PRACTICAL COLOR TELEVISION

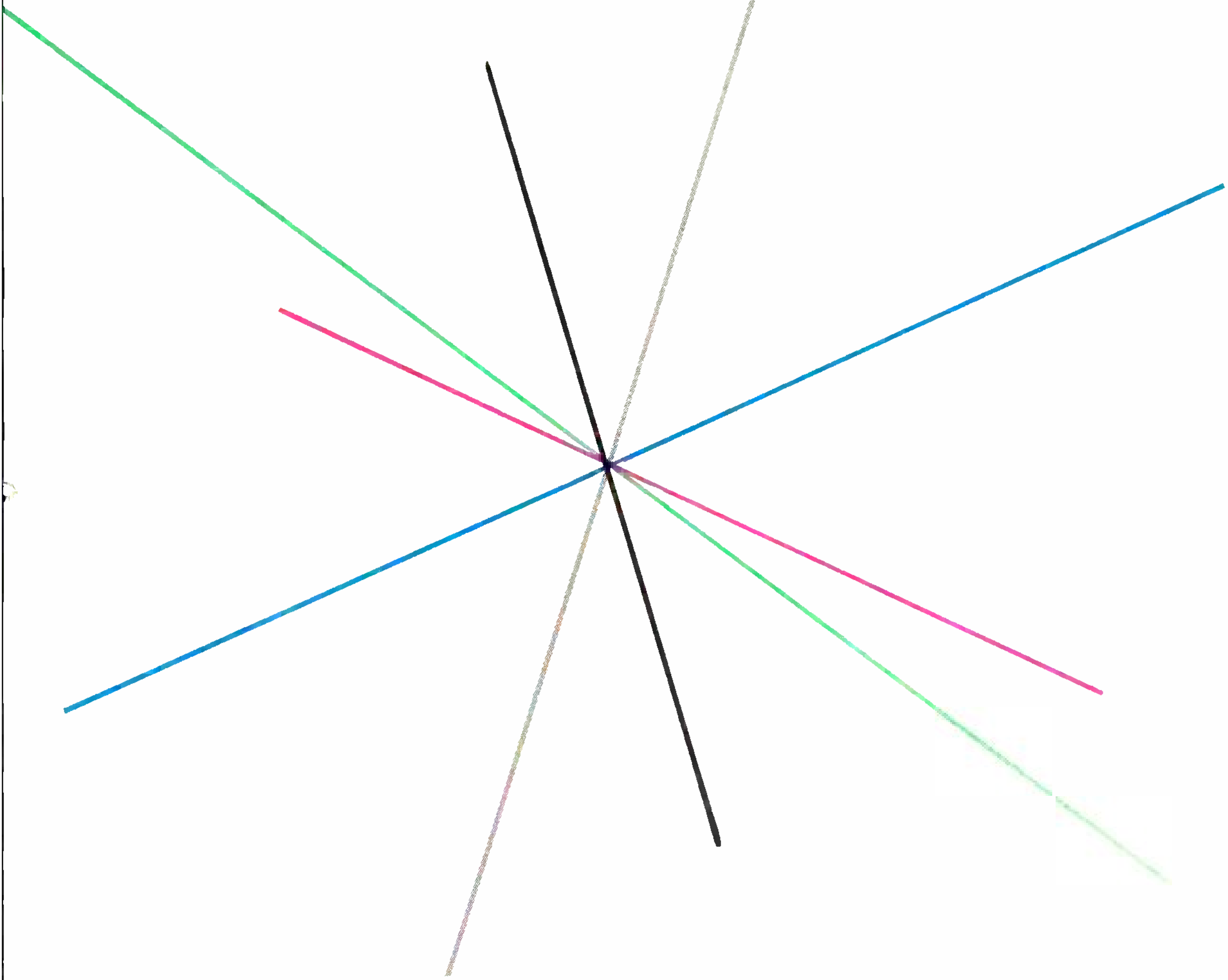
for the service industry

RCA SERVICE COMPANY, INC.
A RADIO CORPORATION OF AMERICA SUBSIDIARY
CAMDEN, N. J.

Price $2.00

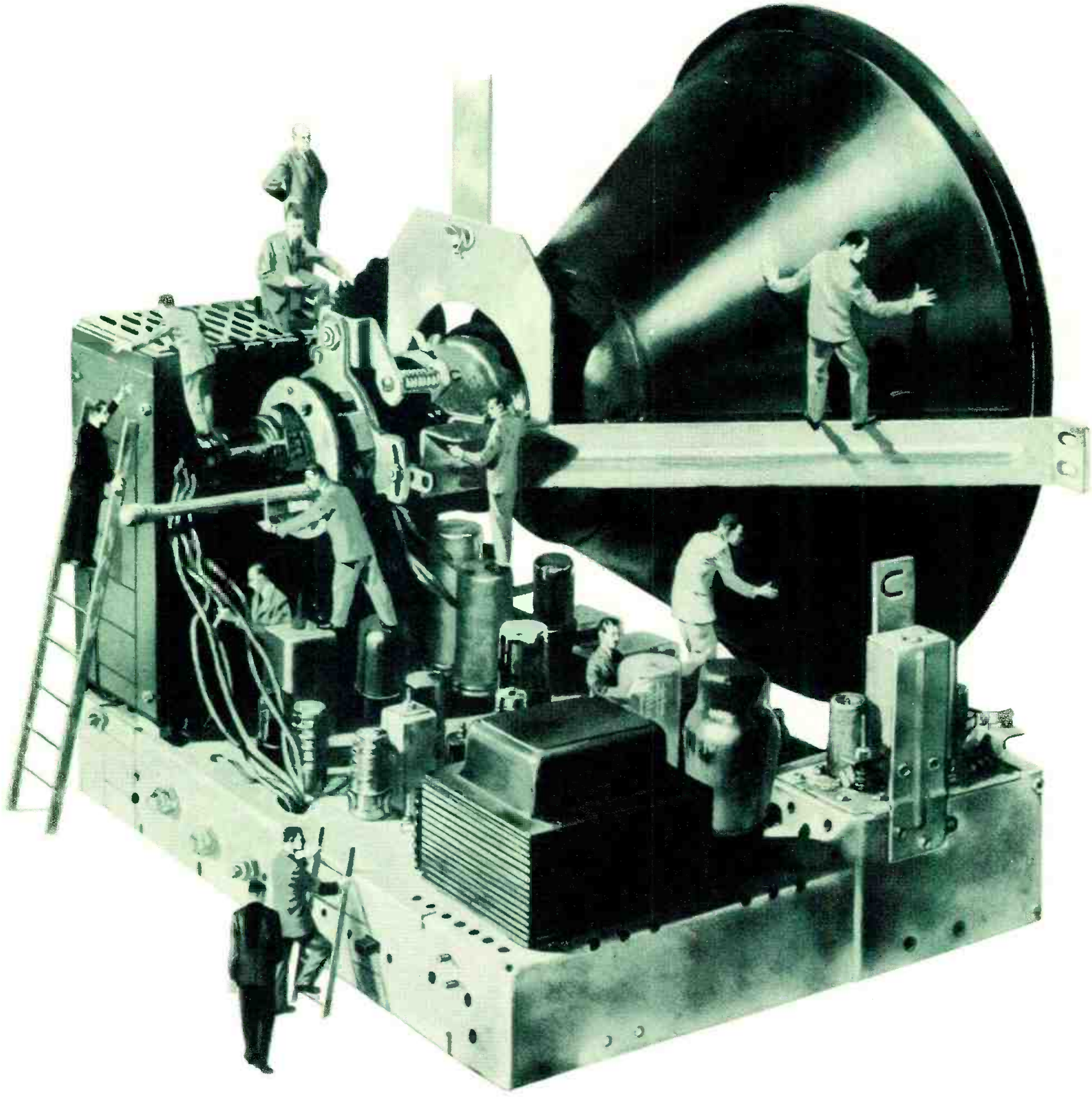
PRACTICAL COLOR TELEVISION

FOR THE SERVICE INDUSTRY



RCA SERVICE COMPANY, INC. A RADIO CORPORATION OF AMERICA SUBSIDIARY

TO THE MEN BEHIND



First Edition
First Printing—December 1953

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 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 Technicians, each an expert in his particular phase of color television servicing.

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.

CONTENTS

SECTION I

Fundamentals Relating to Color Television

SECTION II

Color Receiver Circuitry

SECTION III

Color Receiver Installation and Service

SECTION I

Fundamentals Relating to Color Television

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 system, and therefore assumes 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 receiver. While circuit details of color 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.

On reading this volume we believe the service technician will understand that, while 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 about them that he 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 better to understand the basic principles of the color medium . . . 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 Natural Step Forward

EVERYONE knows that the human eye in association with its 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. When we see the scene in color we see things as they are — not as they might be. 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 sticks sketches on the walls of limestone caves which were, no doubt, the first black and white (monochrome) pictures. Early man saw color in nature but with his limited tools could not reproduce 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 as brushes, produce a colored picture of what he saw or thought he saw on a handy surface. 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, eventually to be reproducible rapidly on cheap paper, so they could be seen by all mankind everywhere — not just the few people privileged to view the few oil paintings of the masters in churches, art galleries, etc. 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.

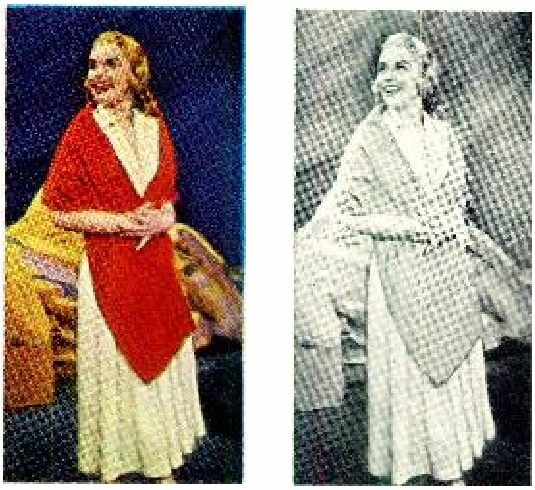


Figure 1 — The Appeal of Color

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." And as color printing and color photography processes are more complex than black and white processes, it follows that color television too is more complex to handle than monochrome television.

While color television in itself is a great natural step forward from black and white television, *com-*

patible color television, as developed by RCA, is a still greater step forward. Webster defines compatibility as "capable of existing together." Compatible color television simply means that color television broadcasts are receivable on the millions of black and white receivers already in the public's hands without any change whatsoever 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 TV broadcasts without any modification whatsoever. The feature of compatibility is important to all. For the broadcaster, and the sponsor, it means maintenance of a program audience, in which large monies have been invested for build-up, regardless of whether the broadcast is in color or black and white. And even more important, the public's investment of billions of dollars in black and white receivers, purchased and in use to date, is protected since they can view the color broadcast as a black and white receiver picture without any additional cost whatsoever.

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 can 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. And 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 familiar and tremendous speed of 186,000 miles a second, or 300,000,000 meters per second, and differ only in wavelength and frequency in the familiar 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 familiar electromagnetic or 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 milli-microns (thousands of a millionth 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 are presented to the eye in certain nearly equal quantities we receive the sensation of *colorless* or "white" light—the same white light of the black and white television picture tube when the cathode ray electron beam energizes the viewing screen phosphors. 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.

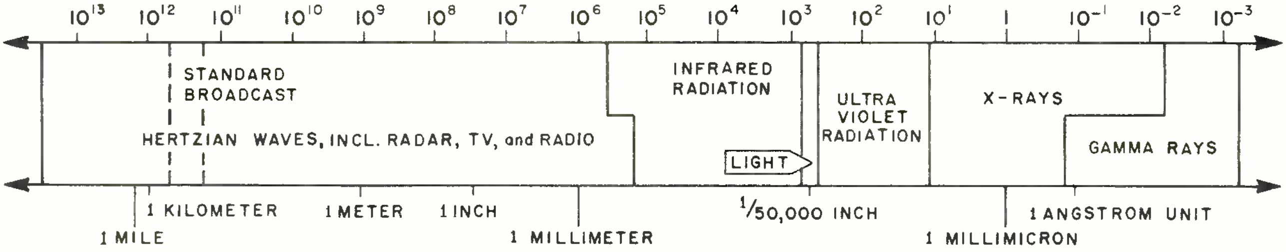


Figure 2 — The Radiant Energy Frequency Spectrum

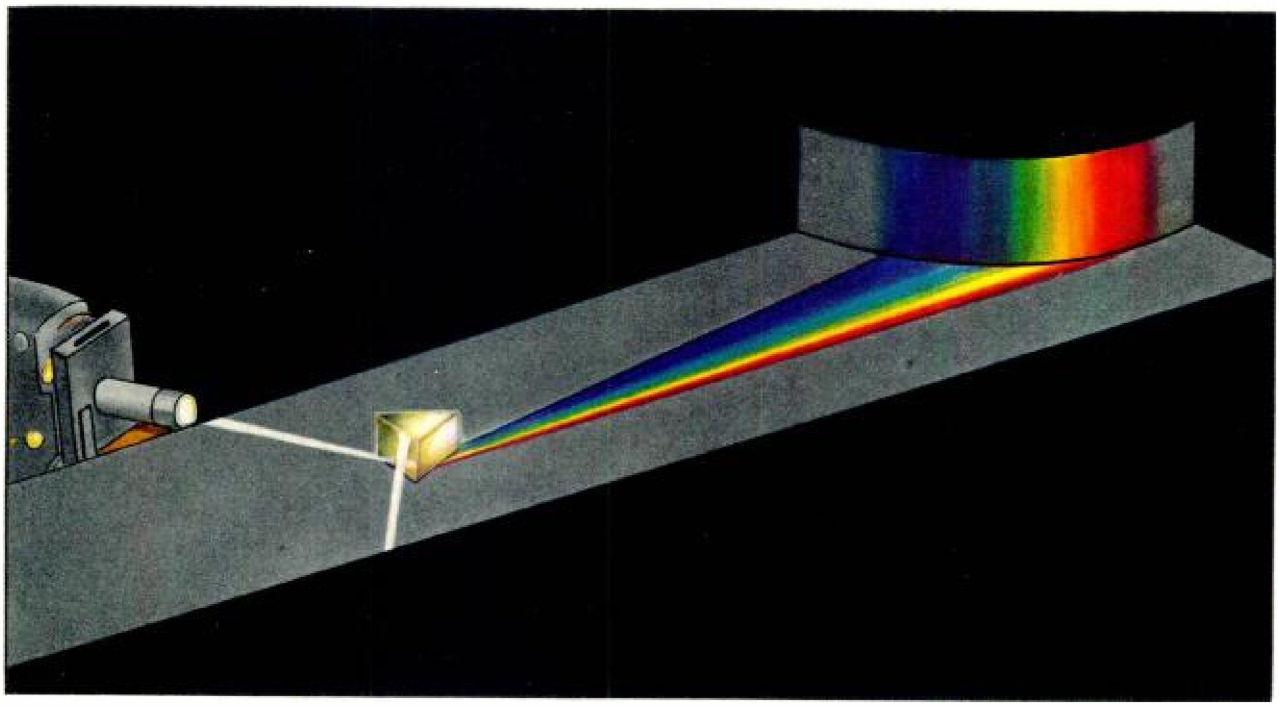


Figure 3—Separation of White Light Through a Prism

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 shown is called the *visible spectrum of light* and the principal colors as reproduced are seen to be red, yellow, green and 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 signals 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 three typical blue, green, and red sources are shown in Figure 4. A set

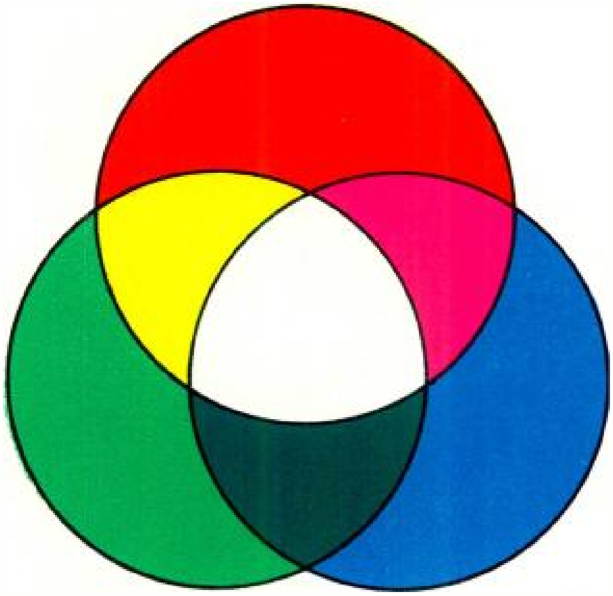


Figure 4 — The Additive Primaries

of three such colored lights are known as *additive primaries*. Actually, the three additive color primaries are not necessarily restricted to blue, green, 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 to 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, man's average 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!) The eye's brightness response isn't uniform as shown in Figure 5.

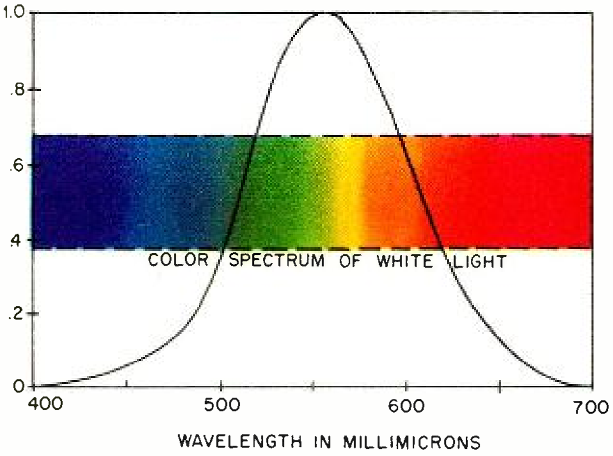


Figure 5 — Luminosity Response of the Human Eye

This curve, in reality, describes the spectral characteristics of the *brightness sensation* only. Note the curve peaks near the green wave length. The curve shows then that a given amount of light energy may appear *much brighter* at some wave lengths 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 naturally determined by *radiant purity*, or freedom from white. (Note the word "purity" as it is used as a common term in color television. For example, a color TV receiver has "purity" adjustments on its picture tube to insure complete saturation — full "hue" output — of the color phosphors.)

Figure 6 shows the spectral radiation energy curve spread out more or less uniformly over the visible spectrum. When such a condition holds, our eyes tell us we are seeing "white." If such a curve has a small peak, as at "A," the color is seen as a

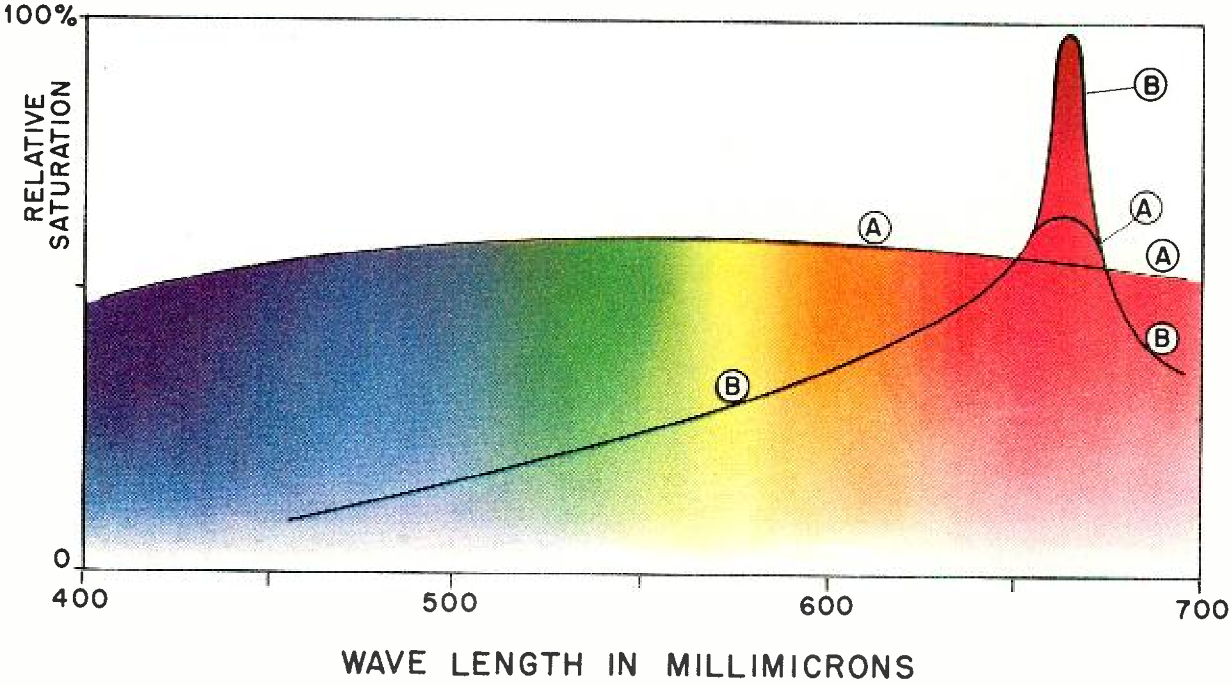


Figure 6—The Spectral Radiation Curve of White, Pink and Red Objects

pale or pastel shade—in this case pink—a low saturation of the dominant wavelengths "hue" of red. If the curve spectral energy was like that shown as "B" the color is seen as a high saturation, vivid one 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 third a strip divided by a "red hue" at low "saturation A" and high "saturation B" 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 color but the same bright white of black and white television) by the three basic characteristics of color; namely, 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."

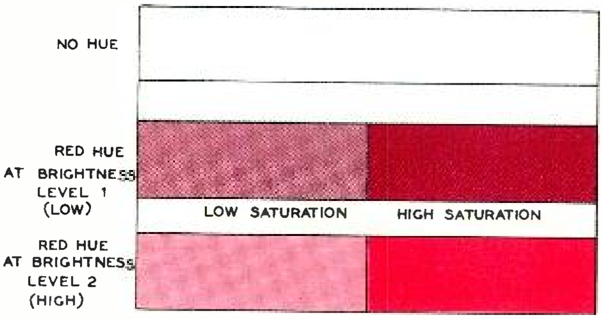


Figure 7 — Relationship of Brightness and Saturation

A basic tool for "colorimetry"—the study of color — is the "color solid" which is shown at the left in Figure 8. It is self-explanatory and should help to understand the basic relationships in "hue," "saturation," "brightness" and their range as compared to the simple "brightness" scale at the right which represents the picture content "contrast" range in black and white television. As you expected, black and white television is that simple as compared to color television. 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 basic primary

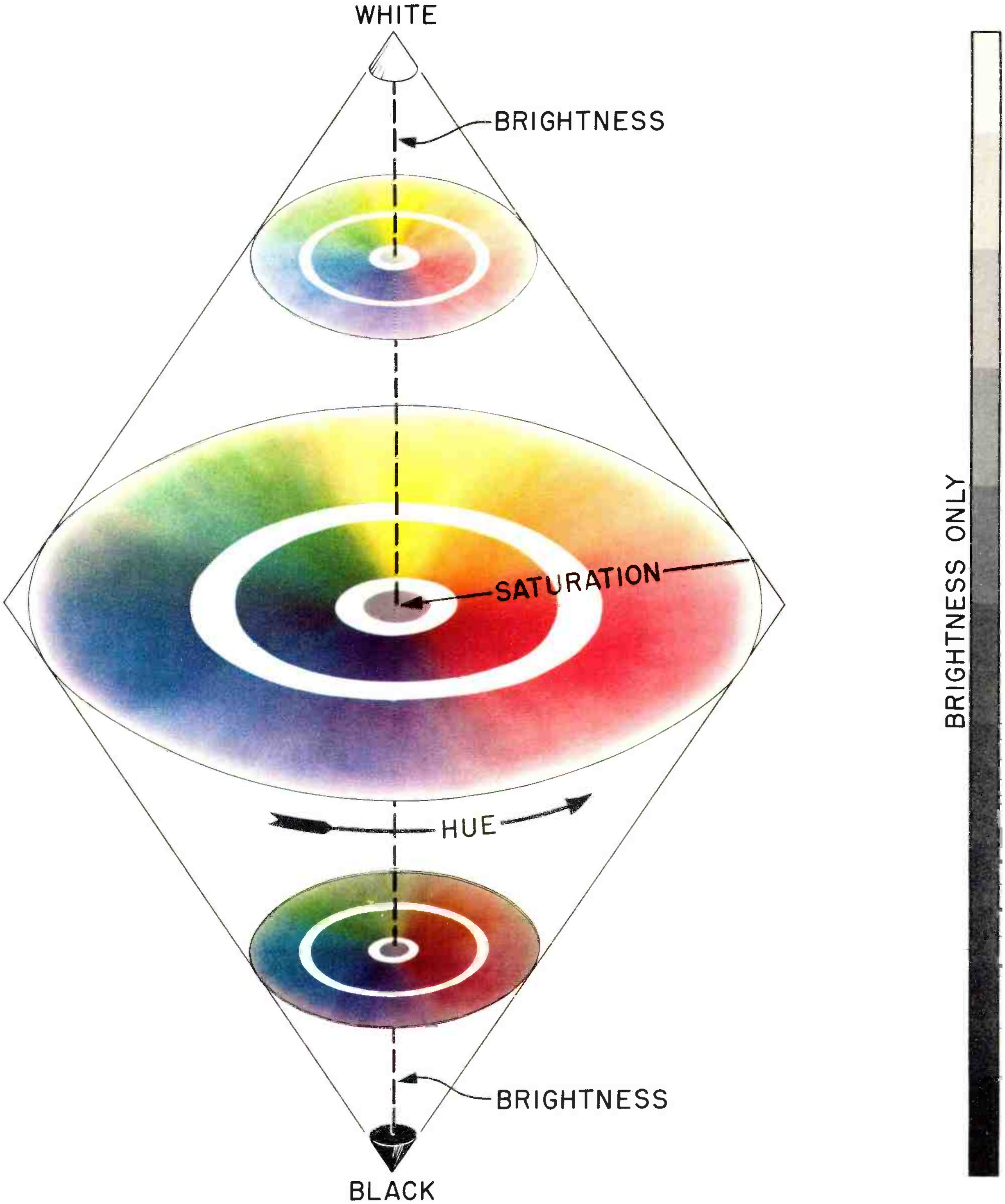


Figure 8 — Relationship of Brightness, Hue and Saturation

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*.

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 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.

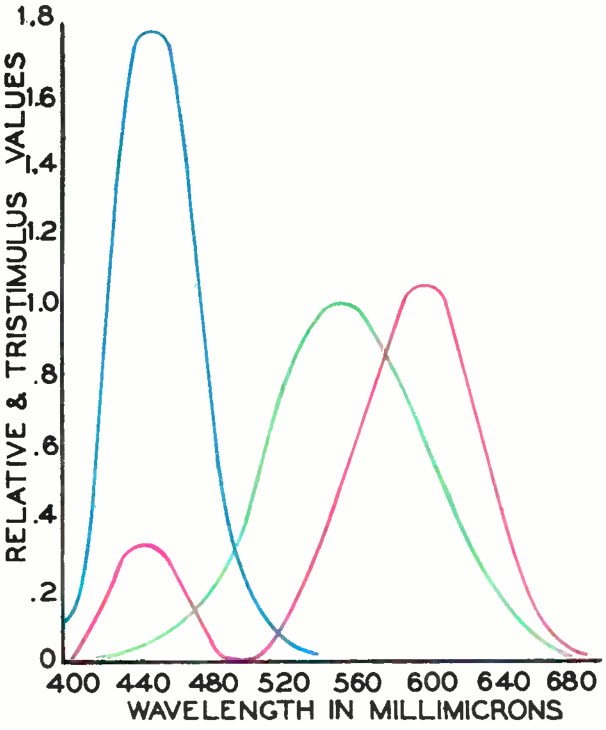


Figure 9 — Fundamental Color Mixture Curves

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 NTSC 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 NTSC range of all hues and saturations with respect to point W, white. The shaded area represents colors not 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 11 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 11 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 NTSC chromaticity specification for the hue and saturation range for color television.

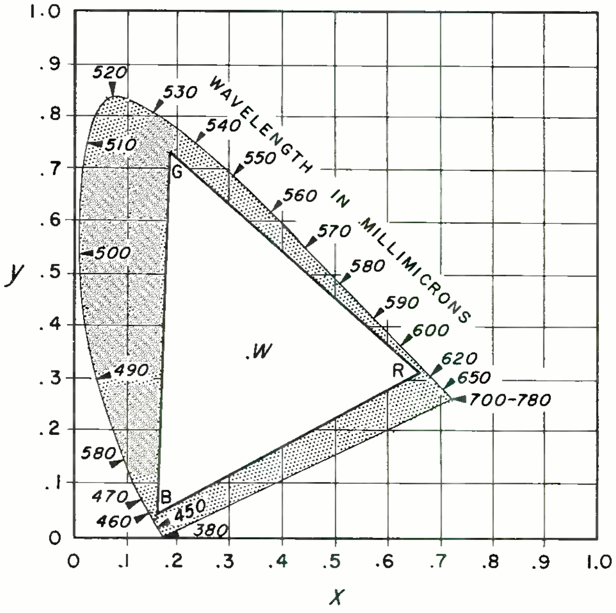


Figure 10—CIE Chromaticity Diagram

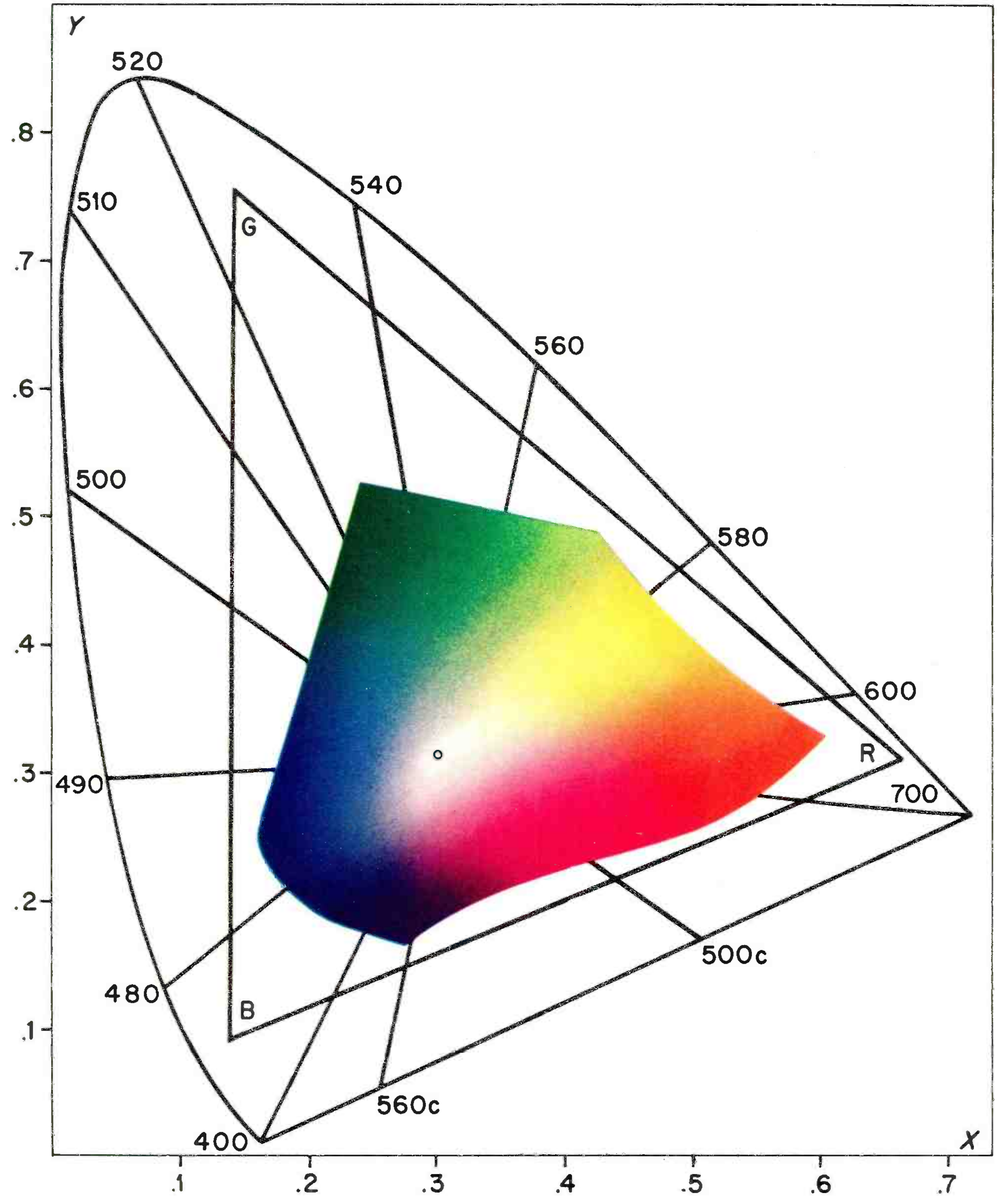


Figure 11 — The Gamuts of Printing Inks and Color Television

Development of the Transmitted Color Signal

Compatibility Requirements

One of the first requirements of a color TV system is to provide black and white pictures for present standard black and white receivers without any modifications to the receivers. This means that a color telecast must provide a full 4 MC black and white signal with the same amplitude modulation, sync and blanking characteristics as does any ordinary standard black and white TV transmitter. Secondly, the chrominance information must be transmitted within the standard 6 MC TV spectrum and, thirdly, the transmitted chrominance information must not in any way cause objectionable interference with the black and white signal (sometimes referred to as the Y signal).

At first glance, this seems to be a difficult thing to do, since the 6 MC channel is already well filled. It has been found, however, that an additional carrier may be transmitted within the same spectrum space occupied by the Y signal without causing objectionable interference. This additional carrier will be the means of transmitting the chrominance information.

The reason that spectrum space is available for signals other than the "Y" signals 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 line scanning frequency (15,750 cps) and that nearly half the space between the frame and line scanning frequency harmonics, up to video (brightness) band pass cutoff, is relatively devoid of any video information. This situation for the line scanning frequency harmonics is shown in FIGURE 12. Here then is a means of "inter-leaving" the chrominance sidebands without causing objectionable interference (i.e. "cross-talk") with the normal black and white sideband signals. This multiplexing technique is sometimes called "frequency interlace."

When the chrominance carrier frequency is chosen as an odd multiple of *one-half* the line frequency the chrominance sidebands are caused to appear in the empty spaces of FIGURE 12. These chrominance sidebands are shown as dotted lines in FIGURE 13.

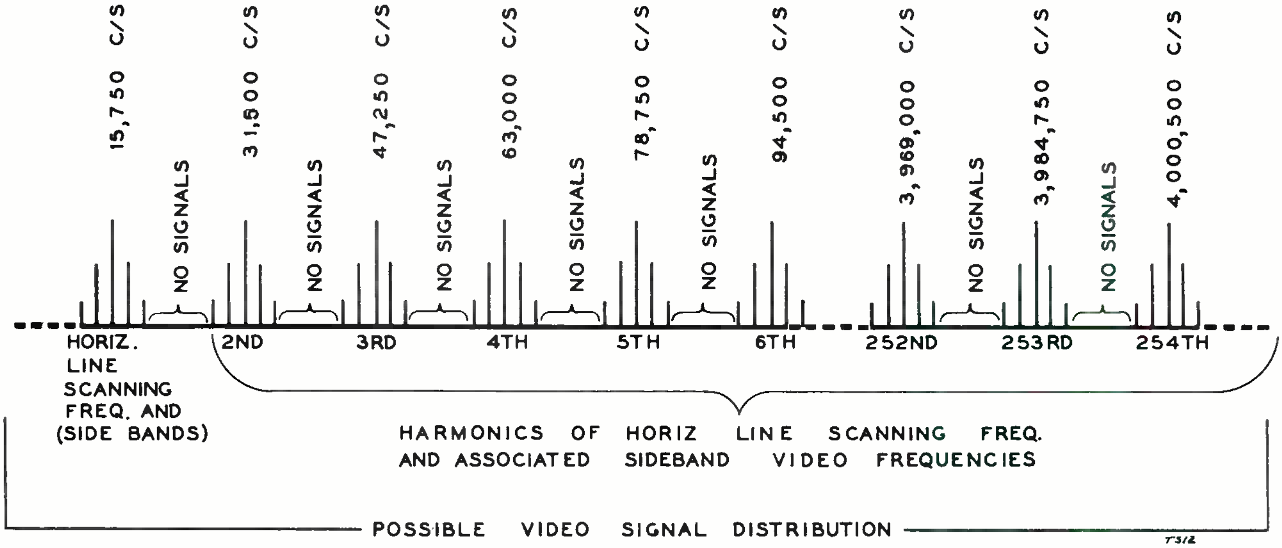


Figure 12 — Disposition of Video Information in a Black and White Signal

To help understand how a properly chosen "frequency inter-leaving" of the chrominance signals assures least "cross-talk," or least visible effect, on a black and white receiver when it is receiving a color telecast, it is helpful to show the normal black and white or "luminance" signal as wave (a) of FIGURE 14 and the "chrominance" signal as wave (b) assuming this condition represented both signals for a very small section of one's scanning line in the receiver picture.

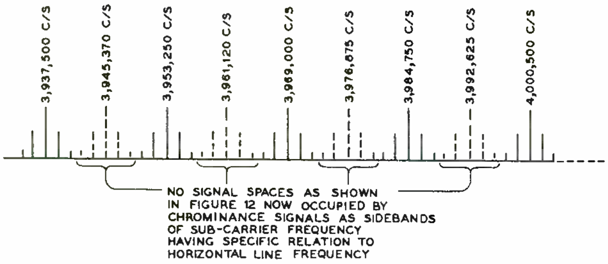
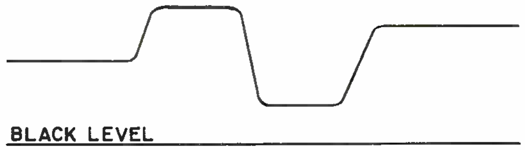


Figure 13 — Position of Interleaved Chrominance Sidebands

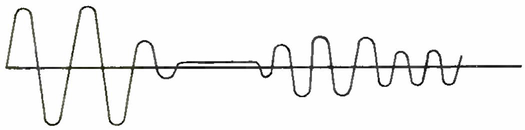
Because of frequency interlace, the chrominance signals produced on the same line during the next scan (1/30th of a second later) is 180° out of phase with the original chrominance signals (the subcarrier goes through some whole number of cycles plus one half during each frame period). The chrominance signal for the second scan is shown as the dotted wave in (c). The sum of the luminance and chrominance signals for both scans is shown in (d). A cancellation effect takes place with respect to the chrominance signal. Because of persistence of vision, the stimulation is averaged out after two scans, so the eye effectively sees the signals at (e), which is practically the same as the original black and white signal at (a). It should be noted that this cancellation is not 100% effective because of picture tube cut-off characteristics which can, under certain conditions of picture signal, generate spurious harmonics of the chrominance signal. Choice of system standards are such that these spurious "crosstalk" signals are of such high frequencies that at normal viewing distances where the scanning line structure disappears, the spurious crosstalk also disappears from the eye's view.

After considerable field testing, it was found that the chrominance information could best be transmitted by modulating a carrier frequency of 3,579,545 c/s (3.58 MC for short) which is the 455th harmonic of one-half the line frequency, when the line frequency is specified as 2/572 times 4.5 MC (the standard spacing between picture and sound carriers in a TV channel). The line frequency is established in this way to minimize a beat problem between the chrominance carrier and the sound carrier. The chrominance subcarrier is high enough in frequency to insure any spurious black and white crosstalk, resulting from picture tube cut-off, disappearing at normal viewing distance and low enough to permit transmission of sufficient chrominance sidebands for acceptable color fidelity.

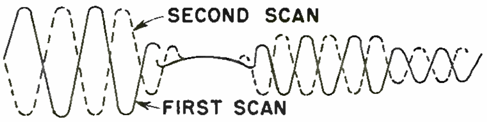
Another very important requirement of compatibility is that the transmitted chrominance information meet the psycho-physical and psychological



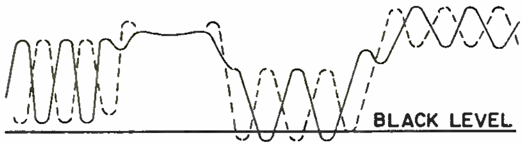
(a) LUMINANCE BLACK AND WHITE SIGNAL



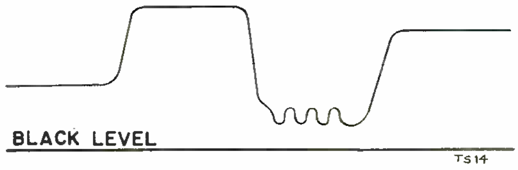
(b) CHROMINANCE SIGNAL, FIRST SCAN



(c) CHROMINANCE SIGNAL, COMBINED FIRST AND SECOND SCANS



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



(e) AVERAGE LIGHT OUTPUT AFTER TWO SCANS

Figure 14 — Frequency Inter-leaving of the Chrominance Signal

requirements of the human eye. In developing the present RCA color television system, RCA engineers made deep researches into the fundamental properties of the eye's color vision requirements. In the previous section the fundamental color sensations of the eye, namely; hue, saturation, and brightness have been described. It should be obvious that any color television system must provide means of handling these characteristics. The black and white TV system is based on (1) breaking up the picture into very small elemental areas, (2) producing and transmitting the brightness signals corresponding to these picture elemental areas, (3) receiving these signals in synchronism with the scanning at the transmitter and then (4) reproducing the brightness values of the original scene by having the signal control the production of white light by the picture tube electron scanning beam. It has long been known the human eye's color vision response was somewhat dependent on the finite size of various color areas observed, so RCA made picture viewing tests to determine this important characteristic of color vision as it applied to color television. This work showed that as colored test objects are decreased in size, four things are found to happen in succession. First, blues become indistinguishable from grays. In the same color area size range where this happens browns are confused with crimsons, and blues with greens, but reds remain clearly distinct from blue-greens. Third, with still further decrease in color area size, reds merge with grays of equivalent brightness. Fourth, and finally, blue-greens also become indistinguishable from gray.

People with normal vision, then, see rather small objects in just the same way that certain color blind people see all objects. For exceedingly small objects, normal vision sensations are *devoid of all color perception* and *only the perception of brightness remains.*

It can be seen that color television reproduction on a full three-color basis for all details of all objects, regardless of size, is not necessary to be compatible with color vision requirements of the eye and therefore can be a rather wasteful process. It has been found that any color, in a small enough patch well centered in the field of vision, can be matched by mixing only two, and not three, primary colored lights. Further tests have indicated that the two primaries mixed to match the color of a tiny object should be chosen as an orange red and greenish blue.

In summary, a color television system, to satisfactorily handle the compatibility requirements of the eye's color vision, should have the following properties:

1. *Hue* or dominant wavelength, *saturation* or purity (freedom from white) and *brightness* or luminance information should all be transmitted for color patches subtending relatively large areas at the eye.
2. *Saturation only* (within reduced limits as represented by two hues, orange red and greenish blue) and *brightness* information need be transmitted *for quite small color detail.*
3. *Brightness only* need be transmitted *for the finest detail.*

It is to be noted that all three color vision conditions listed require *brightness* of the picture element areas regardless of size. It is known from experience with black and white television that the eye's resolution for the fine brightness detail at normal viewing distance is well satisfied with the signals resulting from the standard 525 line scanning process, which results in video signal frequencies up to around 4 MC. It should, therefore, be readily seen that our present standard black and white signal is entirely satisfactory to handle the brightness characteristic of all color picture detail.

Color Signal Development

As has been stated previously the signal requirements of a color TV system are as follows:

1. A full 4 MC black and white signal to produce high quality black and white pictures, without any objectionable interference, on a standard black and white receiver.
2. Chrominance information to meet the requirements of the normal human eye to be modulated upon a 3.58 MC subcarrier "inter-leaved" with the standard black and white signal to produce high quality color pictures on a color TV receiver.

The present color TV camera consists of three camera tubes representing red, green, and blue. The original scanned color scene is separated by the use of dichroic mirrors and filters into these three primary colors and the three camera tubes transform these light energies into electrical impulses. At the output of the color TV camera there are three separate electrical signals each representing a primary color.

In the previous section it was shown that a mixture of the additive light primaries of red, green, and blue produced white light. It has been established as a color television standard that a white

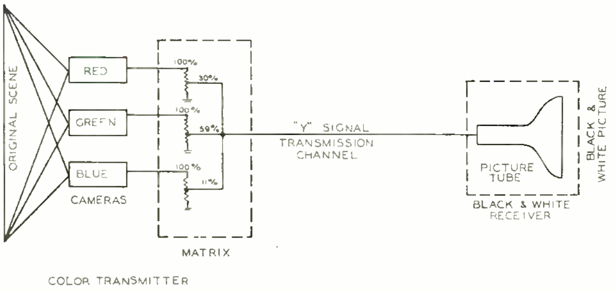


Figure 15 — Color to Black and White Compatibility

signal, designated as "Y" can be made up by mixing 30% of the red camera signal, 59% of the green camera signal and 11% of the blue camera signal. These proportions correspond to the spectral brightness characteristic of the eye. "Y" then is equal to 0.30R + 0.59G + 0.11B, where R, G and B represent output signal values of the red, green, and blue camera.

FIGURE 15 illustrates the simplest possible representation of the color to black and white compatibility of the RCA color television system and is largely self-explanatory. The "matrix" is a simple resistance network in the *transmitter only* which insures no change whatsoever in the black and white receiver. It adds the proper proportions of the red, green, and blue signals to form the "Y" or brightness signal. Conversely, FIGURE 16 illustrates the simplest possible representation of the black and white to color compatibility of the RCA color television system and is largely self-explanatory. The "matrix" in this case is in the color TV receiver and divides the "Y" signal in proper proportions so each of the color picture tube's phosphors are excited to produce white when the three primary color pictures are super-imposed with proper registration.

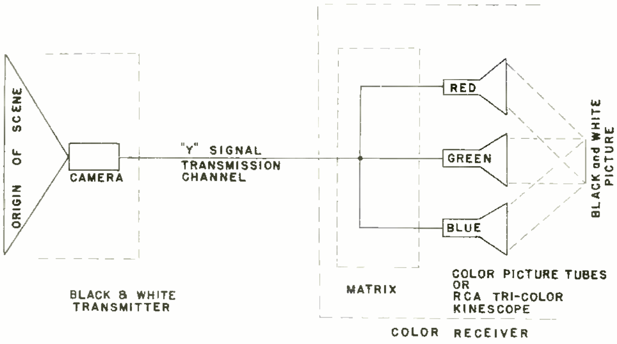


Figure 16 — Black and White to Color Compatibility

The RCA Tri-color tube, having an electron gun for each primary color and groups of red, green, and blue phosphor dots on the viewing screen provides accurate super-imposition for proper picture element registration.

Fulfilling the requirements of handling the chrominance information (hue and saturation), by the use of a 3.58 MC subcarrier is the most difficult problem encountered in color signal transmission. The color camera output signal voltages must by some means modulate the 3.58 MC subcarrier in such a way that the signal voltages can be separated at the receiver in order to drive the red, green and blue guns of the tri-color kinescope. We have already shown that we should transmit a certain mixture of red, green and blue (30% R, 59% G and 11% B) as the black and white or luminance signals which control brightness. Since color has only three variables, we need only two additional signals to convey all the information needed to produce a color picture. It has been found through research that two color difference signals, consisting of a certain mixture of red, green and blue, can convey all the necessary chrominance information. These two signals show how the various colors in the picture differ from the neutral group of the same brightness that would be produced by the luminance signal alone. These two color difference signals are modulated upon two 3.58 MC subcarriers, separated by a 90° phase displacement, producing a single resultant (3.58 MC) chrominance subcarrier which varies both in amplitude and in phase (ordinary AM waves vary only in amplitude). The in-phase component of the subcarrier is called the I signal, and the quadrature-phase (90°) component is called the Q signal. At the receiver, the I and Q chrominance signals are separated from the subcarrier by synchronous detectors, which compare the incoming subcarrier with reference 3.58 MC carriers generated by an oscillator within the receiver. Special synchronizing information must be transmitted to keep the receiver oscillator "locked in" to the master 3.58 MC oscillator at the transmitter.

A simple representation of the system just described is shown in block diagram form in FIGURE 17. Proper amplitudes of the red, green and blue camera output signal voltages are cross-mixed to

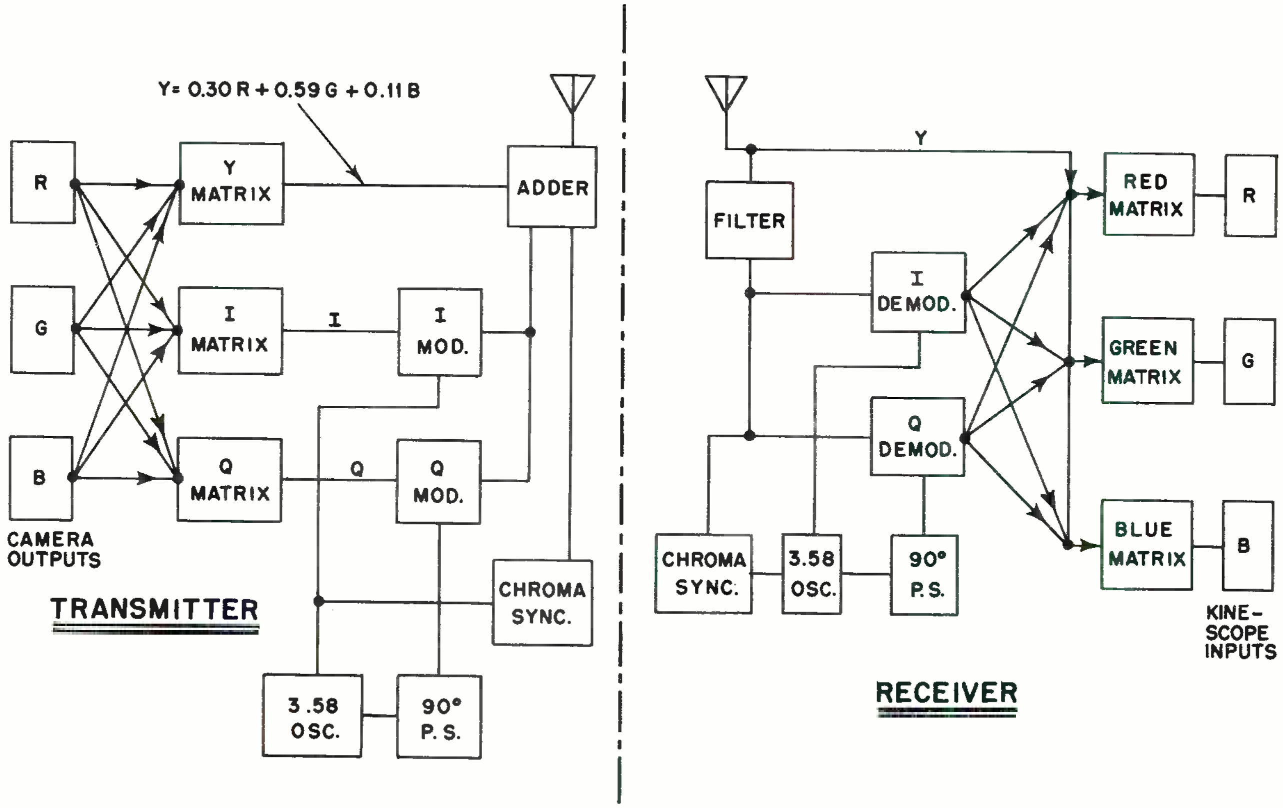


Figure 17 — Block Diagram of a Color Transmitter and Receiver

develop the Y, I and Q signals in the transmitter matrix blocks. In the receiver proper amplitudes of Y, I and Q signal voltages are combined in the matrix blocks to produce the original color camera outputs in the red, green and blue channels.

It has already been shown that the Y (brightness) signal consists of 30% red, 59% green and 11% blue. Developing the I and Q signal formulas, however, required extensive research relating to the perception of color by the human eye. It was found that the I and Q chrominance signals, representing the saturation characteristic of the three primary hues, could be limited in bandwidth to a frequency of 0.5 MC and still satisfy the requirements of the eye in the reproduction of *large* color areas. It was also found that just one of the chrominance signals could handle the reproduction of *small* color areas by extending its bandwidth to a frequency of 1.5 MC. This is possible, since (as it was previously stated) small color areas can closely match large color areas by the saturation characteristics of only *two* primary hues instead of three—namely, an orange red and greenish blue. The I chrominance signal has been allotted the extended 1.5 MC bandwith. It is readily seen that video frequencies up to 0.5 MC, representing large color areas of a televised color scene, are handled by the Y (brightness) signal plus the I and Q chrominance signals. Video frequencies from 0.5 MC to 1.5 MC are handled by Y plus I signals, the Q signal not being transmitted (in this case the 3.58 MC sub-carrier is modulated by the I signal alone). Video frequencies above 1.5 MC are handled by the Y signal alone, the I and Q chrominance signals not being transmitted. Under this latter condition the transmitted signal is that of a standard black and white transmission. Therefore at the transmitter all frequencies above 0.5 MC are filtered out of the Q chrominance signal and all frequencies above 1.5 MC are filtered out of the I chrominance signal before they are phase modulated. Utilizing these considerations, the formula for the I and Q chrominance signals are as follows:

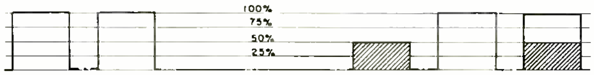
$$I = -0.28G + 0.60R - 0.32B$$

$$Q = -0.52G + 0.21R + 0.31B$$

In order to better understand how the Y, I and Q signals handle the three characteristics of color (hue, saturation and brightness) the evolution of the composite color signal from a scanned color scene is shown graphically in FIGURE 18. For purposes of illustration only, the hues in FIGURE 18 (a) have been selected as typical areas of a color scene. White, having no hue or saturation, can be divided into equal amounts of red, green and blue by the color TV camera. The highly saturated red, green, blue and yellow hues have complete freedom from white. Yellow is composed of equal amounts of red and green camera signals. Green and yellow hues of low saturation do not have complete freedom from white and the white portion is proportioned into red, green and blue by the color TV camera. The signal waveforms of the red, green and blue color TV camera are shown graphically in FIGURE 18 (b), (c), and (d) for the hues indicated in (a). Yellow and green hues of low saturation are represented by 50% saturation signal and 50% white signal. The shaded areas of signal from all three camera tubes is the amount required to produce the 50% white signal. Hue is determined by the remaining unshaded portions of camera signal. The formation of the Y signal is shown in FIGURE 18 (e). Since white is proportioned into equal amounts of red, green and blue, it is a 100% signal voltage value (Y = 0.30 of 100% red + 0.59 of 100% green + 0.11 of 100% blue). Low saturated green is a 79% signal voltage value (0.30 of 50% red + 0.59 of 100% green and 0.11 of 50% blue). Highly saturated yellow is a 89% signal voltage value (0.30 of 100% red + 0.59 of 100% green). Low saturated yellow is a 95% signal voltage value (0.30 of 100% red + 0.59 of 100% green + 0.11 of 50% blue). The formation of the I chrominance signal is shown in FIGURE 18 (f). White is a 0% signal voltage value (0.60 of 100% red — 0.32 of 100% blue — 0.28 of 100% green). Low saturated green is a —14% signal voltage value (0.60 of 50% red — 0.28 of 100% green — 0.32 of 50% blue). Highly saturated yellow is a 32% signal voltage value (0.60 of 100% red — 0.28 of 100% green). Low saturated yellow is a 16% signal voltage value (0.60 of 100% red — 0.28 of 100% green — 0.32 of 50% blue). The formation of the Q chroma signal is shown in FIGURE 18 (g). White is a 0% voltage value (0.21 of 100% red + 0.31 of 100% blue — 0.52 of 100% green). The remainder of the Q signal is formed in a manner similar to the I signal.

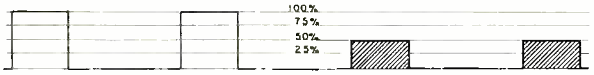
It was previously stated that the I and Q chrominance signals are modulated on two 3.58 MC car-

(a) TYPICAL AREAS OF COLOR SCENE

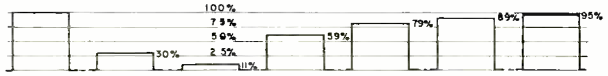


(b) RED CAMERA SIGNAL OUTPUT –
RED KINESCOPE SIGNAL INPUT

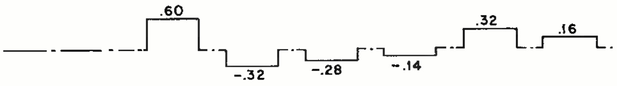
(c) GREEN CAMERA SIGNAL OUTPUT –
GREEN KINESCOPE SIGNAL INPUT



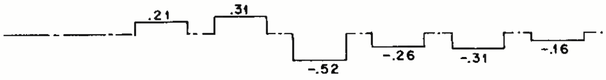
(d) BLUE CAMERA SIGNAL OUTPUT –
BLUE KINESCOPE SIGNAL INPUT



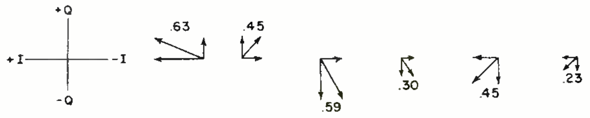
(e) LUMINANCE (brightness) SIGNAL
Y = 30% R + 11% B + 59% G



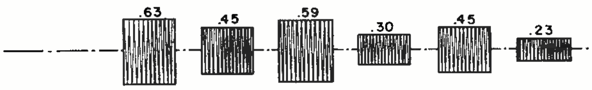
(f) I SIGNAL- I = 0.60R-0.32B-28G



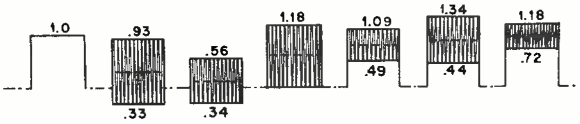
(g) Q SIGNAL- Q= 0.21R+0.31B-0.52G



(h) CHROMA SUB-CARRIER VECTORS



(i) CHROMA SUB-CARRIER ENVELOPE



(j) COMPOSITE COLOR SIGNAL

Figure 18 — Evolution of the Composite Color Signal

riers, phase separated by 90°, producing a *single* resultant 3.58 MC subcarrier. This is shown graphically in FIGURE 18 (h). For example, highly saturated red is represented by 60% I and 21% Q, producing a resultant of 63% of the total red camera output signal. Highly saturated green is represented by a negative 28% I and a negative 52% Q, producing a resultant of 59% of the total green camera output signal. It will be noted that phase angles for high and low saturated green are the same; however, the amplitude varies with the degree of saturation.

Each hue has a different phase angle in reference to the I or Q axes. This shows that *saturation* varies the *amplitude* of the chrominance subcarrier envelope and *hue* varies the *phase* as shown in FIGURE 18 (i). The composite color signal (Y plus the subcarrier envelope) minus the synchronizing information is shown in FIGURE 18 (j). In summation, the relationship of the major hues with respect to the I and Q axes is shown in FIGURE 19.

Subcarrier synchronizing information must be transmitted so that the receiver may accurately separate the I and Q chrominance signals from the resultant subcarrier. This is transmitted in the form of a "burst" of about eight cycles at the subcarrier frequency transmitted during the horizontal blanking period after each horizontal sync pulse. This burst pulse is described in greater detail in a later section.

The addition of the I and Q signals in the receiver matrix produce "color difference" signals, namely, R-Y, G-Y and B-Y. These signals are then added to Y to produce red, green and blue signals. Referring to FIGURE 19, the subcarrier envelope amplitudes and phase angles are shown for the colors red, green and blue. In FIGURE 19(a) the red, green and blue amplitudes are the resultants of the vector addition of I and Q. If the amplitudes and phase angles are kept constant but the I and Q axis rotated to the 0.877 (R-Y) and 0.493 (B-Y) positions shown in FIGURE 19(b) new values of red, green and blue are then assigned to these new axes. R-Y would then equal 0.70R – 0.59G – 0.11B and B-Y would equal — 0.30R — 0.59G + 0.89B. Adding Y to these signals would then produce red and blue signals.

In the color receiver the phase of the local oscillator could be rotated 33° and the synchronous detectors would demodulate on R-Y and B-Y instead of I and Q. The addition of —0.51R-Y and —0.19B-Y in the color receiver produces a G-Y signal equal to – 0.30R + 0.41G – .11B.

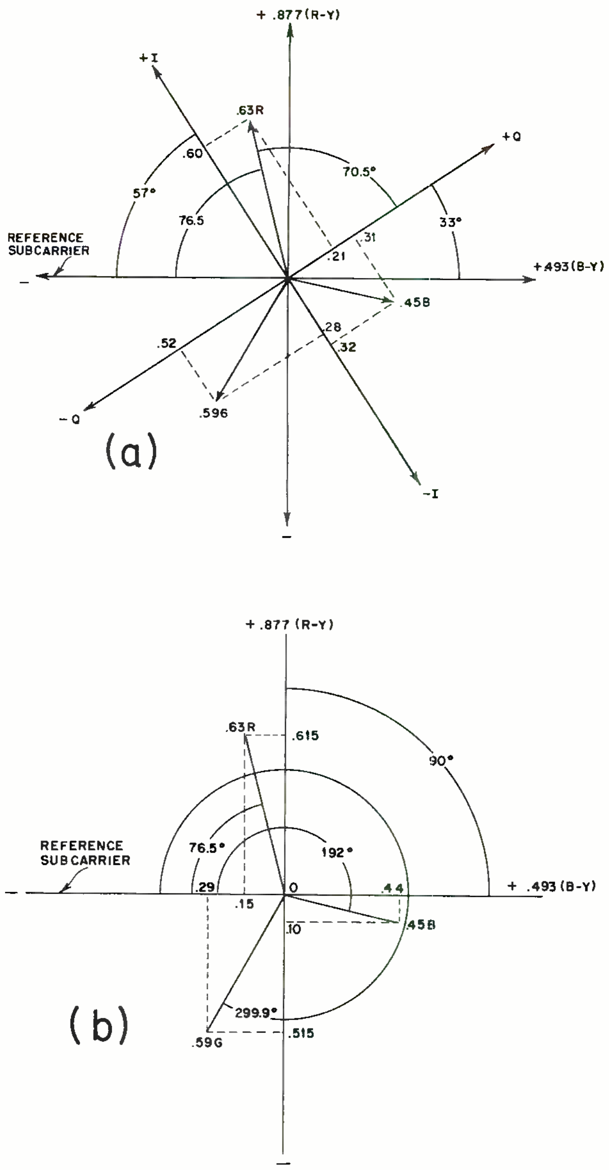


Figure 19 — Relationship of Hues to Chrominance Carriers

It can be seen from FIGURE 19(a) that both .877 (R-Y) and .493 (B-Y) can be developed from the vector addition of I and Q. Since I is transmitted with an extended bandwidth (0-1.5 MC) both R-Y and B-Y contain I signals. Therefore when demodulating on R-Y and B-Y in the color receiver both signals must be limited to 0-.5 MC in bandwidth in order to prevent crosstalk. This lower bandwidth decreases color definition; however, circuitry can be made simpler in the R-Y and B-Y receiver since the matrixing now can be done in the color kinescope.

Description of RCA Compatible Color TV System

It will be helpful to understand color television principles if the system signal generation and reception is built up step-by-step. Figure 20 is a block diagram of the present system in its simplest possible form, using three wire channels to carry the picture information. (Synchronizing is omitted for simplicity.) The blocks labeled green, red and blue represent the green, red and blue camera pick-up tubes and all associated voltage amplifiers, clampers and even "gamma" correctors (necessary to provide light-to-voltage transfer characteristics to compensate for the non-linear voltage-to-light characteristics of the receiver's picture tube phosphors). The receiver's tri-color kinescope is simulated by the triangular symbol at the right of Figure 20.

The green, red, and blue output signals are fed into a resistance mixer (sometimes called a "matrix") to form the "Y" or "brightness" black and white signal. Green, red and blue signals are mixed so that Y = 0.30R + 0.59G + 0.11B. It has already been shown that all that is needed to feed the receiver in addition to the Y signal are two chrominance signals, I and Q. The two chrominance signals are developed by taking portions of the red, green, and blue camera signals and passing them through two mixer sections. We now have a Y signal, an I signal and a Q signal. These could be fed over three coaxial cables, as shown, to the video portion of the color receiver.

The I and Q signals are handled in the video portion so that proper amplitudes and polarities of I and Q signal voltages are obtained. These voltages are added to the Y signal in the adders to produce the required red, green, and blue signal voltages to control the three electron beams of the Tri-Color Kinescope.

The coaxial cable feed was merely used as an example, and in practice the transmission and reception of continuous radio waves is used, modulated to carry the same picture information as would be sent over a wire channel. Figure 21 shows a simple block diagram to illustrate the signal paths. In this diagram the transmitter section forms the I and Q signals as previously explained. These signals are then used to modulate a "double balanced type modulator" which suppresses the actual subcarrier frequency but passes on the resulting sidebands. Note also that special synchronizing information has been introduced to keep the receiver 3.58 MC subcarrier oscillator in phase with the transmitter subcarrier oscillator.

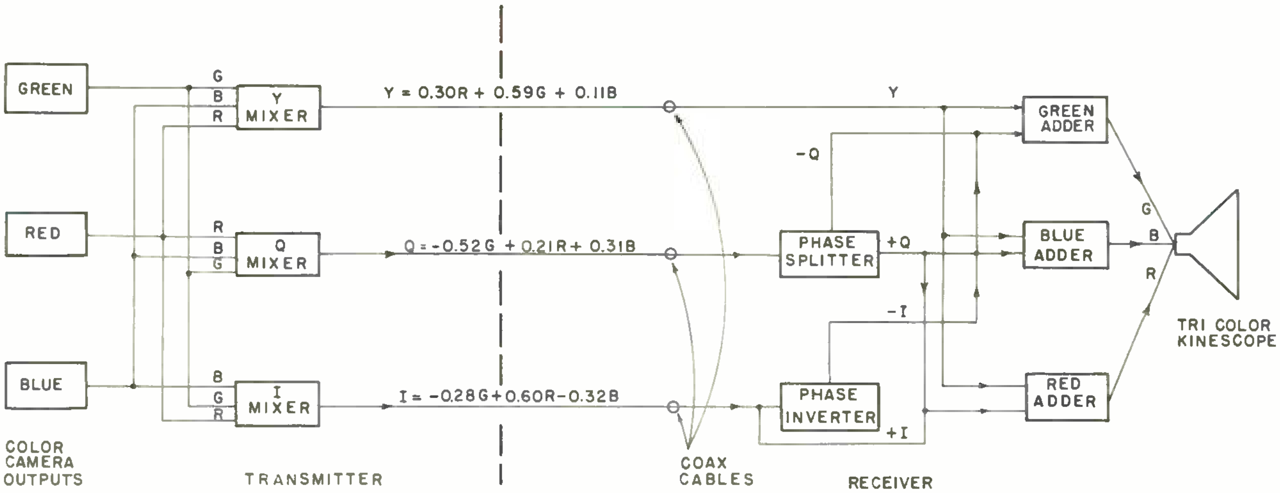


Figure 20 — An Elementary Color Television System

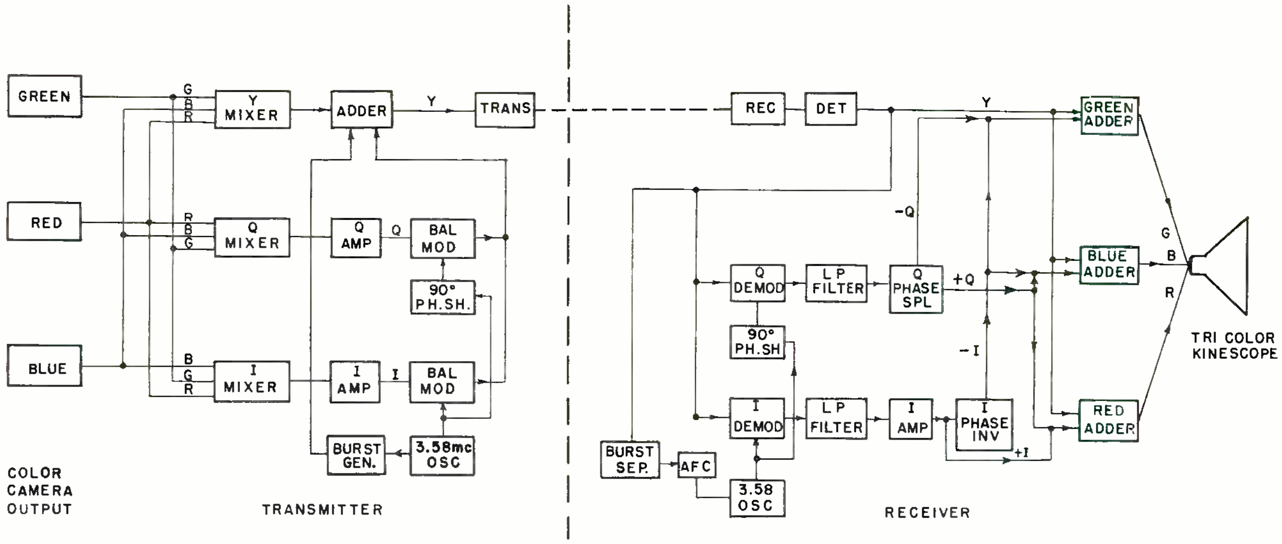


Figure 21 — Block Diagram of a Practical Color TV System

This synchronizing signal is simply a "burst"—meaning a few cycles—of the originating transmitter subcarrier oscillator. Its addition to the standard black and white horizontal synchronizing signal is best shown in FIGURE 22.

The actual spectrum of the transmitted signal appears as shown in FIGURE 23. The cross-hatched area represents the Q sidebands and the line area *plus* the cross-hatched area represents the I sidebands. In transmission the chrominance sidebands (I & Q) of the suppressed chrominance subcarrier are "inter-leaved" between the brightness (Y) sidebands of the picture carrier.

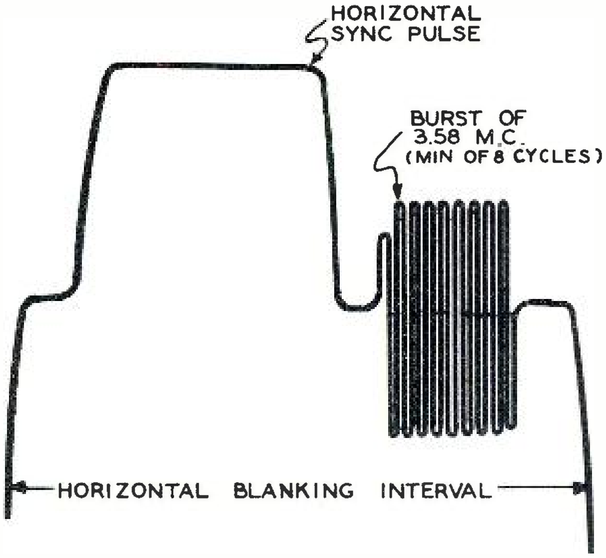


Figure 22 — The Color Synchronizing Signal

Upon reception, this transmitted signal is detected in a conventional manner; however, the output of the detector contains two types of information: the Y or luminosity information and the chrominance information. This chrominance information is demodulated with proper phase relation being maintained by the 3.58 MC burst oscillator. The demodulators develop the required I and Q signals which, when added to the Y signal in proper amplitude and polarity, produce the required red, green and blue signal voltage to drive the tri-color kinescope.

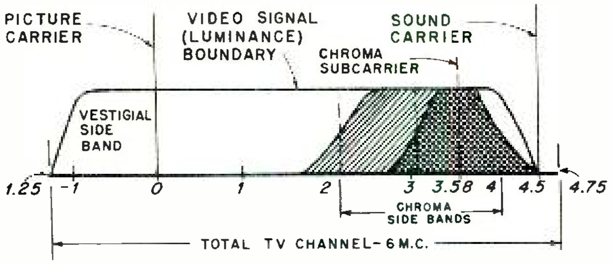


Figure 23 — Spectrum of the Transmitted Color Signal

A burst, or sample of the chrominance subcarrier must be transmitted along with the composite video signal, since the chrominance carrier is suppressed at the transmitter in the interests of reducing cross-talk. This necessitates re-inserting the chrominance carrier at the receiver. The burst is a reference to determine the correct frequency and phase of the receiver local oscillator that reinserts the chrominance carrier.

The RCA Tri-Color Kinescope

It has been mentioned that 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 of the previous section explained the necessary circuits of the receiver so as to provide the necessary red, green, and blue picture signals for operation of the three 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 average 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 important 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 modern 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. One such means would be straight-forward super-position such as is done in the color photographic process. 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 reproducer, 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 chroma (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.

The Search for a Practical Cathode Ray Tube Color Reproducer

There were many proposals for color cathode ray picture tubes and the first were extensions of the black and white technique. To list and describe all of them would be interesting but would serve no specific purpose to aid the TV service man.

However, a few examples especially chosen should be helpful in following the research road traveled in arriving at the present RCA Tri-Color Kinescope tube.

The first attempts used only one electron scanning beam since sequential systems were under consideration. FIGURE 24 shows an example of a color cathode ray picture tube whereby the viewing screen was divided into phosphor lines of red, green, and blue.

Another method shown in FIGURE 25 allowed a single electron scanning beam to cover three color phosphor areas and then by optical means combined the three color scannings into a color picture. An optical system could be avoided by super-positioning the three phosphor arrays and then changing the electron beam velocity so that at any given time a colored area would be scanned by an electron beam corresponding to a given velocity somewhat as shown in FIGURE 26. This scheme requires switching of high voltages.

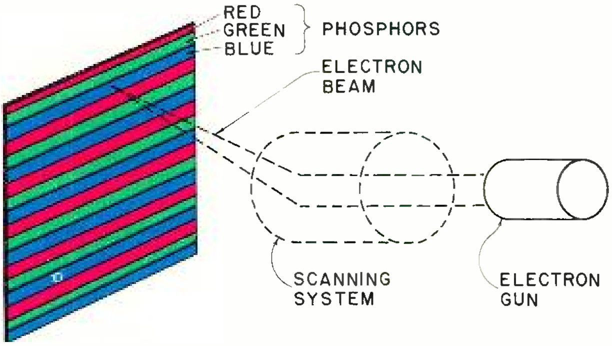


Figure 24 — A Signal Beam Line Scanning System

Another early method was to use deflection plates so that the electron beam could be deflected to excite color phosphor lines somewhat in the manner as shown in FIGURE 27.

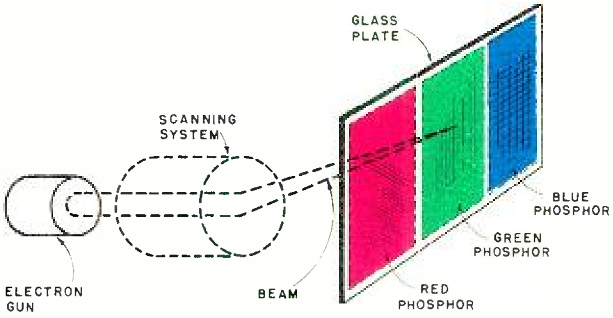


Figure 25 — Single Beam Scanning with Optical Super-positioning

It can be seen that complicated electronic switching would be necessary and that picture detail would still be limited by line structure.

One of the early proposals for obtaining better color picture element detail was a cubical pyramid non-planar color screen. The sides of the cubes were arranged to face in different directions and were coated with different color phosphors somewhat as shown in FIGURE 28.

In this particular case a departure was made from

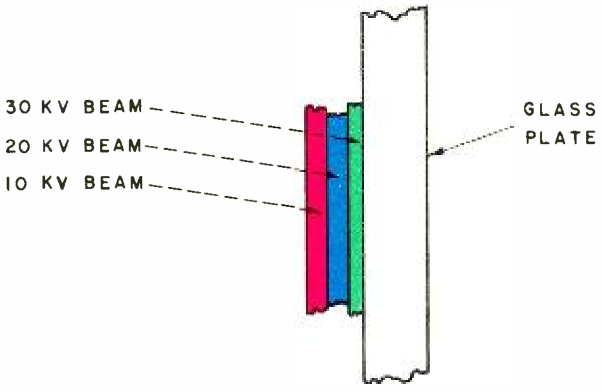


Figure 26 — The Velocity Switching Technique

the single electron beam to three electron beams, but with the beams physically located to arrive at the screen from three different angles. This required a three neck type picture tube. Finally, the idea of a shadow grid or shadow mask took form using color phosphor lines. The method is shown in FIGURE 29.

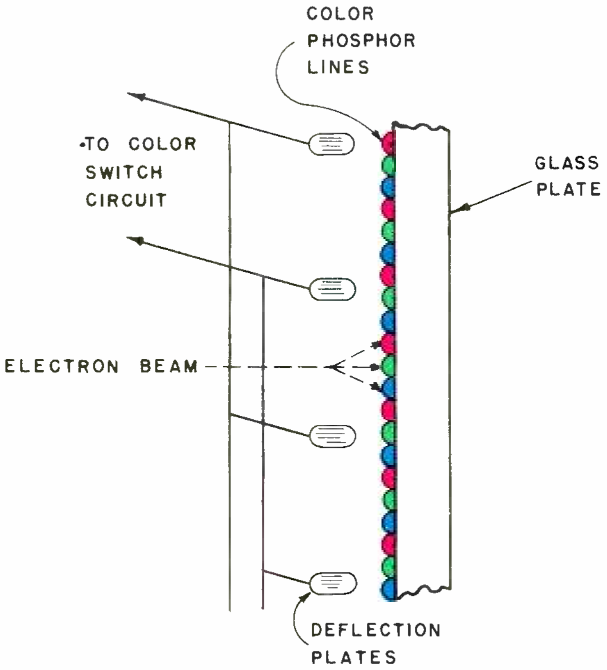


Figure 27 — The Beam Deflecting Technique

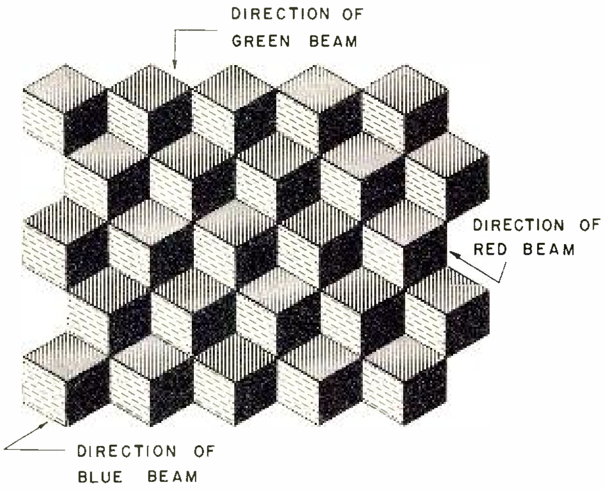


Figure 28 — A Non-planar Three-Gun System

Note that while the three electron scanning beams approached the picture screen from one source allowing a one neck picture tube construction, the limiting factor was low picture element detail obtained because of the phosphor line construction on the screen.

Many more various methods could be shown but by 1950 RCA research engineers had settled upon the shadow mask method using a picture screen consisting of an array of the three primary colors in dot form. Three electron beams were used and controlled in a common neck structure for scanning simultaneously the dot phosphors of red, green and blue.

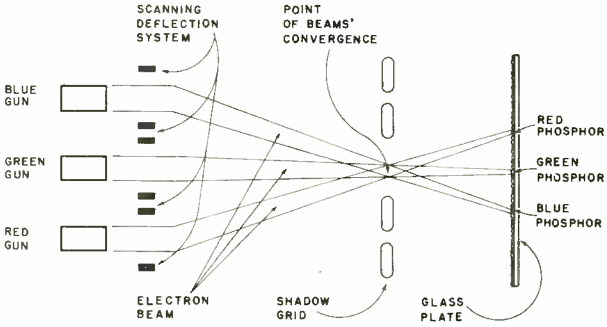


Figure 29 — The Shadow-mask Line Scanning System

The 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 Viewing Screen
2. Shadow Mask
3. Three Electron Gun Assembly
4. Envelope

Phosphor 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 triangle 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 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 of 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 only limitation is the relatively lower light output of the red phosphor compared to the blue and green phosphors. This relationship is shown in FIGURE 30. However, this limitation is not serious because it is relatively simple to drive the red phosphor harder by applying a greater control grid signal voltage to the red electron gun as compared to the blue and green guns.

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.

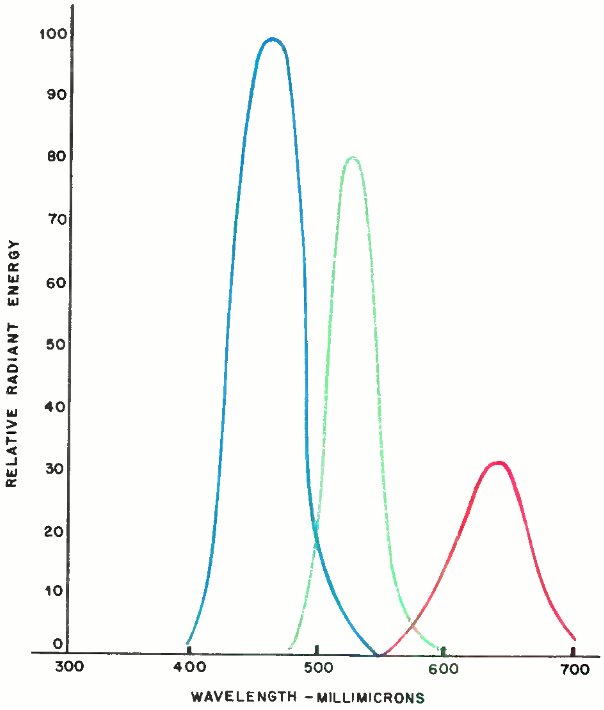


Figure 30 — Relationship of Phosphor Light Output

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 tube and the coventional 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 31 shows its position in relation to the over-all envelope while FIGURE 32 shows the relationship of the shadow mask holes and the phosphor dots.

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

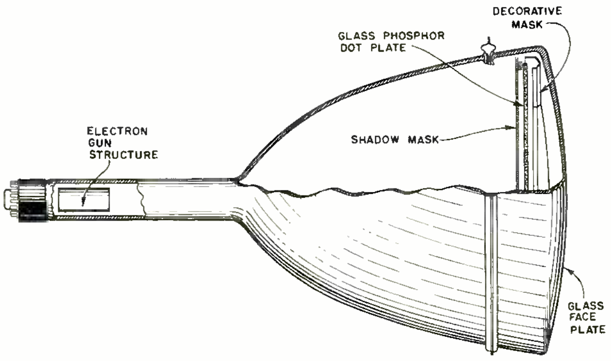


Figure 31 — The RCA Tri-Color Kinescope

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 33 shows the details of a typical gun assembly.

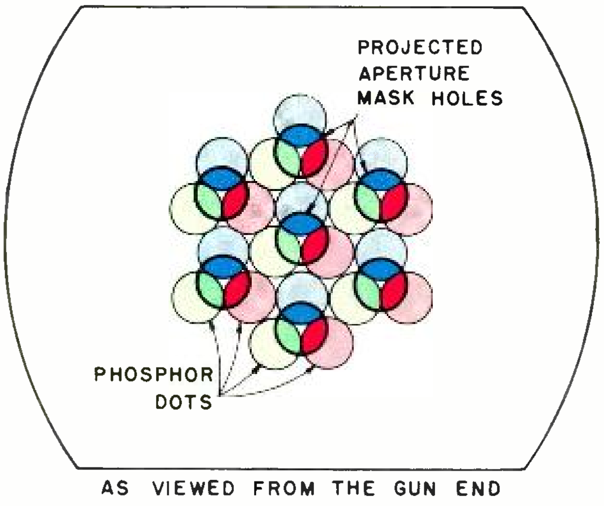


Figure 32 — Relationship of Shadow-mask to Dot Phosphors

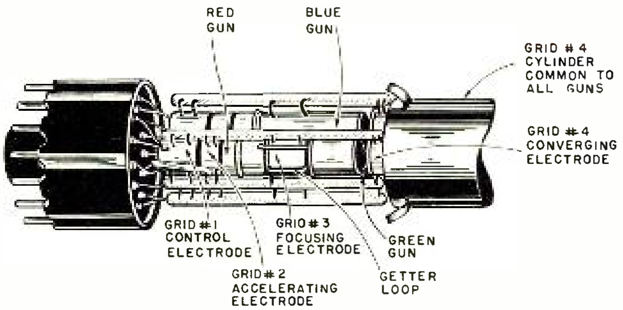


Figure 33 — A Typical Electron Gun Assembly

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 is included within the tube envelope that determines the picture size.

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 34 shows a representation of the operating components of the Tri-Color Kinescope. The actual relationship of the three electron scanning beams, shadow mask and phosphor-dot plate is well 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

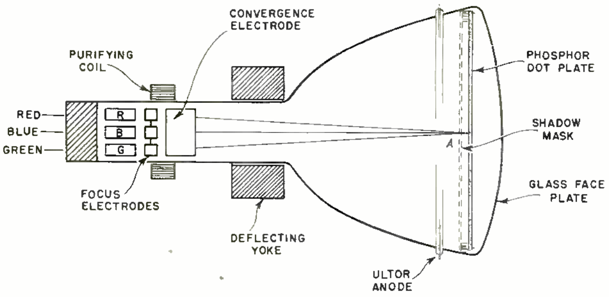


Figure 34 — Operating Components of the Tri-Color Kinescope

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 (small pieces of ALNICO mounted on separate rods with latter hand adjustable by ball and socket and sleeve support) located near electron guns. This is called *static* convergence and is one of the first adjustments the color TV receiver service man will have to handle.

Because the shadow mask and the phosphor-dot screen are flat, it can be seen from FIGURE 35 that convergence would take place at (B) when the three beams were moved by the deflecting yoke. Obviously, convergence must take place such as at point (C) in FIGURE 35 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.*

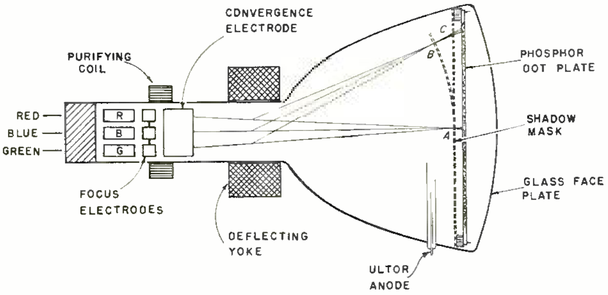


Figure 35 — The Need for Convergence Voltage

As can be seen from FIGURE 36 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 33) 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 36 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 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.

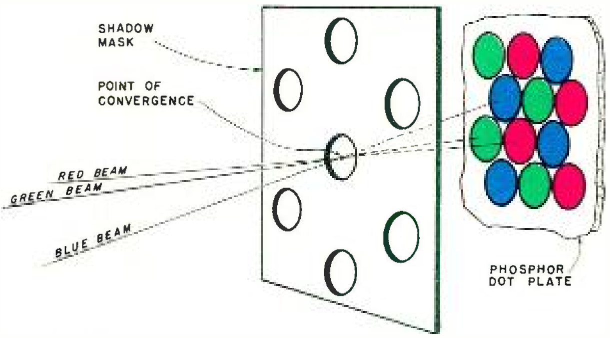


Figure 36 — Convergence Relationship to the Shadow Mask

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.

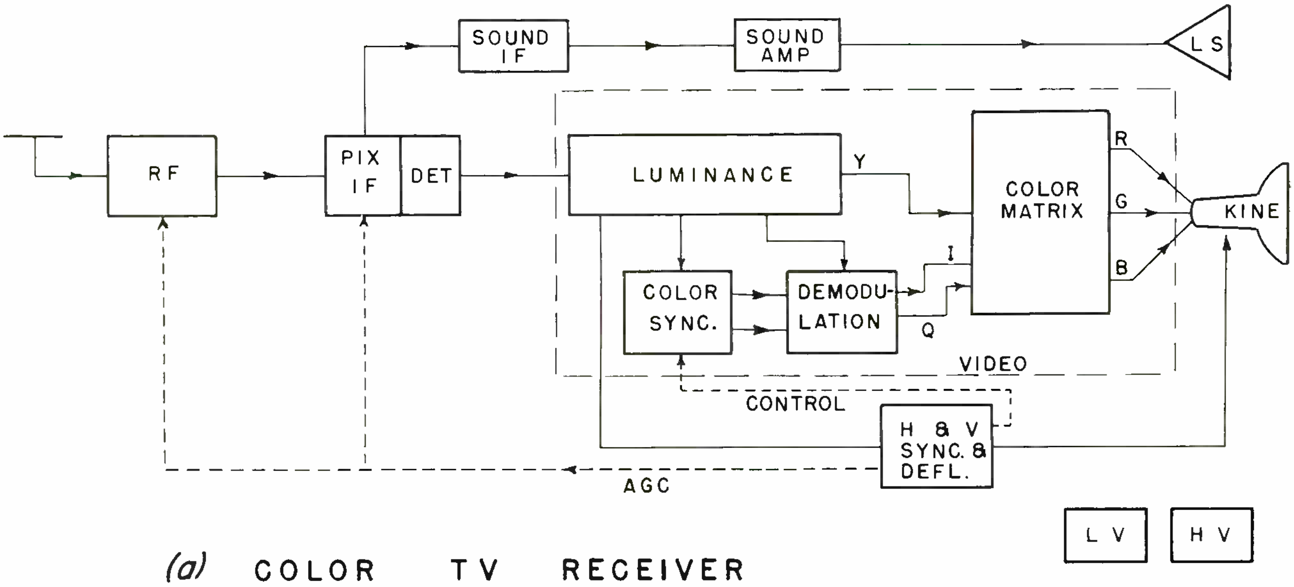
SECTION II

Color Receiver Circuitry

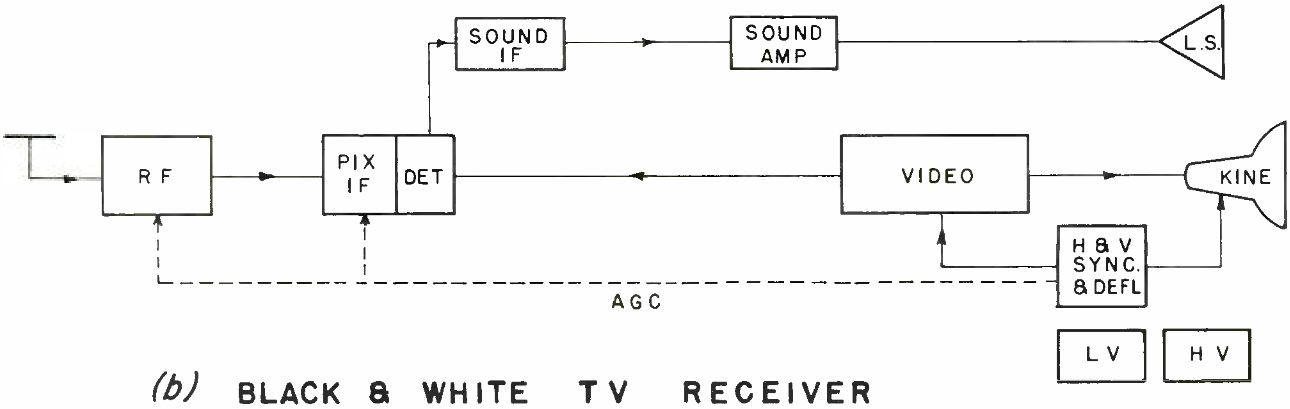
Basic Circuit Description of a Typical RCA Color TV Receiver

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 37 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 color receiver only differs from the black and white receiver by the addition of three new sections, labeled Color Synchronizing, Demodulation (Chrominance) Section and Matrix Section. The Lumi-



(a) COLOR TV RECEIVER



(b) BLACK & WHITE TV RECEIVER

Figure 37 — Color and Black and White Receiver Block Diagram Comparison

nance 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 subcarrier and the sidebands received. In order to permit a more detailed description and understanding of the specific Video Section of a color TV receiver, FIGURE 38 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 at the end of the book.

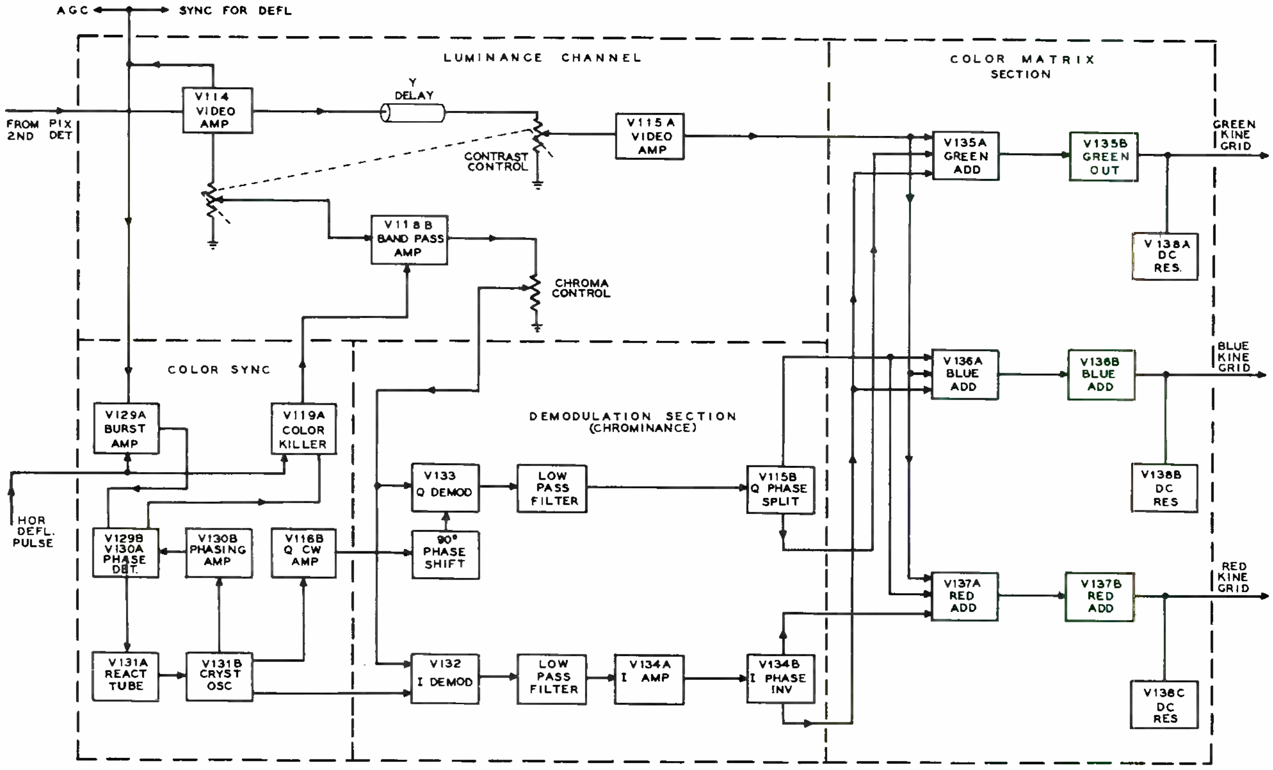


Figure 38 — Block Diagram of a Color Receiver's Color Handling Circuits

Referring to FIGURE 38, the composite color picture signal rectified from the picture I.F. by the Second Detector passes through a pentode tube section (V114) which provides positive polarity signal at the plate for horizontal and vertical synchronizing, A.G.C. 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 color subcarrier information (sidebands) is extracted from the composite picture signal in the Band Pass Amplifier and fed to the Demodulation Section through the chroma control.

The Band Pass Amplifier is biased off by the Color Killer, tube section V119A, if the latter is not held cut-off by the negative D.C. from the Phase Detector, tube section V129B. This action insures no input to the Demodulators in the absence of a "burst"; i.e., with black and white transmissions.

The output of the Burst Amplifier (V129A) supplies a burst reference voltage at 3.58MC to the

Balanced Phase Detector, (V129B-V130A). Here the reference signal is compared to a local RF signal (from V131B via V129B) and an error voltage fed to the Reactance Tube (V131A) keeps the Crystal Oscillator (V131B) on frequency and in phase with the burst reference.

Color subcarrier frequency 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 operation of the Luminance Channel, Demodulation Section (Chrominance Channel) and the Color Synchronizing Section have now been briefly described. The Y, I and Q signals are ready for the Matrix Section and algebraic addition to obtain R, G, and B control signals for the respective red, green, and blue electron gun control grids of the Tri-Color Kinescope. The algebraic adders need both positive and negative quantities of both I and Q signals, so two Phase Splitters, tube sections (V115B) and (V134B) are used. Suitable amounts of positive or negative I and Q and the Y signal are added resistively 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.

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 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—KRK12

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 KRK12 is a turret type tuner with provision for sixteen inserts that may be individually aligned to any combination of 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 1N82 silicon crystal to produce the IF which is further amplified by V3 (6BQ7A) to obtain added gain before being fed to the IF amplifiers on the main chassis. A 6S4 tube (V4) is used as a shunt regulator to insure optimum plate voltage on the 6AF4 oscillator, promoting low drift and long tube life. 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 at 41.25 MC. Although there is an IF stage on the KRK12 unit (V3) the first 6CB6 tube will be called the first picture IF amplifier. This is followed by four additional IF stages, 6CB6's 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. T107 and T108 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 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 addition to the conventional adjacent channel picture trap, adjacent sound, and accompanying sound traps, there is an absorption type trap in T109. The function of this trap is to give the proper slope to the response curve in the vicinity of the picture carrier.

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 39 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.)

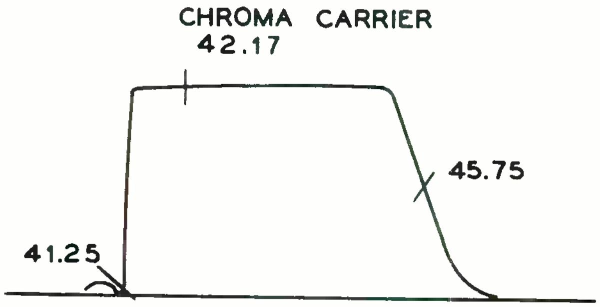


Figure 39 — Color Receiver IF Response

Sound IF Detector Audio

The sound IF detector and audio stages are conventional in design and are similar to the KCS-81. A 6AU6 is used in the first and second IF stages (V101, V102). A 6V8 (V103A, B) combines the functions of ratio detector and first audio (dual diode and a triode). A 6AQ5 (V104) as the audio output gives maximum power output of approximately 3.0 watts.

The sound take-off transformer is located in the plate 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. The circuit features a variable resistance control for AM balance.

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 by the transformer in the plate of the video amplifier (T114). The secondary of this transformer is tuned to 3.58 MC and 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 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 6U8, amplifies a band of frequencies with a bandwidth of approximately 2.4 to 5.0 MC as shown in FIGURE 40.

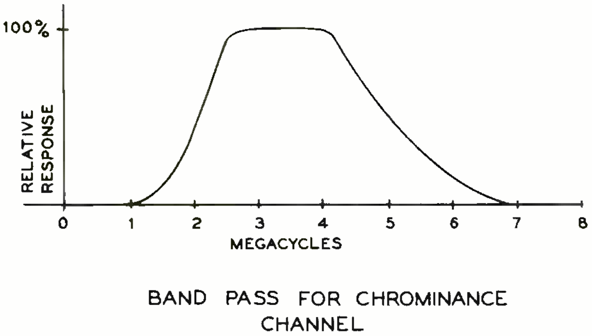


Figure 40 — Band Pass for the Chrominance Channel

It will be noticed that the screen of this amplifier (V118B) 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 the DC Restorers setting up on burst rather than on sync tips.

The output of the Band Pass Amplifier is terminated in a chroma 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, V116A) and directly coupled to the grid of the Horizontal Sync Separator (triode section of a 6U8, 117B). 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 6U8, 118A). Another noise limiting circuit is featured here in the grid circuit. A 1-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 6V8, 117A) is a large positive pulse from the horizontal output transformer. The charging capacitor, C135, 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 of positive polarity is used for the luminance channel. This is obtained from a split plate load resistor (R199-R200) and fed to the grid of the Second Video Amplifier through a delay line and contrast control. The delay line is nothing more than 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 to the luminance channel.

The Second Video Amplifier (pentode section of 6U8, 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 generated at a frequency of 3.58 MC. 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 frequency and 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 the same manner as 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 by a positive voltage applied to the cathode from the horizontal output transformer. By applying a negative flyback pulse to the cathode, the tube is allowed to conduct during blanking time, thus amplifying only the burst. The horizontal pulse is obtained from a small winding located on the horizontal flyback transformer.

The burst plate transformer (T122) 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 6U8 tubes (V129B, V130A). These triodes are actually grid-cathode diodes and the plates act merely as shields. 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) but is applied to the phase detectors through a Color Phasing Amplifier (V130B). 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 Color Phasing Amplifier contains a phase control that permits manual adjustment of 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.

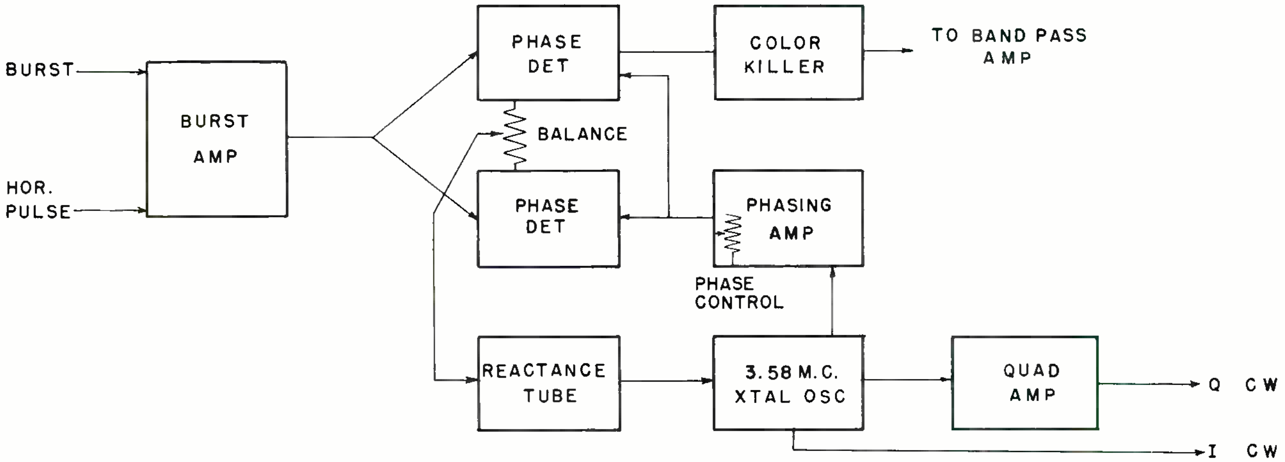


Figure 41 — Block Diagram of the Chrominance Sync Circuits

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

This has established the in-phase CW signal (called "I"). The take-off point for I is T124 in the cathode of the 3.58 MC oscillator in the manner of a cathode follower. Operating the oscillator as a cathode follower has the advantage of eliminating spurious oscillation to the Reactance Tube plate coil (L126).

In order to establish a CW signal that is 90° out of phase with I CW, a Quadrature Amplifier is coupled to the 3.58 MC oscillator. With a tuned transformer in the plate circuit it is possible to obtain a CW signal that is 90° out of phase with the signal on the grid. This is referred to as the quadrature CW signal, or simply Q CW. In summarizing, the preceding has shown how both CW signals, I CW and Q CW, have been generated in this block together with a means of maintaining accurate frequency and phase for proper color synchronization. The purpose for this is detailed in the description of the demodulators.

One circuit included in this block but not yet mentioned is the Color Killer (V119B). 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 the plate lead. When the positive pulse drives the tube into conduction, capacitor C252 is charged. In discharging to ground through R296 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 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 R295 and is sufficient to cut off the tube, preventing conduction, so that no bias is presented to the Band Pass Amplifier.

I and Q Demodulator

It has been stated previously that the chrominance information is composed of an I and Q signal voltage. The Q signal has a bandwidth of 0 to .5 MC and contains both sidebands. The I signal has a bandwidth of 0 to 1.5 MC and contains two sidebands from 0 to .5 MC and only one sideband from .5 to 1.5 MC. This relationship is shown in FIGURE 42. These signals are modulated at the transmitter by two 3.58 MC subcarriers 90° out of phase. The I and Q sidebands are transmitted and the subcarriers are suppressed.

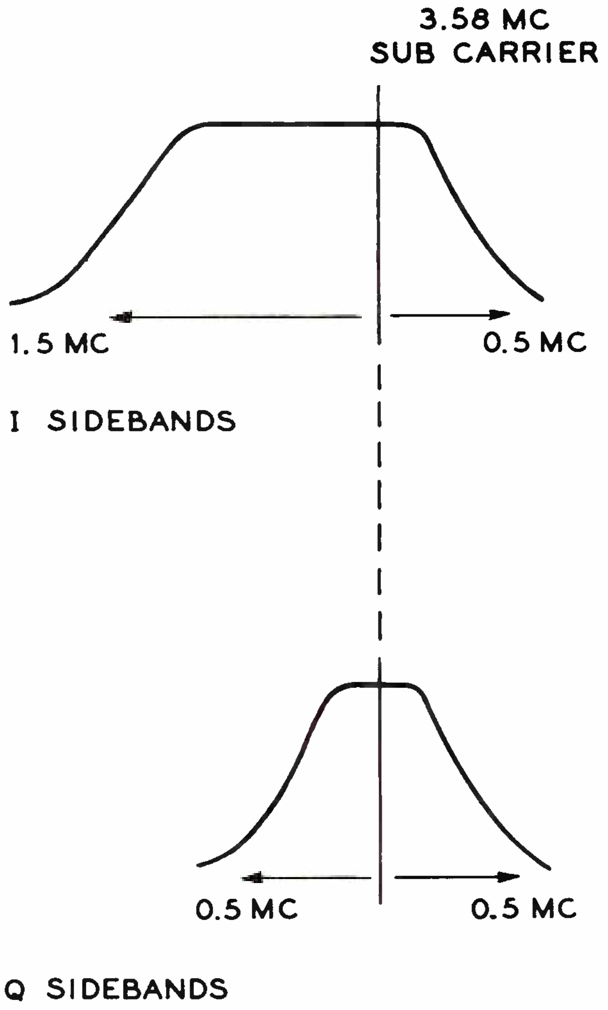


Figure 42 — I and Q Signals Before Demodulation

The purpose of the demodulator is to separate the chrominance information into the I and Q signal voltages. To accomplish this demodulation or "detection," the two continuous wave 3.58 MC voltages must be added vectorially (I CW and Q CW from the Chroma Sync Stage), to the chrominance signal. This is done by using two 6AS6 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. The same thing will happen 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 L130, L301, L131, C270 and R306. The I filter passes signals from 0 to 1.5 MC in frequency. This filter is composed of C276, L128, R345 and R347. These filters will also eliminate any high frequency brightness information. Bandpass characteristics of these filters are shown here in FIGURE 43.

From here the Q signal enters the Q Phase Splitter stage producing 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 to the matrix and the cathode is A.C. coupled.

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

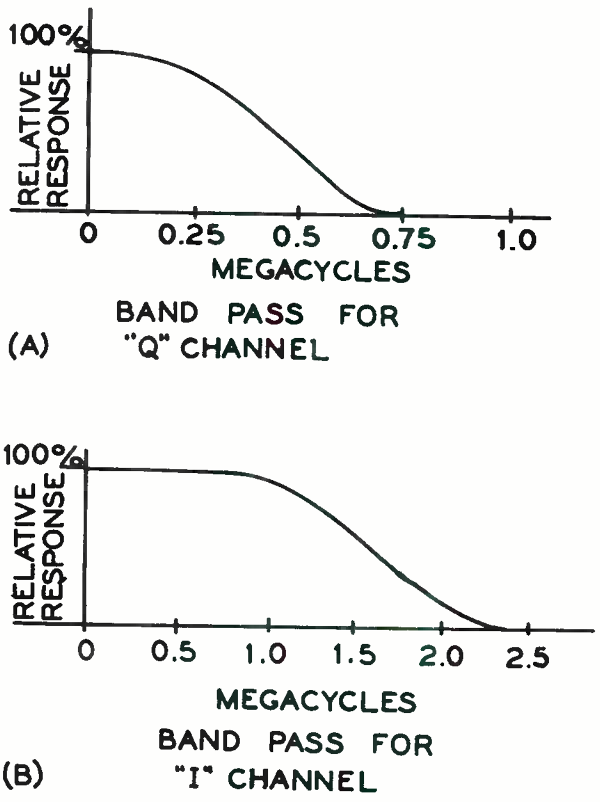


Figure 43 — Band Pass for the I and Q Channels

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 44.

FIGURES 45, 46, and 47 show graphically how the Y, I and Q signal voltages are combined to provide red, green and blue output voltages, using a color bar signal as an example.

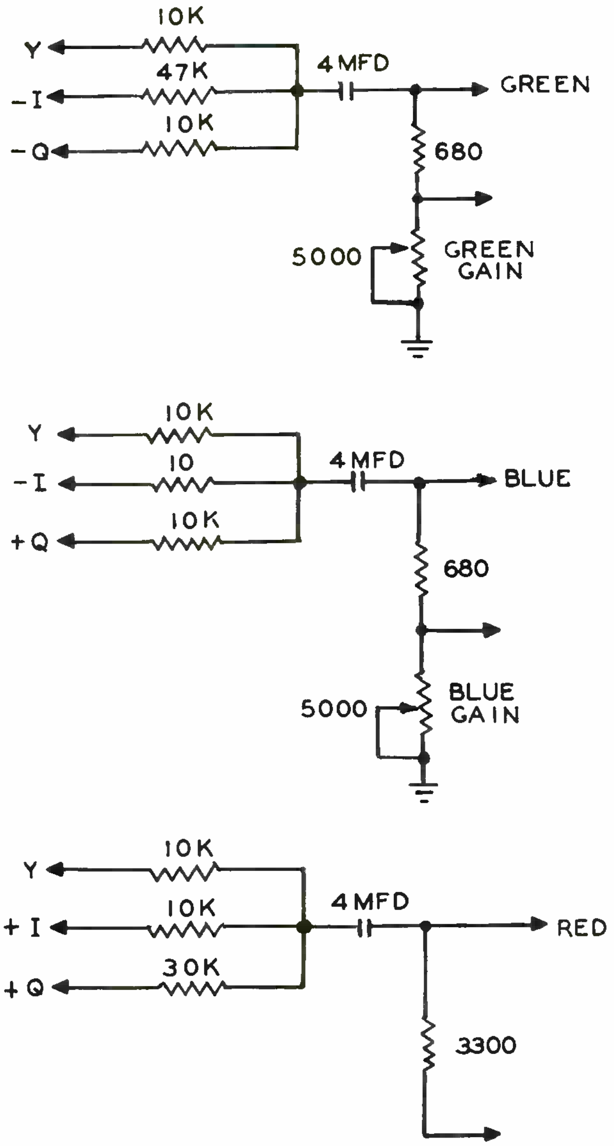


Figure 44 — Green, Blue and Red Matrix Circuits

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 it does 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.

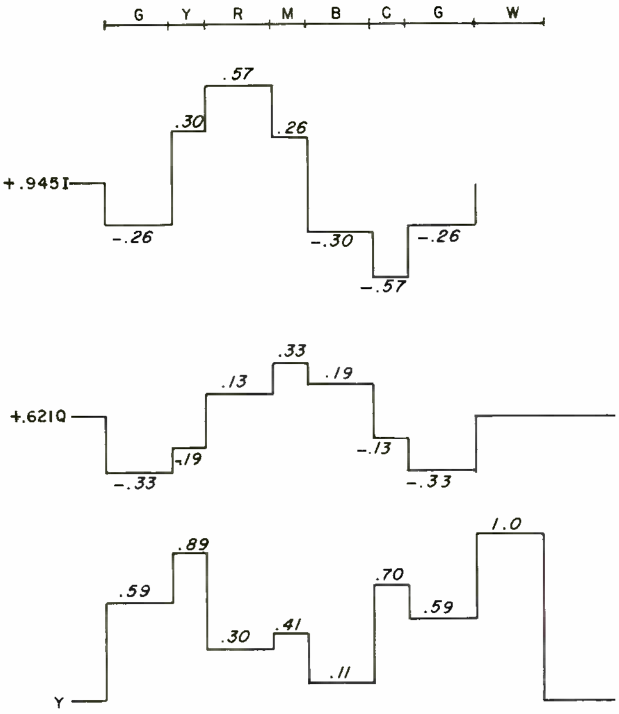


Figure 45 — I, Q and Y Voltages at the Red Matrix for a Typical Bar Pattern

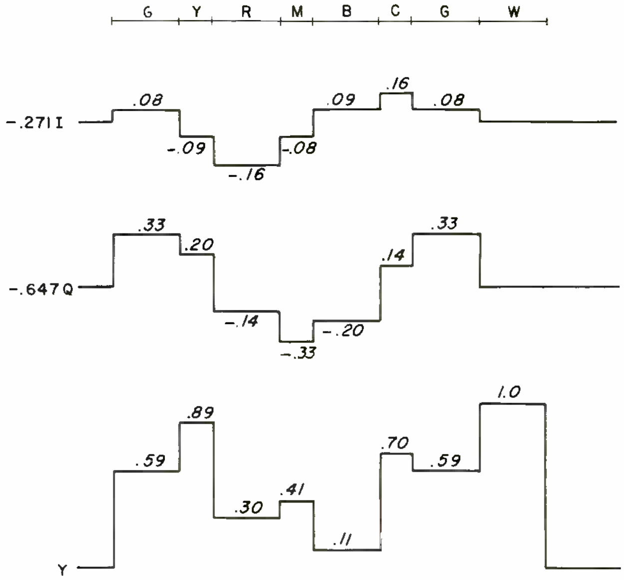


Figure 46 — I, Q and Y Voltages at the Green Matrix for a Typical Bar Pattern

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 is bypassed to ground by a 560 mmfd capacitor. The high frequencies will be bypassed to ground and the low frequencies will cause some degeneration to the signal in the grid circuit. Some low frequency degenerative voltage is fed back to the Adder grids through the resistors

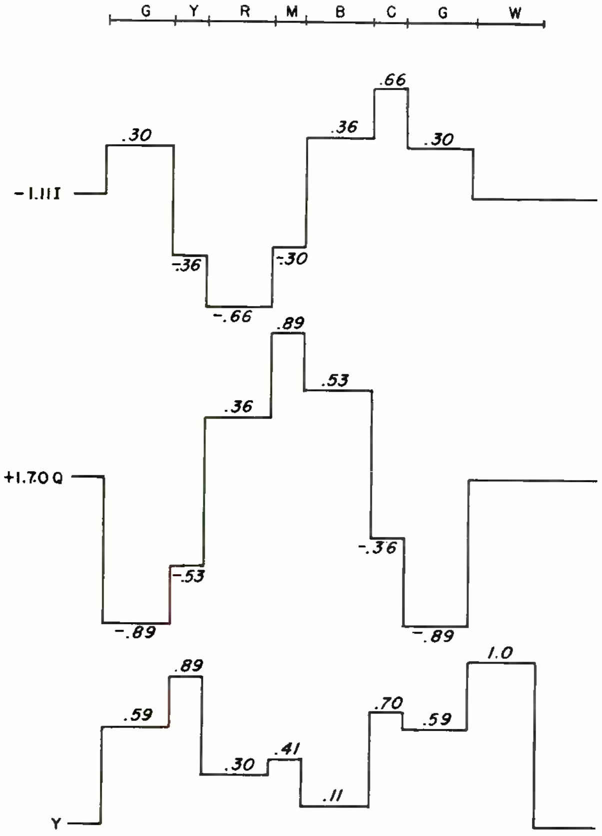


Figure 47 — I, Q and Y Voltages at the Blue Matrix for a Typical Bar Pattern

(R214, R315, R362). A 6CB7 tri-diode tube is incorporated for DC restoration and the circuits are schematically 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 DC convergence; and (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. The familiar flyback transformer is used in the output circuit to develop horizontal sweep and high voltage. 20,000 volts of high voltage are produced in a voltage doubler using three High Voltage Rectifier tubes, V121, V122, V123. The first and third tubes are connected as a doubler with the middle diode acting in the place of a series of resistors. Therefore, this tube is referred to as a High Voltage Coupler, since it serves to provide a more stable means of doubler operation.

The high voltage for the kinescope is regulated by the Shunt Regulator Tube, V120, that has the effect of maintaining a constant load on the high voltage. During an all black picture (no electron beam current) the regulator would absorb the entire load. Conversely, during all white picture, the kinescope takes the load and the regulator very little. A voltage divider network taps down on high voltage 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 (C206) filters the rectified voltage so that it may be applied to the kinescope focusing anode. A five megohm potentiometer controls the amount of the voltage applied to the focusing anode and thereby controls the size of the spot formed by each of the three electron beams. The Convergence Amplifier is included in this block since its output modulates the 10,000 volt convergence voltage, and one of the input voltages to the amplifier is a waveform from the Horizontal Output Tube. The purpose of the Convergence Amplifier (one section of a 6BL7, V119B) is to create a varying voltage that modulates the 10,000 voltage 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 similar in radius to the curvature of the faceplate of a glass black and white kinescope as shown in FIGURE 48.

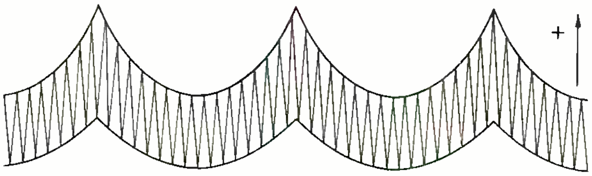


Figure 48 — Dynamic Convergence Voltage Waveform

The logical place to find such a waveform in a receiver is in the cathode circuit of Horizontal and Vertical Output tubes. Therefore, the convergence controls are potentiometers located in the cathode of the deflection amplifiers. Both horizontal and vertical waveforms are capacitively coupled (C200 and C201) to the grid of the Convergence Amplifier. However, some shaping of the waveform is necessary, and is accomplished by L114 for horizontal and R238 for vertical.

In the plate circuit a double transformer (T115-T116) is used to step up the voltage to approximately 1,500 volts. The secondary windings of the transformers are combined to obtain a composite horizontal and vertical waveform. This voltage is now coupled to the DC convergence voltage by a high voltage coupling capacitor C193.

Returning to the horizontal output transformer once more, the Damper Tube (6AU4) 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 B plus and the centering control. To accomplish this the horizontal linearity coil, constructed in bifilar fashion, is inserted in series with the centering control.

Vertical Amplifier

One tube, a 6BL7 (V128), is used in the vertical section. One of the triodes is used for a Blocking Oscillator and the other section for the Vertical Output Stage. Both circuits are conventional and do not vary from present black and white receiver design.

Electrical centering instead of magnetic is used for vertical positioning of the raster.

R263, C227, and C226 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 49 it can be seen that the master background control is nothing more than a brilliance control, as it controls the voltage on the kinescope grid making it less positive than the cathode.

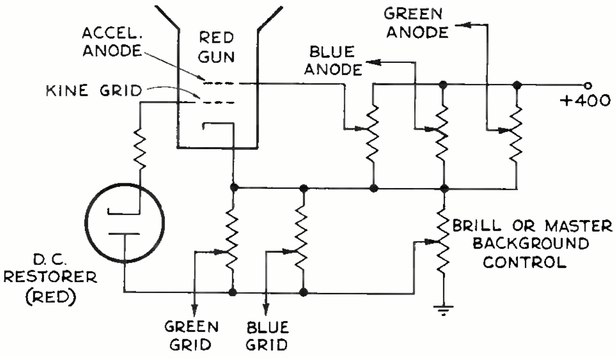


Figure 49 — Simplified Schematic Diagram of the Kinescope Controls

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 was slightly blue, a slight adjustment of the blue background control will increase the bias on the blue gun and the effect will be to produce a white raster, as all three colors will 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 usually is done while adjusting for a white screen of the proper color temperature.

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 is obtained from the voltage doubler, which is a slightly higher value than most black and white receivers. The power transformer supplying the AC voltage to the seleniums is therefore correspondingly larger. The 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 300 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 300 volt bus.

The low voltage block also supplies centering control and purity control currents. A negative five volts created in the ground return of the doubler supplies a needed voltage for the suppressor grids of the 6AS5 Demodulator tubes.

SECTION III

Color Receiver Installation and Service

Instructions to Customer for Operating Receiver

The following is a procedure for teaching a customer the proper technique in adjusting a typical color 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 judgement 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.

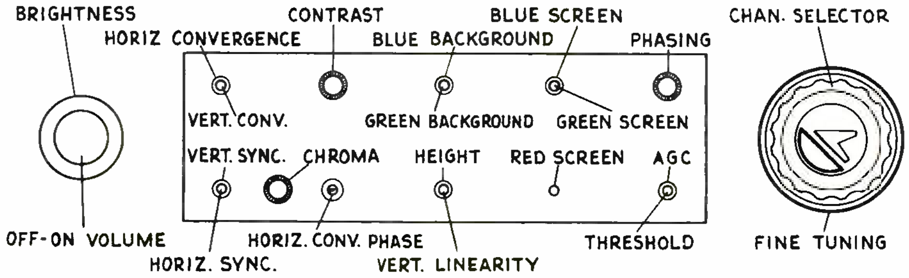


Figure 50 — Typical Front Panel Controls

Basic Receiver Adjustments

1. Turn set on and let it warm up for a few minutes before making adjustments.
2. With the channel selector, select an operating channel. Turn up volume control.
3. Turn the chroma control off (counterclockwise).
4. Turn the contrast control off.
5. Turn the brightness control clockwise, until illumination appears, then back off until screen just goes dark.
6. Turn up the contrast control for most pleasing picture.
7. Recheck the fine tuning control. For proper operation, it should be adjusted until sound beats or bars are seen in the picture and then readjusted until a clear picture is obtained. It is very important that the fine tuning be set correctly. If the fine tuning is misadjusted on a color picture, it is possible to lose color although black and white pictures are still satisfactory.

Note: *If color is being transmitted, a 920 KC beat between sound and color subcarrier will be noted. Fine tuning should be adjusted to the point of minimum beat.*

8. Vertical and horizontal hold controls should be adjusted if necessary. Thus far all of the customer adjustments have been made in the same manner as on a black and white transmission.

Color Adjustment

9. The chroma control should be fully counterclockwise, then turned up until a pleasing color saturation is obtained. The customer may be told to adjust the vividness of the colors to a point that is most pleasing to the eye. If color is not obtained when the chroma control is turned up (on a known color telecast) a check of the fine tuning adjustment should be made. Due to the differences in the transmission characteristic of the various stations it might be a good practice to have the customer adjust the fine tuning for maximum color with minimum sound interference.

Note: *If the chroma control is operated wide open on a strong signal there will be a degradation of color due to the kinescope guns drawing grid current. If overdriven for a period of time damage to the kinescope may result.*

10. Adjustment of the phase control should be made to give a known object its proper color. As an example, the phase control should be adjusted until proper flesh tones are reached. The range of this control is quite wide and it is possible to obtain a picture in which the flesh tones will reverse color.

Note: *In the 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 function of the two additional color controls.*

11. In switching from one color telecast to another it may be necessary to readjust fine tuning, the chroma control and the phase control for best picture on each channel.

Antenna Considerations for Color Reception

In general the requirements for color reception are similar to black and white. When the antenna will deliver a clear, sharp picture, free of interference, reflections and noise on black and white, it will also produce an excellent color picture.

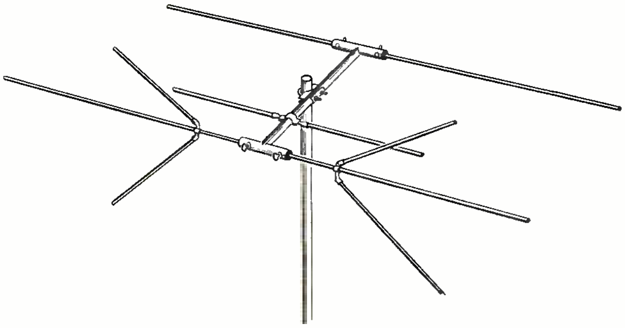


Figure 51 — A Typical Antenna Suitable for Color Reception

Antenna Characteristics

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

Bandwidth:

Almost all standard designs of broad band 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.

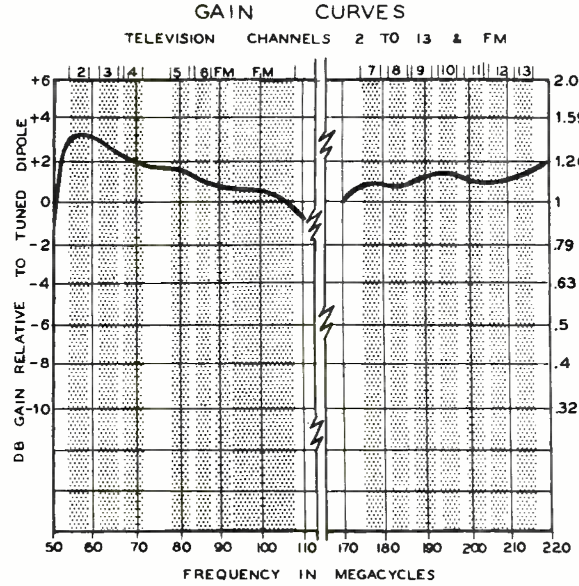


Figure 52 — Gain Curves for the Antenna Shown in Figure 51

Directivity:

This requirement is the same as black and white. Narrow beam widths help 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 shows up as in black and white but in various colors, may also sometimes be reduced by good directivity.

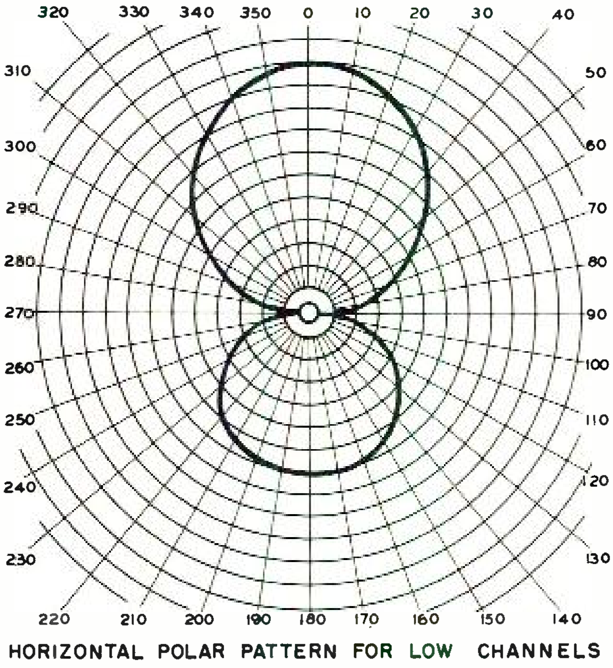
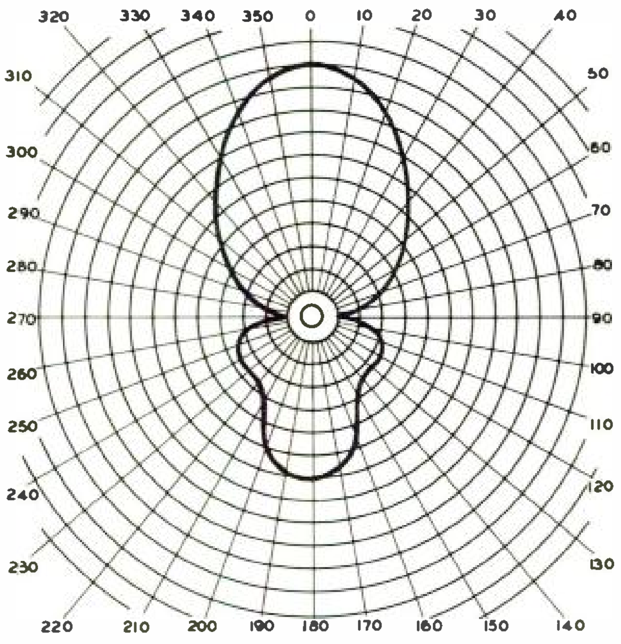


Figure 53 — A Polar Pattern for the Antenna Shown in Figure 51



HORIZONTAL POLAR PATTERN FOR HIGH CHANNELS

Figure 54 — A Polar Pattern for the Antenna Shown in Figure 51

Gain:

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

Standing Wave Ratio:

Impedance matching as it effects V.S.W.R. between the transmission line and antenna does not seem too important. A V.S.W.R. 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 responsibility of R.F. unit design and currently available units with a V.S.W.R. of 2- or 3-to-1 seem satisfactory. The service man can confine himself to insuring proper adjustment of the input tuned circuits, and using a transmission line to match the design impedance of the R.F. unit input. A deliberate mismatch, such as attaching a 50 ohm cable directly to a 300 input without matching transformers or pads can cause the same troubles as mentioned for reflections, particularly if the line is an odd multiple of a quarter wavelength long at the transmitted subcarrier frequency.

The Use of R.F. Booster Amplifiers

General receiver R.F. Unit design has progressed to a point that 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 is used) and a booster is required the bandwidth and V.S.W.R. requirements listed under "Antenna Characteristics" also applies.

The suitability of any booster or R.F. 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 D.B. 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 used together may cause a lack of color information.

Multiple outlet, amplified distribution systems have the same requirements except that each individual unit (i.e.—amplifiers, transformers, tapoffs) must be good enough so that the *multiplication* of each unit's bandwidth and V.S.W.R. deficiencies does not cause a lack of color information.

Receiver Set Up Procedure

Step One: Installation of Kinescope.

a. Remove cabinet top (remove two screws and the entire top comes off).

b. The next step is the installation of the RCA Tri-Color Kinescope. The tube is somewhat bulkier than a conventional black and white kinescope of comparable screen size and care must be taken in handling.

1. Install the mu-metal shield on kinescope.
2. Install yoke assembly.
3. Install purifying coil on neck of kinescope with external leads to the rear.

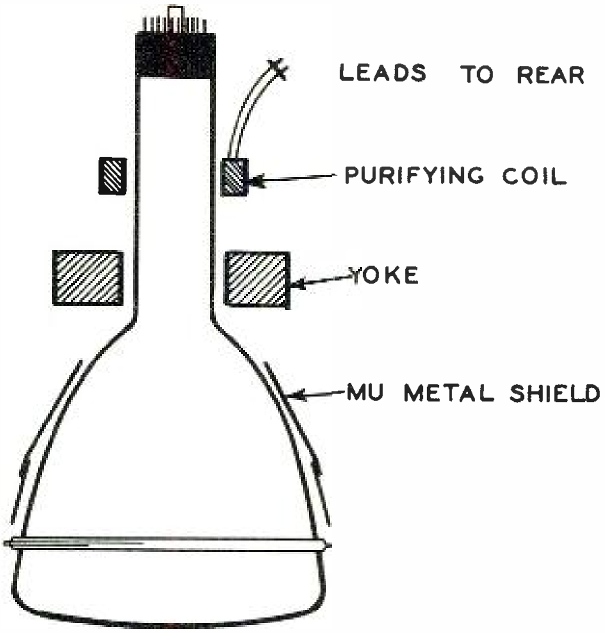


Figure 55 — The Kinescope and its Associated Components

c. The entire yoke, purifying coil, mu shield and kinescope assembly should be installed in cabinet.

d. Align the internal mask of the tube with the front of the cabinet, keeping the blue gun to the top.

Step Two: Location of Purifying Coil.

a. Leave the yoke assembly in its normal position, but do not tighten down.

b. Set the purifying coil just forward of the kinescope gun structure. The back edge of the coil should be 4½″ from the edge of the kinescope socket. If the purifying coil comes much closer to the kinescope gun structure, focus distortion of the beams may result.

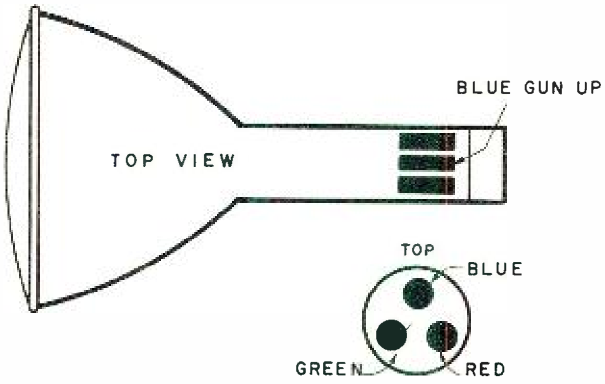


Figure 56 — Correct Installation Position of the Kinescope

c. Plug in the high voltage lead, yoke, purity coil and kinescope socket.

d. Turn set on.

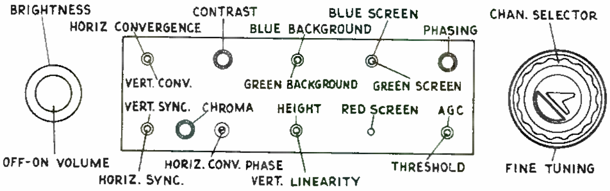


Figure 57 — Typical Receiver Front Panel Controls

Step Three: Linearity and Size Adjustments.

a. Turn the chroma control R302 off (CCW) to the minimum (no color) position.

b. Tune in a black and white transmission in the normal manner by adjusting fine tuning, contrast, brightness and AGC.

c. Make sure that the linearity of the picture is correct, as any adjustment of the linearity controls will affect dynamic convergence voltages.

d. Be very careful *not* to overscan the picture, as this will affect color purity. This has the effect of producing secondary electrons in sufficient quantity to contaminate color purity. Use the centering controls to determine effective raster size.

e. Check the horizontal oscillator control circuit to make sure it is correct. Any later adjustment will change horizontal dynamic voltages.

Step Four: High Voltage Set Up.

a. Using a high voltage probe with a vacuum tube volt-meter, measure the high voltage

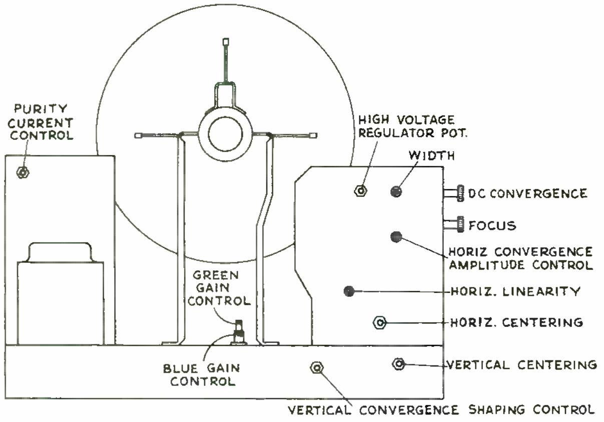


Figure 58 — Rear Apron Controls of a Typical Color Receiver

at the kinescope. The voltage should measure 20,000 volts.

b. If the voltage is too high or too low, adjust the voltage regulator control R245 until the proper 20 KV is obtained.

c. With the meter 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 adjustment of the voltage regulator control may be necessary.

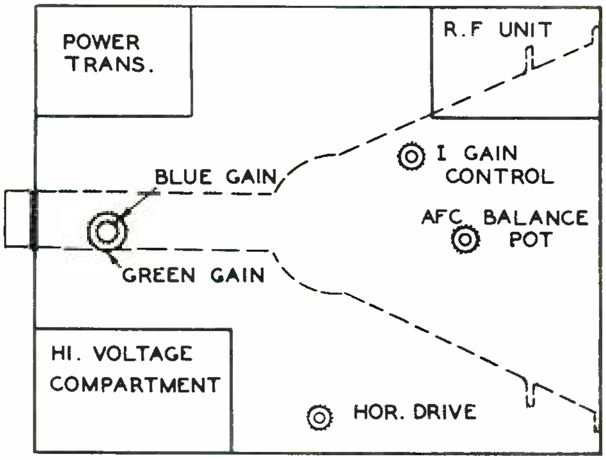


Figure 59 — Top-of-the-Chassis Controls

Step Five: Color Purity Adjustments.

a. Turn the contrast control R198 to a minimum to remove the picture signal.

b. Turn the red screen R227 up (CW).

c. Turn the blue (R225B) and green (R225A) screens down (CCW). (This should leave you with a red raster close to that shown in Figure 60.)

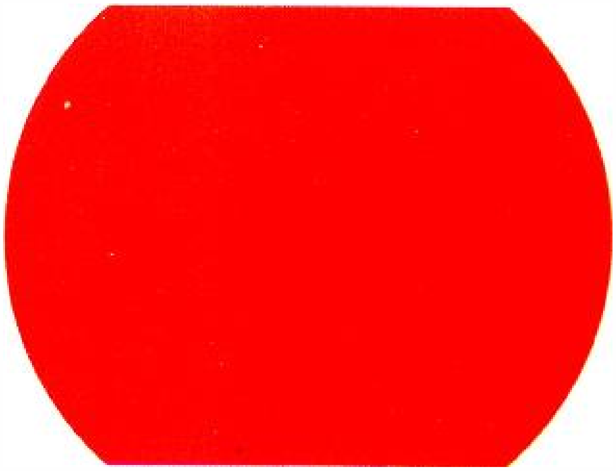


Figure 60 — Raster with Blue and Green Screen Controls CCW, Red Screen Control CW

d. Pull the convergence magnets out away from the neck of the kinescope.

e. Slide the yoke to the rear as far as possible.

f. The color purifying coil produces a uniform transverse magnetic field which serves to orient the three electron beams with respect to the central axes of the kinescope. Adjust the purifying coil rotation in connection with the purity current control R106, until the most uniform red appears in the *center area* of the tube as shown in Figure 61. Disregard the purity condition along the sides and at the top and bottom. As little purifying coil current as possible should be used. Figure 62 indicates incorrect purifying coil adjustment.

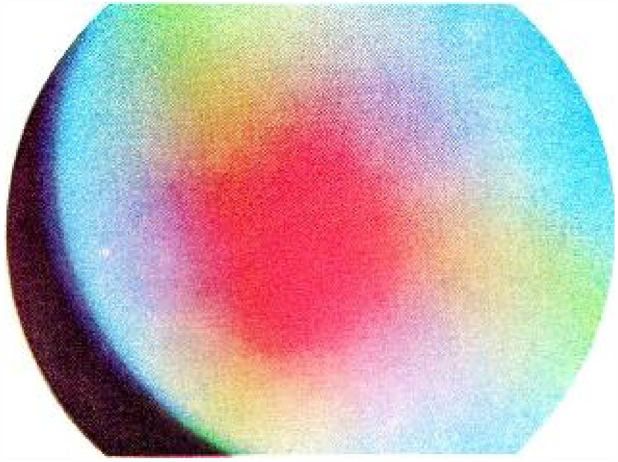


Figure 61 — Correct Purifying Coil Adjustment

g. Adjust the screen purity for most uniform red by sliding the yoke forward until best purity is reached. Make sure that there are no neck shadows at this point due to improper yoke location. If

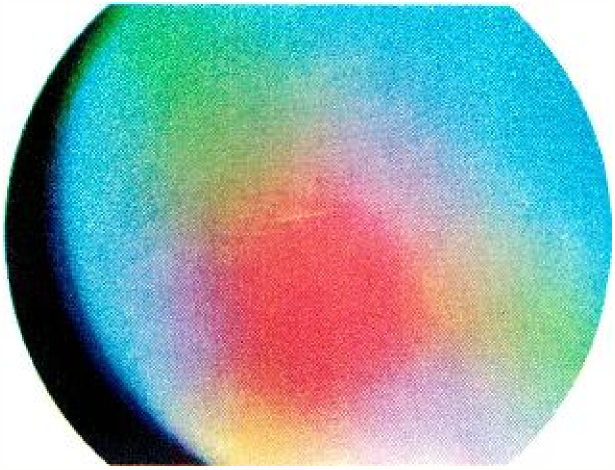


Figure 62 — Incorrect Purifying Coil Adjustment

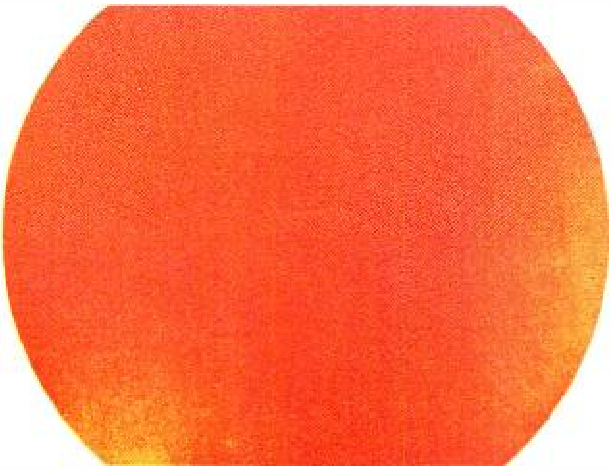


Figure 63 — Raster Showing Purity Contamination

some purity contamination occurs, as in FIGURE 63, slight readjustment of the purifying coil and purity current may result in better purity. FIGURE 64 shows the correct purity coil adjustment for the red screen.

h. Next check the blue purity by turning down the red screen R227 and turning up the blue screen. Green purity should be checked in the same manner. If some contamination results it may be necessary to make a compromise adjustment for best results on all three fields. Correct purity adjustment on the green and blue screens is shown in FIGURES 65 and 66, respectively.

i. Color purity may be affected by an external magnetic field. If color purity makes an abrupt shift at any time during the adjustment procedure, look for an external field causing trouble (magnetic tools, etc.).

Step Six: Setting the Kinescope to White.

a. With chroma and contrast controls to a minimum turn the brightness control to a maximum.

b. By the use of the red, blue and green screens adjust for a low brightness white as in FIGURE 67.

Step Seven: Convergence Adjustments.

a. General Considerations.

The object of the convergence adjustments is to cause the beams from the three parallel guns to be bent toward the central axis of the kinescope and to converge at the aperture mask. This is accomplished by the application of a high DC potential modulated with signals of horizontal and vertical frequency. These signals have an approximation of a parabolic wave shape and are used to compensate for the longer distance the beam has to travel to

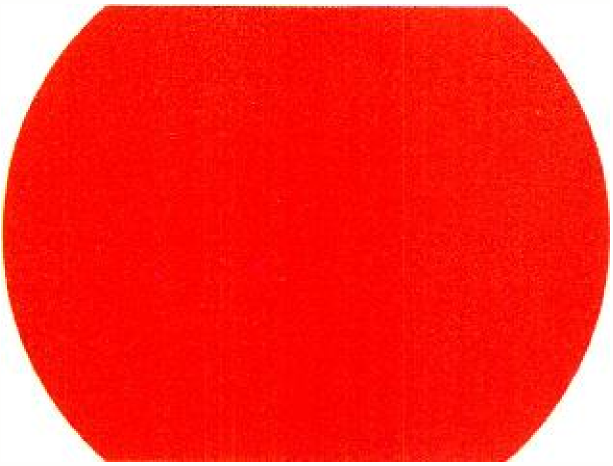


Figure 64 — Correct Purity Adjustment for the Red Screen

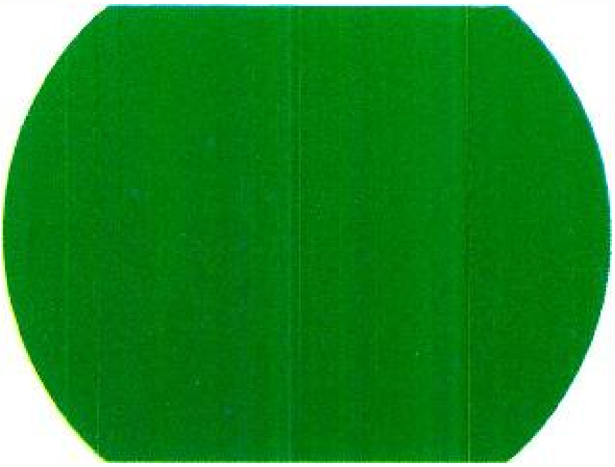


Figure 65 — Correct Purity Adjustment for the Green Screen

reach the edges of the tube. The modulated DC, if used in conjunction with three permanent magnets could be considered a vernier convergence adjustment.

Convergence adjustments are indicated in this book as being best accomplished by a dot generator. This device provides a means of obtaining white dots on a black background. The illustrations in this book that deal with convergence are based on the dot system of convergence, although this does not necessarily mean that convergence can *only* be done by this method, or that this method as presented is the best.

b. Dot Generator Adjustment.

The dot generator is adjusted by means of horizontal and vertical controls to get the dots approximately square and about one half an inch apart. Set the brightness control to a normal position to prevent "blooming" of the white dots. A properly converged dot pattern is shown in FIGURE 68.*

c. Initial Receiver Adjustment.

Turn the horizontal dynamic wave form amplitude control R250A to a minimum (CCW). Turn the vertical dynamic wave form amplitude, control R250B, and shaping control, R238, to a minimum (CCW).

Pull the convergence magnets as far away from the neck of the kinescope as possible.

Turn the DC convergence voltage R243 to a low

**Proper convergence is shown with slight misregistration around the extreme edges. This photograph was taken from an early developmental tri-color kinescope, and indicates the best convergence obtainable on that tube. Convergence standards will no doubt improve as the art progresses, insuring optimum convergence at all points on the kinescope screen.*

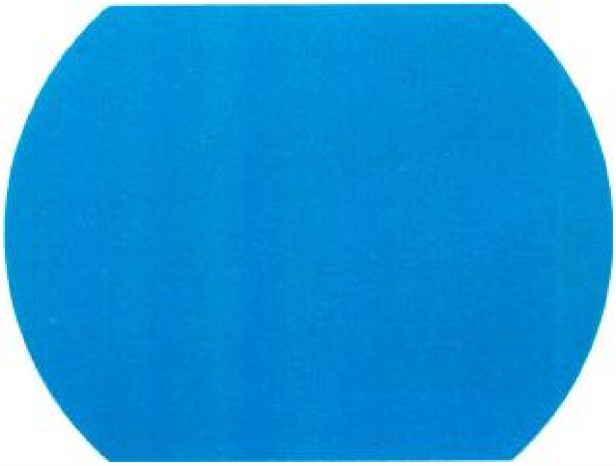


Figure 66 — Correct Purity Adjustment for the Blue Screen

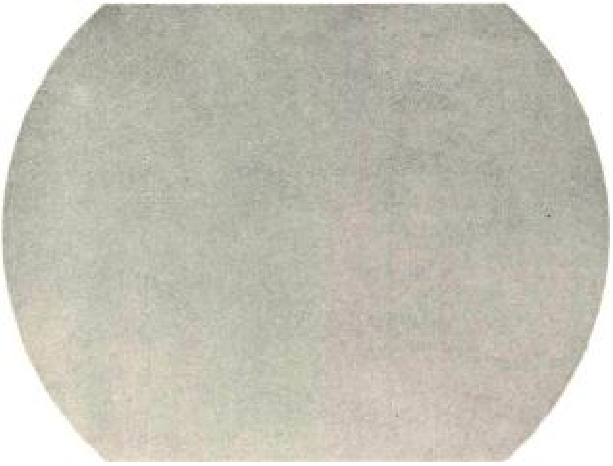


Figure 67 — Proper White Balance Between Red, Green and Blue Screens

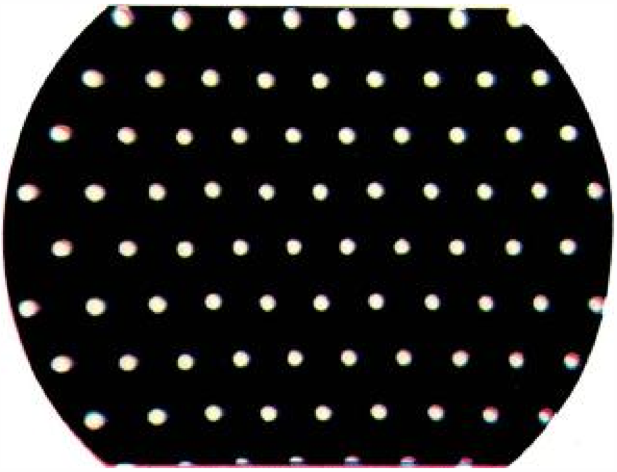


Figure 68 — Properly Converged Dot Pattern

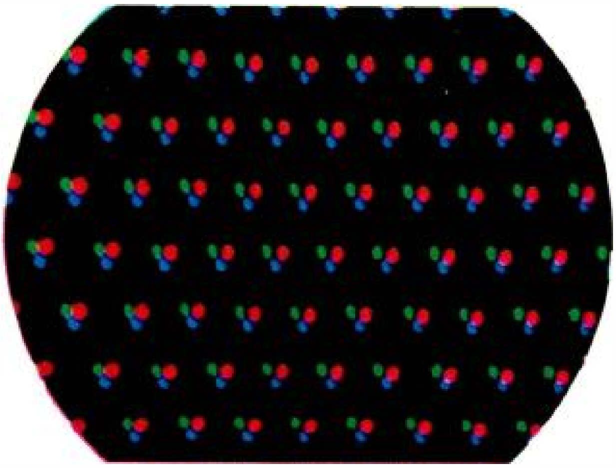


Figure 69 — Dot Pattern Out of Convergence

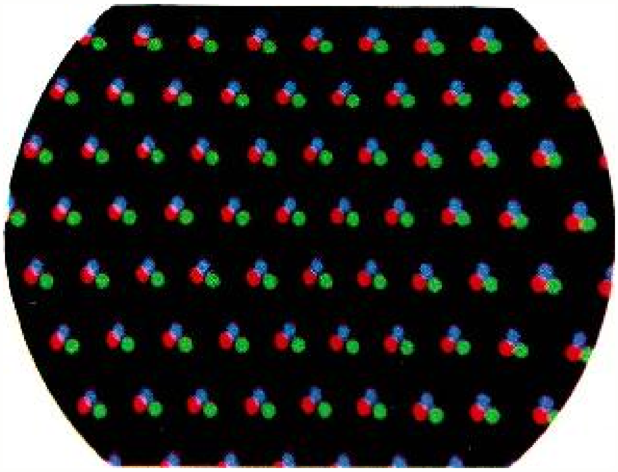


Figure 70 — DC Convergence Voltage Too High

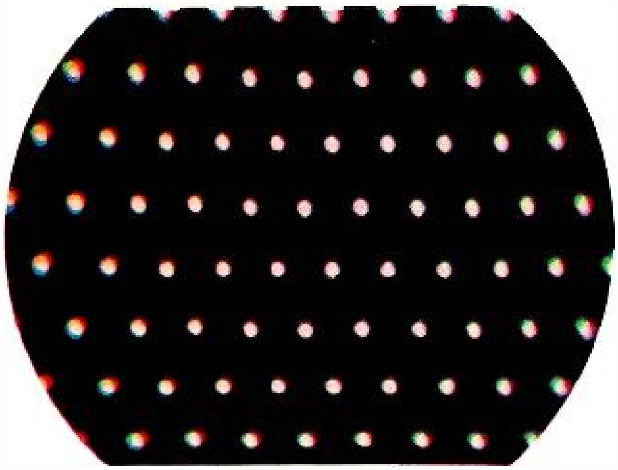


Figure 71 — DC Convergence Correct

value (CCW). This will give a pattern with the blue dot low, red dot to the right and green dot to the left as in FIGURE 69.

The reverse triangular situation indicates convergence voltage is too high—shown in FIGURE 70.

An understanding of this relationship will help a great deal in handling the application of dynamic voltages.

d. DC Convergence Adjustment.

Simultaneously adjust DC convergence voltage and position of the three convergence magnets to get dot overlap in the center of the raster. Proper dot overlap will cause single white dots in the center area of the kinescope (see FIGURE 71).

NOTE: *Many of the convergence adjustments are interdependent; i.e., adjusting one may affect one or more other adjustments. As an example, adjusting the kinescope convergence magnets affects the DC convergence control setting; adjusting DC convergence affects the focus adjustment. It will be well to note that the convergence magnets should not be positioned too close to the kinescope neck in final adjustment, or beam focus distortion may result.*

e. Dynamic Convergence Adjustment.

The dynamic convergence adjustments are made next. Vertical and horizontal dynamic convergence adjustments provide correct dot overlap of the dot generator pattern at the top, bottom and sides of the raster. The two controls are inter-acting, and the adjustment of one affects the adjustment of the other. It has been found best to adjust vertical dynamic convergence first.

Vertical Dynamic Convergence.

Adjust the vertical dynamic convergence control

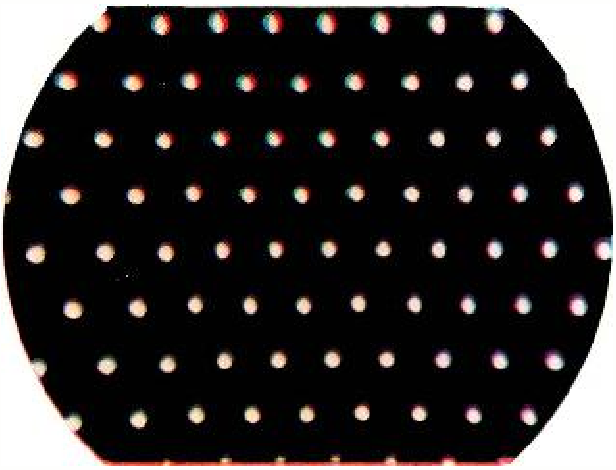


Figure 72 — Vertical Dynamic Convergence Correct

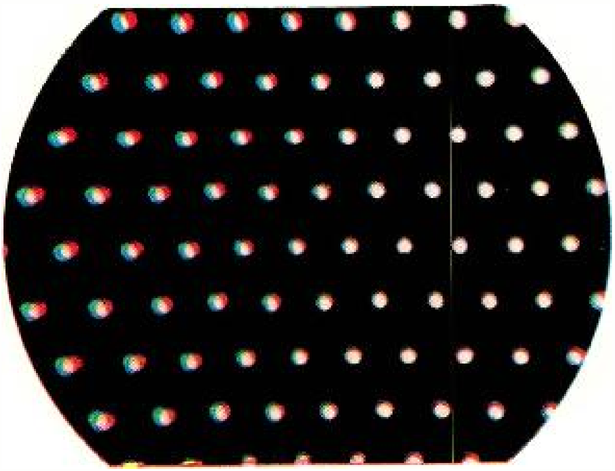


Figure 73 — Horizontal Dynamic Convergence Voltage in Phase Error

(R250B) until the extreme top and bottom dots show an equal displacement error.

Adjusting the DC convergence control will converge the dots on a vertical line down the center of the raster.

Horizontal Dynamic Convergence.

Adjust the horizontal dynamic control R250A until the extreme left and extreme right center dots are equally displaced.

A change in DC convergence will converge the dots on the horizontal center line. If the horizontal dynamic voltage appears in phase error (as observed by one side of the raster not converged, FIGURE 73) it may be corrected by adjusting the horizontal dynamic phasing control L114.

f. Dynamic Convergence Check.

Because the horizontal and vertical convergence adjustments interact it will be necessary to check back and forth until the best overall convergence is reached over the major portion of the tube.

As a check on the accuracy of the dynamic wave forms, variation of the DC convergence voltage will indicate if further adjustment of dynamic voltages are needed. If, through the range of DC convergence voltage, the dots do not overlap, convergence cannot improve with dynamic voltage application. If convergence at the edges will improve with an application of DC convergence voltage, adjustment of the dynamic voltages will improve convergence. As an example, if in the area of mis-convergence the blue dot were low it would indicate that more dynamic voltage need be applied. If the blue dot were high it would indicate that the dynamic voltages were too high and need be reduced.

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 chroma control and contrast control to minimum.

b. Turn brightness control to maximum.

c. Adjust the red screen control R227, blue screen R225B, and green screen control R225A to 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.

Step Nine: Highlight Adjustment.

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

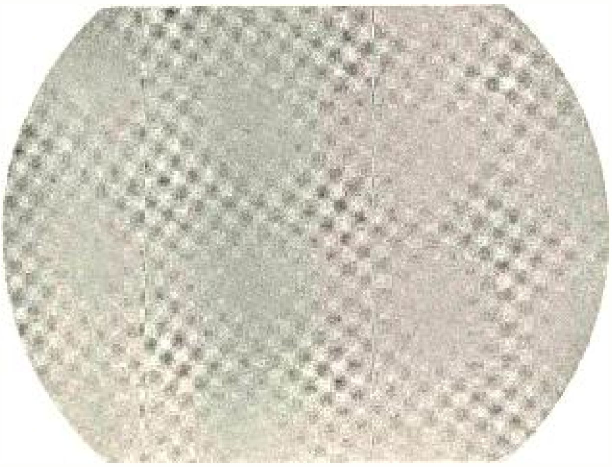


Figure 74 — Correct White Adjustment

b. Tune in a black and white picture.

c. Adjust the blue background control R216B and the green background control R216A until a white (same reference white as in step eight) appears on the high brightness high lights in the picture. FIGURE 75 illustrates insufficient blue and green background control drive, while FIGURE 76 illustrates correct white highlight adjustment.

Step Ten: Low Light Adjustment.

a. With the contrast control still at mid-position, turn the brightness control down to a reduced value. Adjust the blue (R233A) and green (R233B) background controls to reach an equal white on the low lights in the picture (See FIGURE 77). Steps Nine and Ten should be repeated until the "white" is made to track from high lights to low lights using the contrast control.

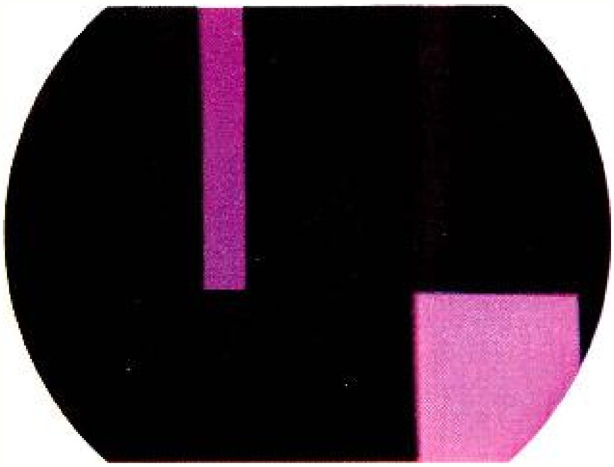


Figure 75 — Insufficient Blue and Green Background Control Drive on a Typical Bar Pattern

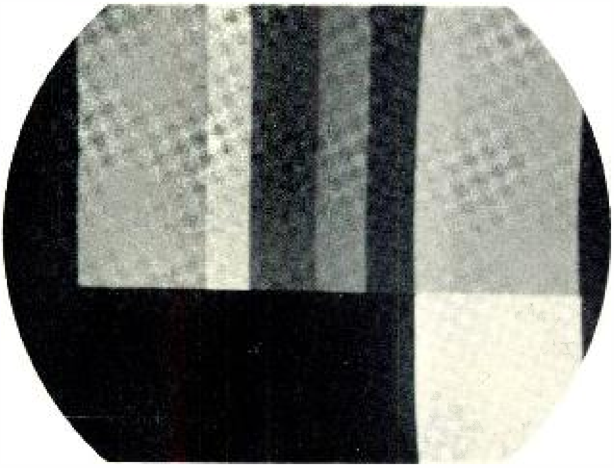


Figure 76 — Correct White Highlight Adjustment

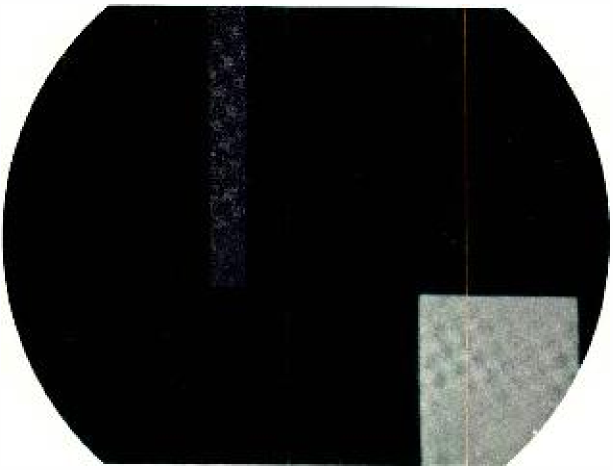


Figure 77 — Correct Low Light Adjustment

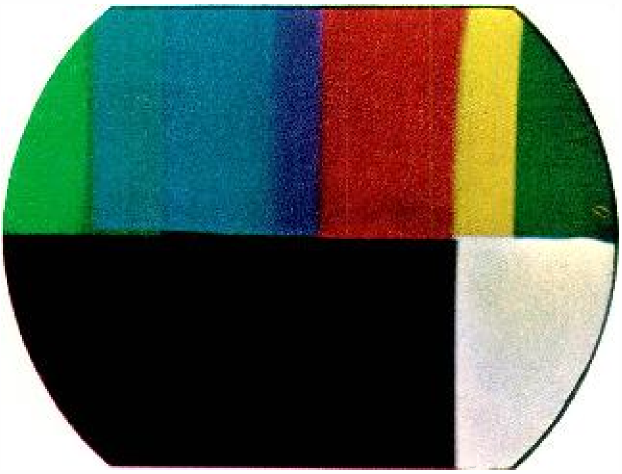


Figure 78 — Correct Color Adjustment on a Typical Bar Pattern

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 to become proficient in the diagnosis and location of troubles. The schematic diagram of this RCA color 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 a basic 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 should 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 tube cannot be made to converge in the center of the raster through a range of the DC convergence control, a check of the convergence voltage should be made. The voltage may be either too high or too low. Use of a meter with a high voltage probe will confirm this. Figure 79 shows how improper convergence affects a black and white picture.

Figure 79 — Improper Convergence on a Black and White Picture

2. If the raster will converge in the center but both sides are out, check the horizontal dynamic voltages by rotating the control and noting the difference. If no difference is noted, check the dynamic convergence circuits with an oscilloscope. 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 before the other, a recheck 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, a check of the vertical dynamic

amplitude and phase should be made. FIGURE 80 illustrates this condition, which should be checked with a scope. A fault in the Vertical Output stage can cause this voltage to be off.

Figure 80 — Effect of Incorrectly Adjusted Vertical Dynamic Voltages

5. If the convergence voltages are correct and the raster cannot be made to converge through a range of the DC convergence control, the kinescope 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 very similar to the trouble outlined in 6 may be caused by low emission in 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 obvious 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 working 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 low lights 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 some mid-position.

b. Tune in a black and white picture.

c. Adjust the blue gain control R216B and the green gain control R216A until a white of the same "color" as the raster appears on the high brightness high lights in the picture.

Low Light Adjustment

a. With the contrast control still at mid-position, turn the brightness control down to a reduced value. Adjust the blue (R233A) and green (R233B) background controls to reach a match on the low lights in the picture. It may be necessary to repeat the Highlight and Low Light 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 Color Sync block or Demodulation—Phase Inversion block. Troubles can occur in these two blocks that will not affect the reproduction of a black and white picture.

There are three types of troubles that can originate in one or both of these blocks:

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

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 chroma control should be advanced and the fine tuning properly set. Also check the following:

1. Check operation of 3.58 MC Crystal Oscillator. A good check here is to measure the voltage at the suppressor grids of the Demodulator tubes. This will not only indicate whether the oscillator is functioning, but also whether or not the oscillator signal is reaching the Demodulator tubes. If the CW signals are driving the suppressor grids properly, the voltage should be approximately —5 volts. With no oscillation, fixed bias is the only voltage

present—about —1.8 volts. If drive to the suppressor grids is lacking but grid voltage is present on the Crystal Oscillator, the oscillator may be greatly off frequency. Check frequency against a standard. Also check the 3.58 MC crystal, the transformer T124 and the Reactance Tube circuit.

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, T126, 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. See Figure 81.

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. Phase control misadjusted

Before trouble shooting for this fault it is advisable to check the phase control on the front panel of the receiver. An example of this is shown in Figure 82, as opposed to a normal scene in Figure 83.

2. Quadrature Amplifier Phase Off

The Quadrature Amplifier 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.

3. I or Q Signal Missing

The I and Q channels pass a band of frequencies that are responsible for certain color components. This is best illustrated by showing a color photograph of the kinescope with the I and Q channels disabled. Figure 84 shows a color picture minus the I signal, while Figure 85 shows a color picture

Figure 81 — Loss of Color Sync

Figure 82 — Incorrect Phase Control Adjustment

Figure 83 — Normal Picture

minus the Q signal, as compared to the same scene under normal conditions as shown in FIGURE 86.

4. Quadrature Distortion

Narrow bands of incorrect color appearing at adjacent vertical edges of a sharp color transition is commonly called Quadrature Distortion. This occurs when the CW drives to the I and Q Demodulators are not 90 degrees displaced in phase.

Figure 84 — Color Picture Minus the I Signal

Figure 85 — Color Picture Minus the Q Signal

Figure 86 — Normal Picture

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. This loss of high video frequencies, it might be added, 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.

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 can occur in the Luminance Amplifier section that will affect color is the delay line. 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 channels. Hum appears as green and purple bars in the Q channel and as orange and cyan bars in the I channel. FIGURE 87 illustrates hum in the Q channel.

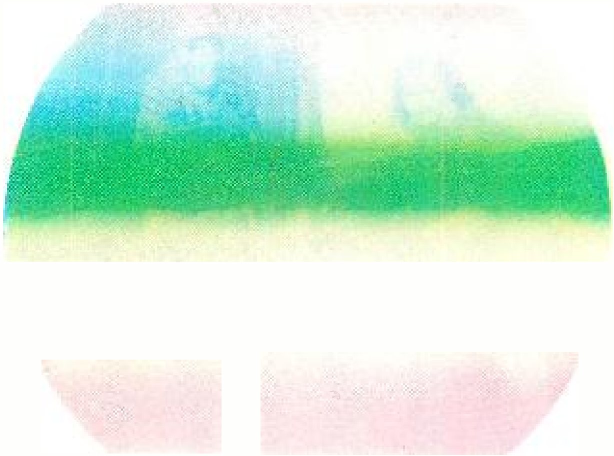


Figure 87 — Hum in the Q Channel

Test Equipment for Color 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. During early research in color television design and servicing it was RCA and RCA Service Company's experience that suitable test equipment for color television has necessarily been of a laboratory type, since there has been no demand for such equipment in the past. Test equipment for color television, therefore, may be of a specialized nature for the service industry until the time that the industry can develop suitable test equipment for use with the new medium. RCA and RCA Service Company have been pursuing simplified test equipment design for field servicing, and their findings and end products will be made available to the industry directly following the field testing of advanced designs.

The following is the present thinking on test equipment requirements for the initial production RCA color television receivers:

1. Oscilloscope

Oscilloscopes that have good frequency and phase response from low frequency or from DC, up to 500 kilocycles, such as the RCA WO-88A, WO-57B or WO-56A, are 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. For certain other applications, such as measurement of the 3.58 MC signals, a wide-band oscilloscope with flat response up to 4 MC, may be desirable.

The oscilloscope should have a compensated isolating probe to minimize loading effects, and it should have voltage calibration for the vertical amplifier in order to determine the amplitude of any waveform.

2. Sweep Generator

In addition to the usual RF and IF ranges, the sweep generator should have a video-frequency range covering from approximately 50 kilocycles to 6 megacycles. The video range is required in checking the frequency response of the video amplifier, and in checking and adjusting the band-pass filter and the I and Q filters. Some brands and models of TV sweep generators do not include a video range, or do not cover video frequencies under 3 MC. The RCA WR-59C sweep generator covers the video range down to 0.3 MC, and this range may be extended down to 50 KC by making a relatively simple modification in the generator. Other essential requirements in the sweep generator include flat voltage output and good linearity.

It is necessary to provide markers to identify specific frequencies on the sweep response curves of the video amplifier, the band-pass filter, and the I and Q filters. Absorption-type markers are satisfactory.

3. Calibrator

The contour and frequency limits of the over-all RF-IF response curve are much more important in color receivers than in black and white receivers. For this reason it is essential to use an accurate crystal calibrated marker generator. The RCA WR-39C or WR-89A calibrators are recommended for alignment of color receivers.

4. Vacuum Tube Voltmeter

A vacuum tube voltmeter with high voltage probe will be necessary equipment for color servicing. The RCA VoltOhmyst with accessory probe is ideally suited for color purposes.

5. Convergence and Linearity Checker

In order to permit proper observation of superimposition of three separate electron beams in the RCA Tri-Color Kinescope, a symmetrical pattern of light and dark patches, similar to a checkerboard, is desirable. Convergence can best be observed in one of two ways: by a pattern of equally spaced dots, or by a cross hatch pattern of horizontal and vertical lines. In either case, there must be a sharp transition between light and dark patches so that convergence may be observed horizontally, vertically and obliquely. Equal spacing between light and dark patches is desirable so that the convergence checker will also serve the dual function of a linearity checker. In the interests of servicing convenience, the convergence checker should be applied to a color receiver with a minimum of connections while maintaining reasonable initial cost.

6. Color Bar Generator

The section of this book dealing with color signal development impresses the point that accurate phase relationships between the I signal, Q signal and burst must be maintained in order to produce proper color fidelity. Therefore, a signal comprised of static color bars representing this phase relationship will provide an accurate means of color phase adjustment. The color bar generator will also prove invaluable in adjusting the various gains and signal balance through the Color Matrix section, and in troubleshooting the specialized color circuits.

As this book goes to press such equipment, of a practical nature, is in the advanced design stages that will efficiently do the job of color phasing adjustment rapidly and at a practical cost for the service organization.

Alignment of the TV Color 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 — TV Sweep Generator
Oscilloscope
TV Signal Calibrator
Bias Voltage Supply
Vacuum Tube Voltmeter

Picture IF Alignment

1. Short the grid (pin 1) of the fourth picture IF tube (V112) to ground.
2. Connect the scope to the junction of L109 and R190 (picture detector load resistor). Use a 10K ohm isolating resistor on the oscilloscope probe.
3. Connect the TV sweep generator to the grid (pin 2) of the fifth picture IF tube. (V113). Adjust the output of the sweep generator for six volt peak to peak trace on the scope.
4. Couple the signal calibrator to obtain markers.
5. Adjust top core of T113 for minimum response at 41.25 MC.
6. Adjust top core of T112 for minimum response at 47.25 MC.
7. Adjust bottom core of T113 and T112 for maximum gain and response, as shown in **Figure** 88.
8. Connect a 180 ohm resistor across the secondary of the second picture IF coil (T109).

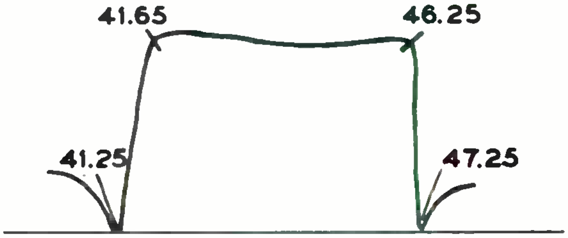


Figure 88 — Fifth Picture IF Response

9. Connect a diode probe to the scope cable and connect to the grid (pin 1) of the third picture IF tube (V111).
10. Connect the positive lead of a bias box to the chassis and negative lead to the IF AGC bus (junction of L102 and C157) and adjust to —8 volts.
11. Reconnect the sweep generator to the grid (pin

1) of the first picture IF tube (V109) through a 1000 mmf. ceramic capacitor.

12. Couple the signal calibrator loosely to the sweep generator leads.

13. Adjust the top core of the first picture IF transformers (T107, T108) for minimum response at 39.75 MC and 47.25 MC respectively.

14. Adjust bottom core of T107 and T108 for maximum gain and response as shown in FIGURE 89.

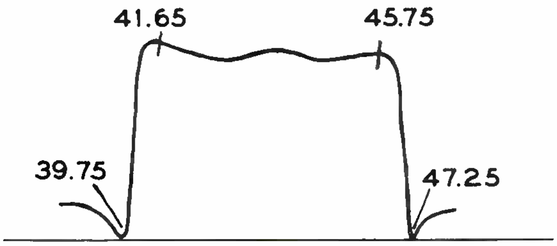


Figure 89 — First Picture IF Response

Alignment of the Overcoupled Stage

1. Short the grid (pin 1) of the fourth picture IF tube (V112) to ground.

2. Set the channel selector to channel 4.

3. Connect a 180 ohm resistor from the plate of the first picture IF tube to the junction of R165 and R166.

4. Connect the scope diode probe to the plate (pin 5) of the first picture IF tube.

5. Ground the picture IF AGC bus and set AGC control to maximum clockwise position.

6. Connect the sweep generator to the front terminal of the 1N82 crystal on the tuner, using a 1000 mmf. capacitor with very short leads.

7. Couple the signal calibrator loosely to the sweep generator.

8. Adjust the top core of T106 and R158 for minimum response at 41.25 MC.

9. Adjust T1 and T2 on the tuner, and the bottom core of T106 for maximum response as shown in FIGURE 90.

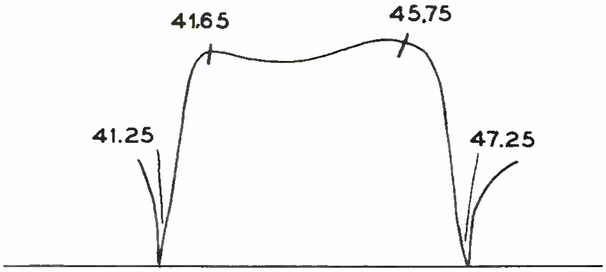


Figure 90 — Converter-Picture IF Response (Overcoupled Stage)

NOTE: *The sound control, R158, must be adjusted so that 41.25 MC is 30 times down from the picture IF carrier.*

Overall Picture IF Alignment

1. Set the receiver channel selector on channel 4.

2. Connect the scope to the junction of L109 and R190 using a 10K ohm isolating resistor.

3. Set the sweep generator to channel 4 and connect to the receiver antenna terminals.

4. With the fine tuning control set in middle of range, adjust oscillator on channel 4.

5. Loosely couple the signal calibrator.

6. Apply —8 volts to IF AGC bias.

7. Adjust T109, T110, and T111 for response curve as shown in FIGURE 91. Keep the sweep output so that the scope trace is six volts peak to peak.

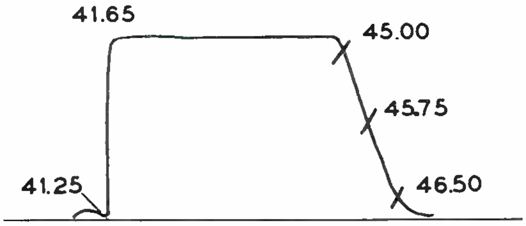


Figure 91 — Overall Picture IF Response

8. Adjust bottom core of T109 to assist in adjusting the linearity of the picture carrier slope.

Sound IF Alignment

Equipment Required: Sweep Generator (must have separate crystals for sound and picture carriers).

Oscilloscope
Vacuum Tube Voltmeter

1. Set the receiver channel selector, fine tuning, and bias box as in the overall picture IF alignment.

2. Adjust the sweep generator as follows:

Set to channel four.

Amplitude modulate the crystal sound carrier 30% at 400 cycles. Adjust the sound carrier to 70% of the level of the picture carrier.

Adjust output for 1.5 volts across picture detector load resistor.

3. Connect the vacuum tube voltmeter to terminal "C" of T103 using a 10K ohm isolating resistor.

4. Adjust sound take-off transformer T102 and sound IF transformer T103 for maximum response.

5. Reconnect the vacuum tube voltmeter across the 5 mfd. capacitor, C123.

6. Adjust the top core of T104 ratio detector transformer for maximum indication.

7. Connect two 100K ohm resistors in series and connect across C123. Place a jumper between the junction of these resistors and C119. Connect the vacuum tube voltmeter on this jumper and adjust bottom of T104 for zero DC voltage reading on the meter.

8. Adjust the AM balance control for minimum AM on the scope. Remove the 100K resistors and jumper.

Video Alignment

1. Disconnect the grid (pin 2) of the video amplifier (V114) and connect the sweep generator to pin 2.

2. Connect the scope to the cathode (pin 1) of V114.

3. Set the signal calibrator to 4.5 MC and adjust L110 for minimum response. Refer to FIGURE 92.

Figure 92 — First Video Amplifier Response

4. Remove the scope and connect to the cathode (pin 7) of the Second Video Amplifier (115A).

5. Adjust the contrast control so that a response is obtained on the scope.

6. Set the signal calibrator to 3.58 MC and adjust both cores of T114 for response as shown in FIGURE 93.

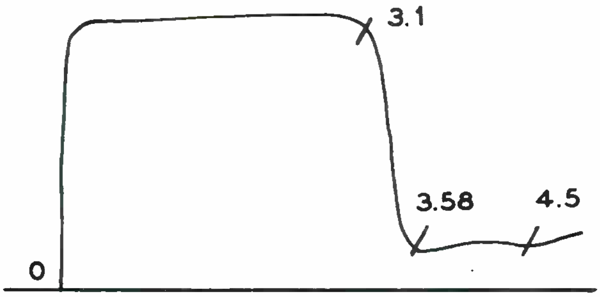


Figure 93 — Video Response After Burst Take-off

7. Connect the scope to each of the three kinescope grids successively and check for response as shown in FIGURE 94.

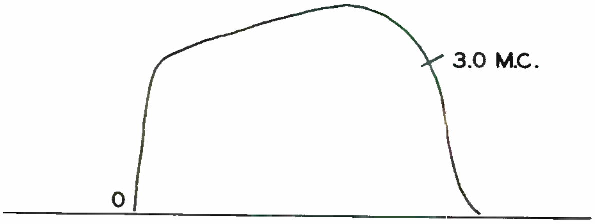


Figure 94 — Overall Video Response

8. Short out the resistor, R296 in the Color Killer circuit.

9. Leave the sweep generator on the grid of the first Video Amplifier.

10. Connect the scope to high side of the chroma control.

11. Adjust T126 and L129 of bandpass filter until maximum gain and response is obtained as shown in FIGURE 95.

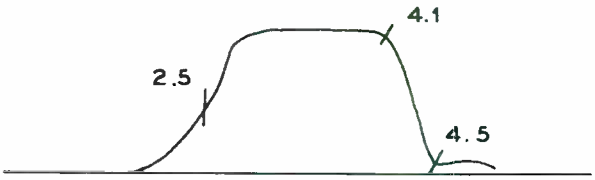


Figure 95 — Band-Pass Amplifier Response

12. Remove the short on the grid of the Color Killer and connect the sweep generator to the arm of the chroma control.

13. Short the suppressor grids of the 6AS6 Demodulators to ground.

14. Connect the scope to the cathode (pin 8) of the "Q" Phase Splitter. A response curve should appear as shown in FIGURE 96.

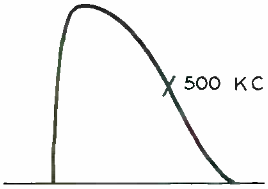


Figure 96 — Q Channel Response

15. Connect the scope to the junction of L133 and C280 in the I Amplifier, V134A. The response curve should appear as shown in FIGURE 97.

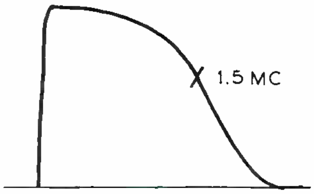


Figure 97 — I Channel Response

Chroma Synchronization Alignment

1. Set the receiver fine tuning control to proper position for reception of a color bar pattern or other suitable color standard.
2. Short the grid (pin 2) of the Burst Amplifier (V129A) to ground.
3. Using a low capacity probe, connect the scope to "A" on T124.
4. Adjust the oscillator coil core for five volts peak to peak.
5. Connect the vacuum tube voltmeter on pin 8 of V129B.
6. Tune the primary of the Color Phasing Amplifier transformer (T123) for maximum indiction. Tune the secondary for maximum indication while rocking the phase control (R327) about a mid-range position.
7. Remove the short on grid of the Burst Amplifier.
8. Connect the scope to the cathode (pin 8) of the Q Phase Splitter.
9. Ground the junction of C239 and R291 in Reactance tube (V131A) grid circuit.
10. Adjust the core of L300 until the trace on the scope becomes stationary.
11. Remove the ground from the grid circuit of the Reactance Tube.
12. Reconnect the vacuum tube voltmeter to pin 8 on V129B.
13. Adjust the core of burst coil, T122 for maximum indication.
14. Adjust secondary of T114 for maximum indication.
15. Connect the vacuum tube voltmeter to the junction of C239 and R291.
16. Connect a 10 mmf capacitor across the 3.58 MC crystal to make the receiver fall out of color lock.
17. Adjust the AFC balance potentiometer for zero DC.
18. Remove the 10 mmf capacitor from the 3.58 MC crystal.
19. Connect the scope to junction of L133 and C280.

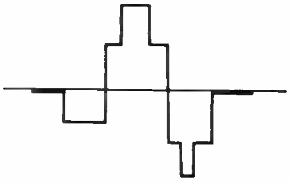


Figure 98 — I Channel Response for a Typical Bar Pattern

20. Observe the color bar trace on the scope and adjust the phase control to make the trace as shown in FIGURE 98.
21. Move the scope to the cathode (pin 8) of the Q Phase Splitter (V115B). Observe the trace and adjust the secondary of the Quadrature Amplifier transformer (T125) to obtain response as shown in FIGURE 99.

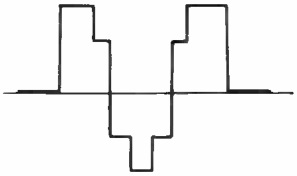


Figure 99 — Q Channel Response for a Typical Bar Pattern

"I" Gain Adjustment

1. Adjust the fine tuning for proper reception of color bar signals or other color standard.
2. Connect the scope to the grid of the blue gun in kinescope.
3. Adjust the chroma and I gain controls to cancel all response excepting the blue and white bars.
4. Check red and green guns similarly for cancellation of undesirable colors.

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.

BIBLIOGRAPHY

Generation of NTSC Color Signals—J. F. Fisher—Institute of Radio Engineers—Proceedings—Volume 41—Pages 338-43, March, 1953.

Lock-in Performance of an AFC Circuit—G. W. Preston and J. C. Tellier—Institute of Radio Engineers—Proceedings—Volume 41—Pages 249-51, February, 1953.

Three Beam Guns for Color Kinescopes—H. C. Moodey and D. D. Van Ormer—RCA Review—Volume 12, Part 2, Pages 583-92—September, 1951.

Also in Institute of Radio Engineers—Proceedings—Volume 39—Pages 1236-40, October, 1951.

Cathode Ray Tubes for Color Television—Volume 193-Page 115-6, Number 5008, Engineer—January 18, 1952.

Principles of NTSC Compatible Color Television—C. J. Hirsh, W. F. Bailey, B. D. Loughlin—Electronics—Volume 25, Number 2—February, 1952, Pages 88-95.

Requisite Color Bandwidth for Simultaneous Color Television Systems—K. McIlwain—Institute of Radio Engineers—Proceedings—Volume 40, Number 8—Pages 909-12, August, 1952.

Three Beam Guns for Color Kinescopes—J. B. Law—RCA Review—Volume 12, Part 2, Pages 466-86—September, 1951.

Also in Institute of Radio Engineers—Proceedings—Volume 39—Pages 1186-94, October, 1951.

Elimination of Moire Effects in Tri-Color Kinescopes—E. G. Ramberg—Institute of Radio Engineers—Proceedings—Volume 40, Number 8—Pages 916-23, August, 1952.

Three Gun Shadow Mask Color Kinescopes—H. B. Law—Electrical Engineering—Volume 71, Number 8—Pages 723-28, August, 1952.

Theory of Synchronous Demodulator As Used in NTSC Color Television Receivers—D. C. Livingstone—Sylvania Technologist—Volume 5, Number 3—Pages 60-63, July, 1952.

NTSC Color Television Synchronizing Signal—R. B. Dome—Electronics—Volume 25, Number 2—Pages 96-97, February, 1952.

Gamma Correction in Constant Luminance

Color Television Systems—Institute of Radio Engineers—Proceedings—Volume 40, Number 10—Pages 1185-95, October, 1952.

Frame Synchronization for Color Television—D. Richman—Electronics—Volume 25, Number 10—Pages 146-50, October, 1952.

Deflection and Convergence in Color Kinescopes—A. W. Friend—RCA Review—Volume 12, Part 2, Pages 612-44—September, 1951.

Also in Institute of Radio Engineers—Proceedings—Volume 39—Pages 1249-63, October, 1951.

Compatible Color Television Receiver—K. E. Farr—Electronics—Pages 98-104, January, 1953.

Improved Tri-Color Television Picture Tube—Television—Technical—Page 71, February, 1953.

Synchronous Demodulator for Color Television—R. B. McGregor—Electronics—Volume 25—Page 214, October, 1952.

Revised Specifications for Field Tests of NTSC Compatible Color Television—W. R. G. Baker—Institute of Radio Engineers—Proceedings—Volume 41—Pages 466-67, May, 1953.

Synchronization in Color Television—D. G. Fink—Electronics—Volume 26—Pages 170-75, May, 1953.

Standards on Television Definitions of Color Terms—Part 1, 1953—Institute of Radio Engineers—Proceedings—Volume 41—Pages 344-47, March, 1953.

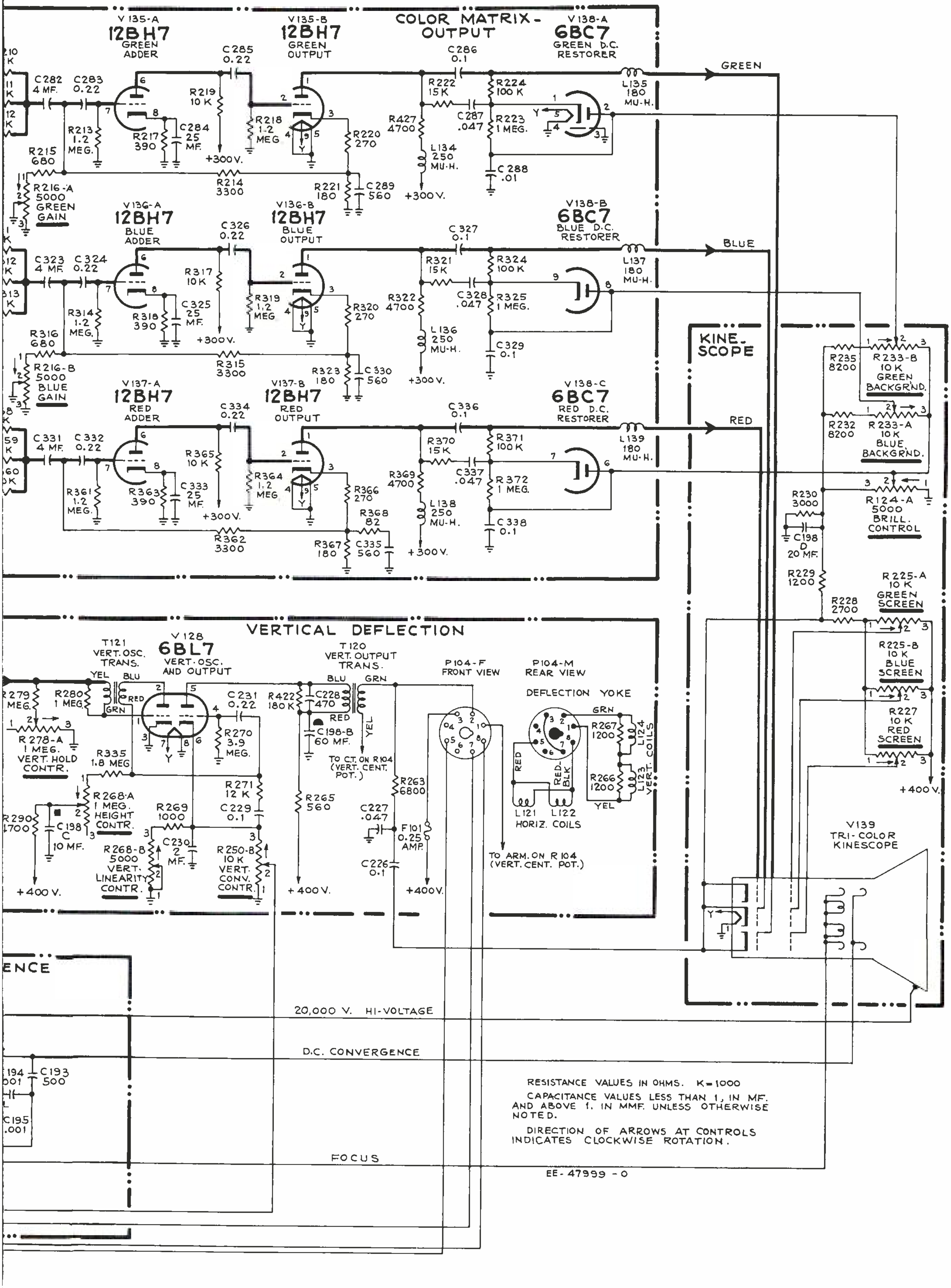
Optimum Utilization of the Radio Frequency Channel for Color Television—RCA Review—Volume 14, Number 2—Pages 133-143, June, 1953.

Principles and Development of Color Television Systems—RCA Review—Volume 14, Number 2—Pages 144-204, June, 1953.

Color Television Signal Receiver Demodulators—RCA Review—Volume 14, Number 2—Pages 205-226, June, 1953.

Colorimetric Analysis of RCA Color Television System—RCA Review—Volume 14, Number 2—Pages 227-258, June, 1953.

Colour—in Theory and Practice—H. D. Murray.

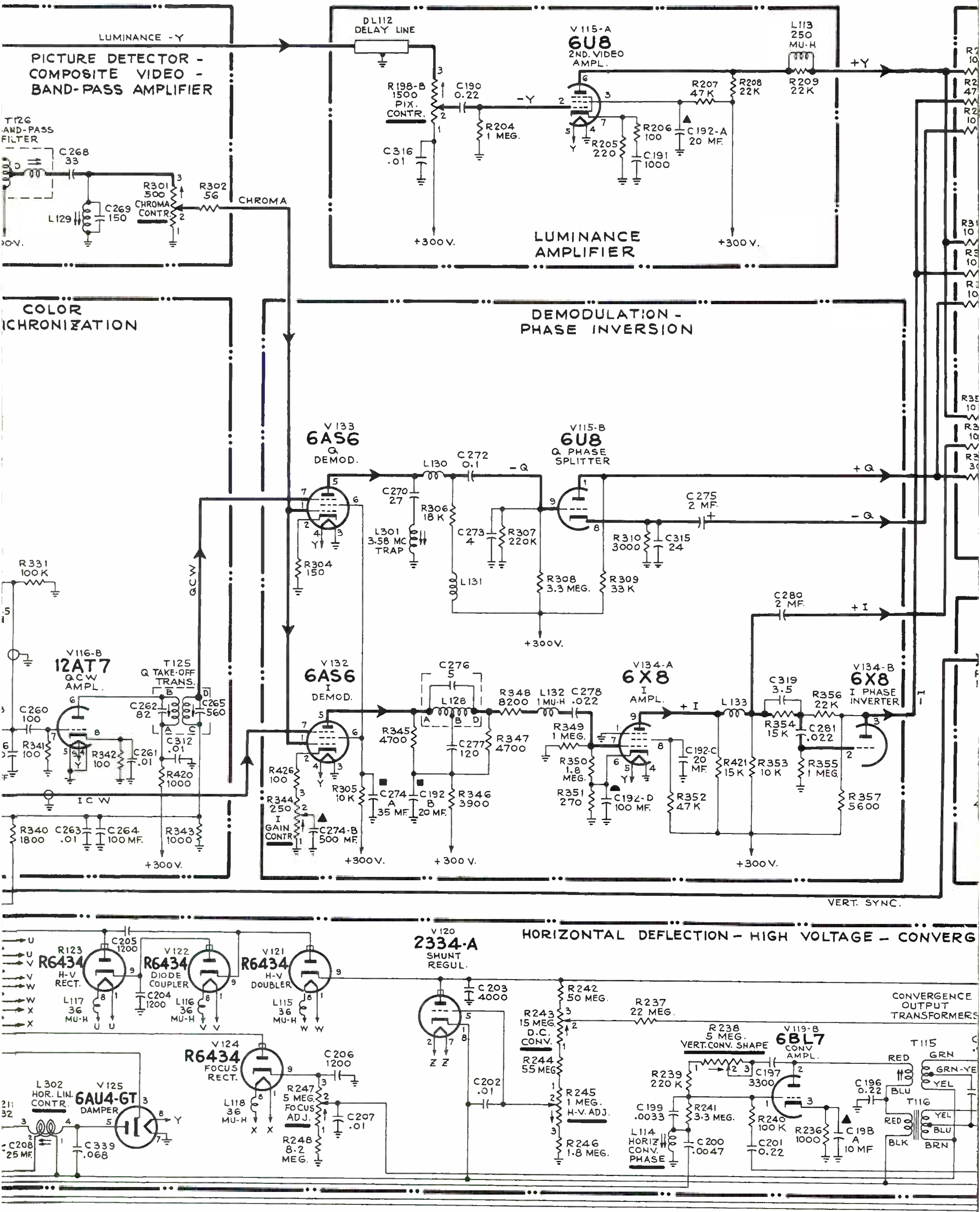


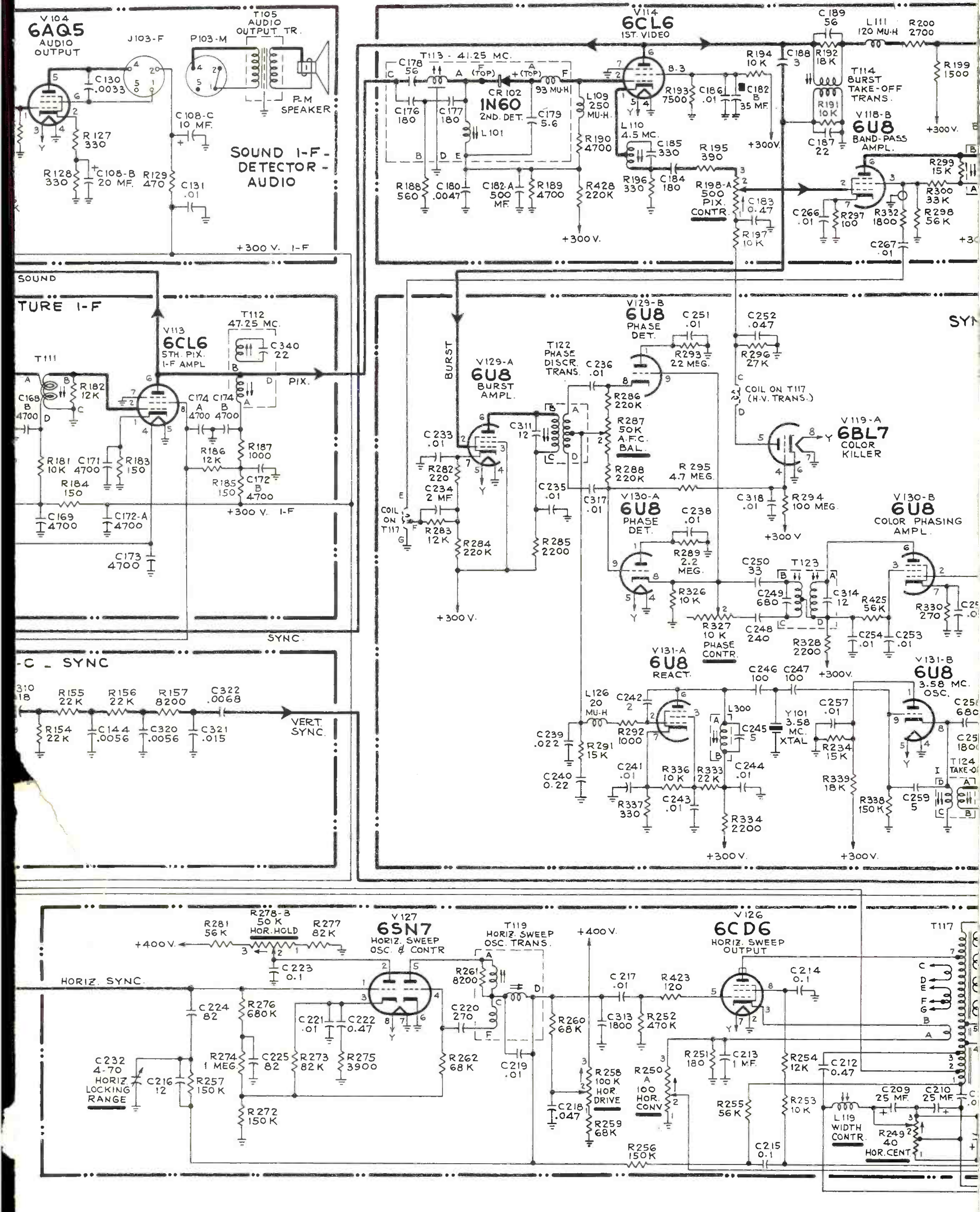
RESISTANCE VALUES IN OHMS. K=1000

CAPACITANCE VALUES LESS THAN 1, IN MF. AND ABOVE 1, IN MMF. UNLESS OTHERWISE NOTED.

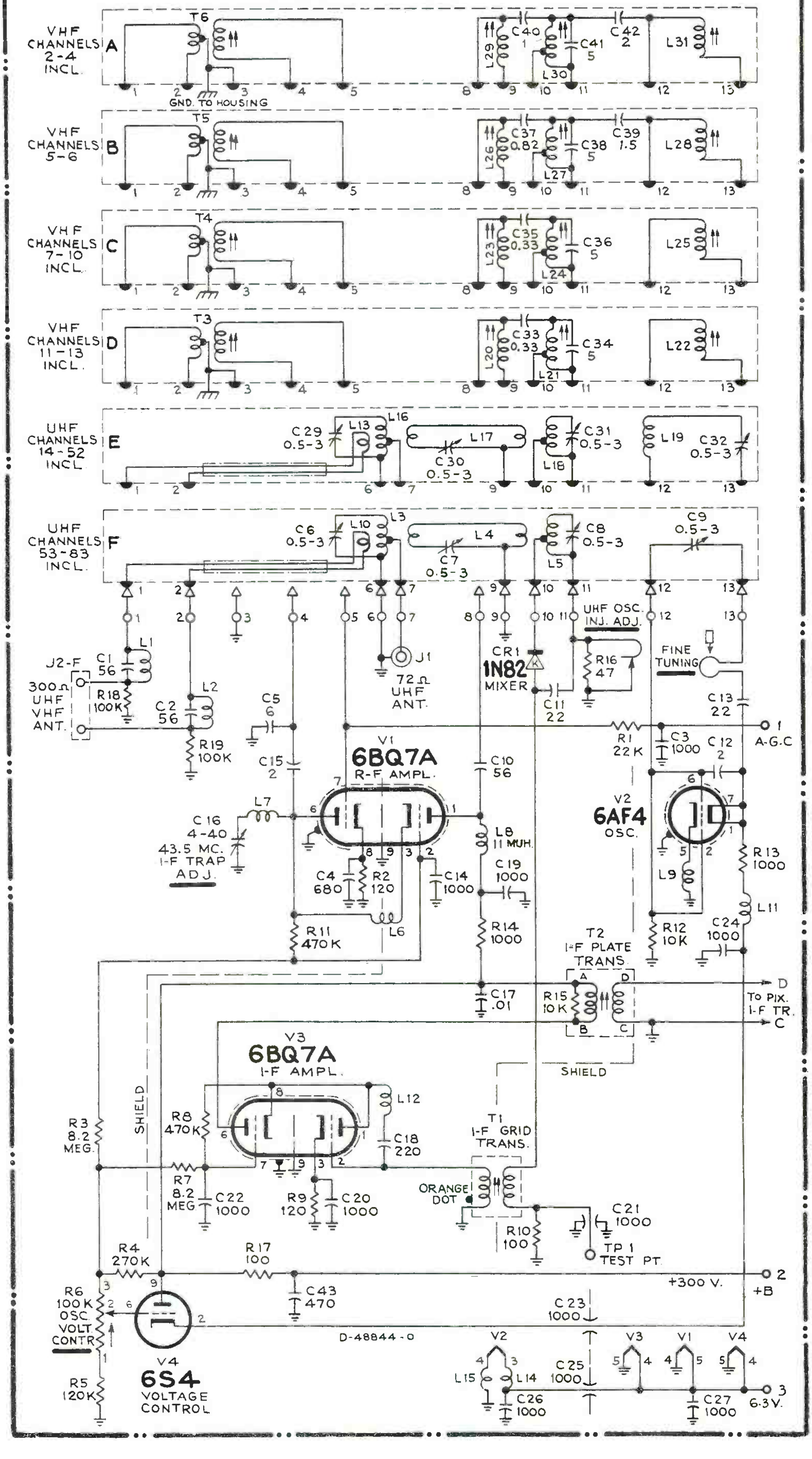
DIRECTION OF ARROWS AT CONTROLS INDICATES CLOCKWISE ROTATION.

EE-47999-0


LUMINANCE -Y
PICTURE DETECTOR - COMPOSITE VIDEO - BAND-PASS AMPLIFIER
T126 BAND-PASS FILTER
C268 33
R301 500 CHROMA CONTR.
R302 56
C269 150
L129
CHROMA
DL112 DELAY LINE
R198-B 1500 PIX. CONTR.
C190 0.22
-Y
R204 1 MEG.
C316 .01
+300 V.
V115-A 6U8 2ND. VIDEO AMPL.
R207 47 K
R208 22 K
R206 100
R205 220
C191 1000
C192-A 20 MF.
L113 250 MU-H
R209 22 K
+Y
+300 V.
LUMINANCE AMPLIFIER
COLOR SYNCHRONIZATION
DEMODULATION - PHASE INVERSION
V133 6AS6 Q DEMOD.
R304 150
L130
C272 0.1
-Q
C270 27
R306 18 K
L301 3.58 MC TRAP
C273 4
R307 220 K
L131
R308 3.3 MEG.
R309 33 K
+300 V.
V115-B 6U8 Q PHASE SPLITTER
+Q
C275 2 MF.
-Q
R310 3000
C315 24
QCW
R331 100 K
V116-B 12AT7 QCW AMPL.
C260 100
R341 100
R342 100
C261 .01
T125 Q TAKE-OFF TRANS.
C262 82
C265 560
C312 .01
R420 1000
ICW
R340 1800
C263 .01
C264 100 MF.
R343 1000
+300 V.
V132 6AS6 I DEMOD.
R426 100
R344 250 I GAIN CONTR.
C274-B 500 MF.
R305 10 K
C274 A 35 MF.
C192 B 20 MF.
R346 3900
+300 V.
+300 V.
C276 5
L128
R345 4700
C277 120
R347 4700
R348 8200
L132 1 MU-H
C278 .022
V134-A 6X8 I AMPL.
R349 1 MEG.
R350 1.8 MEG.
R351 270
C192-D 100 MF.
C192-C 20 MF.
R352 47 K
+I
L133
R421 15 K
C280 2 MF.
+I
C319 3.5
R354 15 K
R353 10 K
R356 22 K
C281 .022
R355 1 MEG.
V134-B 6X8 I PHASE INVERTER
-I
R357 5600
+300 V.
VERT. SYNC.
HORIZONTAL DEFLECTION - HIGH VOLTAGE - CONVERG
R123 R6434 H-V RECT.
C205 1200
L117 36 MU-H
V122 R6434 DIODE COUPLER
C204 1200
L116 36 MU-H
V121 R6434 H-V DOUBLER
L115 36 MU-H
V120 2334-A SHUNT REGUL.
C203 4000
C202 .01
R242 50 MEG.
R243 15 MEG. D.C. CONV.
R244 55 MEG.
R245 1 MEG. H-V. ADJ.
R246 1.8 MEG.
R237 22 MEG.
V124 R6434 FOCUS RECT.
L118 36 MU-H
C206 1200
R247 5 MEG. FOCUS ADJ.
C207 .01
R248 8.2 MEG.
L302 HOR. LIN. CONTR.
V125 6AU4-GT DAMPER
C208 25 MF.
C339 .068
R238 5 MEG. VERT. CONV. SHAPE
V119-B 6BL7 CONV AMPL.
R239 220 K
C197 3300
C199 .0033
R241 3.3 MEG.
L114 HORIZ CONV. PHASE
C200 .0047
R240 100 K
C201 0.22
R236 1000
C198 A 10 MF
C196 0.22
CONVERGENCE OUTPUT TRANSFORMERS
T115
T116
RED
GRN
GRN-YEL
YEL
BLU
BLK
BRN


V104
6AQ5
AUDIO OUTPUT
J103-F
P103-M
T105
AUDIO OUTPUT TR.
P-M SPEAKER
C130 .0033
R127 330
R128 330
C108-B 20 MF.
R129 470
C108-C 10 MF.
C131 .01
SOUND I-F-DETECTOR-AUDIO
+300 V. I-F
SOUND
TURE I-F
T111
C168 B 4700
R182 12K
V113
6CL6
5TH. PIX. I-F AMPL.
T112
47.25 MC.
C340 22
PIX.
C174 A 4700
C174 B 4700
R187 1000
R186 12K
R185 150
C172 B 4700
R181 10K
C171 4700
R183 150
R184 150
C169 4700
C172-A 4700
C173 4700
+300 V. I-F
SYNC.
-C _ SYNC
R155 22K
R156 22K
R157 8200
C322 .0068
R154 22K
C144 .0056
C320 .0056
C321 .015
VERT. SYNC.
V114
6CL6
1ST. VIDEO
T113 - 41.25 MC.
C178 56
F (TOP)
A (TOP)
CR102
1N60
2ND. DET.
93 MU-H
C176 180
C177 180
L101
C179 5.6
L109 250 MU-H.
L110 4.5 MC.
R188 560
C180 .0047
C182-A 500 MF.
R189 4700
R190 4700
R428 220K
+300 V.
R193 7500
C186 .01
C182 B 35 MF.
R194 10K
C188 3
C185 330
R195 390
R196 330
C184 180
R198-A 500 PIX. CONTR.
C183 0.47
R197 10K
+300V.
C189 56
L111 120 MU-H
R200 2700
R192 18K
R191 10K
T114 BURST TAKE-OFF TRANS.
R199 1500
C187 22
V118-B
6U8
BAND-PASS AMPL.
+300V.
R299 15K
R300 33K
R298 56K
C266 .01
R297 100
R332 1800
C267 .01
BURST
V129-A
6U8
BURST AMPL.
C233 .01
R282 220
C234 2 MF.
COIL ON T117
R283 12K
R284 220K
+300 V.
C311 12
T122 PHASE DISCR. TRANS.
C236 .01
C235 .01
R285 2200
V129-B
6U8
PHASE DET.
C251 .01
R293 22 MEG.
R286 220K
R287 50K A.F.C. BAL.
R288 220K
R295 4.7 MEG.
C317 .01
C252 .047
R296 27K
COIL ON T117 (H.V. TRANS.)
V119-A
6BL7
COLOR KILLER
C318 .01
R294 100 MEG.
+300 V
V130-A
6U8
PHASE DET.
C238 .01
R289 2.2 MEG.
R326 10K
R327 10K PHASE CONTR.
C250 33
C249 680
T123
C314 12
C248 240
R425 56K
R328 2200
C254 .01
C253 .01
+300V.
V130-B
6U8
COLOR PHASING AMPL.
R330 270
SYN
V131-A
6U8
REACT.
L126 20 MU-H
C242 2
R292 1000
C239 .022
R291 15K
C240 0.22
L300
C245 5
C241 .01
R336 10K
R333 22K
C244 .01
R337 330
C243 .01
R334 2200
+300 V.
C246 100
C247 100
Y101 3.58 MC. XTAL
V131-B
6U8
3.58 MC. OSC.
C257 .01
R234 15K
R339 18K
R338 150K
C259 5
T124 TAKE-O
+300 V.
R281 56K
R278-B 50K HOR. HOLD
R277 82K
+400 V.
C223 0.1
HORIZ. SYNC.
C224 82
R276 680K
V127
6SN7
HORIZ. SWEEP OSC. & CONTR
C221 .01
C222 0.47
R274 1 MEG
C225 82
R273 82K
R275 3900
C232 4-70 HORIZ. LOCKING RANGE
C216 12
R257 150K
R272 150K
T119
HORIZ. SWEEP OSC. TRANS.
R261 8200
C220 270
R262 68K
C219 .01
+400 V.
R260 68K
C218 .047
R258 100K HOR. DRIVE
R259 68K
C217 .01
C313 1800
R423 120
R252 470K
R256 150K
V126
6CD6
HORIZ. SWEEP OUTPUT
C214 0.1
R251 180
C213 1 MF.
R250 A 100 HOR. CONV.
R255 56K
C215 0.1
R254 12K
R253 10K
C212 0.47
L119 WIDTH CONTR.
C209 25 MF.
C210 25 MF.
R249 40 HOR. CENT.
T117

TUNER UNIT KRK-12



RCA