HOLD WITHIN ±20% WITH 117 V. A.C. SUPPLY.
EE-139 024-0
NOTE:
NUMERICAL PREFIX TO SYMBOL NUMBERS INDICATES LOCATION OF CIRCUIT IN RESPECTIVE SUB-ASSEMBLIES.
No. 1 - R-F, I-F BASE.
2 - MAIN BASE.
3 - HI-VOLTAGE POWER SUPPLY.
4 - GREEN VIDEO BOARD.
5 - BLUE VIDEO BOARD.
6 - RED VIDEO BOARD.


RCA