Using
SCOPES
in
COLOR TV

BY ROBERT G. MIDDLETON

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Preface

Scope applications in color TV include all the uses that we have learned in black-and-white TV troubleshooting, plus numerous tests that are unique to chroma circuitry. This book concentrates on chroma-circuit waveform analysis and interpretation of special patterns, such as vectorgrams. The discussion starts with oscilloscope requirements, and explains how a narrow-band scope can be used to make certain tests of wideband circuit action. This is a technique that is often overlooked by the beginning technician.

In the second chapter, basic color waveform analysis is explained, with careful distinction made between ideal and practical waveforms. Fundamental relations between circuit characteristics and waveshapes are illustrated by typical examples. This is of great importance, because we cannot use a scope advantageously unless we know how to interpret waveform distortions. Even the most basic scope will remain merely a "bench warmer" unless we understand the basic principles of waveform analysis.

Most scope applications in chroma circuits require the use of a color-bar generator. Unless the generator is accurate, we will be misled and will waste time. Therefore, a basic coverage of color-bar generator operation and maintenance is provided in the third chapter. The unkeyed rainbow generator, keyed rainbow generator and single-bar and multiple-bar NTSC generators are covered. Explanations of the various output signals that are provided. Practical troubleshooting and adjustment procedures are noted.

Color-sync problems often turn out to be time-consuming jobs at the bench. Therefore, color-sync waveform analysis is considered in some detail in the fourth chapter. The relation of black-and-white sync action to color-sync action is presented, since the beginning technician often overlooks this interrelationship. Color-burst processing and the

associated circuit waveforms are explained, both for normal and for abnormal operation. Both the crystal-ringing and reaction-control systems are analyzed. Emphasis is placed throughout the book on waveform interpretation.

Bandpass-amplifier and chroma-demodulator troubles are second only to color-sync troubles in routine color servicing, and they are the subject of the fifth chapter. Waveforms in the chroma-demodulator circuits are rather complex, compared with waveforms in the bandpass-amplifier circuit. This complexity is the result of phase characteristics, in addition to the more familiar aspects of waveshape and amplitude characteristics. Considerable attention is given to the basic waveform characterstics in the six types of demodulator circuits likely to be encountered by the technician. The important topic of baseline distortion is fully explained.

The matrix section may follow the demodulator sections, or it may be an integral part of demodulator circuit action in some color receivers. Waveform development and analysis in both of these systems are discussed step-by-step in the sixth chapter. Since the RGB matrix arrangement used in the most recent receivers is unique in some ways, the circuit actions and waveform characteristics are explained and illustrated in some detail. The use of keyed rainbow and NTSC signals to check RGB matrix action is fully discussed.

The final chapter presents a most comprehensive analysis of vectorgrams. Both keyed rainbow and NTSC vectorgram characteristics are analyzed. It is shown why the central region of a vectorgram may be displayed as a circle, an ellipse, or as a straight line, instead of the simple point that is predicted by theory. The absence of "petals" in an NTSC vectorgram is explained, with discussion of pattern evaluation. This discussion includes useful follow-up tests, employing the special test signals supplied by an NTSC generator.

Professional technicians will find this book to be a helpful supplement to more generalized books on color-TV troubleshooting, as the primary emphasis is placed on color-waveform analysis. It is assumed that the reader is familiar with basic scope operation and with the general principles of color receiver operation. Mathematics has been minimized in the text, and full advantage is taken of graphical presentations and waveform photos. Although the book is primarily intended as a reference for the practicing technician, technical institutes will also find it useful as a classroom text.

ROBERT G. MIDDLETON

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Action — Chroma–Demodulator Waveform Analysis — Vector-
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Color-TV Oscilloscope
Requirements

Both narrow-band and wideband scopes find useful application in color-TV maintenance and servicing procedures. However, we will find that a narrow-band scope has a comparatively limited field of application. That is, a wideband scope provides almost all the applications of a narrow-band scope, plus many other important uses. A wide-band dc scope meets certain color-TV service requirements that are more difficult to accomplish with a wideband ac scope. Although a wideband dc scope with triggered sweeps is the most useful type of scope in the hands of an experienced technician, beginners are advised to become familiar first with the simpler types of scopes having free-running nontriggered sweeps.

NARROW-BAND SCOPES

A typical narrow-band scope is illustrated in Fig. 1-1. It has a vertical-amplifier frequency response that is flat within ±1dB from 15 Hz to 100 kHz; the response is down 6 dB at 250 kHz. Scope manufacturers sometimes provide graphs of frequency response for vertical and horizontal amplifiers, as shown in Fig. 1-2. In this example, switches are provided for either ac or dc response. Note that on the ac function, the frequency response starts to drop off at 5 Hz. On the other hand, on the dc function, flat response is maintained down to zero frequency (dc).

Beginning technicians should recognize that the *cathode-ray tube* in a narrow-band scope has *extremely high* frequency response. Therefore, a high-frequency signal voltage can be displayed without distortion if it is coupled directly to the deflection plates in the CRT, as

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shown in Fig. 1-3. Coupling capacitors are used to avoid disturbance of the dc voltages on the plates. In this example, the signal voltage is applied to P2, and the opposing plate P1 is bypassed to ground. This is the most common method used in color-TV work, because the chroma circuits are usually single-ended amplifiers.
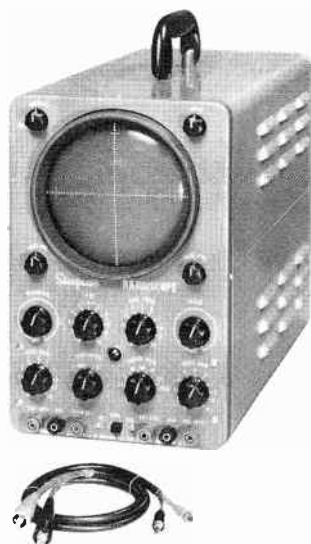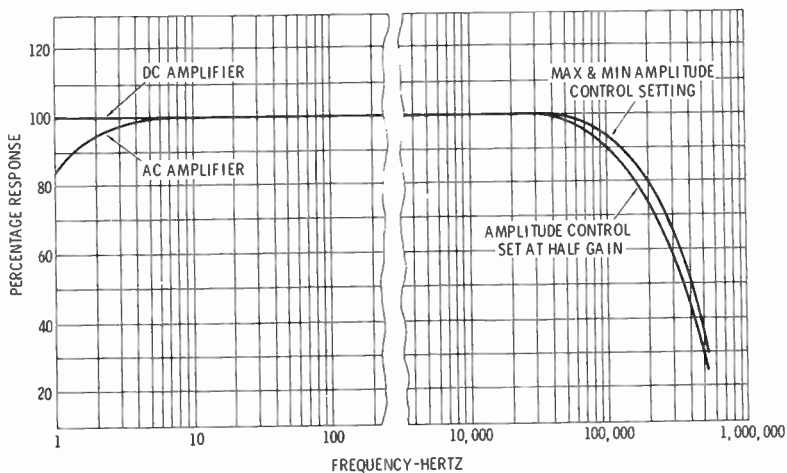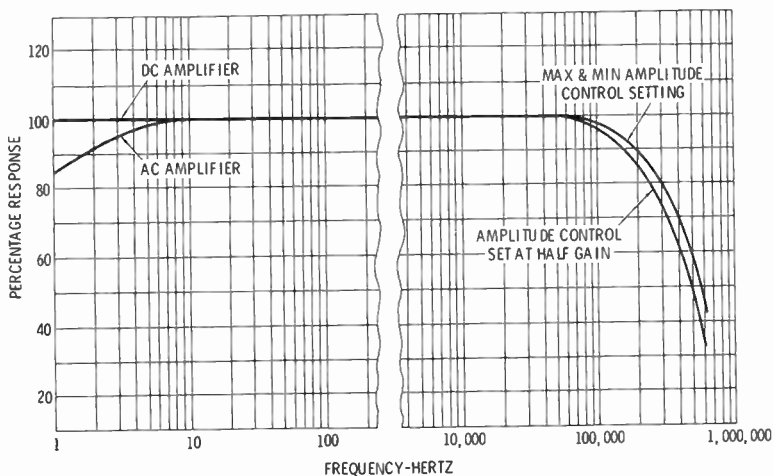

Fig. 1-1. A typical narrow-band scope.

Courtesy Simpson Electric Co.

Note in Fig. 1-3 that resistors R1 and R2 are connected between P1 and P2 and the internal circuitry of the scope. These resistors have a high value, in the range from 0.5 meg to 3 megs. They are used to provide a dc path from the deflection plates to the internal circuitry of the scope, so that the centering controls remain operative, although links L1 and L2 are open. Since R1 and R2 have high resistance values, they impose negligible loading on P1 and P2 with respect to the signal-voltage source. In ordinary narrow-band scopes, R1, R2, L1, and L2 are mounted on an insulating board on the back of the scope case.

To anticipate subsequent discussion, let us briefly consider a practical application for the test method depicted in Fig. 1-3. We will find that one of the standard procedures for checking chroma-circuit operation utilizes a test setup such as shown in Fig. 1-4A. That is, the red lead to the color picture tube is coupled to a vertical deflection plate of the CRT, and the blue lead to the color picture tube is coupled to a horizontal deflection plate of the CRT. The opposing vertical and horizontal deflection plates are coupled to ground. If a color-bar signal

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(A) Y amplifier.

(B) X amplifier.

Fig. 1-2. Narrow-band scope frequency response.

is applied to the receiver, a *vectorgram* pattern is displayed on the scope screen, as shown in Fig. 1-4B.

We are not concerned with details of pattern analysis at this time, but only with an example of the application of a narrow-band scope in a comparatively wideband test procedure. A photo of a practical vectorgram pattern is seen in Fig. 1-4C. A vectorscope for color-TV service work employs the typical circuitry shown in Fig. 1-4D. The CRT configuration is often supplemented by a built-in color-bar gen-

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erator. Note that direct coupling can be used to the deflection plates in the CRT because the chroma signal level is comparatively high at the input of the color picture tube. Note that from 80 to 100 volts are required to obtain one inch of deflection on the screen of a cathode-ray tube. Potentiometer R1 is a focus control, and R2 is an intensity control.
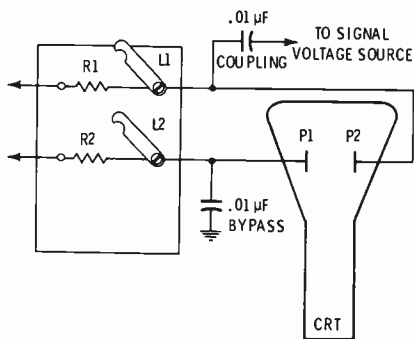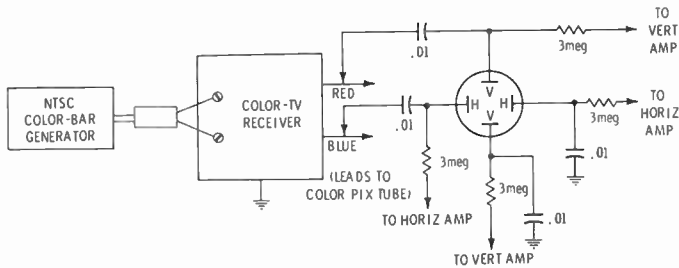

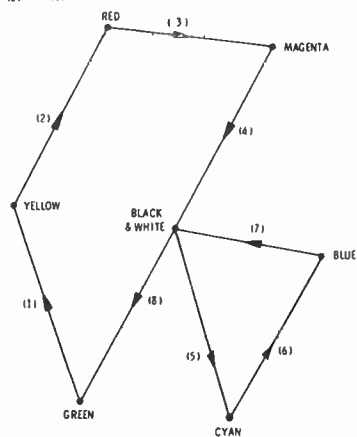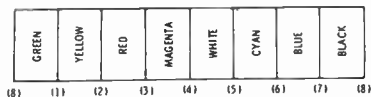Fig. 1-3. Signal is coupled directly to plate P2.

Either a 1-inch or a 2-inch CRT can be used in the circuit shown in Fig. 1-4. When a larger screen, such as three inches or five inches is utilized, a higher accelerating voltage is necessary to obtain a bright pattern. Fig. 1-5 shows a circuit suitable for a 5-inch CRT. Horizontal and vertical centering controls are also provided in this configuration. Centering controls are not essential in a vectorscope, provided that the coupling capacitors have very high insulation resistance. In practice, capacitors may have a slight leakage resistance, which tends to de-center the pattern on the screen. Therefore, it is a practical convenience to have centering controls available.

Next, let us look at the block diagram for a narrow-band scope shown in Fig. 1-6. Vertical and horizontal amplifiers are provided to step up weak signals to a value sufficient to produce full-screen deflection. A sawtooth sweep generator produces a *time base* for display of waveforms on a horizontal time axis. Note that a switch is provided so that the horizontal amplifier can be connected either to the saw-tooth sweep generator, or to an external horizontal-signal input. The use of this external signal function is explained in detail in following chapters. Note also the rear terminal block depicted in Fig. 1-6; this is the block that was mentioned in discussion of Fig. 1-3.
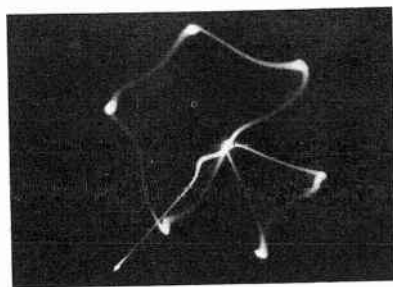
Fig. 1-7 shows a circuit diagram for a basic narrow-band scope. V1 and V2 are conventional RC-coupled amplifiers. However, V3 is a thyratron tube; it generates a sawtooth waveform as a result of the associated capacitors and resistors. Several capacitance values can be selected by switch S3, in order to adjust the horizontal-deflection rate.

(A) Test setup.

(B) Ideal vectorgram.

(C) Practical vectorgram.

C1 - 0.01 μF 400-VOLT PAPER
C2 - 0.5 μF 800-VOLT PAPER OR OIL-FILLED
C3 - 0.1 μF 600-VOLT PAPER
C4 - 0.1 μF 600-VOLT PAPER
R1 - 50,000 - OHM VARIABLE
R2, R5 - 0.5 MEGOHM VARIABLE

R3 - 1 MEGOHM, 1-WATT
R4 - 0.5 MEGOHM, 1-WATT
S1 - S. P. S. T. TOGGLE SWITCH
T1 - REPLACEMENT-TYPE TRANSFORMER;
350 VOLTS, 40 MA; 5 VOLTS 3 AMPERES;
6.3 VOLTS, 2 AMPERES

(D) Circuit for a small vectorscope.

Fig. 1-4. Vector scope.

The pattern size is determined by the settings of the vertical and horizontal attenuators. These are potentiometers, with a value between 0.5 and 1 megohm.
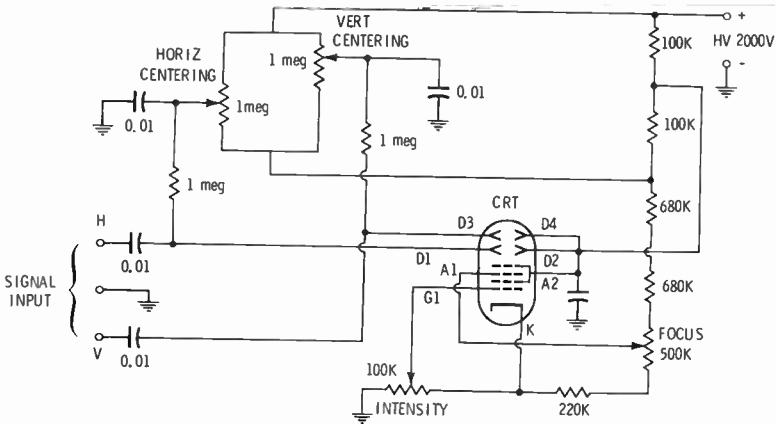

Fig. 1-5. Circuit for a 5-inch CRT.

A time base must be locked to the displayed waveform (synchronized) to keep the pattern from drifting horizontally on the screen. This is the function of the sync-amplitude control in Fig. 1-7. We see that when S2 is set to its *internal sync* position, a sample of the vertical-channel signal is fed to the grid of the thyratron sawtooth oscillator. This is the usual mode of operation. However, specialized tests
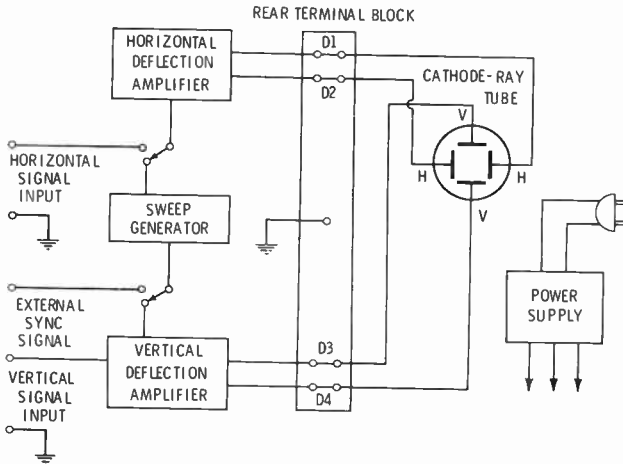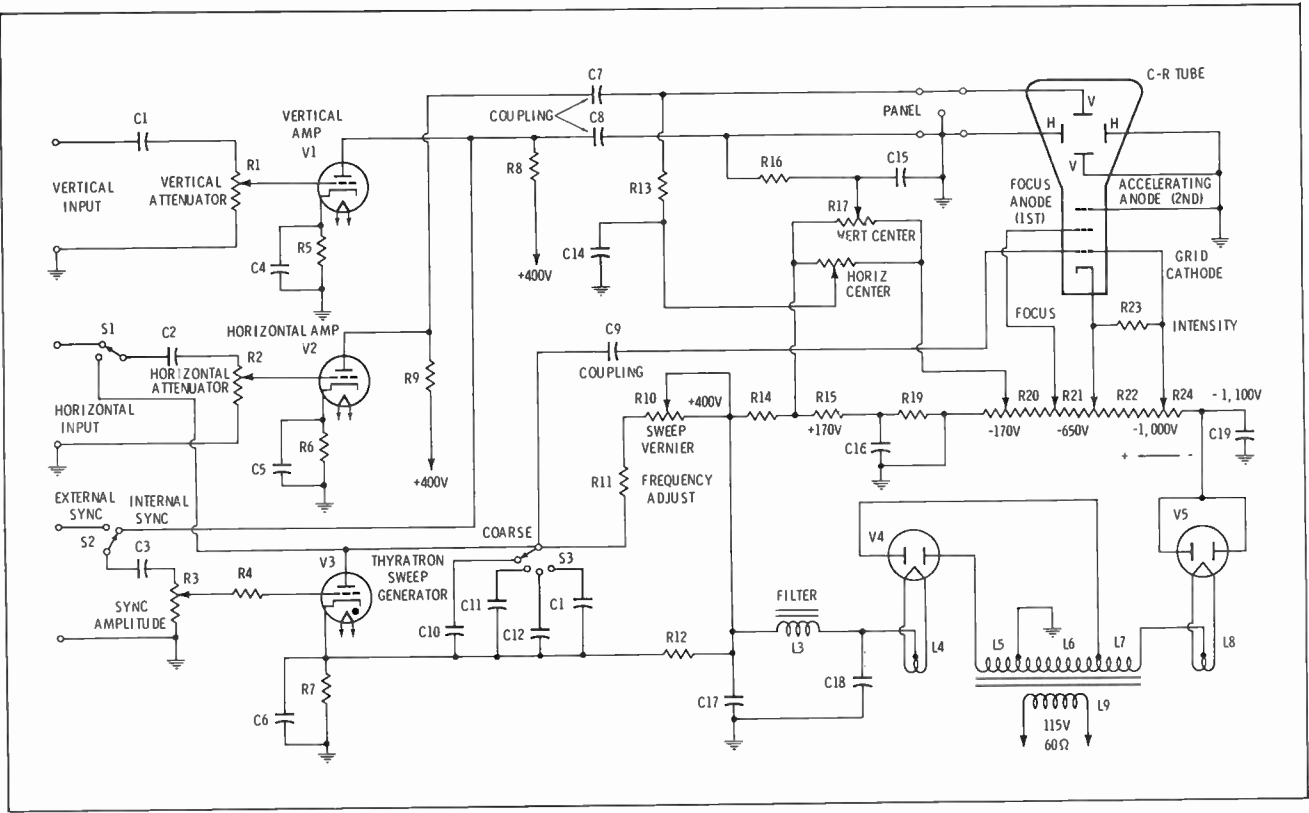

Fig. 1-6. Simplified block diagram for a narrow-band scope.

Fig. 1-7. Circuit diagram for a basic narrow-band scope.

occasionally require the use of *external sync;* therefore, an external-sync position is provided by S2.

Note C9 in Fig. 1-7. This is a coupling and waveshaping capacitor. It permits a *blanking pulse* to be applied to the grid of the CRT. This blanking pulse eliminates the retrace from the pattern. Although the blanking function is not essential, a visible retrace line can be confusing and it is general practice to blank the retrace. We will observe that the CRT deflection plates operate at comparatively low voltage, with respect to the cathode and grid. This voltage distribution is used in order to maintain the screen of the CRT at low potential, and thereby avoid the possibility of shock to the operator.

Let us analyze the values of the plate-load resistors R8 and R9 in Fig. 1-7. When the plate-load resistor has a high value, the gain of the amplifier will be high, but the bandwidth will be limited. Increased bandwidth can be obtained by using a low value of plate-load resistance, but the gain is reduced. Therefore, the value of plate-load resistance used in a simple scope is necessarily a compromise. Typical narrow-band scopes have plate-load resistances in the range from 25k to 100k. When 100-k plate loads are used, the frequency response is limited to the audio range.

A narrow-band scope is as satisfactory as a wide-band scope for *visual-alignment* procedures in color TV. Since the scope need only have good 60-Hz square-wave response in this application, the test signals may be passed without distortion through the vertical and horizontal amplifiers. Again, to anticipate later discussion, let us note a test setup for checking the frequency response of a chroma bandpass amplifier. With reference to Fig. 1-8, the center frequency of the bandpass amplifier is 3.58 MHz. However, since a *demodulator probe* is employed in the test, only low frequencies are actually applied to the vertical-input terminals of the scope.

In general, narrow-band scopes have greater sensitivity than wide-band scopes. High sensitivity is often an advantage in checking color circuits that have low gain, or circuits that impose signal loss, such as
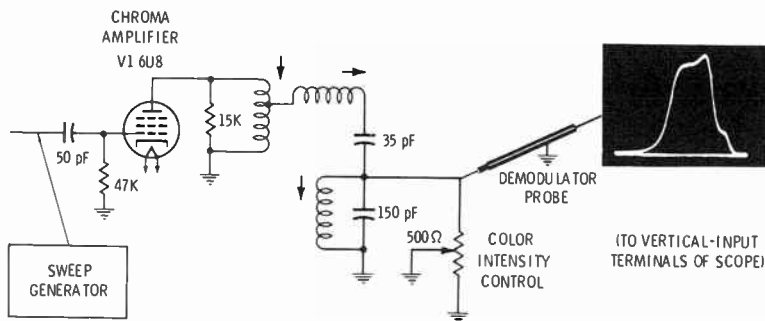

Fig. 1-8. A narrow-band scope can be used in this test.

emitter-follower circuits. A typical narrow-band scope has a vertical-amplifier sensitivity of 30 rms millivolts per inch of deflection. Horizontal amplifiers may have equal sensitivity, but we will find that, in general, the horizontal sensitivity is considerably less. For example, a narrow-band scope that has 30 mV/in vertical sensitivity might have a horizontal sensitivity of 70 mV/in. Note also that the frequency of a horizontal amplifier might be comparatively limited; a vertical amplifier with 100-kHz response might be accompanied by a horizontal amplifier with 20-kHz response.

Chart 1-1 shows the effects of oscilloscope control adjustments.

WIDEBAND SCOPES

Fig. 1-9 illustrates a wideband scope with a vertical amplifier that has flat frequency response to 4.5 MHz. Since the complete color signal has frequencies out to 4.1 MHz, this type of scope is required to display the output from a color-bar generator. The response of the scope illustrated in Fig. 1-9 is shown for a color-bar signal in Fig. 1-10, for both the narrow-band and wideband functions. It is evident that wideband response is necessary for undistorted reproduction of the high-frequency color-bar signal.
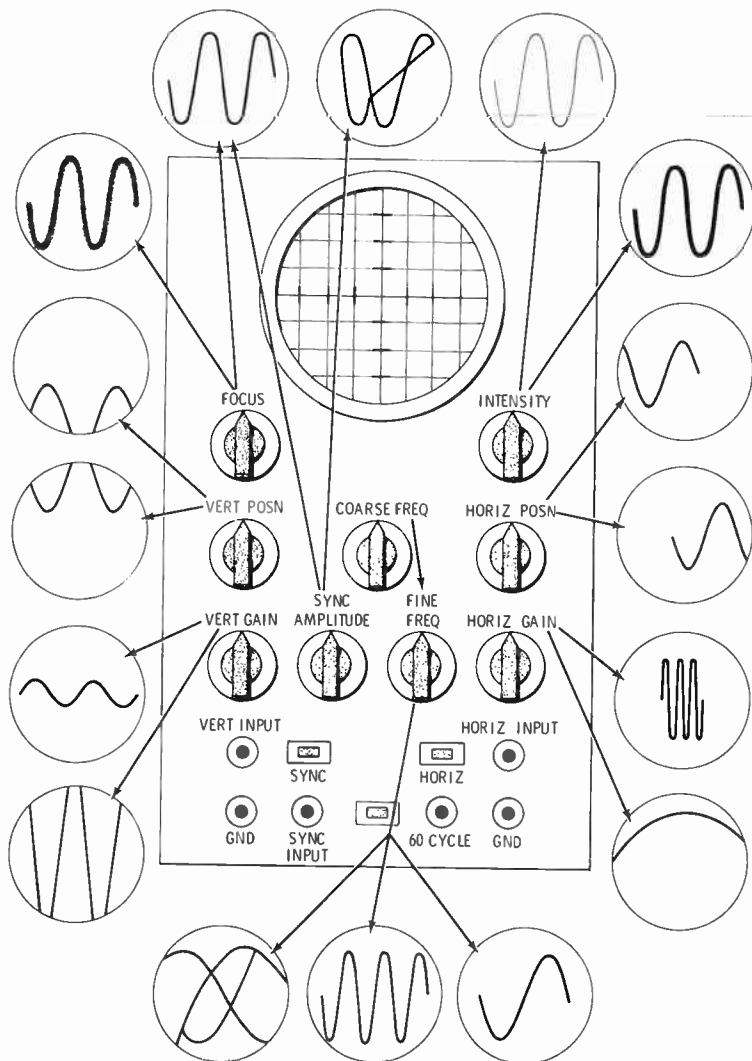
When a scope provides a choice of narrow-band and wideband functions, we will find that the sensitivity is much greater for narrow-band operation. For example, the foregoing scope has a vertical sensitivity of 40 mV/inch on its wide-band function, compared with 15 mV/inch on its narrow-band function or about three times as sensitive. The horizontal amplifier has narrow-band response only, with

Fig. 1-9. A wideband scope with flat response to 4.5 MHz.

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Chart 1-1. Effects of oscilloscope control adjustments.

moderate sensitivity. Provision of both narrow-band and wideband vertical response is often helpful in color-TV work, because the technician occasionally needs high gain and can dispense with wideband response. Service-type wideband scopes use vertical amplifiers with comparatively low values of plate-load resistors, supplemented by shunt-series peaking coils to obtain extended high-frequency response.

Wideband scopes usually have higher horizontal-deflection rates than narrow-band scopes. This feature is useful in expanding high-

(A) Test setup.

(B) Display on narrow-band scope.　　　(C) Display on wideband scope.
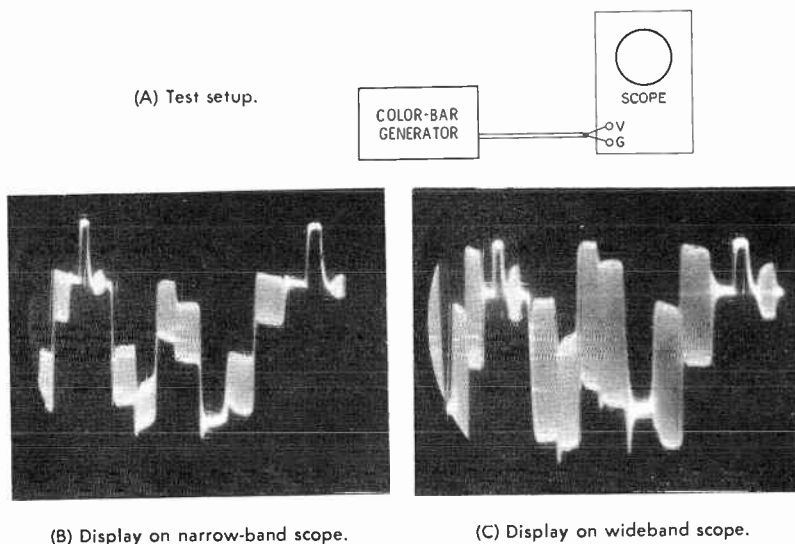
Fig. 1-10. Comparison of wideband and narrow-band scope.

frequency waveforms, as shown in Fig. 1-11. Irregularities or other types of distortion in a high-frequency waveform are difficult to evaluate at a slow horizontal-deflection rate. On the other hand, small irregularities become quite apparent at high deflection rates. This is an extensive topic, and detailed explanation must be reserved for the chapter on waveform analysis.

We will find that wideband scopes are always provided with frequency-compensated vertical attenuators. On the other hand, narrowband scopes generally use simple potentiometers for vertical signal attenuation. Let us see why frequency-compensated attenuators are required for display of high-frequency waveforms. Fig. 1-12 shows a potentiometer type of attenuator; its total resistance might be one megohm. At some intermediate point, R_T forms a voltage divider with
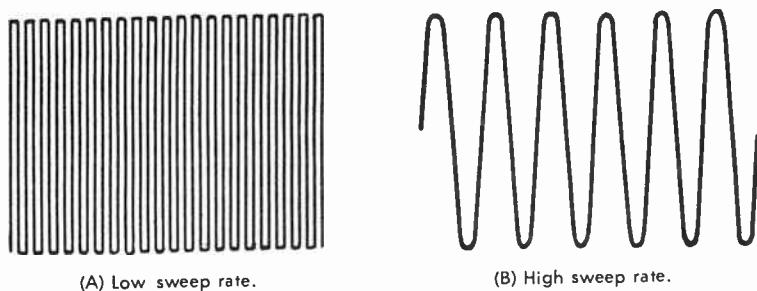

(A) Low sweep rate.　　　(B) High sweep rate.

Fig. 1-11. Output of color oscillator.

sections R1 and R2. Each section is shunted by stray capacitances, indicated as C_{S1} and C_{S2}. In turn, differentiating and/or integrating action occurs at various intermediate points on R_T. The result is that a high-frequency square wave becomes distorted, as shown in Fig. 1-12B.

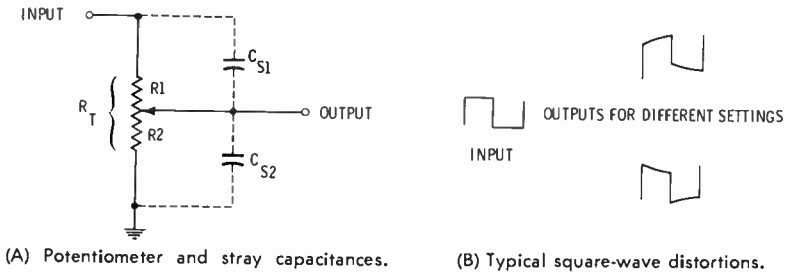(A) Potentiometer and stray capacitances.   (B) Typical square-wave distortions.

Fig. 1-12. Stray capacitances.

To avoid high-frequency distortion in the attenuator section, wideband scopes employ the basic compensated step-attenuator circuit shown in Fig. 1-13. Trimmer capacitor C_t is adjusted to make the time constant of $R1C_t$ equal to the time constant of $R2C_{in}$. With this equality of time constants, the attenuator passes high-frequency waveforms without distortion. In a complete step-attenuator circuit, several of these basic attenuator sections are provided, and are commonly marked $R \times 1$, $R \times 10$, $R \times 100$, etc. There is no signal attenuation on the $R \times 1$ step; the signal is attenuated to 0.1 of its source value on the $R \times 10$ step; the signal is attenuated to 0.01 on the $R \times 100$ step, and so on.

Another feature common to all wideband scopes, and to most narrow-band scopes is a vertical voltage-calibrating function. This feature gives a scope the facility of a voltmeter, for measurement of waveform voltages. In practical color-TV work, it is just as important to measure waveform voltages as to check waveshapes. Various methods are provided by scope manufacturers for waveform voltage measurements. A reference value of calibrating voltage may be built into the scope, which is switched into the vertical amplifier on a calibrating position of the vertical attenuator. Again, a push-button switch might be provided. The more elaborate scopes have voltage-calibrated step attenu-
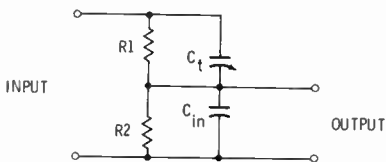

Fig. 1-13. Basic compensated step attenuator.

ators A scope is the only piece of test equipment that will accurately measure the voltage of a complex waveform. We will return to this topic in following chapters.

It is occasionally necessary to measure waveform frequencies in color-TV work. Conventional service scopes of both the wideband and narrow-band types often provide a rough indication of the horizontal-deflection frequency. That is, the step horizontal frequency control is often marked in frequencies, such as 14-250 Hz, 140-2500 Hz, 1400 Hz-25 kHz, and 14-250 kHz. However, accurate measurement of the horizontal-deflection frequency must be made indirectly with service type scopes.
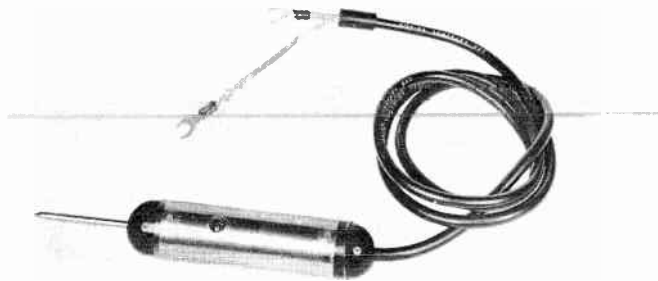
PROBES FOR WIDEBAND SCOPES

Scope tests in color-TV circuitry usually require the usc of a *low-capacitance probe*. The function of this probe is to reduce circuit loading, and thereby avoid waveform distortion. Although a wideband scope has a high input resistance, such as one or two megohms, its input capacitance is in the order of 20 or 30 pF. Moreover, a shielded input cable must be used to eliminate stray-field pickup which would confuse the display. Therefore, the total input capacitance to the scope might be 80 to 100 pF.

A shunt capacitance of 80 pF will seriously load many color-TV circuits. Accordingly, this input capacitance is reduced by use of a low-capacitance probe. Fig. 1-14 shows the configuration of a typical low-C probe. The probe reduces the input capacitance of the scope to 0.1 of its actual value (such as from 80 pF to 8 pF). At the same time, the probe reduces the signal voltage to 0.1 of its source value. This is one of the reasons why high vertical-amplifier sensitivity is desirable in practical work. With reference to Fig. 1-14, trimmer capacitor C_t is adjusted to make the time constant of the probe equal to the time constant of the scope input circuit. When these time constants are equalized, high-frequency waveforms will pass undistorted.
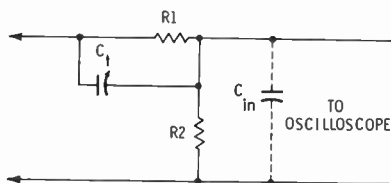
Note that it is impractical to use a low-capacitance probe with a narrow-band scope that does not have a compensated vertical attenuator based on the fact that the input impedance of an uncompensated attenuator is not constant. That is, the input impedance of an uncompensated attenuator changes whenever the attenuator setting is changed. On the other hand, a compensated step attenuator has the same value of input impedance on each step. This is another important advantage provided by a wideband scope.

Fig. 1-8 shows an application for a *demodulator probe*. This is a detector-type probe with the typical configuration shown in Fig. 1-15. Its basic usefulness is in extending the effective high-frequency response of a scope. Since the modulated waveform is rectified by the
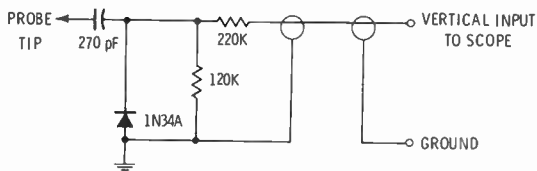
(A) Physical appearance.

(B) Schematic diagram.

Fig. 1-14. A high-impedance, frequency-compensated probe.

(A) Test setup.

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FREQUENCY RESPONSE CHARACTERISTICS:
RD CARRIER RANGE        . . . . . . . . . . . . . .500 kHz to MHz
MODULATED-SIGNAL RANGE . . . . . . . . . . .30 to 5000 HERTZ
INPUT CAPACITANCE (APPROX.) . . . . . . . . . . . . . . 2.25 pF
EQUIVALENT INPUT RESISTANCE (APPROX.):
  AT 500 kHz    . . . . . . . . . . . . . . . . . . . . 25,000 OHMS
     1MHz       . . . . . . . . . . . . . . . . . . . . 23,000 OHMS
     5 MHz      . . . . . . . . . . . . . . . . . . . . 21,000 OHMS
     10 MHz     . . . . . . . . . . . . . . . . . . . . 18,000 OHMS
     50 MHz     . . . . . . . . . . . . . . . . . . . . 10,000 OHMS
     100 MHz    . . . . . . . . . . . . . . . . . . . .  5000 OHMS
     150 MHz    . . . . . . . . . . . . . . . . . . . .  4500 OHMS
     200 MHz    . . . . . . . . . . . . . . . . . . . .  2500 OHMS
MAXIMUM INPUT:
                                              20 RMS VOLTS
AC VOLTAGE   . . . . . . . . . . . . . . . . . . 28 PEAK VOLTS
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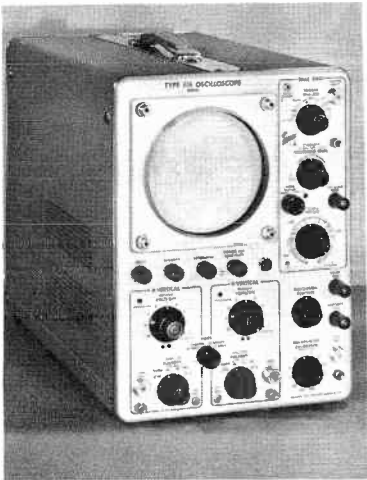
(B) Specifications.

Fig. 1-15. Demodulator probe circuit and characteristics.

probe, the scope responds only to the envelope frequencies of the demodulated waveform. For example, the probe can process carrier frequencies from 0.5 kHz to 250 MHz; on the other hand, it is capable of applying envelope frequencies from 30 Hz to 5 kHz to the vertical-input terminals of the scope. In visual-alignment requirements, it is necessary only that a demodulator probe have good 60-Hz response to modulated waves.
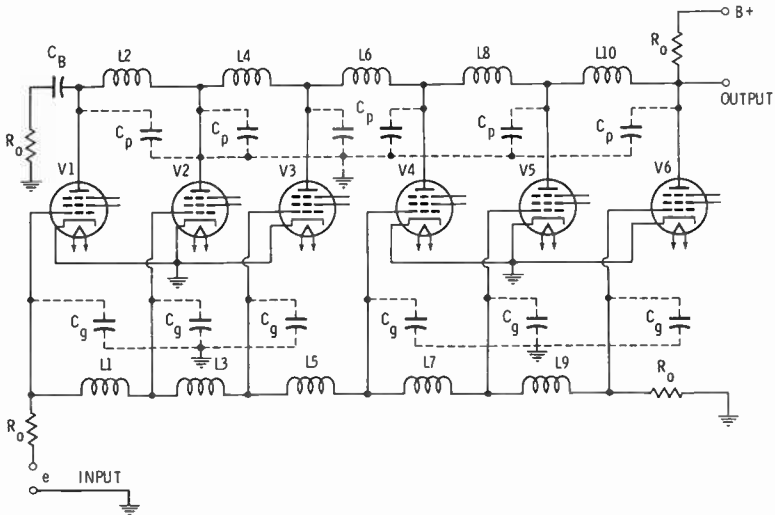

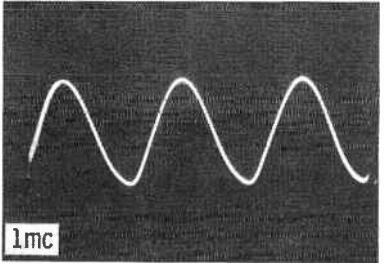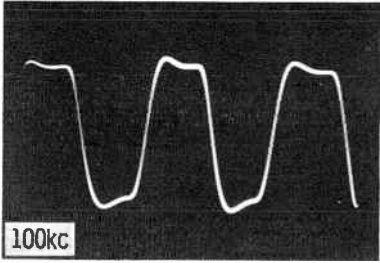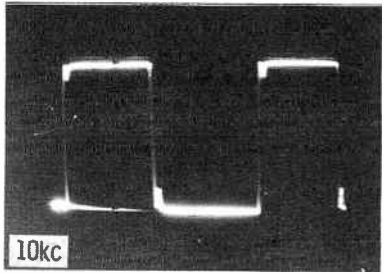Fig. 1-16. A lab-type scope.

Courtesy Tektronix, Inc.

Fig. 1-17. Typical distributed-amplifier configuration.

(A) Response of a service-type 100-kHz scope.
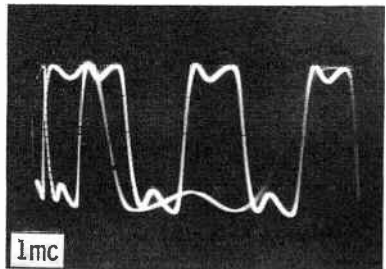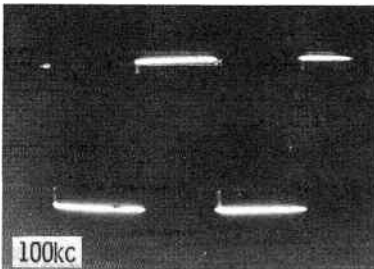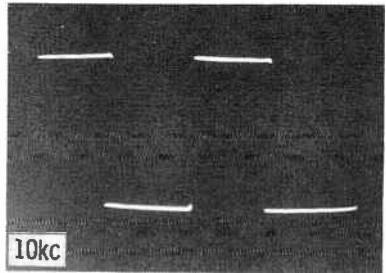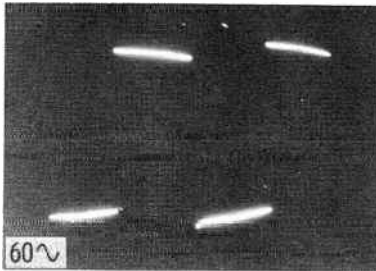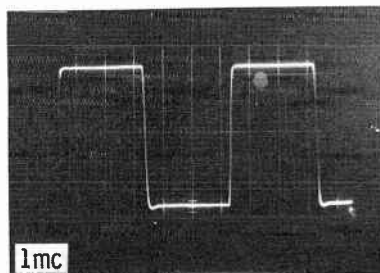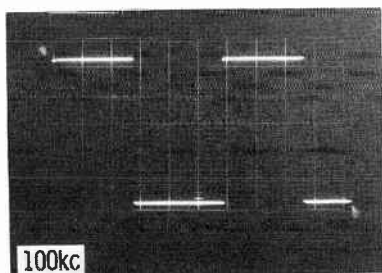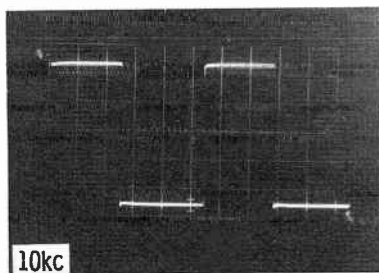

(B) Response of a service type 4-MHz scope.

Fig. 1-18. Square-wave response

LAB-TYPE SCOPES

A lab-type scope is illustrated in Fig. 1-16. This type of scope provides advanced waveform analysis techniques, and has various useful features, as follows:

1. Triggered sweeps permit expansion of a selected portion of a waveform, such as the color burst.
2. Accurately calibrated sweeps provide precise measurement of frequency and elapsed time.
3. Accurately calibrated vertical attenuators permit precise measurement of complex waveform voltages.
4. When differential input is provided, waveforms across components can be displayed, although both ends of the component operate above ground.
5. Extended bandwidth permits evaluation of comparatively high-frequency interference in color-TV waveforms.
6. Jitter in displayed waveforms is practically eliminated by triggered sweep action making it possible to observe time or phase jitter in the waveform.
7. Flexible sync facilities permit selection of a chosen portion of a waveform under difficult conditions.

(C) Response of a lab-type 15-MHz scope.

of three different oscilloscopes.

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Extended high-frequency response and good transient response is obtained by means of *distributed amplifiers*, as shown in Fig. 1-17. Small inductors are used to couple one stage to the next, and each inductor operates in combination with the input and output capacitances of the associated tubes. In effect, the amplifier is an artificial line with amplification at each LC section. As many as 15 or 20 stages may be used in the vertical amplifier of an elaborate lab-type scope. Fig. 1-18 shows the superior square wave response of a lab-type scope, compared with that of narrow-band and wideband service-type scopes.

Courtesy Simpson Electric Co.
Fig. 1-19. An intermediate-type scope.

Classifications of service-type and lab-type scopes are not sharply defined, and certain scopes fall in a borderline class; these are often called intermediate scopes. An intermediate scope provides more utility than an ordinary wideband scope, but has less utility than a professional lab scope. For example, Fig. 1-19 illustrates a typical intermediate-type scope. Although this scope has a vertical bandwidth of 5 MHz, it provides triggered sweep functions with calibrated rates of 5, 50, 500, and 5000 μs per inch. Its vertical sensitivity is 6 mV/in. Thus, this scope represents a sophisticated wideband type of scope.

A *synchroscope* is also an intermediate class of scope. Many of the scopes purchased by technicians on the surplus market are synchroscopes. A synchroscope is defined as an oscilloscope designed particularly for display of nonrepetitive waveforms such as nonperiodic pulses and transients. It has calibrated triggered sweeps, and serves as

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a useful introduction to elaborate lab-type scopes. A block diagram of a simple synchroscope is shown in Fig. 1-20. The major difference between this arrangement and that of an ordinary wide band scope is the provision of triggered sweeps and delay circuits (delay lines).

To operate the instrument with a free-running sweep, the switches are set as shown in Fig. 1-20. On the other hand, to utilize the calibrated time base, the triggered-sweep function and delay network are switched into operation. The trigger signal may be taken from the trigger generator or from an external source through the sync amplifier.
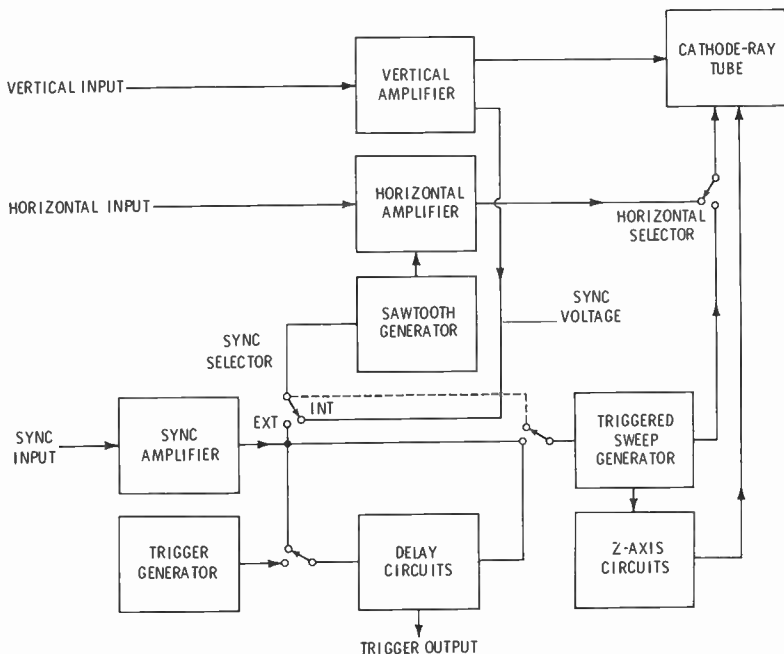

Fig. 1-20. Simplified block diagram of the synchroscope. The switches are shown in in position for oscilloscope-type measurements.

A more detailed block diagram is shown in Fig. 1-21. Note that the output from the coupling amplifier passes through a delay network. A vertical delay network serves to hold back the waveform for approximately 0.5 μs, thus giving the sweep circuits time to start; this prevents loss of the leading edge of the waveform on the screen display.

The horizontal sweep channel is of major interest. Two types of sync signal are available at the input of the horizontal channel. A positive pulse derived from the signal input may be taken from the coupling amplifier, or, some external sync signal may be applied. With the switch in the *internal sync* position, a positive pulse is taken from the

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Fig. 1-21. Block diagram of basic synchroscope.
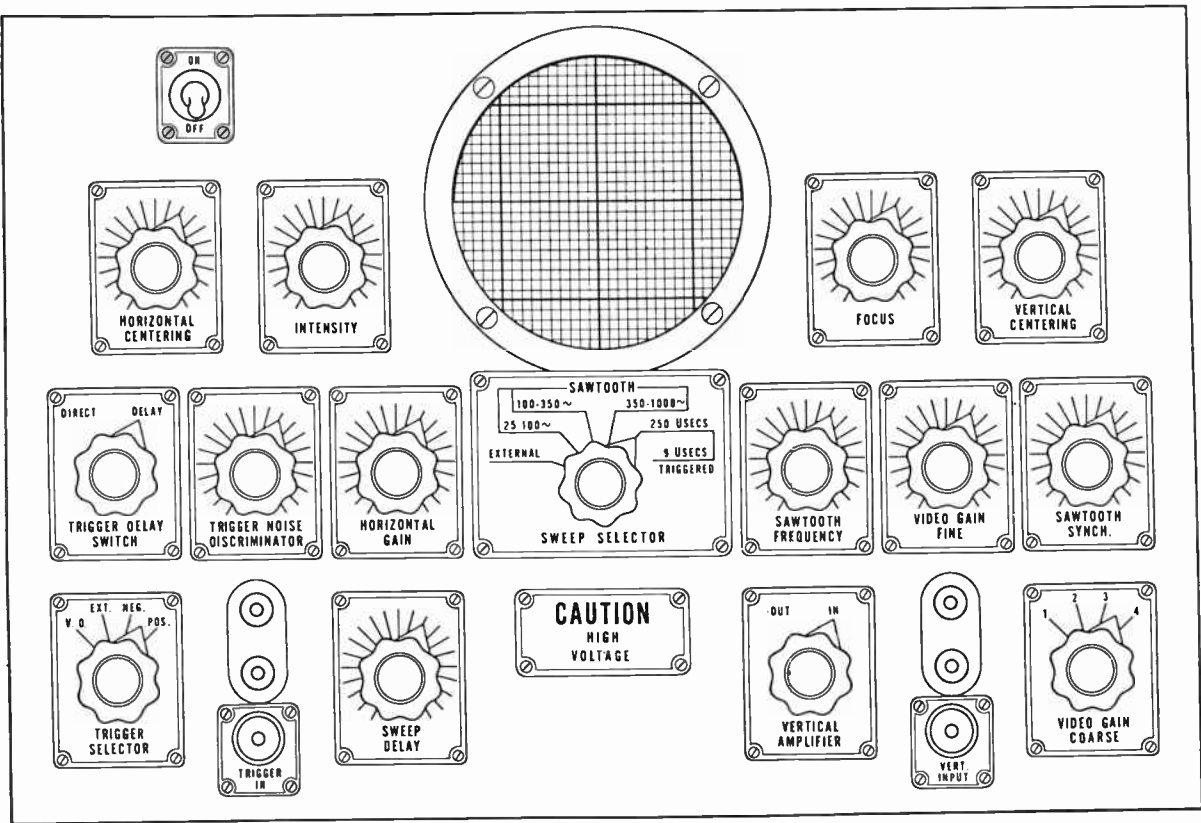
Fig. 1·22. Control panel of oscilloscope-synchroscope.

plate of the coupling amplifier in the vertical channel. This pulse is fed to the *synchronizing pulse amplifier*. Here, it is amplified and shaped so that a sharp negative pulse is developed. This insures precise trigger action.

Sawtooth waves are generated by the *start-stop multivibrator*. This circuit is activated by the negative pulse from the sync-pulse amplifier. A complete sawtooth wave is generated once for each incoming negative pulse. Note that the CRT is normally biased beyond cutoff, and the screen is dark until the triggered sweep circuit is activated. At this time, an *unblanking pulse* is applied to the grid of the CRT. Thus, the beam becomes visible for the duration of the forward scan. This feature prevents damage to the CRT from the high-intensity beam during the resting intervals between trigger pulses.
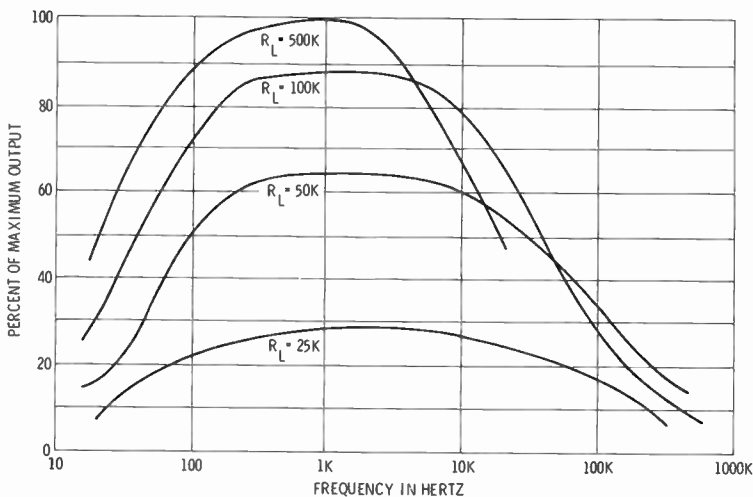

Fig. 1-23. Frequency response versus plate-load resistance for an RC-coupled stage.

Fig. 1-22 shows the panel layout for a typical oscilloscope-synchroscope. This type of instrument is provided with a choice of free-running or triggered sweeps. Note the trigger-noise discriminator control. This is an adjustable low-pass filter which permits the operator to adjust the bandpass of the sync amplifier. In turn, noise pulses can be minimized, which would otherwise cause false triggering. A professional lab scope has this function, and usually provides a choice of positive or negative slope triggers, also. The term "positive slope" refers to the rising portion of a waveform, whereas "negative slope" refers to the trailing portion of a waveform.

It is helpful to have a slope trigger function available, because it assists the operator in picking out a desired portion of a waveform for expansion on the scope screen. A *trigger level* control is also provided

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in professional lab scopes, which permits the operator to trigger the time base at any desired point on the leading or trailing edge of a waveform. The technique of picking out a small interval in a waveform for individual display will be explained later.

SUMMARY

Oscilloscopes are generally classified into narrow-band, wideband, and laboratory types.

A cathode-ray tube has very high frequency response, and a narrow-band scope can display high-frequency waveforms if the signals are fed directly to the deflecting plates of the CRT.
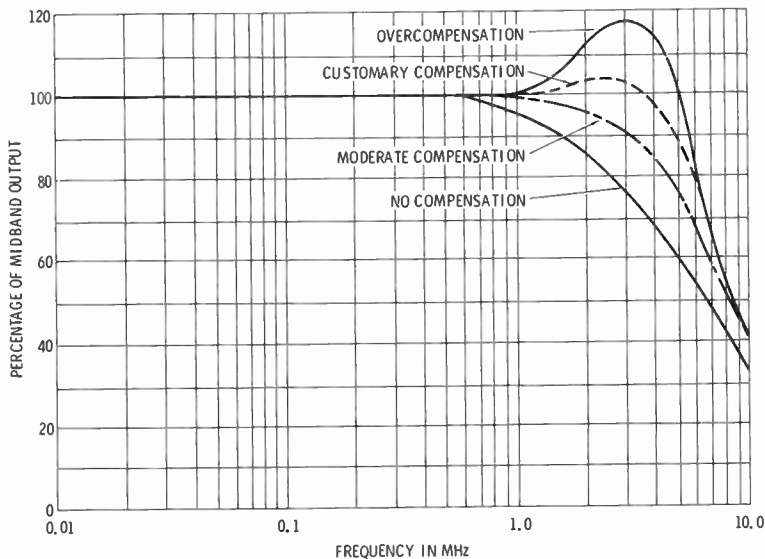
Fig. 1-24. Response with various amounts of high-frequency compensation.

Because of the substantial signal voltage required to drive a CRT directly, only a limited number of tests can be made in this manner.

Narrow-band scopes are useful for visual-alignment procedures, and for signal-tracing high-frequency circuitry with a demodulator probe.

Wideband scopes used in color-TV troubleshooting have a vertical-amplifier response which is flat from dc (or a low audio frequency) to approximately 4 MHz.

All service-type scopes have free-running time-base circuitry.

Wideband scopes employ compensated step attenuators in the vertical-amplifier channel; narrow-band scopes generally use simple potentiometers for vertical attenuation.

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Lab-type scopes provide functions such as triggered and calibrated sweeps, calibrated vertical attenuator, extended vertical-amplifier frequency response, and elaborated sync facilities.
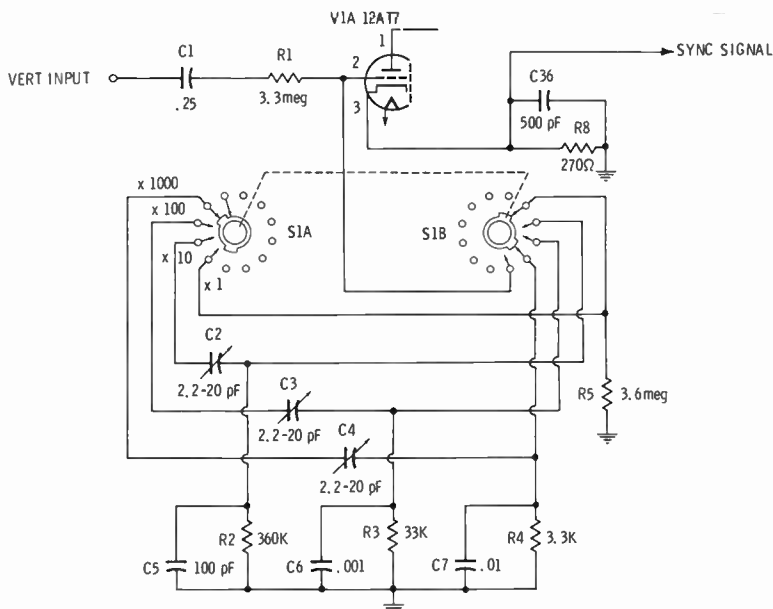

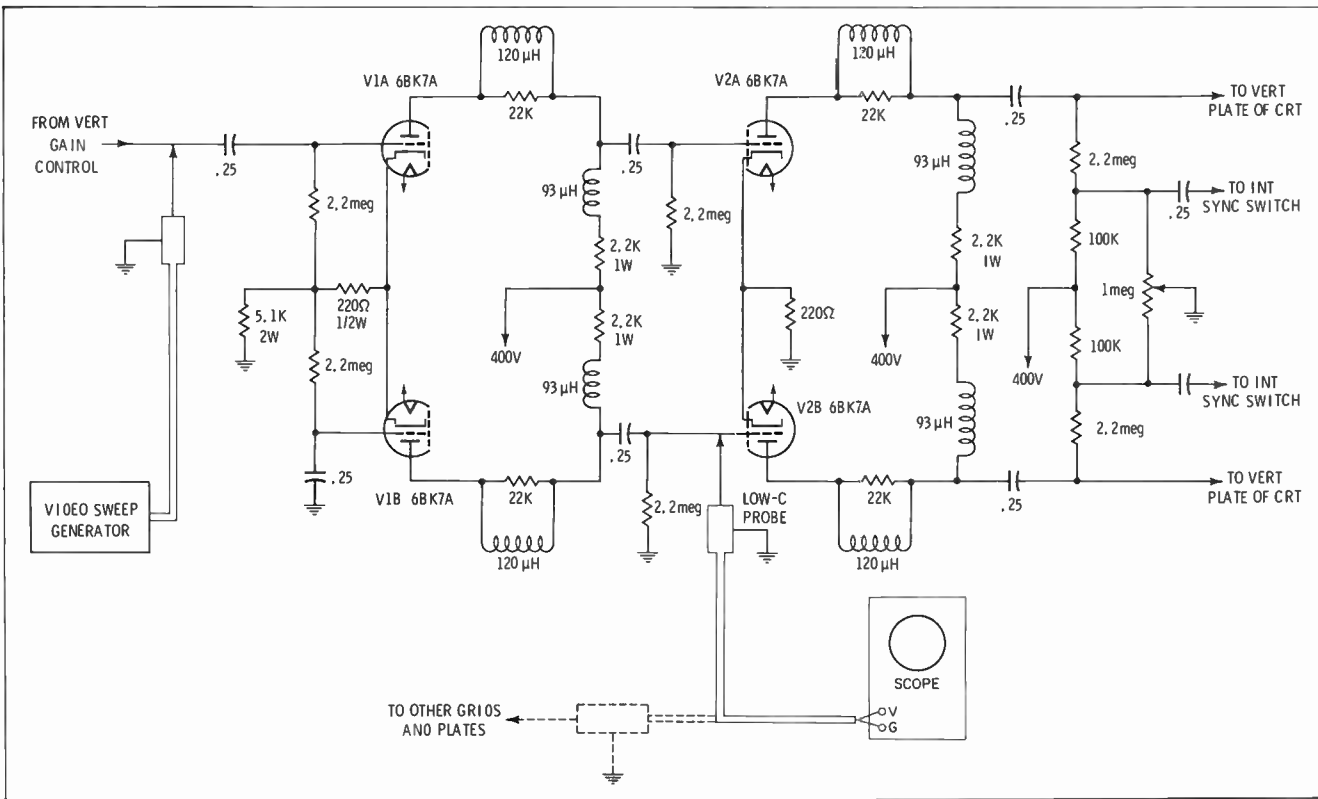Fig. 1-25. A compensated vertical step attenuator.

Intermediate-type scopes and synchroscopes provide some, but not all of the operating features of a lab-type scope.

Although a lab-type scope has considerable advantage in color-TV troubleshooting, the operator must have had adequate experience with scope techniques and waveform analysis to utilize the full capabilities of the scope.

REVIEW QUESTIONS

1. Fig. 1-23 shows frequency-response curves for a vertical-amplifier stage with various values of plate-load resistance, and relative gains. If a 500-k load resistor is replaced with a 25-k load resistor, how many stages will be required to obtain the same gain as before?
2. Fig. 1-24 shows the response curves for a vertical-amplifier stage with a constant value of plate-load resistance, for no peaking coils, one peaking coil, two peaking coils, and three peaking coils (two in the plate circuit and one in the grid circuit). What is the advantage,

Fig. 1-26. Signal tracing in a vertical amplifier.

Fig. 1-27. A typical scope sweep oscillator.

in terms of bandwidth, for customary compensation compared with no compensation?

3. Fig. 1-25 shows the circuit for a compensated vertical attenuator. If the square-wave response should become distorted on the ×100 setting, which trimmer capacitor would you adjust?

4. Fig. 1-26 shows a vertical-amplifier configuration for a wideband scope. If a signal-tracing test shows no waveform at the grid of V2B, what defect would you suspect? (Assume that the tubes have been checked out satisfactorily).

5. Fig. 1-27 shows a sweep oscillator circuit for a scope. If there is no sync lock, what defect would you suspect? (Assume that the tubes are not defective).

2

Basic Color
Waveform Analysis

The synchronizing waveform consisting of the horizontal sync pulse
and color burst is the most fundamental color waveform. Fig. 2-1
shows how the color burst is located on the back porch of the sync
pulse. Analysis of this waveform starts with its components, which
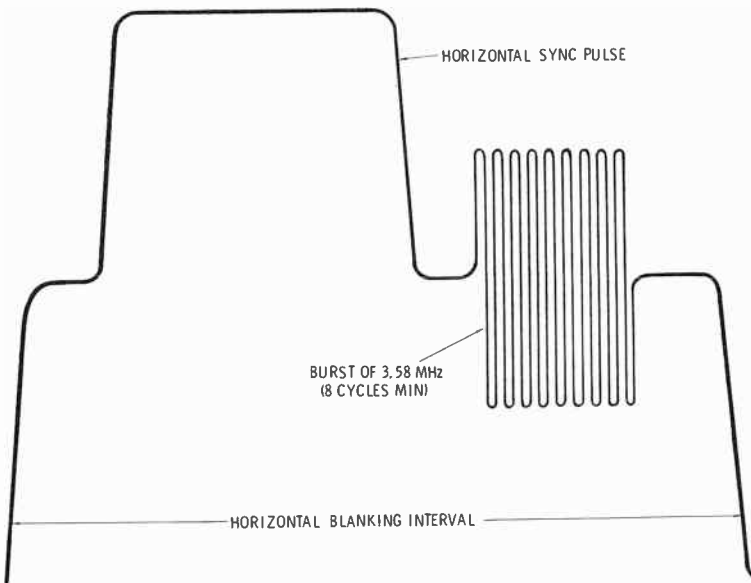consist of pulses and a sine wave. We observe that the sync pulse rides

Fig. 2-1. Horizontal sync pulse and color burst.

on a wider pulse that is called the *blanking pedestal*. In turn, the sine-wave component rides on the latter portion of the blanking pedestal. The next step in analysis is to note that the burst amplitude is the same as the sync-pulse amplitude. As shown in the diagram, the burst has a frequency of 3.58 MHz, and consists of approximately eight cycles.

TIME RELATIONS

Since the horizontal sync pulse has a repetition rate of 15,734.264 ± .044 pulses per second (pps) in this waveform, there are approximately 63.55 microseconds (μs) of elapsed time from one sync pulse to the next. Note that the *width* of the sync pulse is measured in terms of elapsed time, and is slightly less than 5μs. The width of the blanking pedestal is about 11 μs, and the width of the burst is about 2.25 μs. It is helpful to analyze waveforms in terms of time relations, because elapsed time is easily measured with a scope that has triggered and calibrated sweeps.

VOLTAGE RELATIONS

Waveform voltages are measured in peak-to-peak values. In the case of a sine wave, we may also specify its rms voltage. Fig. 2-2 shows the relation of rms voltage to peak voltage and to peak-to-peak voltage in a sine wave. Since the positive-peak voltage of a sine wave is equal to its negative-peak voltage, we can compile the following useful relations of sine-wave voltages:

PEAK-TO-PEAK VOLTAGE = 2 × PEAK VOLTAGE
PEAK VOLTAGE = 0.5 × PEAK-TO-PEAK VOLTAGE
RMS VOLTAGE = 0.707 × PEAK VOLTAGE
PEAK VOLTAGE = 1.414 × RMS VOLTAGE
PEAK-TO-PEAK VOLTAGE = 2.828 × RMS VOLTAGE

Although special techniques can be used to measure the rms voltage of a complex waveform such as a sync pulse, this is not necessary in color-TV work. Therefore, we restrict voltage measurements of complex waveforms to peak-to-peak values. Fig. 2-3 shows some typical TV waveforms and their peak-to-peak voltages. It is important to recognize the relation between rms and pk-pk voltages in a sine wave, because ordinary service voltmeters indicate the rms voltage of a sine wave. In turn, if we use an rms sine-wave voltage to calibrate the vertical amplifier of a scope, we must change this rms voltage into its corresponding peak-to-peak value.

For example, if we use the voltage from a heater line to calibrate a scope, a service voltmeter may indicate 6.3 volts rms. In turn, we multiply 6.3 by 2.83 to find the peak-to-peak voltage, and obtain 17.8
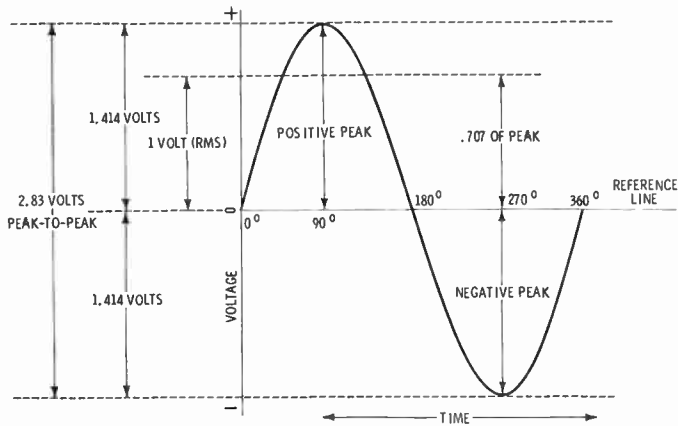
34

Fig. 2-2. The fundamental sine wave.

volts pk-pk, approximately. In general, the peak voltages of a complex waveform are unequal. This is one of the basic differences between a complex wave and a sine wave. For example, the pulse waveform shown in Fig. 2-4 has unequal positive-peak and negative-peak voltages; nevertheless, its peak-to-peak voltage is equal to the sum of its positive-peak and negative-peak voltages.

(A) Cathode of vertical output tube.

(B) Input to second video amplifier.

(C) Horizontal oscillator transformer.

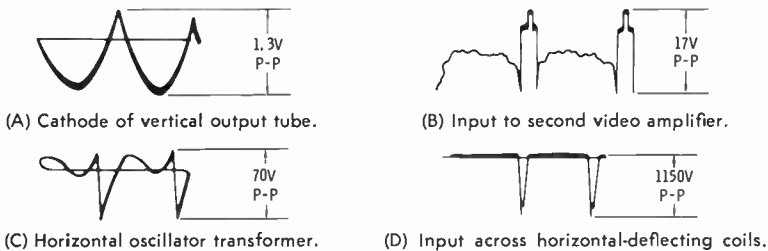(D) Input across horizontal-deflecting coils.

Fig. 2-3. Typical television waveforms.

We will find that a peak-to-peak voltage is equivalent to the same value of dc voltage. This fact is important in the operation of a dc scope. Fig. 2-5 shows the response of a dc scope to dc voltages of positive and negative polarity. If we calibrate a dc scope for 1 volt dc per
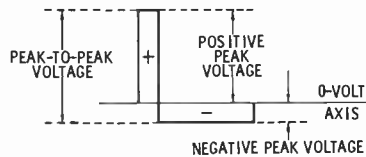
Fig. 2-4. Voltages of a pulse waveform.

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inch, then the scope is also calibrated for 1 volt pk-pk per inch. Suitable test procedures permit the operator to measure the dc component in a complex waveform such as a dc pulse when applied to a dc scope. Fig. 2-6 illustrates various complex waveforms encountered in color-TV work. However, this and related details of waveform analysis will be covered in later chapters.
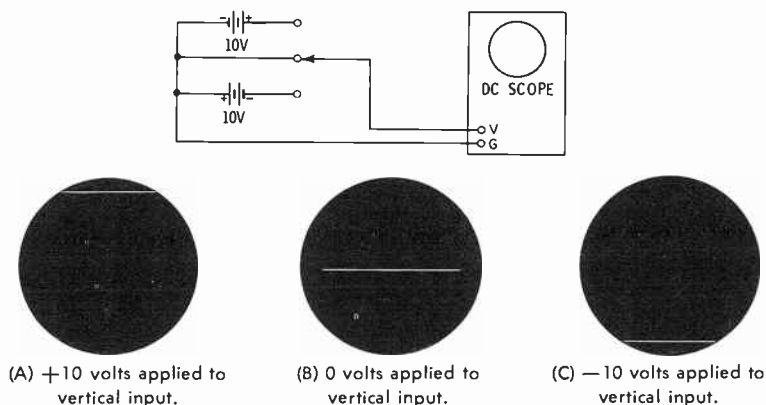

(A) +10 volts applied to vertical input.

(B) 0 volts applied to vertical input.

(C) —10 volts applied to vertical input.

Fig. 2-5. Response of a dc scope.

SQUARE WAVES AND SINE WAVES

Although the sine wave is the most basic waveform in color-TV work, the square wave is almost as important. This fact is evident from an inspection of Fig. 2-1. We observe that the color burst is a sine waveform, and that the sync pulse has the form of a square wave. It can be deduced mathematically and proved experimentally that a square wave can be built up from sine waves, as shown in Fig. 2-7. In theory, it would require an infinite number of sine waves to build up a perfect square wave. However, in practice, about 20 sine-wave components are sufficient to form a reasonable facsimile of a square wave.

As indicated in Fig. 2-7, the sine-wave frequencies that form a square wave have a harmonic relation. That is, a square wave is built up from a fundamental frequency, a third harmonic, a fifth harmonic, a seventh harmonic, a ninth harmonic, and so on. These are *odd* harmonics, inasmuch as they are described by the odd numbers. We will find that other complex waveforms may have even harmonics only, or mixtures of even and odd harmonics. The essential fact to be recognized is that *any* complex waveform can be built up from a fundamental frequency and suitable harmonic frequencies.

The composition of a square wave is related to the bandwidth of a circuit through which the square wave is passed. A narrow bandwidth
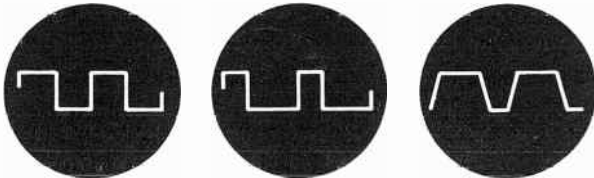
36

CLIPPED PEAKS   DAMPED   PEAKED

(A) Distorted sine waves.
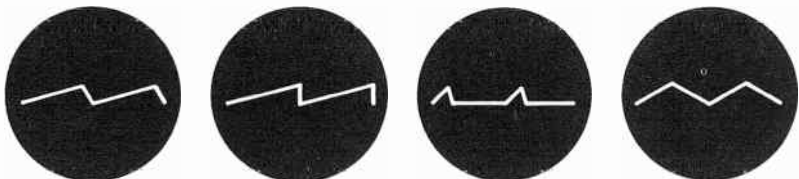
SQUARE   RECTANGULAR   NONIDEAL

(B) Rectangular waves.

SAWTOOTH   IDEAL   CLIPPED   BACK-TO-BACK TRIANGULAR

(C) Sawtooth waves.

(D) Trapezoidal wave.   (E) Exponential wave.

Fig. 2-6. Basic waveforms.

has the effect of removing the higher harmonics from the square wave. This causes the corners of the waveform to become rounded, and causes the sides to slope as can be seen from the progressive build-up shown in Fig. 2-7. We know that the i-f amplifier in a color-TV receiver has a bandwidth of approximately 4 MHz. This bandwidth is sufficient to pass many, but not all of the harmonics in a horizontal sync pulse. Therefore, we expect that the sync pulse will have rounded corners and sloping sides, as shown in Fig. 2-1.

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A: FUNDAMENTAL
B: 3 D HARMONIC
C: FUNDAMENTAL PLUS 3 D HARMONIC
D: 5TH HARMONIC
E: FUNDAMENTAL PLUS 3 D AND 5TH HARMONICS
F: 7TH HARMONIC
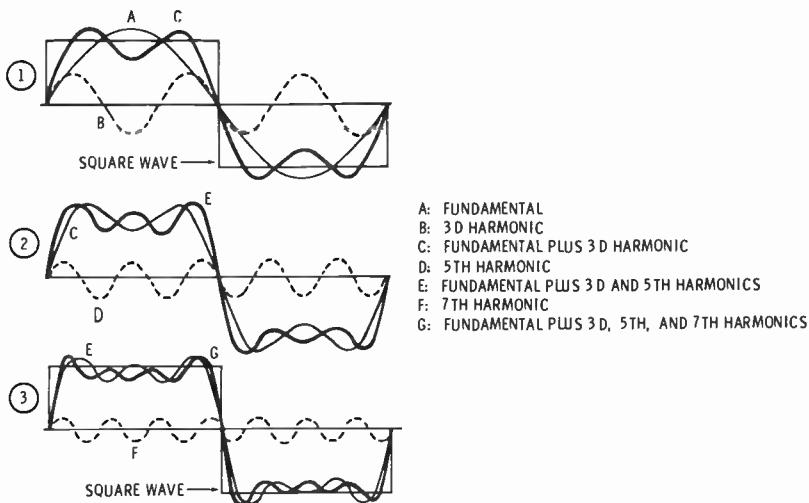G: FUNDAMENTAL PLUS 3 D, 5TH, AND 7TH HARMONICS

Fig. 2-7. Composition of a square wave.

A pulse is basically an unsymmetrical square wave, as shown in Fig. 2-8. There is no sharp distinction between an unsymmetrical square wave and a pulse; however, a pulse waveform is generally regarded as a highly unsymmetrical square wave. That is, when the width of the narrow portion is made much less than the width of the broad portion, it is common practice to describe the waveform as a pulse. It is a basic law in waveform analysis that any *unsymmetrical* square wave has both *even and odd harmonics*, as graphed in Fig. 2-9B. This harmonic diagram also shows that the harmonic voltages decrease less rapidly for a pulse than for a square wave. From a practical point of view, this means that a TV circuit must have a greater bandwidth to pass a pulse, than to pass a square wave without distortion. The bandwidth times the pulsewidth equals approximately one.

It should not be supposed that *all* pulses contain both even and odd harmonics. For example, the pulse waveform illustrated in Fig. 2-10 contains odd harmonics only. If we compare Fig. 2-10B with Fig. 2-7 or Fig. 2-9A, we observe that the pulse has the same harmonic frequencies as a square wave. This fact follows directly from an analysis
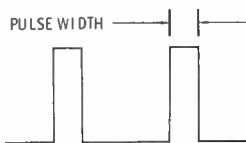

Fig. 2-8. A pulse is basically an unsymmetrical squarewave.
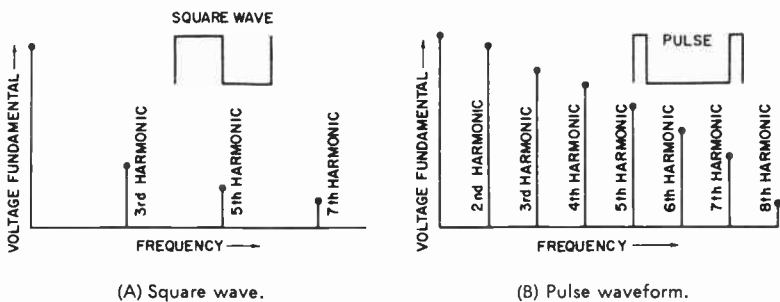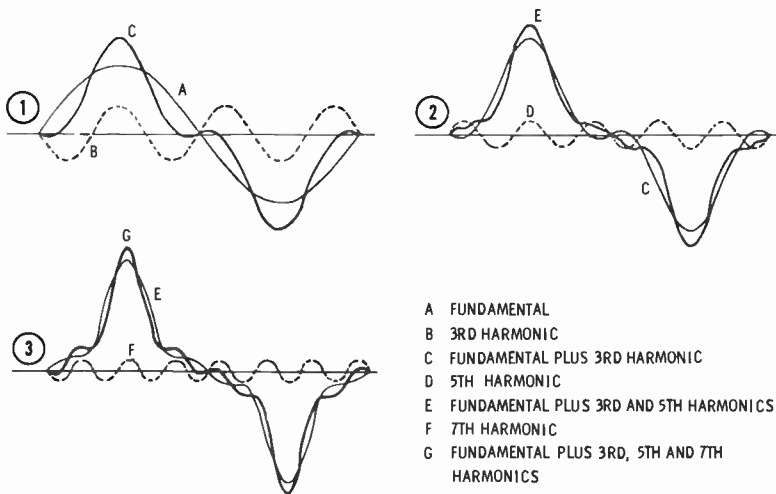
38

(B) Pulse waveform.

Fig. 2-9. Harmonics of a square wave versus a pulse.

of differentiating circuit action. That is, the waveform in Fig. 2-10 is obtained by passing a square wave through an RC differentiating cir-

(A) Oscilloscope display of typical trigger pulse.

A   FUNDAMENTAL
B   3RD HARMONIC
C   FUNDAMENTAL PLUS 3RD HARMONIC
D   5TH HARMONIC
E   FUNDAMENTAL PLUS 3RD AND 5TH HARMONICS
F   7TH HARMONIC
G   FUNDAMENTAL PLUS 3RD, 5TH AND 7TH HARMONICS

(B) Harmonic build-up of a trigger pulse.

Fig. 2-10. Trigger pulses may have both positive and negative excursions.

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cuit. We know that resistors and capacitors are *linear* circuit components. This means that a resistor or a capacitor cannot generate any new frequencies—only the frequencies that are present in the input waveform can appear in the output waveform.

But now, the scope technician asks, "If the input and output waveforms in a differentiating circuit have the *same* frequencies, how does the differentiating circuit change the square wave into a pulse?" The answer to this question is seen in Figs. 2-7 and 2-10. Note that the harmonic *phases* are opposite with respect to the fundamental in these waveforms. Whenever the phase of a harmonic is changed, the result is a change in waveshape. This is the first part of the answer; the second part concerns the high-pass filter action of an RC differentiating circuit. That is, differentiation attenuates low frequencies more than high frequencies. Therefore, the higher harmonics in a differentiated waveform have greater amplitudes with respect to the lower harmonics.

SAWTOOTH WAVES AND SINE WAVES

Another basic waveform in color-TV work is the sawtooth waveform shown in Fig. 2-11. This waveform contains the same harmonic frequencies as an unsymmetrical square wave or rectangular pulse. However, a sawtooth wave is formed as a result of the phases and relative amplitudes of the harmonics. If a sawtooth wave is passed through a differentiating circuit, the frequencies in the output are the same as the input frequencies. However, the lower harmonic frequencies are attenuated with respect to the higher harmonic frequencies. There is also a shift in phase relations from the input to the output of the differentiating circuit. The end result is that the sawtooth wave is changed into a pulse, similar to the pulse shown in Fig. 2-9B. This method is used to produce pulses for blanking the retrace in a color picture tube.

We will note from Figs. 2-11 and 2-7 that sawtooth waves and square waves have one characteristic in common, in that the phase relations of the fundamental and harmonics are the same. However, a sawtooth wave has even harmonics in addition to odd harmonics. Insofar as the rate of decrease in harmonic amplitudes are concerned, these rates are essentially the same for both square waves and sawtooth waves, as seen in Fig. 2-12. From the standpoint of color-TV servicing, the practical conclusion is that the circuit bandwidth required to pass a sawtooth wave without objectionable distortion is the same as required to pass a square wave without objectionable distortion. (This rule assumes that the repetition rates of the sawtooth and square waves are the same). Good reproduction is obtained if the circuit passes the fundamental and approximately 15 harmonics.

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The triangular wave shown in Fig. 2-12 is related to a sawtooth wave; a triangular wave is also called a back-to-back sawtooth. A preliminary analysis of the triangular wave shows that the transition from the positive peak to the negative peak is slow, compared with a sawtooth wave. This gradual slope in a triangular wave corresponds to a rapid rate of decrease in harmonic amplitudes, as seen in Fig. 2-12. From a practical standpoint, this means that less circuit bandwidth is required to pass a triangular wave than to pass a sawtooth wave with-
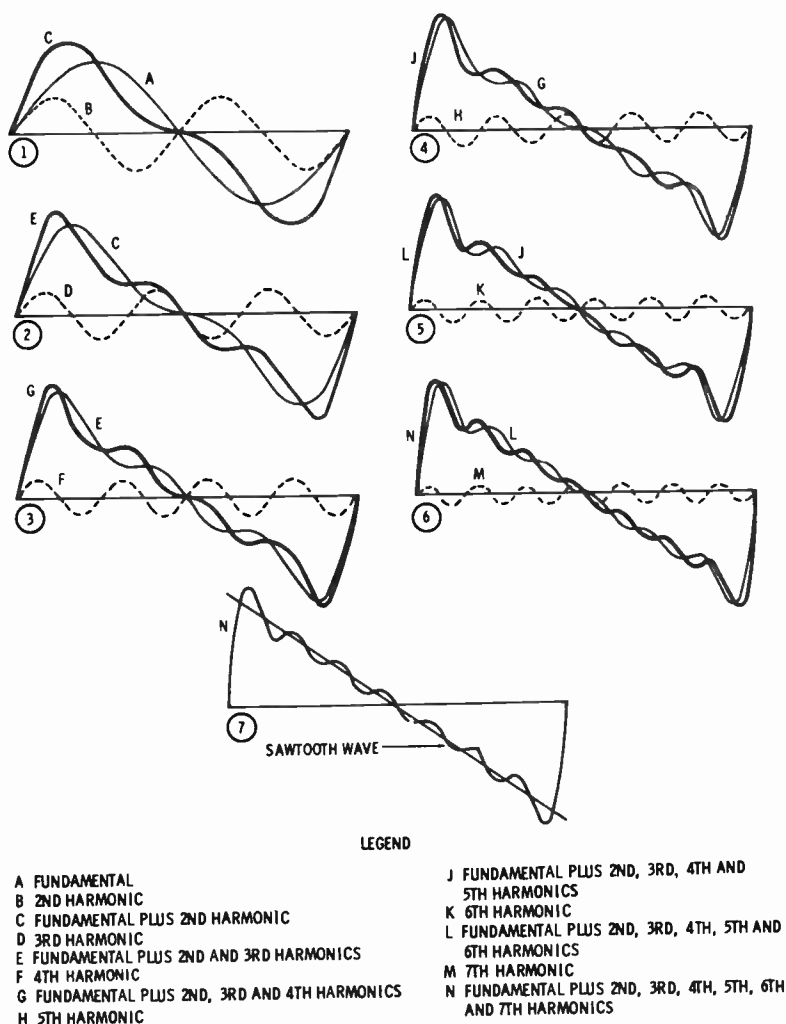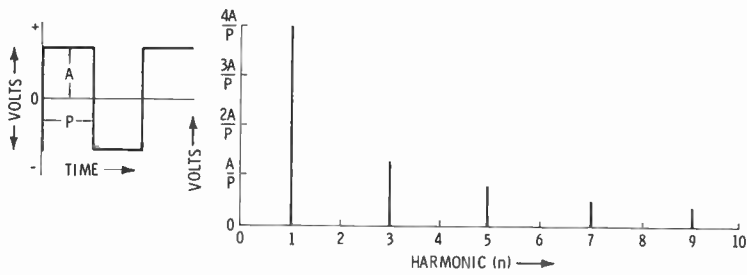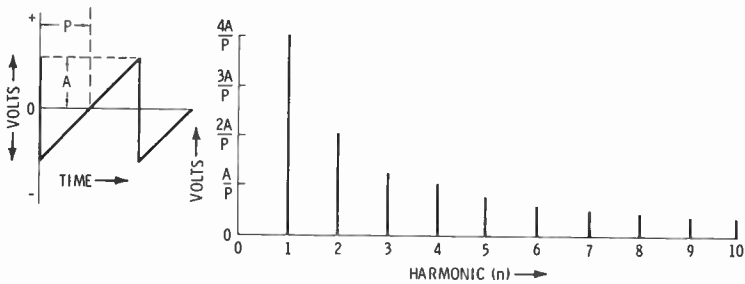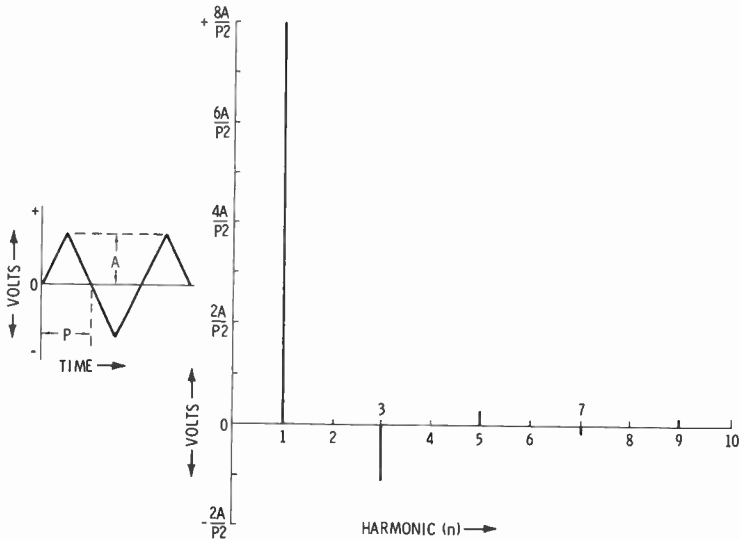

LEGEND

A FUNDAMENTAL
B 2ND HARMONIC
C FUNDAMENTAL PLUS 2ND HARMONIC
D 3RD HARMONIC
E FUNDAMENTAL PLUS 2ND AND 3RD HARMONICS
F 4TH HARMONIC
G FUNDAMENTAL PLUS 2ND, 3RD AND 4TH HARMONICS
H 5TH HARMONIC

J FUNDAMENTAL PLUS 2ND, 3RD, 4TH AND 5TH HARMONICS
K 6TH HARMONIC
L FUNDAMENTAL PLUS 2ND, 3RD, 4TH, 5TH AND 6TH HARMONICS
M 7TH HARMONIC
N FUNDAMENTAL PLUS 2ND, 3RD, 4TH, 5TH, 6TH AND 7TH HARMONICS

Fig. 2-11. Build-up of a sawtooth wave from sine waves.

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(A) Square wave.

(B) Sawtooth wave.

(C) Triangular wave.

Fig. 2-12. Harmonic amplitudes for sawtooth and triangular waves, compared with the harmonic amplitudes of a square wave.

out objectionable distortion. In color-TV work, we will encounter triangular waves in certain types of afc circuits.

Another point of waveform analysis to be observed in Fig. 2-12 is that a triangular wave is different from a sawtooth wave in that it is symmetrical with respect to the zero-volt axis. This is also true of a square wave. It is this symmetry that causes both square waves and triangular waves to be built up from odd harmonics only. As previously noted, the gradual slope of a triangular wave causes these odd harmonics to have a more rapid decrease in amplitude than a square wave.

EXPONENTIAL WAVEFORMS

An exponential waveform was illustrated in Fig. 2-6. Exponential waves are almost as basic in color-TV work as sine waves. Let us see why this is so. We know that any complex waveform can be analyzed as a certain combination of sine-wave frequencies. In some situations, this is the most helpful approach to waveform analysis. In other situations, complex waveforms are analyzed to best advantage as combinations of exponential waves. We will find, for example, that it is much easier to analyze the sync pulse depicted in Fig. 2-1 from the viewpoint of exponential waves, instead of sine waves.

Therefore, let us consider some of the basic characteristics of exponential waveforms. Fig. 2-13 shows a series RC circuit energized by dc voltage through an on and short-circuit switch. Output voltage e_k is called a differentiated waveform, and output voltage e_c is called an integrated waveform. The time constant of the circuit in seconds (or fraction of a second) is equal to the product of R and C, given respectively in ohms and farads. Any series RC circuit has the same *transient* response, as shown in the universal RC time constant chart in Fig. 2-13C.

In TV circuits, vertical sync pulses are often integrated by means of two-section or three-section RC circuits, as shown in Fig. 2-14. The output waveforms in Figs. 2-14B and C are also exponential waveforms, but they are combination waveforms that are built up from more than one basic exponential wave. All two-section or three-section integrators have the same transient response, as shown in the universal RC time constant chart in Fig. 2-14. Note that the integrators shown in the diagram are basic configurations of the symmetrical type. That is, all resistors have the same value, and all capacitors have the same value.

In RC-coupled amplifier circuits, a low-frequency square-wave input is differentiated through a two-section differentiating circuit, as shown in Fig. 2-15. The output waveform differs from that produced by a single-section differentiator in that the waveform undershoots its
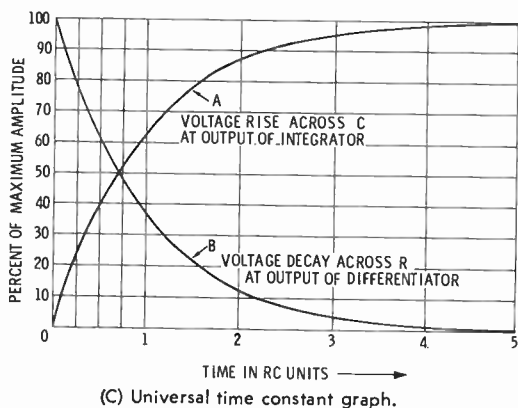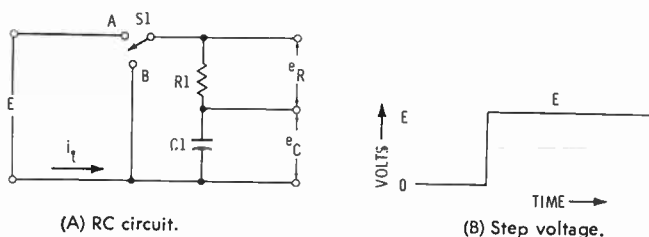
43

(A) RC circuit.

(B) Step voltage.

(C) Universal time constant graph.

Fig. 2-13. Basic exponential waveforms.

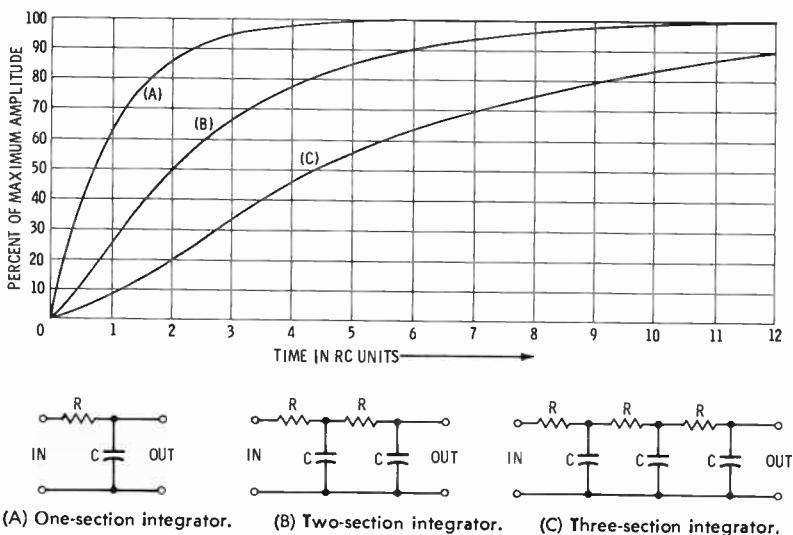(A) One-section integrator.   (B) Two-section integrator.   (C) Three-section integrator.

Fig. 2-14. Universal time-constant chart for one-section, two-section, and three-section integrator circuits.
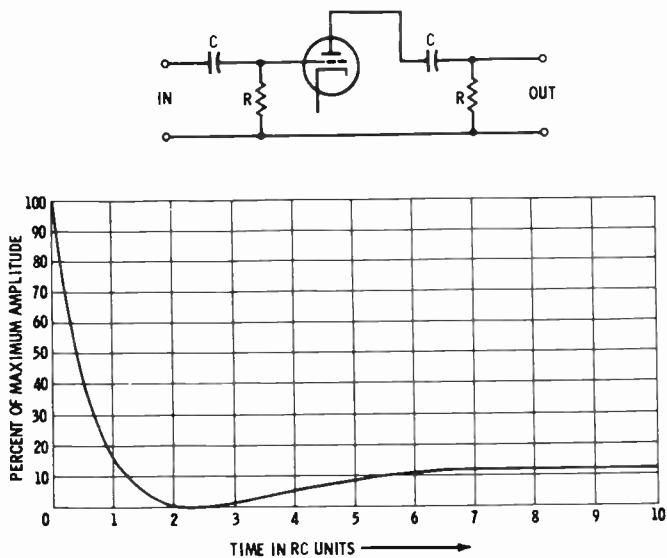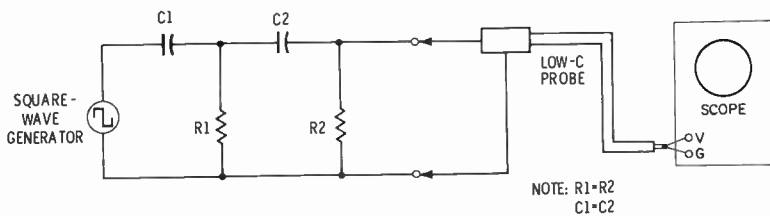
Fig. 2-15. Universal time-constant chart for R-C coupled amplifier with two RC sections.
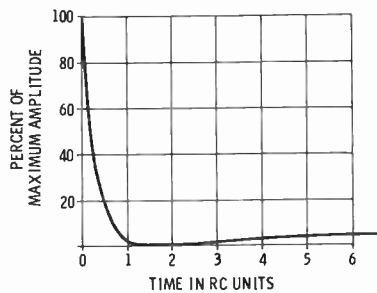

(A) Test setup.

(B) Chart.

Fig. 2-16. The basic symmetrical cascaded differentiating circuit.

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quiescent level. As seen in Fig. 2-15, the peak undershoot occurs at about 2.5 time constants. This is a basic example in which the two-section differentiator is symmetrical—that is, the resistors have equal values, and the capacitors have equal values. All circuits of this type produce the same waveshape, which is given by the universal RC time constant chart shown in Fig. 2-15.

Another type of RC circuitry found in some sync systems consists of two differentiating circuits connected in cascade, as shown in Fig. 2-16. This arrangement is basically different from that of Fig. 2-15 in that tube isolation is not provided between the differentiating sections. In the absence of tube isolation, the second section loads the first section, with the result that the exponential waveforms combine in a somewhat different way. The result is that sharper differentiation and less undershoot is obtained. If R1 and R2 have equal values, and C1 and C2 have equal values, the configuration is a symmetrical cascade differentiating circuit. All such circuits produce the same waveshape, as given by the universal RC time constant chart in Fig. 2-16.

RISE TIME

Sync pulses and other rectangular waveforms observed in TV circuits are not ideal, in that their sides always slope. That is, pulses with perfectly vertical sides exist only in theory. The slope of practical pulses is measured in terms of time, and is called *rise time*. We will find that rise time is related to circuit bandwidth. When a pulse is expanded on the screen of a triggered sweep scope as shown in Fig. 2-17, the rise time can be measured in terms of the calibrated time-base control setting. The difference between an ideal pulse and a practical pulse is shown in Fig. 2-18A. The rise time (T) is measured between the 10 percent and 90 percent of maximum amplitude points, as shown in Fig. 2-18B.

The foregoing specification of rise time eliminates corner effects, which are not directly related to rise time. Cornering is often an important aspect of waveform analysis, but is considered apart from rise time. As an example of the use of rise time in circuit analysis, we can measure the bandwidth of a video amplifier or Y amplifier by applying a pulse or square waveform, and noting the rise time of the output waveform. A basic law of electronics states that bandwidth and rise time are related as follows:

$$T = \frac{0.35}{f_c}$$

where,

T is the rise time of the amplifier,

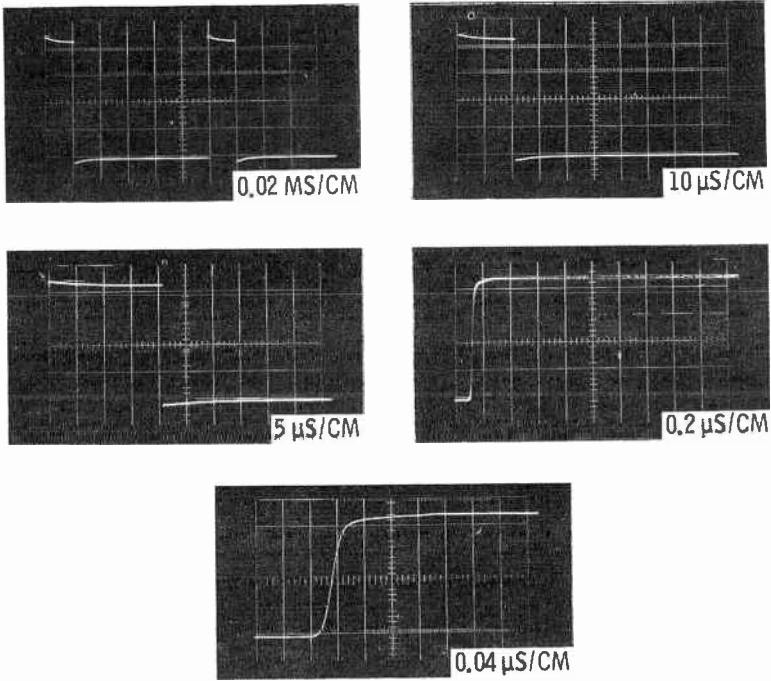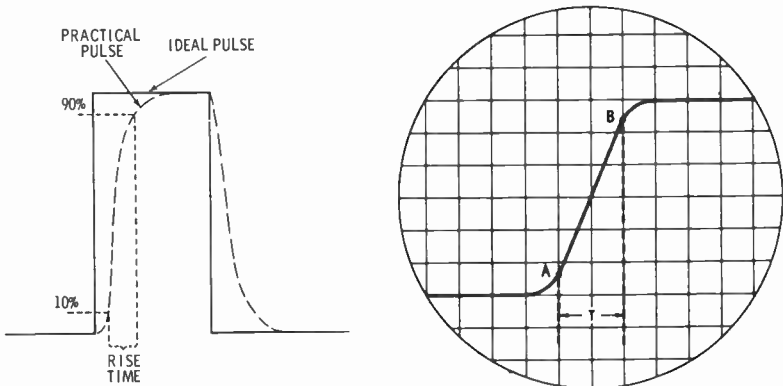f_c is the high-frequency cutoff point of the amplifier.

Fig. 2-17. Expansion of a 20-microsecond pulse as the sweep speed of a triggered-sweep scope is progressively increased.

When measuring the rise time of a pulse or square waveform, it is essential to use a triggered sweep scope that has a delay line in the

(A) Rise time is measured from the 10 percent point to the 90 percent point on the leading edge of the pulse.

(B) A fast pulse must be greatly expanded on the oscilloscope screen in order to measure the rise time T.

Fig. 2-18. Graphical definition of the rise time of a pulse.

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(A) Pulse displayed with delay line switched in.

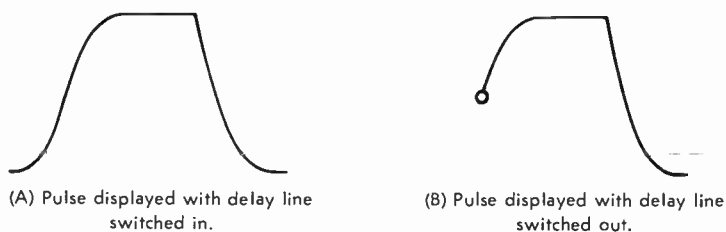(B) Pulse displayed with delay line switched out.

Fig. 2-19. Pulse display on synchroscope.

vertical amplifier. Otherwise, a portion of the leading edge will be lost in the display as shown in Fig. 2-19B, and the rise time cannot be measured. In some types of waveform analysis, the fall time of a waveform is also measured. The fall time is defined as the elapsed time from the 90 percent point to the 10 percent point on the trailing edge,
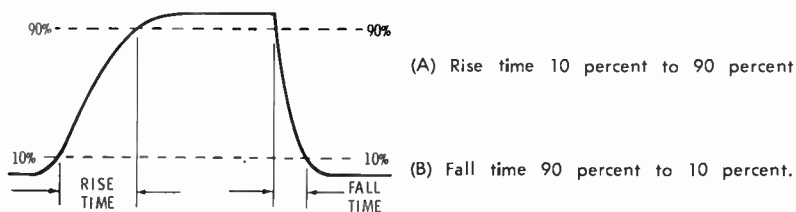

(A) Rise time 10 percent to 90 percent

(B) Fall time 90 percent to 10 percent.

Fig. 2-20. Measuring the rise and fall times on the oscilloscope.

as shown in Fig. 2-20. Pulse widths are often of concern in trouble-shooting color-TV circuitry. As shown in Fig. 2-21, pulse width is defined as the elapsed time between the 50 percent of maximum amplitude points on the leading and trailing edges.
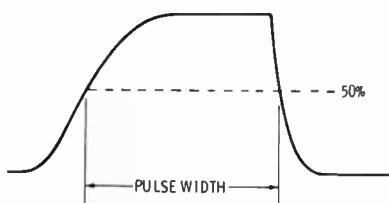

Fig. 2-21. Measurement of pulse width on the oscilloscope.

SURGES AND OSCILLATORY WAVEFORMS

A *surge* is a waveform having a single polarity, which rises to a peak amplitude and then decays to zero. For example, the output waveform from a keyed-agc circuit is a surge. An *oscillatory* waveform alternates from positive to negative values as it decays to zero. For example, a crystal ringing circuit for recovering the color subcarrier is an oscillatory waveform that is called a damped sine wave. These types of waves

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can be analyzed to best advantage by considering the response of a simple RLC series circuit to a suddenly-applied dc voltage (or pulse).

The basic circuit responses are shown in Fig. 2-21. When R has a large value, the circuit responds to a suddenly-applied input voltage by a surge of current. On the other hand, when R has a small value, the circuit response is a damped sine wave. The critical value of R at which this waveform change occurs is given by:

$$R_c = 2\sqrt{L/C}$$

where,

R_c is the critical resistance in ohms,
L is the inductance in henrys,
C is the capacitance in farads.

The surge waveform shown in Fig. 2-22B is for a resistance value considerably greater than the critical value. At the critical value, the peak surge voltage has a maximum value, and the critically-damped waveform appears as shown in Fig. 2-23. Any critically-damped circuit produces the same waveshape, as seen in the universal $2L/R$ time constant chart of Fig. 2-23. The term $2L/R$ is the time constant in seconds. Note in passing that a horizontal-output circuit is basically an oscillatory configuration; however, it is artificially damped by means of a damper diode. This variation of the basic arrangement will be discussed in greater detail later.

With reference to Fig. 2-24, the response of an RLC circuit is regarded as oscillatory if the *capacitor* voltage exceeds the applied voltage at any time, even though only one cycle of oscillation takes place. That is, the only way that we can distinguish a single oscillation from a surge is by the *overshoot* of capacitor voltage that occurs. This is an important characteristic, not only of color-TV circuits such as video

(A) Schematic.

(B) Resistor voltage waveform when R is large.

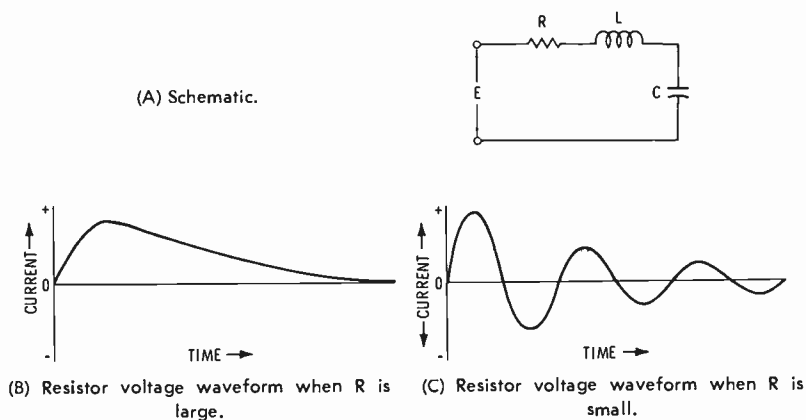(C) Resistor voltage waveform when R is small.
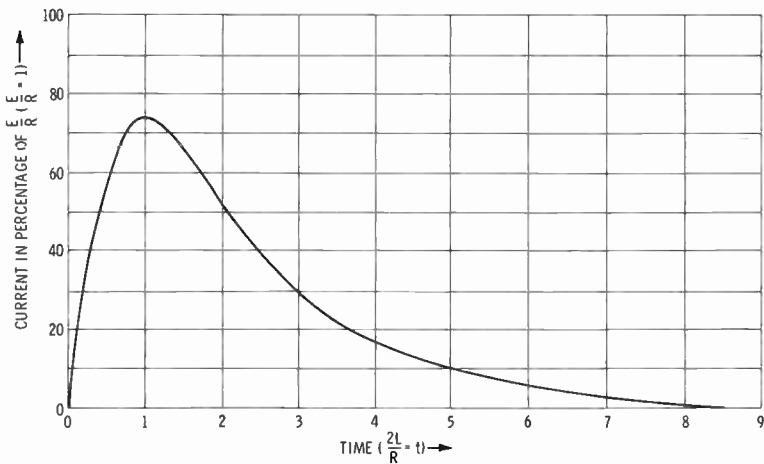
Fig. 2-22. Series RLC circuit.

Fig. 2-23. Critically damped circuit response curve.

amplifiers and Y amplifiers, but also of vertical amplifiers in oscilloscopes. In optimum design, critical damping is employed so that overshoot is avoided. However, in some TV applications, a compromise design is used to obtain faster rise; this compromise entails underdamping to the extent of 5 percent to 10 percent overshoot.

A damped sine wave such as shown in Fig. 2-22C has a frequency which is given approximately by the familiar resonant-frequency formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

However, the exact ringing frequency is formulated:

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

We will find that when R has a small value, as in a color-subcarrier ringing-oscillator circuit, that the familiar resonant-frequency formula gives practically the same answer as the exact formula. The effect of R is to reduce the frequency of ringing, and when R is a large percent-
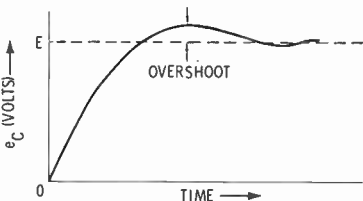

Fig. 2-24. Single oscillation response curve.

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Table 2-1. Reduction in Ringing Frequency
Caused by Circuit Resistance

Resistance (% of R_t)	Reduction in frequency $\left(\% \text{ of } \frac{1}{2\pi} \sqrt{1/LC}\right)$
0 (zero resistance)	0 $f_n = \dfrac{1}{2\pi \sqrt{LC}}$
10	.5
30	4.6
50	13.4
70	28.6
90	56.4
100	100.0 (no oscillation)

age of the critical-resistance value, the reduction in frequency is considerable, as seen in Table 2-1.

The difference in appearance of slightly-damped and highly-damped ringing waveforms is exemplified in Fig. 2-25. We should note that the envelope of the waveform is exponential in either case. All ringing circuits produce the same basic envelope waveshape, as illustrated in the universal 2L/R time constant chart of Fig. 2-26. Note that the term 2L/R is the time constant, and is given in seconds when L is in henrys and R is in ohms. This chart is also called the damping-factor chart because the curve shows how much the ringing waveform has decayed at a given time.

With reference to Fig. 2-26, we observe that if R is increased, the time constant becomes shorter. In turn, the ringing waveform decays more rapidly. For example, if 2L/R is equal to 1 second, the current decays to 37 percent of its maximum value in 1 second. On the other hand, if 2L/R is equal to 0.1 second, the current decays to 37 percent of its maximum value in 0.1 second. Or, if 2L/R is equal to 5 seconds, the current decays to 37 percent of its maximum value in 5 seconds. Note that if L is increased, the time constant becomes greater; in turn, the ringing waveform decays more slowly.
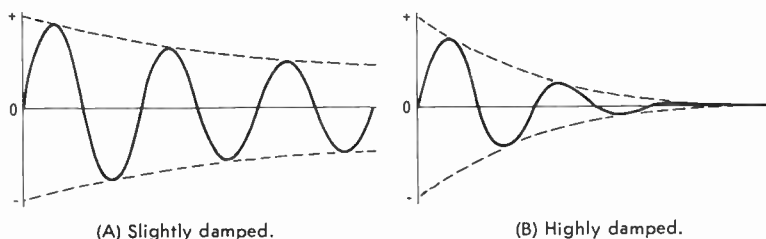

(A) Slightly damped.   (B) Highly damped.
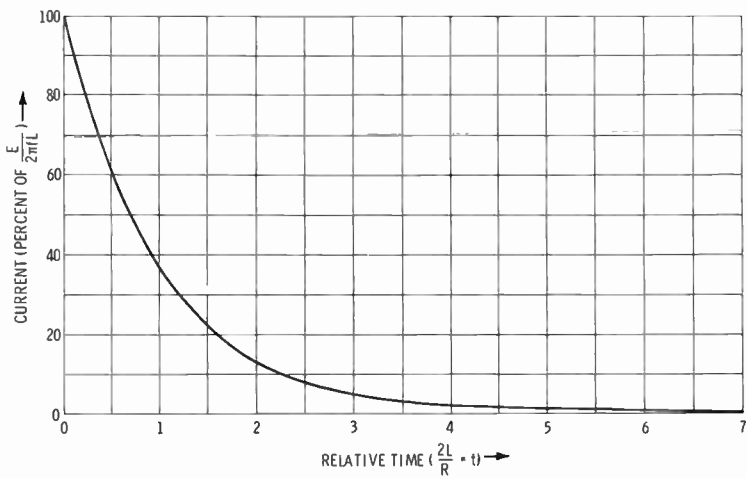
Fig. 2-25. Damped sine wave.

Fig. 2-26. Damping factor curve.

SUMMARY

The most basic color-TV waveform is the horizontal sync pulse and color burst.

Voltage, frequency, time, and waveshapes are fundamental characteristics that are specified and measured in waveform analysis.

Waveform voltages are measured in peak-to-peak value; in the case of a sine wave, either its peak-to-peak or its rms value may be measured.

In dc scope application, a peak-to-peak voltage is equivalent to the same value of dc voltage.

A square wave can be built up from sine waves which comprise a fundamental and odd-harmonic frequencies.

Pulses are basically unsymmetrical square waves (rectangular waves).

A pulse is built up from both odd harmonics and even harmonics, if the pulse is unsymmetrical with respect to the zero-volt reference line.

If a pulse is symmetrical with respect to the zero-volt reference line, it contains only odd harmonics.

A waveshape depends on relative phases of harmonics, as well as frequencies and amplitudes.

The same circuit bandwidth is required to pass either a square wave or a sawtooth wave without objectionable distortion. About 15 harmonics must be passed in either case.

Exponential waveforms are almost as basic as sine waves in TV circuit action.

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A series RC circuit develops an elementary exponential waveform. Series-parallel RC circuits develop derived exponential waveforms.

Elementary and derived waveforms can be summarized by means of universal RC time constant charts.

Waveform amplitude and rise time are as important as waveshape in troubleshooting electronic circuitry.

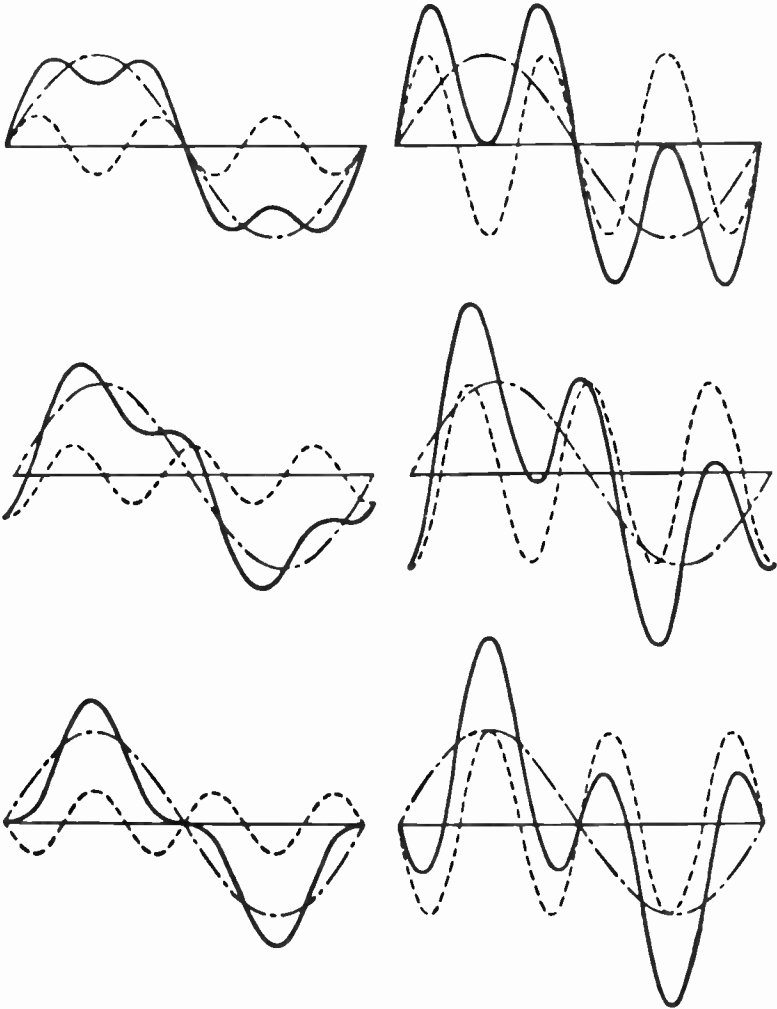The analysis of ringing waveforms is essential in evaluating various types of color-TV circuit action.

Fig. 2-27. A fundamental and third harmonic in shifted phase relations.

Fig. 2-28. Response of a dc scope to ac voltage with a dc component.

REVIEW QUESTIONS

1. Fig. 2-27 shows a fundamental and third harmonic in three phase relations. Does a phase shift cause a change in peak-to-peak voltage? Does a shift in phase cause a change in the power that would be developed in a load resistor?
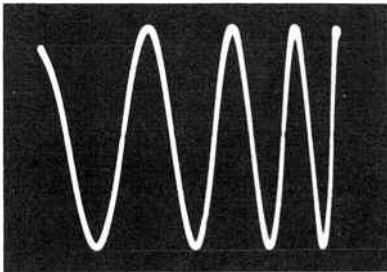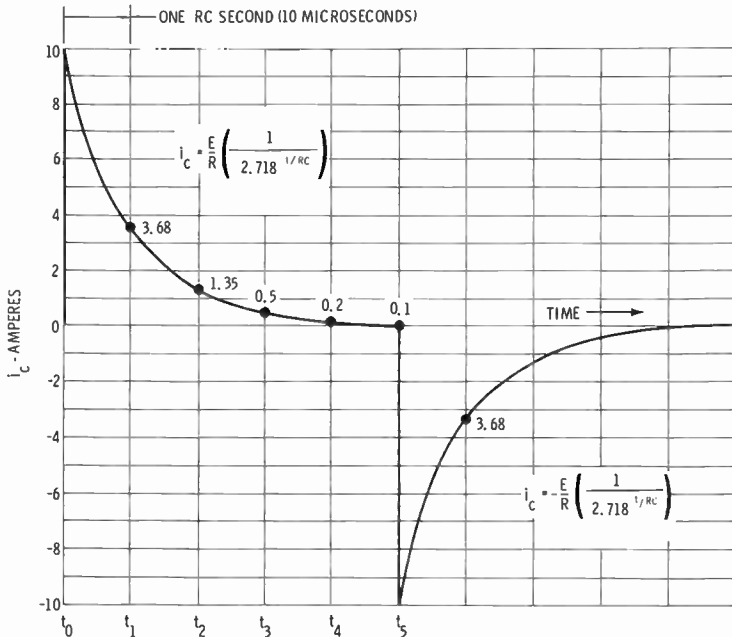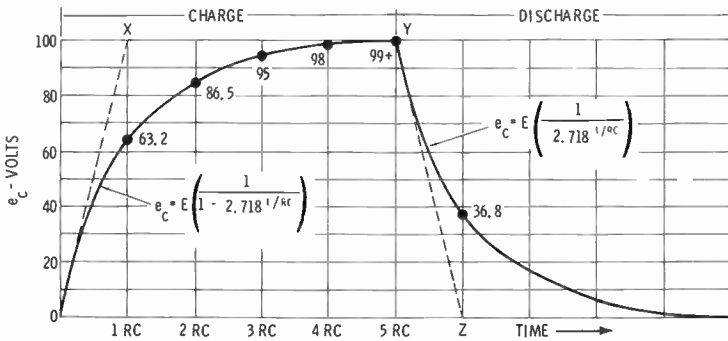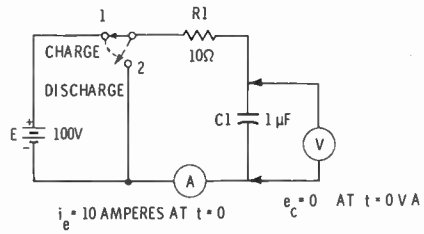

Fig. 2-29. Sine wave cramped at right.

2. Fig. 2-28 shows a sine wave with a dc component displayed on the screen of a dc scope. Does the dc component change the peak-to-peak voltage of the sine waveform? How would you read the value of the dc component?

3. Fig. 2-29 illustrates an example of horizontal nonlinearity. Where would you look for the defect in the scope circuitry?

4. Fig. 2-30 shows a series RC circuit. What is the time constant of the circuit in microseconds? Inspect the waveform and state its rise time; its fall time. (Hint: We know the time constant of the circuit).

5. With reference to Fig. 2-30B and the upper waveform, why does the waveform depart from paths 0X and YZ?

6. With reference to Fig. 2-30B and the upper waveform, determine the pulse width. Determine the pulse width for the lower waveform.

(A) Voltage graph.

$i_e = 10$ AMPERES AT $t = 0$ $e_c = 0$ AT $t = 0$ V A

CHARGE   DISCHARGE

$e_c = E\left(\dfrac{1}{2.718^{1/RC}}\right)$

$e_c = E\left(1 - \dfrac{1}{2.718^{1/RC}}\right)$

$i_c = \dfrac{E}{R}\left(\dfrac{1}{2.718^{1/RC}}\right)$

$i_c = -\dfrac{E}{R}\left(\dfrac{1}{2.718^{1/RC}}\right)$

(B) Current graph.

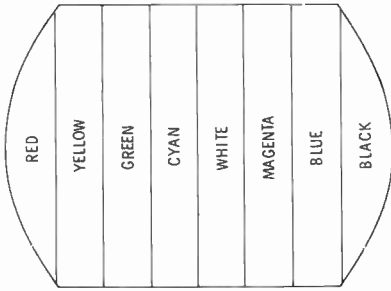Fig. 2-30. RC series circuit for analysis.

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3

Scope Tests in
Color-Bar Generators

Scope tests are often essential in maintenance and troubleshooting of color-bar generators. We can classify color-bar generators into two basic types: (1) Keyed rainbow, and (2) National Television Systems Committee (NTSC) designs. A keyed rainbow generator supplies 10 color-difference bars; an NTSC generator typically supplies six color bars comprising the primary and complementary colors. A white bar is often provided, and a black bar may be included. Figs. 3-1A and B show a comparison of NTSC and keyed rainbow patterns. A *color-difference* signal consists of a chroma signal without any brightness signal, as explained in greater detail later in this chapter.
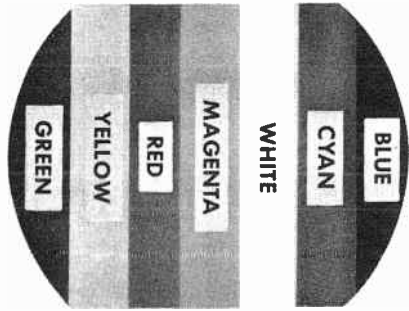
PATTERN VARIATIONS

An *unkeyed* rainbow generator provides a *continuous* spectrum of color-difference information, as shown in Fig. 3-1C. Note that if a defect occurs in the keyer section of a keyed rainbow generator which causes the chroma signal to become ungated, the pattern in Fig. 3-1B then appears as in Fig. 3-1C. The sequence of colors in any keyed rainbow pattern is *always the same*. This is due to the basic signal characteristic. On the other hand, the color sequence is arbitrary in an NTSC pattern. For example, Fig. 3-1A shows the sequence of colors in the NTSC pattern provided by the color-bar generator illustrated in Fig. 3-2. Another common color sequence is shown in Fig. 3-1D.
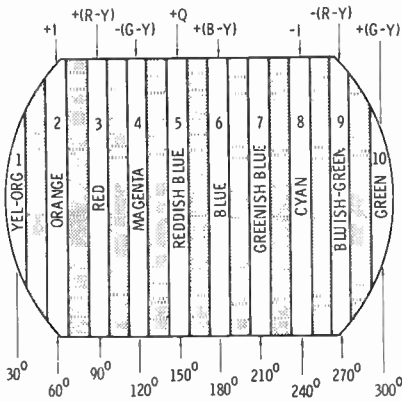
Some NTSC generators provide *single-bar* displays, as shown in Fig. 3-1E. A primary or complementary color is displayed as a vertical bar, flanked by black areas. In a related design, the single color bar is
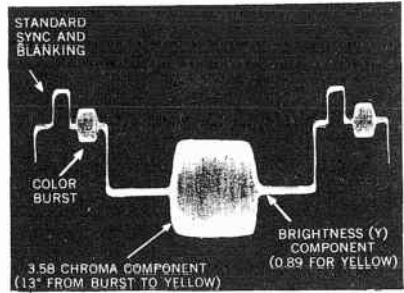
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(A) NTSC generator.

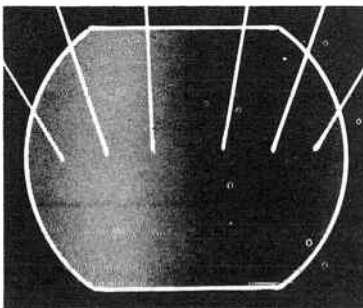

(D) Pattern for another NTSC generator.
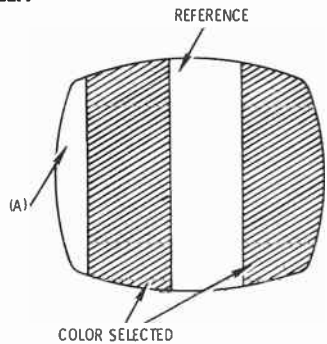

(B) Keyed rainbow generator.

(E) Display of single color bar.

(C) Unkeyed rainbow generator.

(F) Block reference bar flanked by a single split color bar.

Fig. 3-1. Patterns produced by various color signal generators.

split into two vertical bars separated by a black bar, as shown in Fig. 3-1F. We will find that most NTSC generators also provide for display of various single-bar or double-bar color-difference signals. Thus, a typical generator supplies $R - Y$, $B - Y$, $G - Y$, $G - Y/90°$, I, and Q chroma signals, in addition to primary and complementary color signals. (See Chart 3-1).

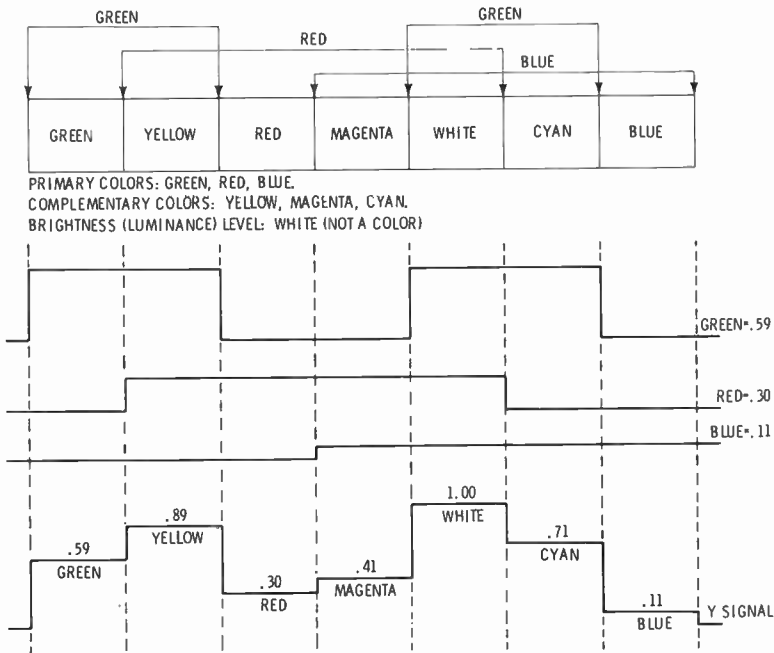Fig. 3-2. A typical NTSC color-bar generator.

BASIC COLOR-GENERATOR WAVEFORMS

The basic rainbow signal is simply a 3.56-MHz (actually 3.563795-MHz) sine wave. It is also called an *offset color-subcarrier* signal, since the color-subcarrier frequency is 3.58 MHz (actually 3.579545-MHz), and the difference or "offset" is 15,750 Hz. It is also called a *sidelock* signal or a *linear phase sweep*. A keyed rainbow signal has a 3.56-MHz component, horizontal sync pulses, and gating pulses that produce 11 "bursts" as shown in Fig. 3-3. The first "burst" after the horizontal sync pulse serves as a *color burst* to lock the color-sync sec-

tion in the receiver. Since the first "burst" is blanked on horizontal retrace, 10 color-difference bars are displayed on the picture-tube screen.

Regarded as a linear phase sweep, a rainbow signal beats with the color-subcarrier oscillator in the receiver, and the corresponding vector rotates through 360° of phase during each horizontal scan. Thus, the color bars are separated by 30°; note that the horizontal sync pulse

Chart 3-1. Relations of primary and complementary colors.

PRIMARY COLORS: GREEN, RED, BLUE.
COMPLEMENTARY COLORS: YELLOW, MAGENTA, CYAN.
BRIGHTNESS (LUMINANCE) LEVEL: WHITE (NOT A COLOR)

is in the "12th bar" space. Both the horizontal sync pulse and the color burst are blanked in the receiver. The visible pattern (see Fig. 3-3) is a phase sweep of 270°. Note the phase angle of each color-difference signal; these angles are approximate and the exact relations will be discussed later.

Phases are usually referenced from the color burst; thus, we state that $+(G-Y) \underline{/90°}$ is 30° from burst, and that $+(G-Y)$ is 300° from burst. Observe that a rainbow signal Fig. 3-3 is centered on the *black level* in the waveform. Fig. 3-4 clarifies the phase relations in a rainbow signal. Since $-Q$ and $-(B-Y)$ are normally blanked, they are not usually visible in a rainbow pattern. However, we will find that there are certain receiver defects that cause phase displacement, whereby the first bar might have the $-(B-Y)$ phase instead of the

$+(G - Y)/90°$ phase, for example. The $-(B - Y)$ phase produces a yellow-green color bar.

As in a standard color burst, there are normally eight or nine cycles of 3.56-MHz signal in a keyed rainbow chroma bar. The exact number of cycles is not critical. However, the number of cycles in a burst (or chroma bar) can be easily checked with a triggered sweep scope

$\begin{array}{c}+ \\ (G-Y) \\ /90°\end{array}$	$+I$	$\begin{array}{c}+ \\ (R-Y)\end{array}$	$\begin{array}{c}- \\ (G-Y)\end{array}$	$+Q$	$\begin{array}{c}+ \\ (B-Y)\end{array}$	$\begin{array}{c}(G-Y) \\ /90°\end{array}$	$-I$	$\begin{array}{c}- \\ (R-Y)\end{array}$	$\begin{array}{c}+ \\ (G-Y)\end{array}$
$30°$	$60°$	$90°$	$120°$	$150°$	$180°$	$210°$	$245°$	$270°$	$300°$

COLOR BURST

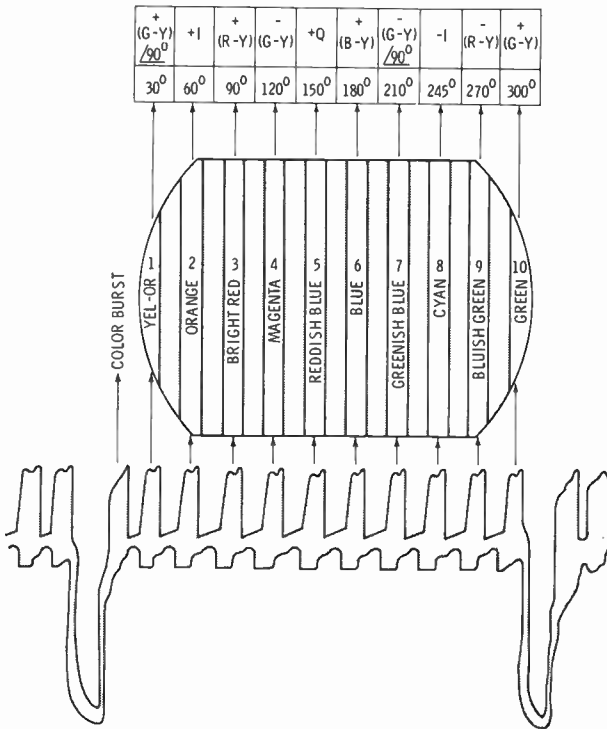1 YEL-OR 2 ORANGE 3 BRIGHT RED 4 MAGENTA 5 REDDISH BLUE 6 BLUE 7 GREENISH BLUE 8 CYAN 9 BLUISH GREEN 10 GREEN

Fig. 3-3. Keyed rainbow chroma signal, screen presentation, and phases.

as shown in Fig. 3-5. The video-frequency signal from the generator is fed to the vertical-input terminals of the scope. In the example shown, there are approximately 13 cycles of 3.56-MHz signal in the waveform. Note also that the envelope of the waveform is not rectangular, as in theory. If we wish to reduce the number of cycles in the waveform to eight or nine, the width of the gating pulse must be adjusted in the generator.

Typical time base settings for expansion of a burst waveform in a keyed rainbow signal are shown in Fig. 3-6. The trigger selector is set to its ac position. If the sync pulse is positive-going, we use the Int. (+) position, since this provides easy triggering on a burst interval. In turn, the Stability and Trigger- Level controls are set to suitable
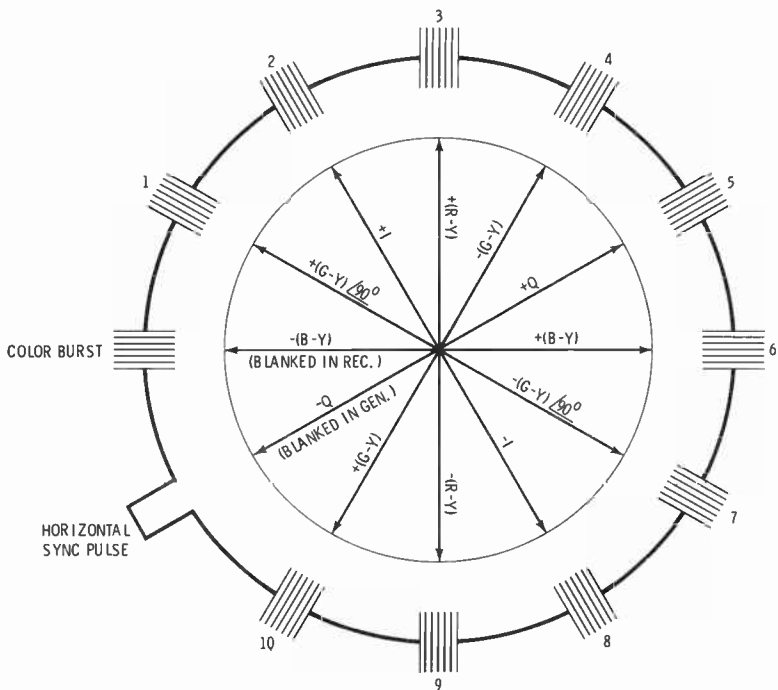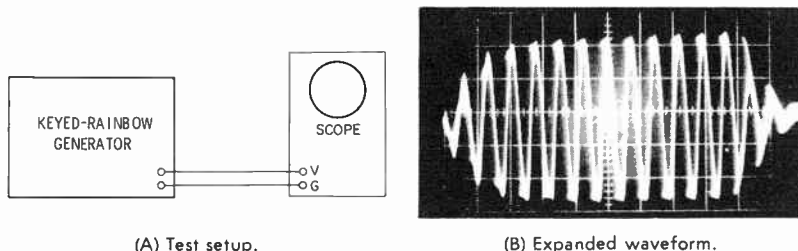
60

Fig. 3-4. Keyed rainbow signal shown with vector relationship.

points on their positive range. Correct settings of these controls provide a stable pattern, with the start of a burst waveform at the extreme left end of the horizontal trace. Finally, we advance the Time/Centimeter control to expand the burst waveform as illustrated in Fig. 3-5B.

We can use either the $1 \mu s$ or the $0.5 \mu s$ per centimeter sweep speed; either setting will provide considerable expansion. When the expansion is increased, the intensity control must be advanced to maintain ample

(A) Test setup.

(B) Expanded waveform.

Fig. 3-5. Expansion of a burst signal with a triggered sweep scope.

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pattern brightness. On the other hand, when the expansion is decreased, the intensity control must be turned down to avoid possible damage to the screen due to excessive brightness. It is comparatively simple to expand a keyed rainbow waveform, because there are only two components in the waveform—the horizontal sync-pulse component and the burst component.
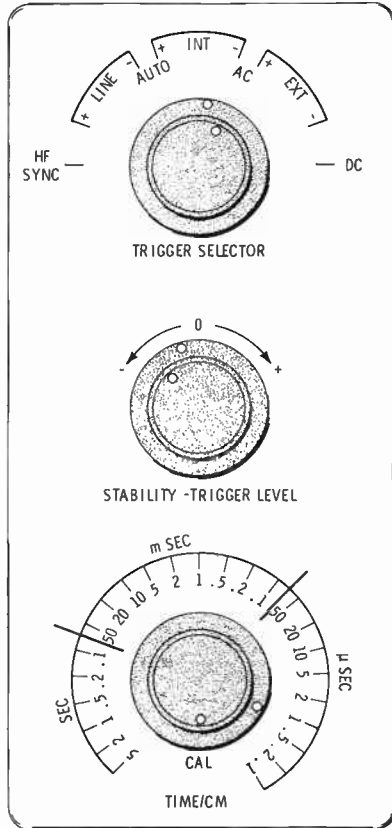

Fig. 3-6. Time base settings for expansion of burst waveform.

Let us consider the time base settings to be used if we wish to expand the horizontal sync pulse. With a positive-going sync pulse, as before, we use the Int.($+$) setting of the trigger selector. In turn, we operate the Stability and Trigger-Level controls at suitable points on their positive range. Correct settings of these controls provide a stable pattern, with the start of the horizontal-sync pulse waveform at the extreme left end of the horizontal trace. Then, the Time/Centimeter control is advanced to expand the sync pulse as desired.

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COUNTER CIRCUIT WAVEFORMS

The most common maintenance procedure concerns correct operation of the *counter circuits* in a keyed rainbow generator. If proper countdown is lost, the pattern appears "scrambled." Note that white-dot and crosshatch functions are usually built into keyed rainbow generators. Dot and hatch patterns will also appear "scrambled" if proper countdown is lost. The reference frequency is usually 189 kHz, and is established by a quartz-crystal oscillator, as shown in Fig. 3-7. There are several ways to check this frequency, and the most straightforward is to feed the oscillator output waveform into a triggered sweep scope, using a low-C probe. The period of a 189-kHz waveform is very close to 5.3 μs, and this period can be measured on a scope screen (see Fig. 3-8).

However, if a triggered sweep scope is not available, a service-type scope and accurate audio oscillator can be used. In this procedure, we feed the quartz-crystal oscillator signal into the vertical amplifier, and feed the audio-oscillator signal into the horizontal amplifier of the scope. When the audio oscillator is tuned so that the two frequencies are nearly the same, a "writhing" pattern is displayed which goes through the waveshapes shown in Fig. 3-9. If the audio oscillator is tuned to zero-beat the signals, one of these waveshapes will appear stationary on the scope screen.

The *Lissajous-figure* method is comparatively difficult to use, because very careful adjustment of the audio oscillator is required to obtain a stationary pattern. Moreover, a slight frequency drift in either the audio oscillator or the quartz-crystal oscillator causes the pattern to "run." It is helpful to power the equipment from a line-voltage regulating transformer, and to observe an adequate warm-up time before proceeding with the frequency measurement.

If the frequency of the quartz-crystal oscillator is incorrect, the most likely trouble is in the associated circuit capacitors. For example, if C1, C2, or C15 (Fig. 3-7) is leaky or off value, the oscillator frequency will be incorrect. It is assumed, of course, that the oscillator tube has been checked or replaced if necessary. The quartz crystal can also become damaged if circuit defects have caused the oscillator tube to draw excessive current. For example, if leakage in the crystal holder permits B+ voltage to bleed into the grid circuit, damage to the quartz crystal is very likely to occur.

After the correct oscillator frequency has been verified, we turn our attention to the counter circuits. Each circuit has a frequency control, as shown in Fig. 3-10. In this example, the counters are synchronized blocking oscillators. The count-down is 189 kHz to 31.5 kHz (frequency division of 6-to-1), 31.5 kHz to 15.75 kHz (2-to-1), 31.5 kHz to 4500 Hz (7-to-1), 4500 Hz to 900 Hz (5-to-1), 900 Hz to
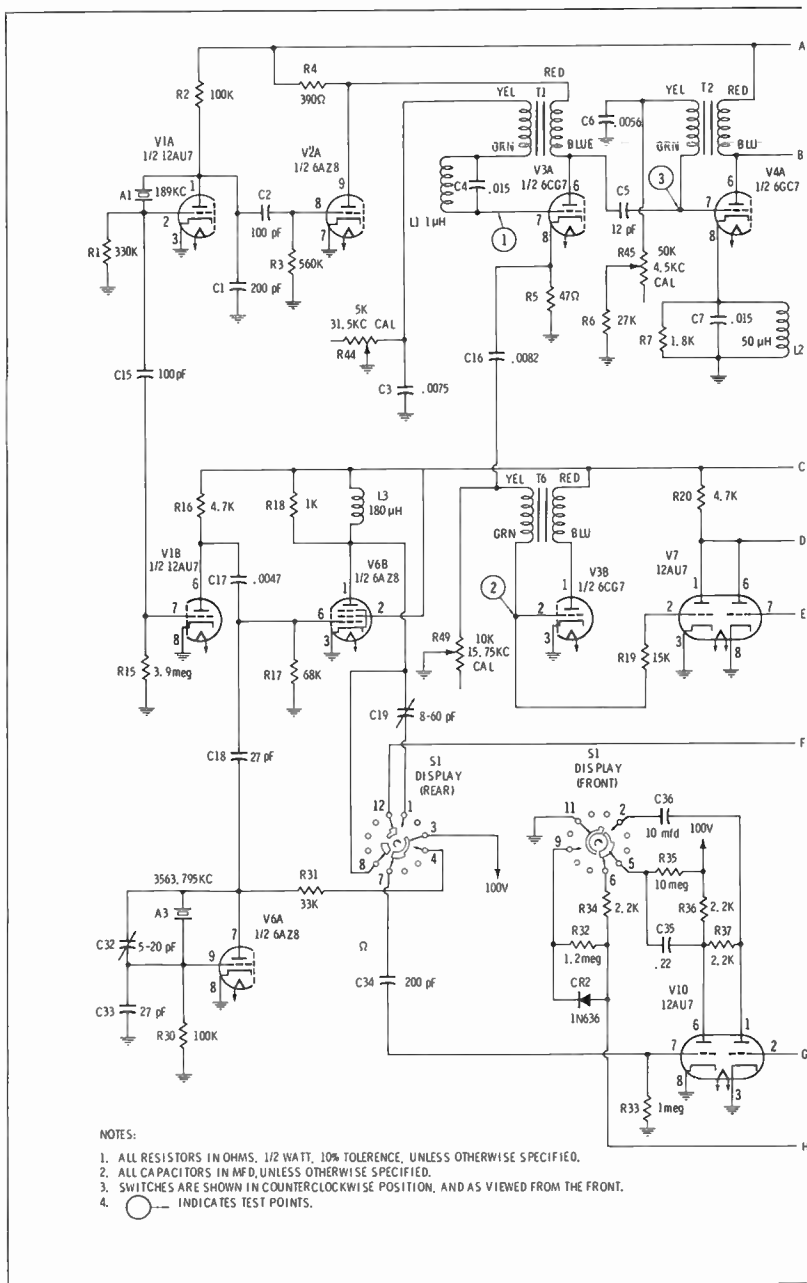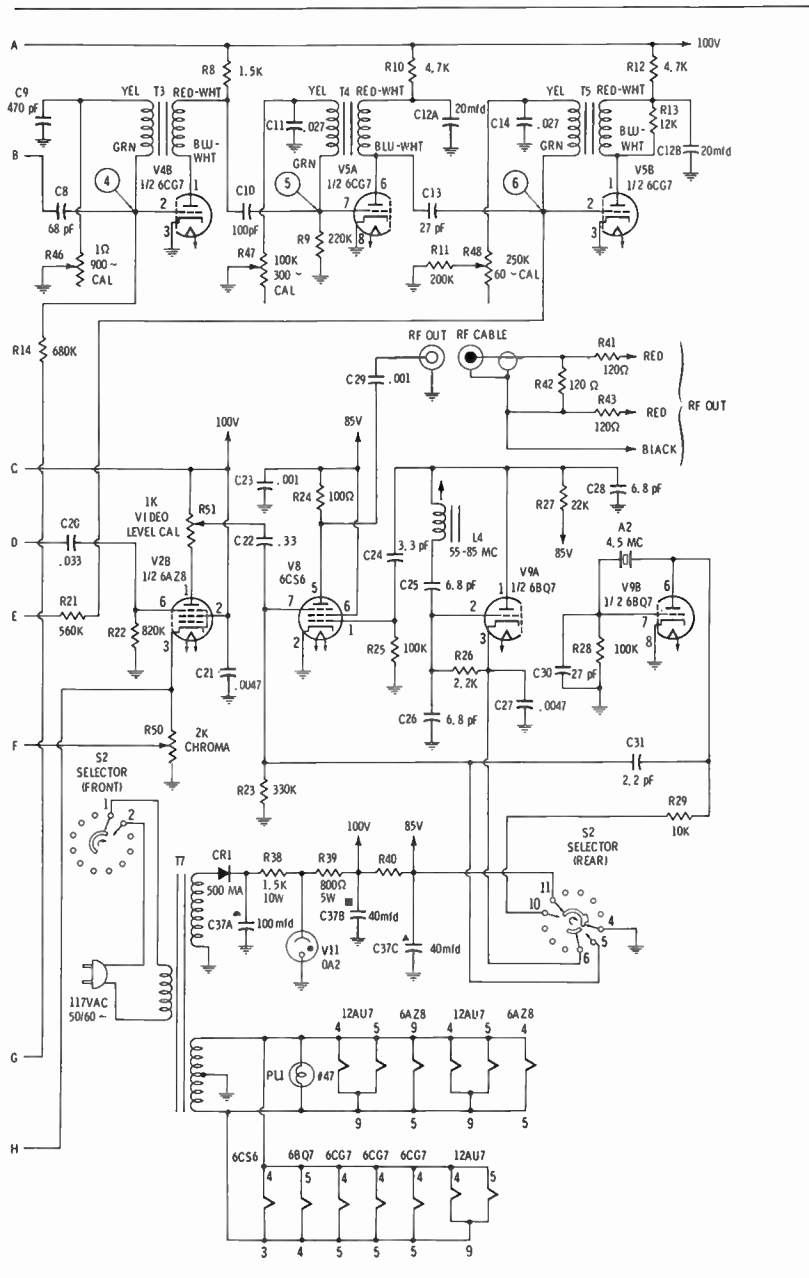
63

Fig. 3-7. Schematic of a

Courtesy Precision Apparatus Co.

typical keyed rainbow generator.

300 Hz (3-to-1), and 300 Hz to 60 Hz (5-to-1). The normal wave-forms are depicted in Fig. 3-11. Note that in A, five small pips appear between the large pulses; these are trigger pulses from the 189-kHz oscillator. Since this is a 6-to-1 frequency division, a sixth trigger pulse is present—however, it is obscured by the leading edge of the large pulse.

In Fig. 3-11B, the waveform corresponds to a 2-to-1 countdown. One small pulse normally appears between the two large pulses. Although a second trigger pulse is present, it is effectively masked by the

Fig. 3-8. Measurement of oscillator period.

leading edge of the large pulse. The next countdown ratio is 7-to-1, and the corresponding waveform is shown in C; six trigger pulses and part of the seventh appear in the waveform. In D, we see the wave-form for the 5-to-1 countdown; four trigger pulses, and the lower portion of the fifth pulse are visible in the waveform. Next, the 3-to-1 countdown waveform is shown in E; two trigger pulses are visible, plus part of the third pulse. Finally, the 5-to-1 countdown waveform is shown in F; four trigger pulses are visible, but the fifth pulse is obscured by the larger conduction pulse.

Whenever waveforms are developed in a frequency divider section, the fundamental frequencies of the successive waveforms must be har-monically related. If a blocking oscillator is adjusted to operate at 1/3 the frequency of the trigger waveform, for example, tight sync lock can be anticipated, barring a component defect. On the other hand,
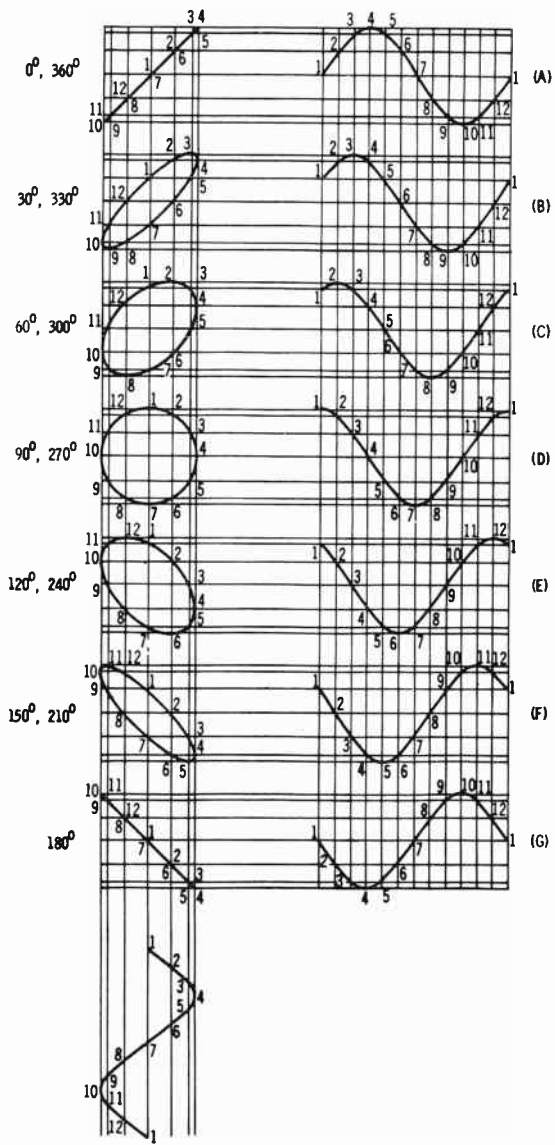
66
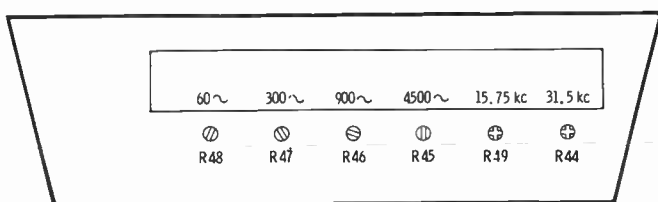
Fig. 3-9. Effect of phase variation on pattern aspect.

Fig. 3-10. Counter control layout.

only erratic lock can be obtained at 1/3.5 of the trigger frequency. The end result will be that the blocking oscillator is triggered part of the time at 1/3 frequency, and part of the time at 1/4 frequency.

MULTIVIBRATOR FREQUENCY DIVIDER

Some keyed rainbow generators employ multivibrators instead of blocking oscillators for pulse countdown. Although the fundamental frequency division principle is the same, the waveforms that we work with are different. Fig. 3-12 shows the basic multivibrator circuit and

(A) 31.5 kHz calibration (V3, Pin 7).

(B) 15.75 kHz calibration (V3, Pin 2).

(C) 4500 Hz calibration (V4, Pin 7).

(D) 900 Hz calibration (V4, Pin 2).

(E) 300 Hz calibration (V5, Pin 7).

(F) 60 Hz calibration (V5, Pin 2).

Fig. 3-11. Counter waveforms.
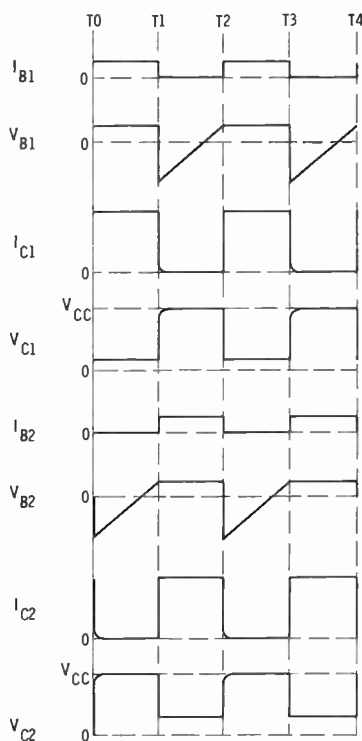
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(A) Schematic.

(B) Waveforms.

Fig. 3-12. Transistor multivibrator.

its normal waveforms. Let us consider the practical features of a triggered multivibrator used in a counter chain. Fig. 3-13A shows the configuration of a 31.5-kHz counter with a 189-kHz trigger applied to the grid of the first triode. The output waveform is taken from the plate of the second triode.
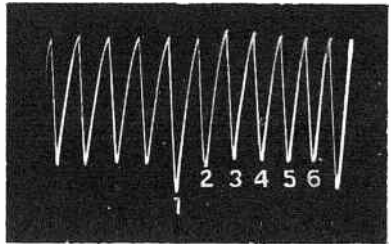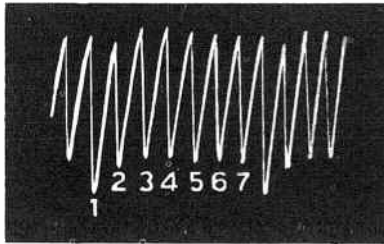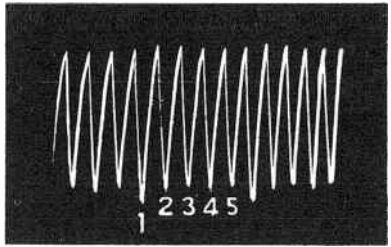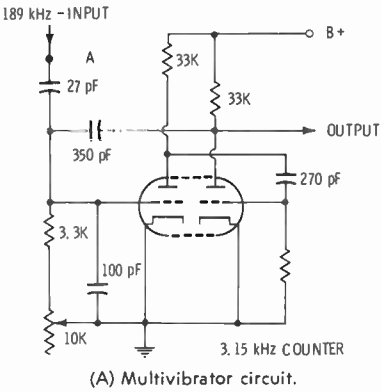

(A) Multivibrator circuit.

(B) 31.5 kHz multivibrator running too fast.

(C) 31.5 kHz multivibrator running too slow.

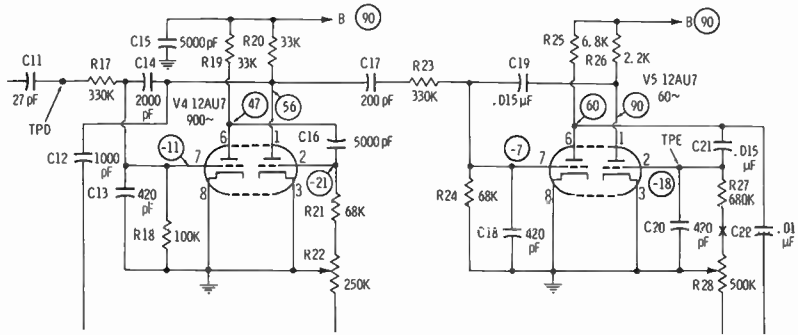(D) 31.5 kHz multivibrator running on frequency.

Fig. 3-13. Circuit and output waveforms of a 31.5 kHz counter.

Both normal and abnormal waveforms are shown in Fig. 3-13. A scope is connected at point A via a low-C probe to check the counter waveform. When the 10-k potentiometer is correctly adjusted in this example, five sawtooth waves are flanked by two larger sawtooth waves. Note that the sawtooth waveshape is produced by the 100-pF capacitor connected between grid and cathode, and also by the action of the 27-pF coupling capacitor. The photos show how the multivibrator will lock in on the fifth or seventh trigger pulse; however, normal operation in this example is obtained when locking occurs on the sixth trigger pulse.

If a counter cannot be locked on the correct frequency, we look for a defective component in the associated stage. In most cases, troubleshooting starts with dc voltage measurements. Some schematic dia-

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grams for color-bar generators, such as the example shown in Fig. 3-14, specify normal dc operating voltages. However, many schematics omit this data. Therefore, it is good practice when a new instrument is purchased, to go through the circuits immediately with a voltmeter, and to make notations of all significant dc voltages. Thereafter, if and when a component defect occurs, you will have the basic servicing information available.

Fig. 3-14. Voltages are specified in this schematic.

In case you must troubleshoot a generator without dc voltage data, greater reliance must be placed on resistance measurements. This approach is more useful for tube-type generators than for transistor-type generators. If transistors are not soldered into the circuits, they can be unplugged in order to make valid resistance measurements. Manufacturers usually solder transistor leads, and it is time-consuming to disconnect and reconnect the transistors. If time is not pressing, it is usually advisable to contact the manufacturer and request a list of dc voltage values. All manufacturers compile voltage data for their color-bar generators, and most of them will release the data on request.

NTSC COLOR-BAR WAVEFORMS

NTSC color-bar waveforms are different from keyed rainbow waveforms in that they are complete color signals, instead of color-difference signals. This is another way of saying that an NTSC signal has a Y or brightness component. Fig. 3-15 shows how an NTSC color-bar waveform is built up from a combination of Y signals and chroma signals. As noted previously, the order of the colors in an NTSC signal is arbitrary. For example, Fig. 3-16 shows another sequence of NTSC colors in common use. Still another sequence with relative voltage levels is shown in Fig. 3-17.

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In addition to a specified voltage level, each NTSC color has a certain phase of 3.58-MHz signal, as seen in Fig. 3-18. Note that in this example, chroma phases are referenced from $+(B - Y)$ instead of burst; thus, $-(B - Y)$ is assigned a phase angle of 180° (actually 179.6° in the diagram). We observe that primary red is displaced 13.4° from $R - Y$; primary blue is displaced 12.5° from $B - Y$; primary green is displaced 4.4° from $G - Y$. To summarize briefly, the
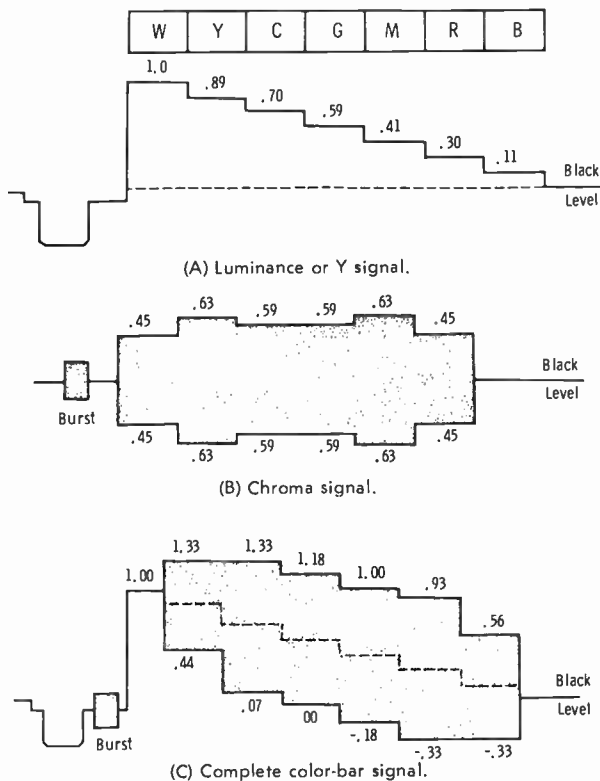

(A) Luminance or Y signal.

(B) Chroma signal.

(C) Complete color-bar signal.

Fig. 3-15. Development of NTSC signal.

chroma phase angle determines the *hue* of the displayed color, whereas the chroma amplitude determines the *saturation* of the color (whether the color is pale or vivid). The Y signal amplitude determines the *brightness* of the color (whether the color is dim or bright).

When an NTSC color-bar generator displays a single color at a time, the corresponding waveform appears as shown in Fig. 3-19. Note that the chroma component is centered on a Y (brightness) level of 0.89. A few economy-type NTSC generators supply the chroma
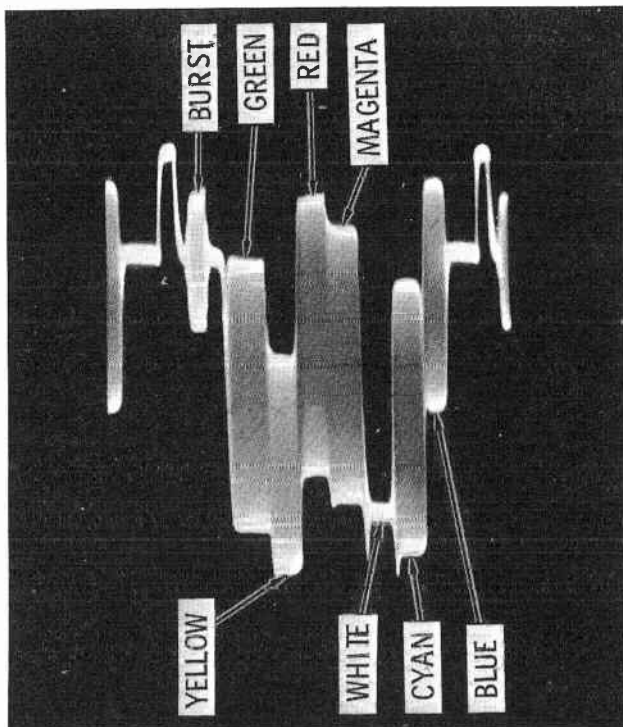
72

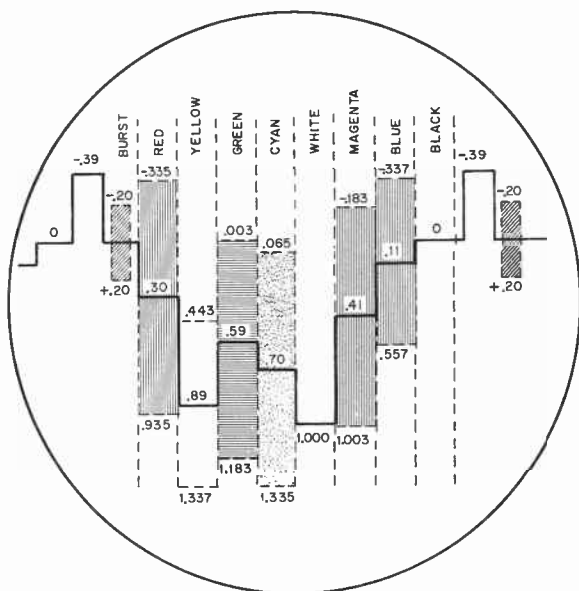Fig. 3-16. This color signal from color-bar generator.

Fig. 3-17. Waveform voltage relations for a 100-percent saturated NTSC color-bar signal.
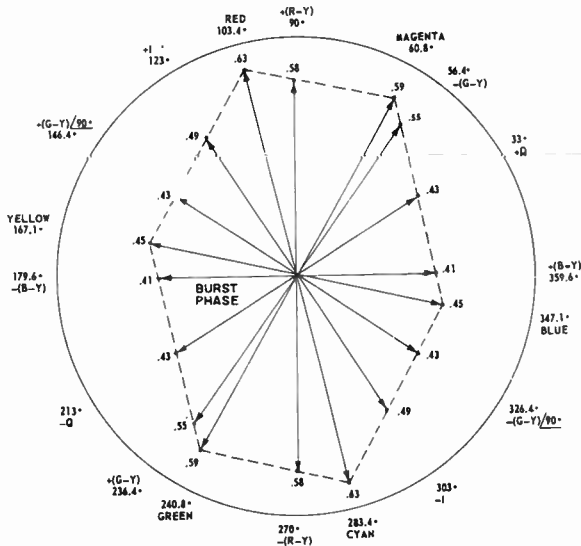
Fig. 3-18. Voltages and phases of the basic chroma signals.

component only; so the brightness component must be obtained in the receiver by suitable adjustment of the brightness control for the particular color. Although a simplified NTSC generator will provide standard colors, it is more difficult to use, because each color bar requires a particular setting of the brightness control. The beginner is likely to become confused by this requirement, and is advised to "cut his teeth" on the elaborated type of generator that supplies a complete signal.

An NTSC generator can be compared with a keyed rainbow generator in that a master oscillator is used, followed by blocking oscillators or multivibrators that operate as frequency dividers. However, due to the complex type of signal that is developed, an NTSC generator employs more waveshapers energized from delay lines. Let us consider the generator sections in Fig. 3-20 that are utilized to produce the single-bar waveform shown in Fig. 3-19. The chroma component
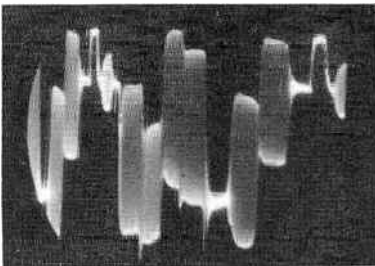

Fig. 3-19. Waveform for an NTSC saturated yellow color bar.

starts with the 3.58-MHz oscillator. The Y component starts with a 15,750-Hz blocking oscillator, which is locked to a 315-kHz quartz-crystal oscillator.

Since the blocking oscillator generates a rounded pulse with comparatively slow rise, a pulse shaper is used to clip the 15,750-Hz pulse and shorten its rise time. This pulse shaper is simply an overdriven amplifier stage. In turn, the output from the pulse shaper triggers the burst multivibrator; this is a one-shot multivibrator which turns the burst-gate tube on for the duration of the color burst. Note that the burst-gate tube is also fed from the 3.58-MHz oscillator. In turn, the color burst is formed (see the color burst on the back porch of the horizontal sync pulse in Fig. 3-19). If we apply a scope at the output of the 3.58-MHz oscillator, we normally see a color burst as illustrated in Fig. 3-5B; at the output of the burst multivibrator we normally see a pulse with a width equal to that of the color burst.

Next, let us consider the subsequent waveforms used to build up the complete color-bar signal. The output from the burst gate in Fig. 3-20 is reversed in polarity by passage through an inverter stage. A branch line from the burst multivibrator feeds the pulse to a delay line; this delay line imposes a delay time equal to the time from the trailing edge of the color burst to the leading edge of the color bar in Fig. 3-19.
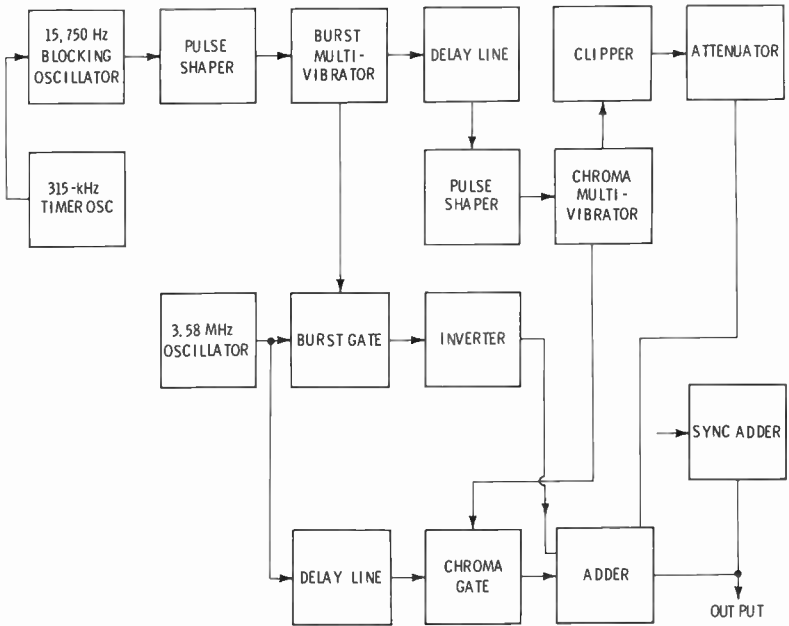

Fig. 3-20. Block diagram of a single-color-bar generator.

After the pulse has been delayed by this amount, it is passed through a pulse shaper (clipper) because the delay line tends to round the top of the waveform. The pulse then triggers the chroma multivibrator; this is a one-shot multivibrator which generates a wide gating pulse. This gating pulse normally has the same width as the color bar in Fig. 3-19.
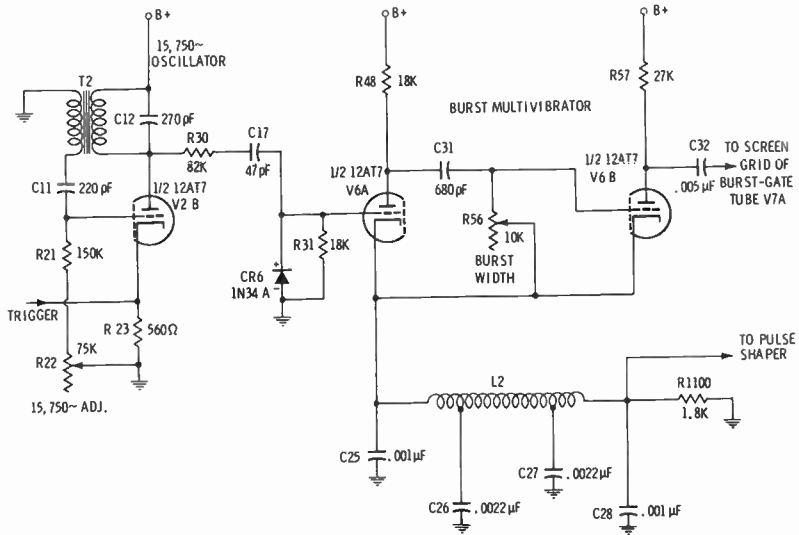
Note that the chroma-gate tube in Fig. 3-20 has two inputs; one input is the gating pulse and the other input is a 3.58-MHz sine wave which has passed through a delay line. This delay line changes the burst phase into the yellow phase in this example (see the required 12.5° difference in Fig. 3-18). We now have the burst and chroma components of the color-bar waveform, which are combined in the adder tube. In addition, the Y component is fed into the adder from an attenuator. That is, a branch line from the chroma multivibrator is fed through a clipper tube to square up the longer interval of the waveform.

When we connect a scope at the output of the clipper in Fig. 3-20, we normally see a rectangular wave with a duration equal to the Y signal in Fig. 3-19. Since the Y signal must have a specified amplitude, it is passed through a suitable attenuator prior to injection into the adder. Finally, the horizontal-sync pulse is added to the color-bar waveform via the sync-adder tube. The sync pulse is generated by circuits similar to those used to form the burst-gate and chroma-gate pulses, except that the trigger timing is different. Now let us consider the circuit action in the foregoing sections of the generator.
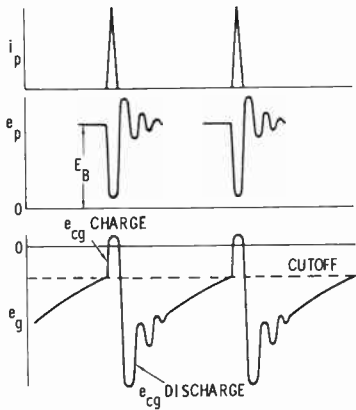
Circuitry for the 15,750-Hz blocking oscillator, pulse shaper, and burst multivibrator is shown in Fig. 3-21A. A pulse is generated by V2B, and the plate output pulse is rounded and sloping as seen in Fig. 3-21B. This pulse is narrowed and clipped in passage through R30, R31, C17, and CR6; in turn, a sharp trigger pulse is applied to V6A. Since V6 operates normally as a one-shot multivibrator, it goes through one cycle of operation for each trigger pulse. Note that if C25 becomes leaky, the cathode bias on V6 will become less, and abnormal free-running operation results. Aside from tubes, defective capacitors are the most common troublemakers.

A simplified one-shot multivibrator circuit and normal waveforms are shown in Fig. 3-22. Note that a delayed pulse is fed from the delay line to the pulse shaper in Fig. 3-21A. The pulse is shaped by the RC and diode circuit shown in Fig. 3-23. Differentiation occurs through C29 and R51, while CR11 clips the negative portion of the spike waveform. The positive spike is passed by CR12, which also serves to isolate the burst multivibrator from the chroma-gating multivibrator. If we connect a scope at the output of the differentiating circuit, a positive spike is normally observed; in case of trouble, we check C29 and the semiconductor diodes.

Fig. 3-24 shows the circuitry for the following Y shaper and adder. This is basically a clipper stage with a gain-control adjustment. Circuitry for the color-subcarrier oscillator and the burst and chroma-gate sections are shown in Fig. 3-25. Troubleshooting of the color-subcarrier oscillator is the same as in a keyed rainbow generator. A burst-gain control is provided in the burst-gate circuit, to adjust the burst amplitude to the proportions shown in Fig. 3-19. Note that the 3.58-MHz input is fed to the grids of V7A and V8A in Fig. 3-25B. Since V8A is fed through the delay line, the chroma component of the color bar follows the color burst in the gated 3.58-MHz output.

(A) Burst-gating pulse is formed in this circuit.

(B) Oscillator waveforms.

Fig. 3-21. Burst circuitry and waveforms.

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(A) Schematic.

LEGEND

e_K - VOLTAGE ACROSS CATHODE RESISTOR

e_{P1} - VOLTAGE AT PLATE OF V1

e_{G2} - VOLTAGE AT GRID OF V2

e_{P2} - VOLTAGE AT PLATE OF V2

(B) Generated waveforms.

Fig. 3-22. Simplified one-shot multivibrator circuit and waveforms.
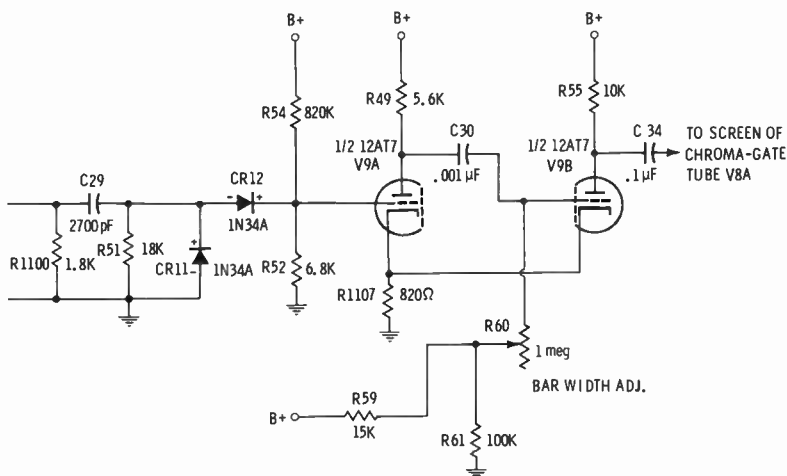
Fig. 3-23. Circuit of chroma-gating multivibrator.

In case these components are absent or distorted in the waveform of Fig. 3-19, we check tubes first, and then test the circuit capacitors if necessary. Waveform analysis will often serve to localize a defective capacitor; dc voltage measurements are often helpful also, provided that normal dc voltages are indicated in the schematic diagram. Settings of the trimmer capacitors in the delay line determine the exact spacing of the color bar from the burst. If a trimmer capacitor needs to be readjusted, it is most likely that one of the fixed capacitors in the circuit is defective.

SUMMARY

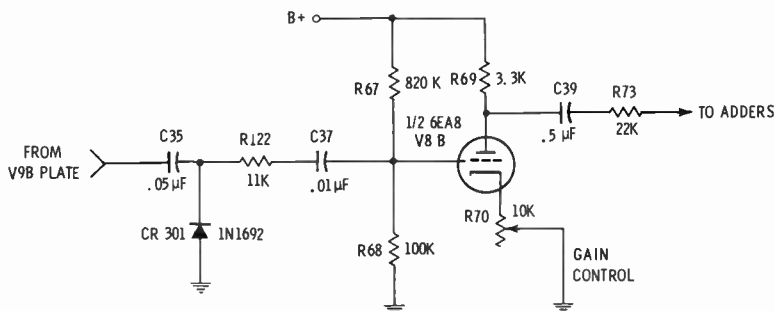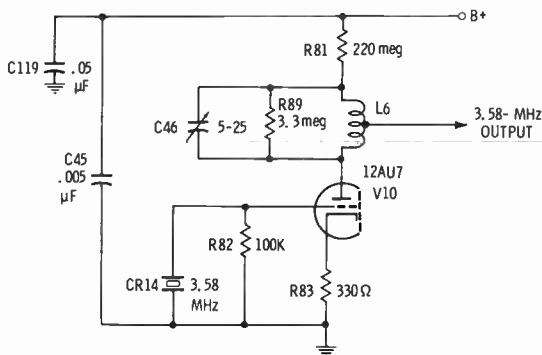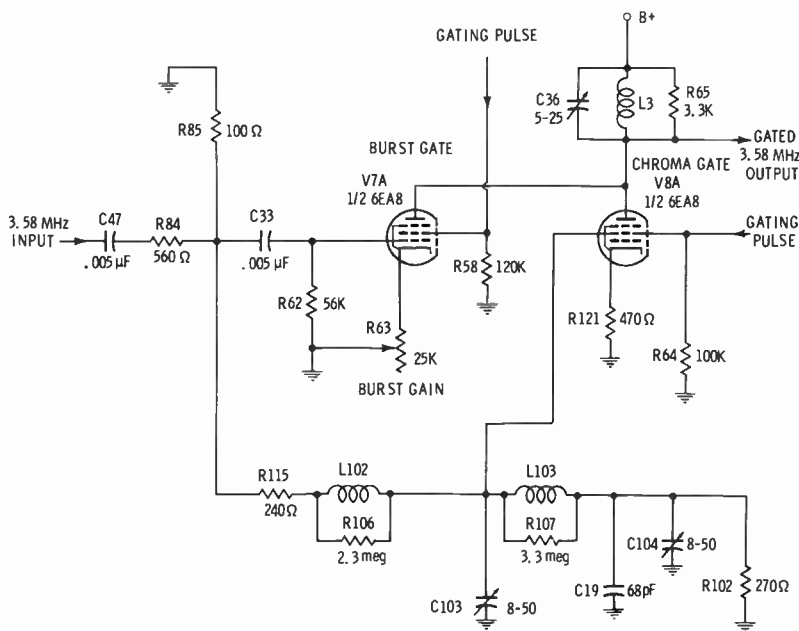A scope is probably the most useful instrument for troubleshooting a color-bar generator.

Fig. 3-24. Y-shaper and adder.

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(A) Color subcarrier oscillator.

(B) Burst- and chroma-gate circuitry.

Fig. 3-25. Chroma circuitry.

An unkeyed rainbow generator provides a continuous spectrum of color-difference signals.
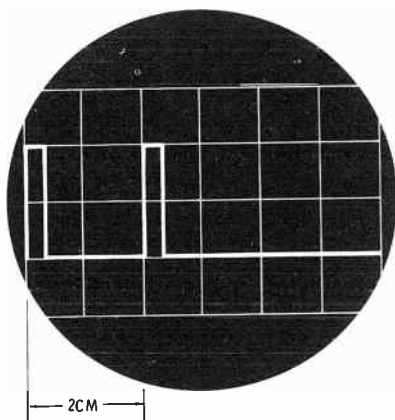
Gating pulses are used to divide a color-difference spectrum into a series of keyed rainbow color bars.

NTSC generators can be classified into single-bar and multiple-bar types.

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Complementary colors are formed by combining primary color signals.

Each bar in a keyed rainbow signal represents a certain chroma signal, such as $R - Y$, $B - Y$, $G - Y$, etc.
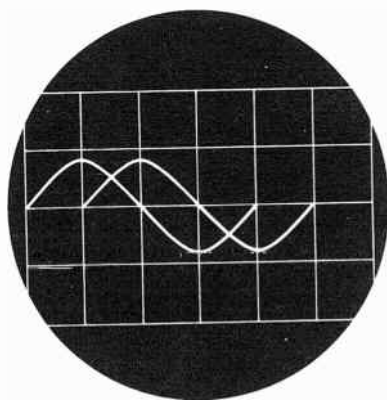

Fig. 3-26. Check of delay line response.

Countdown circuits are used in both keyed rainbow and NTSC generators, and counter action is easily checked with a scope.

Stable frequency division can be obtained only when countdown oscillators are harmonically related.

Fig. 3-27. Alternate check of delay line response.

A typical keyed rainbow generator has six key countdown waveforms.

Blocking oscillators and multivibrators generate imperfect waveforms which must be shaped by clipping and/or differentiation.

An NTSC generator contains circuit sections for producing sync pulses, color bursts, Y signals, and chroma signals.

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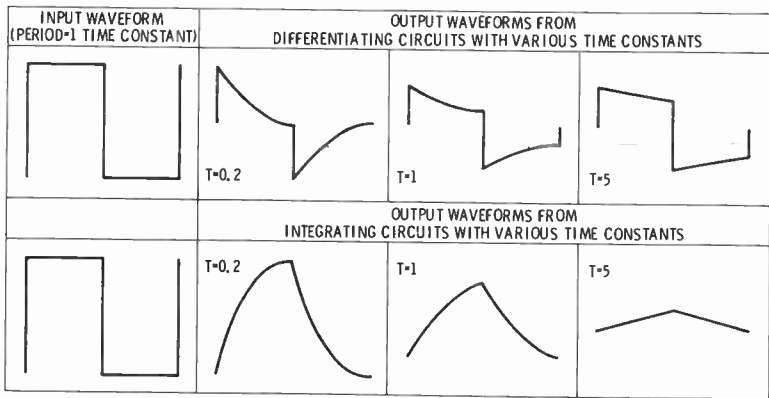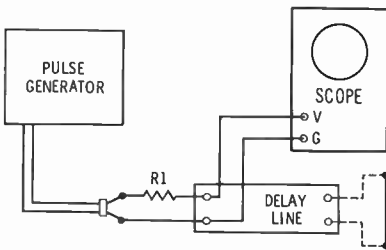| INPUT WAVEFORM (PERIOD=1 TIME CONSTANT)	OUTPUT WAVEFORMS FROM DIFFERENTIATING CIRCUITS WITH VARIOUS TIME CONSTANTS		
	T=0.2	T=1	T=5
	OUTPUT WAVEFORMS FROM INTEGRATING CIRCUITS WITH VARIOUS TIME CONSTANTS		
	T=0.2	T=1	T=5

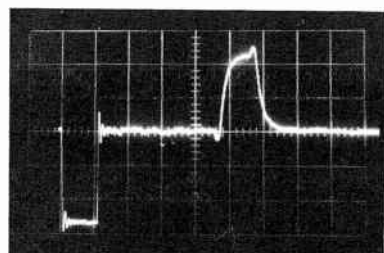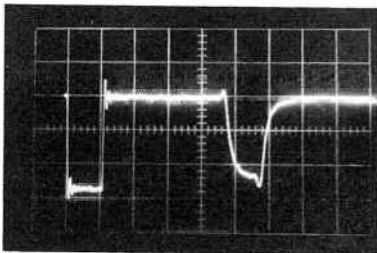Fig. 3-28. Differentiated and integrated square waves.

A typical single-bar NTSC generator employs 15 basic circuit sections, each with its individual waveforms.

Delay lines are used in color-bar generators to change the phase of the color-subcarrier waveform, and to obtain required pulse delays.

When waveforms are absent or distorted, we check tubes first and then test capacitors if necessary. Transistors are less likely to become defective than tubes.

(A) Test setup for checking delay line termination.

(B) Waveform of open-circuited delay line.

(C) Waveform of short-circuited delay line.

Fig. 3-29. Delay line.

REVIEW QUESTIONS

1. When a pulse waveform is checked at the input and at the output of a delay line, the screen displacement is 2 cm, as shown in Fig. 3-26. If the sweep speed of the scope is 10 μs/cm, what is the pulse delay time?

2. When a color-subcarrier waveform is checked at the input and at the output of a delay line, the screen displacement is ¼ cycle, as shown in Fig. 3-27. If the color-subcarrier frequency is 3.58 mHz, what is the delay time of the line?

3. Fig. 3-28 shows common Y-signal distortions. If R68 in Fig. 3-24 changes in value to 10-k, explain the waveform symptom that results.

4. Fig. 3-29 shows the reflected waveforms that occur when the termination of a delay line is an open-circuit or a short-circuit. If R1100 opens up in Fig. 3-21A, explain whether the reflected waveform will be positive or negative.

5. Explain the types of circuits used to develop the following waveforms:
   (a) To change a sine wave into a semisquare wave.
   (b) To change a semisquare wave into positive and negative spikes.
   (c) To reject the positive spike and to pass the negative spike.
   (d) To square a spike into a semipulse waveform.
   (e) To improve the rise time of a semipulse waveform.
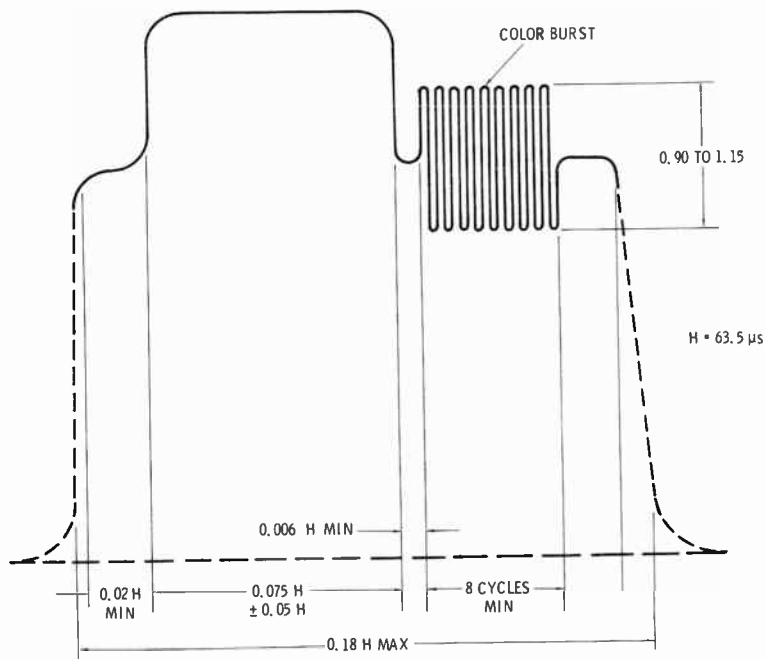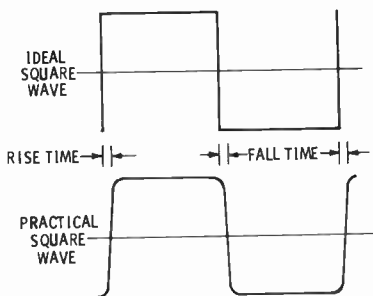
Color-Sync Signal Tracing and Waveform Analysis

We have previously noted the general distinction between ideal and practical waveforms. At this point, it is helpful to consider this distinction in somewhat greater detail. A sync pulse belongs to the family of square waveforms. As shown in Fig. 4-1, an ideal square wave has right-angled corners, vertical sides, and a horizontal top. Although an ideal square wave can be approximated, perfect square waves are not found in practice. A practical square wave has corners that are more or less rounded, and sides that slope. That is, a practical square wave has a certain rise time and a certain fall time.

CAUSE OF CORNER ROUNDING

Square waves or pulses produced by vacuum-tube or transistor circuits always have rounded corners because of the cutoff characteristics of the control device. Let us consider the simple clipping process shown in Fig. 4-2. It appears from the conventional diagram that the tube will cut off suddenly when the grid is driven to −5 volts; this point is marked CO in the diagram. However, if we inspect this process in greater detail, we will find that the plate characteristics become cramped at low values of plate current, as shown in Fig. 4-3A. That is, even if a large negative voltage is applied to the grid, a slight amount of plate current still flows—the plate current does not suddenly become zero at some negative grid voltage.

An expanded view of the cutoff region is shown in Fig. 4-3A. We recognize that when the grid is driven negative, plate current starts to fall rapidly. However, when the plate current has fallen to a comparatively small value, its rate of decrease slows up. In other words, the

(A) Rise and fall times are not instantaneous.

IDEAL SQUARE WAVE

RISE TIME → ←   → ← FALL TIME → ←

PRACTICAL SQUARE WAVE

COLOR BURST

0.90 TO 1.15

H = 63.5 μs

0.006 H MIN

0.02 H MIN

0.075 H ± 0.05 H

8 CYCLES MIN

0.18 H MAX

(B) Normal sync-pulse proportions.

Fig. 4-1. The sync pulse.

plate current falls rapidly as the grid is driven from zero to −5 volts. On the other hand, the plate current then falls slowly as the grid is driven from −5 to −10 volts. The plate current falls still more slowly as the grid is driven from −10 to −15 volts.

In summary, it is impossible to obtain perfectly square corners on a clipped waveform, because of the manner in which the plate characteristics return to zero in the cutoff region of a tube (Fig. 4-3). The same practical principles apply to corners of waveforms obtained by

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clipping with an overdriven transistor. Therefore, we expect that all waveforms in sync circuits will have rounded corners, and our waveform analysis is concerned with abnormal rounding compared with normal rounding. The waveforms shown in receiver service data display a normal amount of rounding.
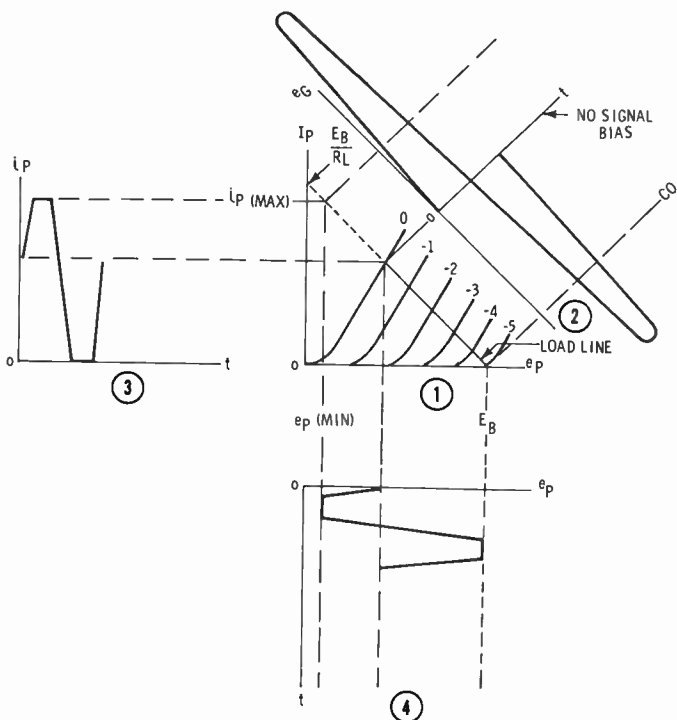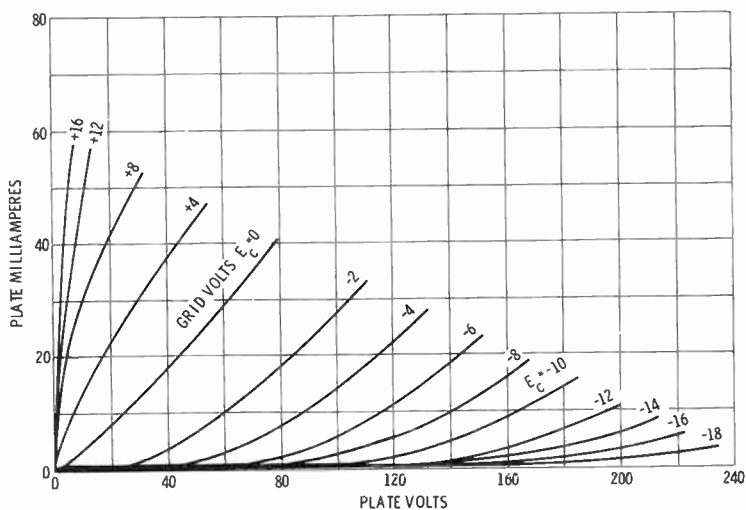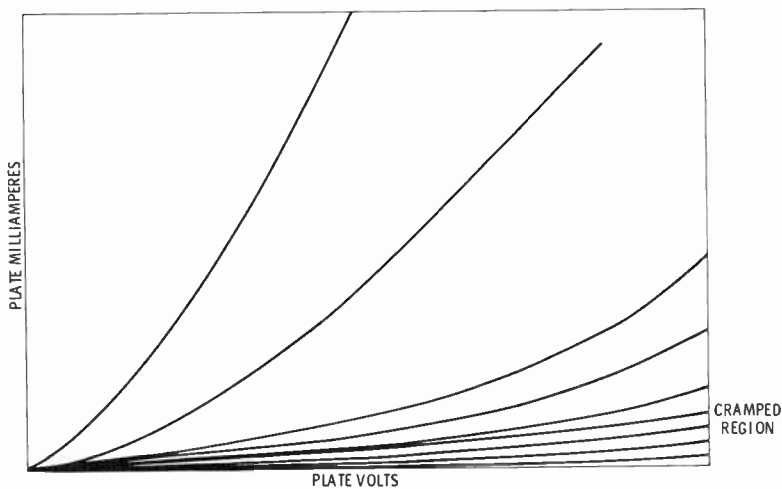

Fig. 4-2. Operation of a wave-shaping circuit that uses both saturation and cutoff clipping.

Next, let us consider another kind of circuit action that contributes to corner rounding. We know that tubes have plate capacitance, and that transistors have collector capacitance. There is also stray capacitance between wires and components in a sync circuit. A *sync clipper* stage has a certain source resistance (usually the internal resistance of the video-output stage). Consequently, we are analyzing a circuit that contains series resistance and shunt capacitance. This is basically an integrating circuit, and we know that an integrated waveform approaches its peak value along a curve. Although there is only a small amount of integration in a well-designed sync clipper, some residual integration is present, and this contributes to corner rounding in the output waveform.

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(A) Average characteristics.

(B) Expanded view of cutoff region.

Fig. 4-3. Characteristic plate curves.

CAUSE OF SLOPING SIDES

The output waveform from a sync clipper always has sloping sides. It is often said that the sloping sides are the result of limited band-

width in a sync circuit (limited bandwidth is employed by manufacturers to minimize noise interference). Let us see how narrow bandwidth causes the leading and trailing edges of a pulse to rise and fall with comparative slowness. A sync circuit has much less bandwidth than a video amplifier because of the integrating action previously noted which contributes to corner rounding. That is, integrating action is the same as low-pass filter action, and a low-pass filter narrows the bandwidth by rejecting the higher frequencies in a waveform.

(A) Diode sync separator.

(B) Transistor sync separator.
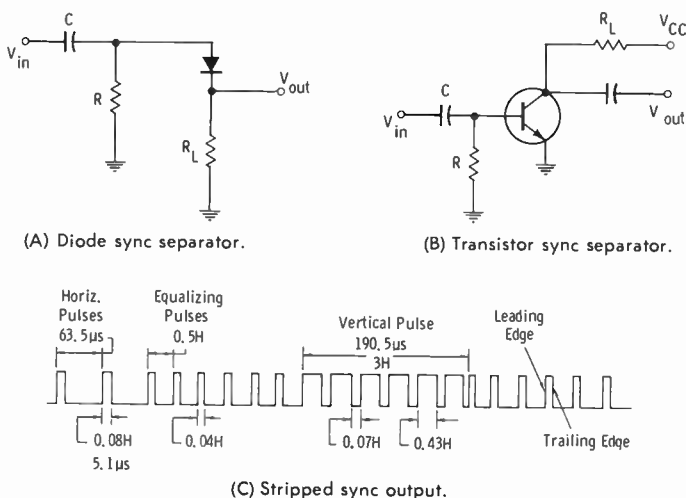
(C) Stripped sync output.

Fig. 4-4. Either a diode or a transistor may be used as a sync separator.

Basic diode and transistor sync clippers are shown in Fig. 4-4. Although stray capacitances and junction capacitances are not shown, they are implied by the diagram. In turn, the output waveform rises at a rate that depends upon the time constant of the effective series resistance and shunt capacitance. The *delay time* of the waveform is different from its rise time. Delay time is defined as the time required for a waveform to reach 50 percent of its peak amplitude, as shown in Fig. 4-5. In the case of a simple integrating circuit, the delay time is equal to 70.7 percent of the time constant.

FEATHERED SYNC PULSE

When signal-tracing in the sync channel, we sometimes observe a type of waveform distortion called "feathering" of the sync pulse. Progressive distortion of this kind is illustrated in Fig. 4-6. The sync pulse is pointed at the top and has a resemblance to the shape of a feather. There are several possible causes for this distortion. For example, the
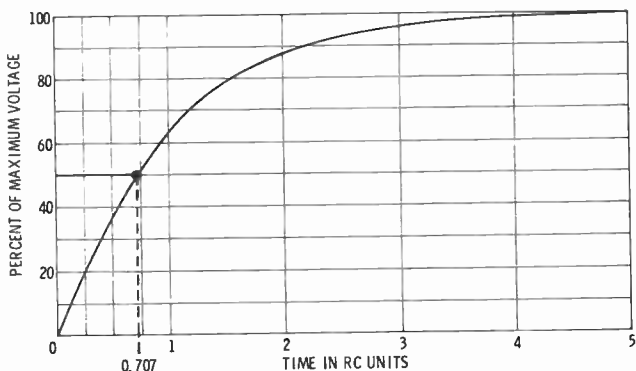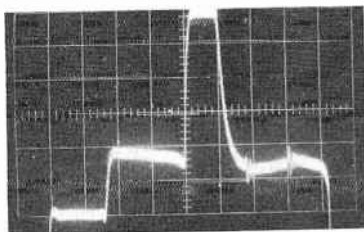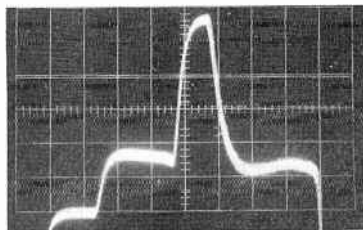
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Fig. 4-5. The delay of a simple RC integrator is 0.707 of the time constant.

scope may have insufficient bandwidth; a scope designed for audio work will distort a horizontal sync pulse. Again, the scope may have adequate bandwidth, but if it is used with a coax cable, capacitive loading of the circuit under test may integrate the sync pulse.
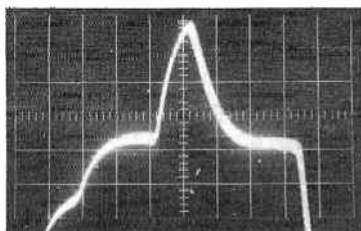
If a wideband scope is used with a low-capacitance probe, a horizontal sync pulse will normally be displayed without distortion. However, the probe must be correctly adjusted (properly compensated). The vertical step attenuator must also be adjusted for distortionless operation on each step. Assuming that the low-capacitance probe and wideband scope are not defective, objectionable "feathering" points to
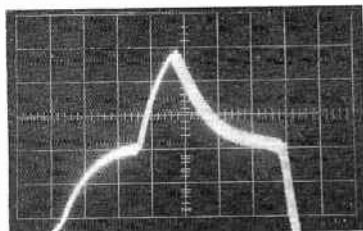

(A) Normal.

(B) Slight distortion.

(C) Medium distortion.

(D) Heavy distortion.

Fig. 4-6. Progressive "feathering" of the horizontal sync pulse.
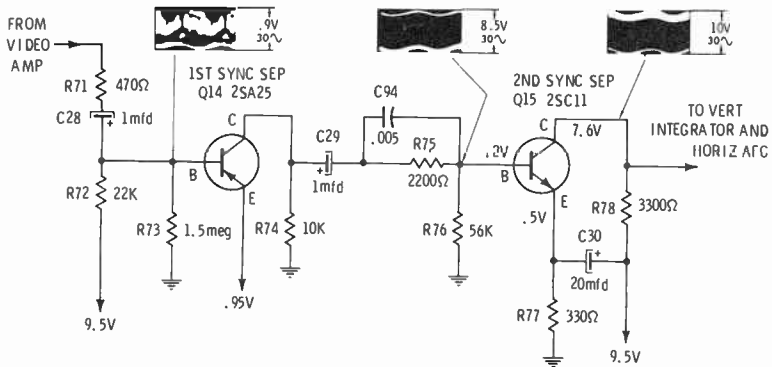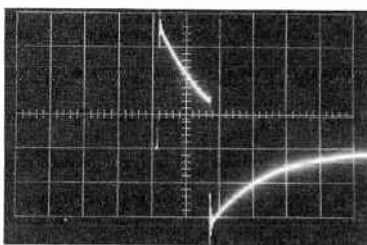
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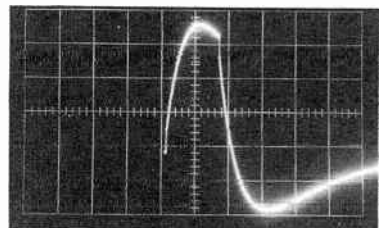Fig. 4-7. A typical transistor sync-separator configuration.

a fault in the sync circuit. For example, a plate-load resistor may have increased substantially in value. In turn, the time constant of the plate circuit becomes considerably longer, with the result that the output waveform becomes integrated.

We know that a coupling capacitor will differentiate a waveform, unless the time constant of the coupling circuit is comparatively long. In the case of transistor sync circuits, a very large coupling capacitor is required to avoid differentiation, due to the fact that a transistor draws base current (has a rather low input resistance). Therefore, it is common practice to use a coupling capacitor of reasonable size, and to include a corrective waveshaping circuit. Thus, the differentiation produced by the coupling capacitors is largely corrected by the waveshaping arrangement.

Fig. 4-7 shows a typical configuration. C94 and R75 provide waveshaping action that corrects previous differentiating action within practical limits. That is, these R and C values result in integrator action. In case C94 becomes leaky, or R75 is off value, the sync pulses applied to the base of the second transistor will have a poor waveshape.
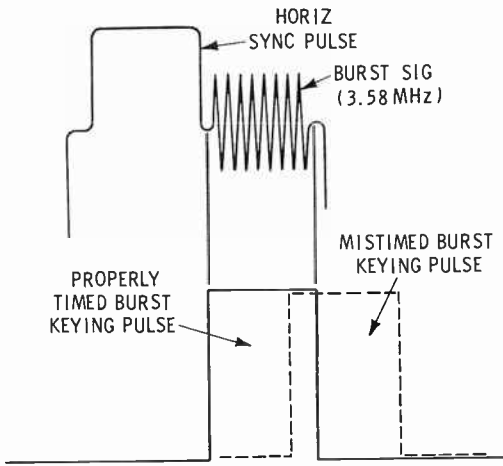

(A) Differentiated wave.

(B) Partial restoration by integration.

Fig. 4-8. Partial correction of differentiation by a following integrating circuit.
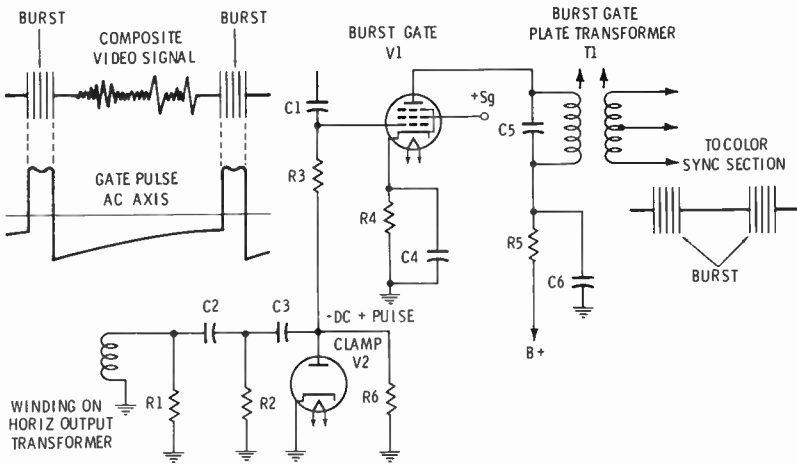
The expanded waveforms illustrated in Fig. 4-8 show how differentiation in a coupling circuit is practically corrected by this kind of wave-shaping circuit. Although the corners are rounded off, the spike-shaped peak is changed into a broad peak that has approximately the same width as in the original waveform.

COLOR-BURST PROCESSING

The color burst is gated out of the horizontal sync pulse by means of a keying pulse, as shown in Fig. 4-9. This is accomplished in the

(A) Waveform.

(B) Schematic.

Fig. 4-9. Typical burst amplifier.

burst-amplifier circuit, and the output waveform appears as illustrated in Fig. 4-10. We note in Fig. 4-9 that the burst keying pulse must be properly timed to coincide with the color burst. Otherwise, more or less of the burst waveform is stopped in the keying circuit. If too much of the burst is lost, color sync becomes erratic. The waveform in Fig.
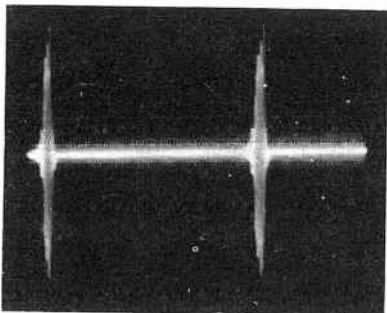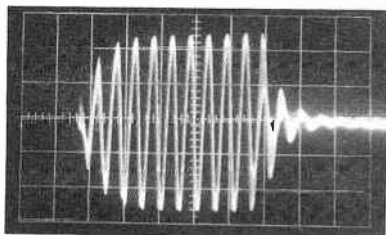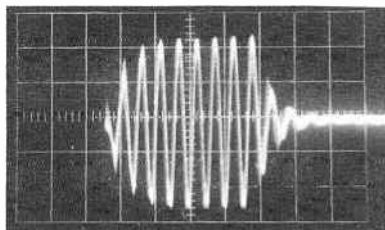

Fig. 4-10. Normal burst-amplifier output waveform.

4-10 is displayed by a conventional service-type scope (wideband type). When a triggered-sweep scope is used, the keyed burst appears as illustrated in Fig. 4-11.

Timing of the burst keying pulse is affected by the setting of the horizontal-hold control. For example, if the horizontal-hold control is misadjusted, the receiver may lose color sync before it loses black-and-white sync. Therefore, this possibility should be checked first when color sync is "touchy." However, in case the horizontal-hold control is set the center of its range, the most likely cause of a "chopped"

(A) Normal keyed burst.

(B) Mistimed keying pulse removes two cycles.

Fig. 4-11. Burst waveforms.

burst is a defect in the burst keyer circuitry. Two types of defects can be responsible for marginal color sync lock—the keying pulse may be mistimed, or, it may be attenuated. In some trouble situations, we find that the keying pulse is both mistimed and attenuated. Capacitors are prime suspects, and leakage is the most common defect. However, the keyer winding can cause malfunctioning if there is leakage from winding to core, or shorted turns.

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CRYSTAL RINGING CIRCUIT ACTION

Two basic types of oscillators are used to produce a continuous 3.58-MHz output in phase with the color burst. The simplest arrangement uses a crystal ringing circuit; a block diagram is shown in Fig. 4-12. Successive color bursts (Fig. 4-10) shock-excite the 3.58-MHz quartz crystal into oscillation. Since the crystal normally has a very high Q value, the ringing waveform does not decay to zero between bursts. However, because some decay is unavoidable, the oscillator is followed by a limiter. In turn, the output from the limiter is a continuous 3.58-MHz sine wave, unless there is a defect in the ringing circuit.

A normal crystal ringing waveform is shown in Fig. 4-13. We observe that there is comparatively little decay of the wave envelope from one burst to the next. For example if Q is 3000 the amplitude decreases only 1 percent in 10 cycles. However, component defects that load the crystal abnormally can cause much more rapid decay. When this happens, the limiter may not be able to maintain a uniform output. In turn, chroma demodulation is affected and color reproduction is more intense at the left-hand side of the screen than at the right-hand side. Or, if the limiter output is very weak, there will be no color reproduction. Common causes of abnormal decay and reduced wave-
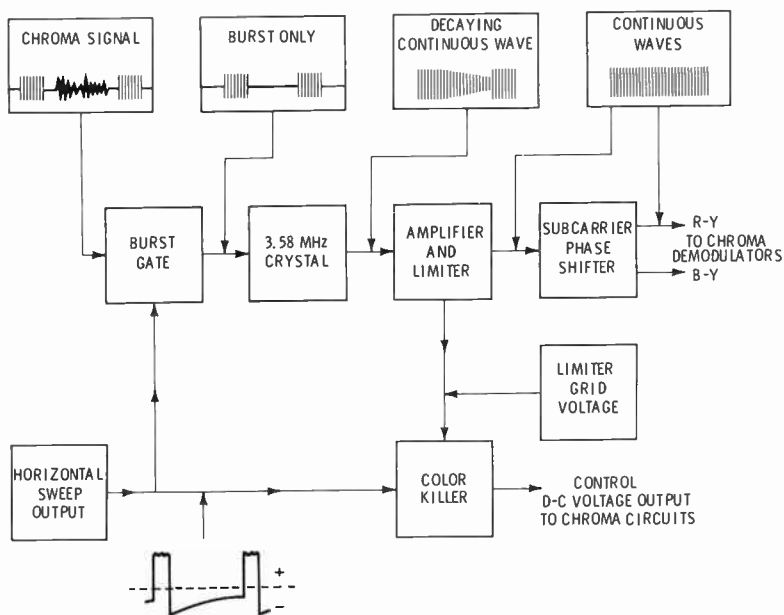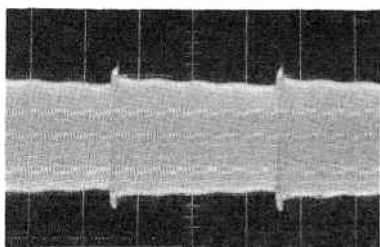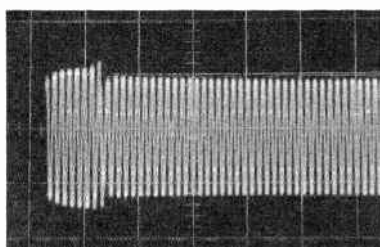

Fig. 4-12. Color sync section that uses a crystal ringing circuit.

(A) Normal.   (B) Expanded.

Fig. 4-13. Crystal ringing waveform.

form amplitude are crystal defects, leaky capacitors, or defective coils in the oscillator section. Sometimes a crystal and holder are dropped on the floor, for example, and the mounting becomes strained, although the crystal is not chipped. In turn, the Q value of the crystal is impaired.

Note that noise pulses will ring a quartz crystal, in addition to the color burst. In other words, if the burst is excessively noisy, a 3.58-MHz output is produced as illustrated in Fig. 4-14. This condition causes touchy color sync, or loss of sync in severe cases. The reason for this difficulty is that noise pulses produce an output that has random phase. Consequently, if the ringing process is dominated by noise pulses instead of the color burst, incorrect random colors are reproduced on the picture-tube screen. When the burst input to the ringing oscillator is excessively noisy, suspicion falls on the burst-gate transistor. That is, a noisy transistor in this section will impair color sync without producing confetti in the picture.

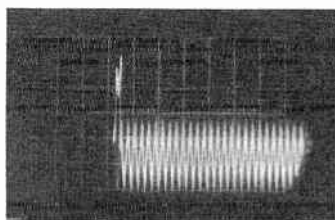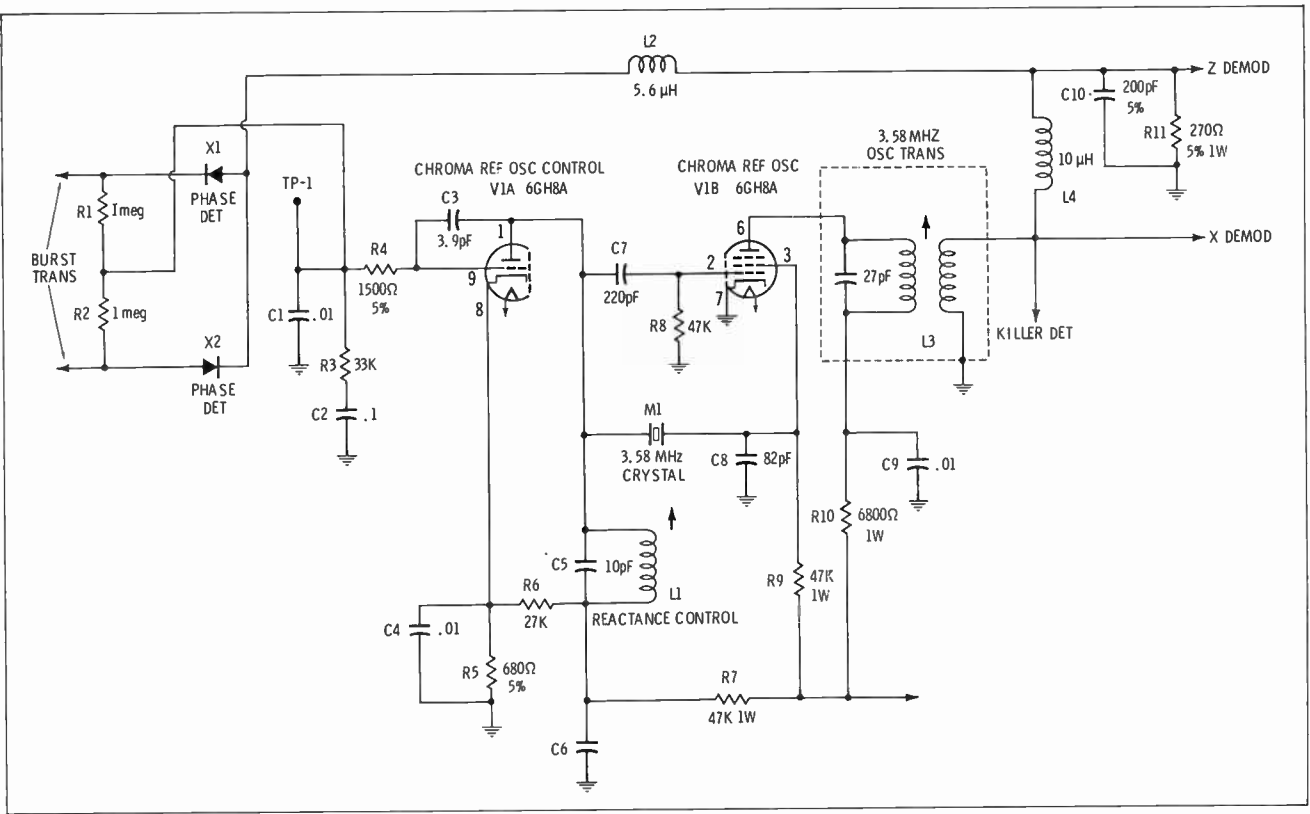Fig. 4-14. Crystal ringing produced by a strong noise pulse.

WAVEFORM ANALYSIS

Fig. 4-15 shows a typical subcarrier oscillator and control circuit. The phase detectors X1 and X2 compare the frequency and phase of the oscillator output with the color burst. The control voltage may swing positive or negative, depending upon whether the oscillator tends to run too fast or too slow. This control voltage is applied to a

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Fig. 4-15. Typical subcarrier oscillator and control circuit.

Labels within the figure:

BURST TRANS

X1 PHASE DET

X2 PHASE DET

R1 1meg

R2 1 meg

TP-1

C1 .01

R3 33K

C2 .1

R4 1500Ω 5%

CHROMA REF OSC CONTROL V1A 6GH8A

C3 3.9pF

9 8 1

C7 220pF

R8 47K

CHROMA REF OSC V1B 6GH8A

2 6 3 7

L2 5.6 µH

3.58 MHZ OSC TRANS

27pF

L3

C10 200pF 5%

R11 270Ω 5% 1W

10 µH L4

Z DEMOD

X DEMOD

KILLER DET

M1 3.58 MHz CRYSTAL

C8 82pF

C9 .01

R6 27K

C5 10pF L1 REACTANCE CONTROL

C4 .01

R5 680Ω 5%

R9 47K 1W

R10 6800Ω 1W

R7 47K 1W

C6

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reactance tube, V1A, which shunts a controlled capacitance across crystal M1. A positive control voltage increases the shunt capacitance, and a negative control voltage decreases the shunt capacitance. Since the quartz crystal can be tuned over a limited frequency range by shunt capacitance, the control circuit keeps the subcarrier oscillator on frequency and in phase with the color burst.

Output from the subcarrier oscillator in Fig. 4-15 is split into two phases by the LCR output network, and fed as the X phase and as the Z phase to the following chroma demodulators. In this example, the X and Z phases are 85° apart in normal operation. When trouble-shooting the oscillator and control section, the first step is to check the waveforms from the burst transformer at the top of R1 and at the bottom of R2. These waveforms normally appear as illustrated in Fig. 4-16A and B, respectively. Although the waveform amplitudes will vary with the incoming signal level, the important requirement is that both waveforms have the same amplitude. The average amplitude is about 80 volts pk-pk.

BURST COMPONENT

SAWTOOTH COMPONENT

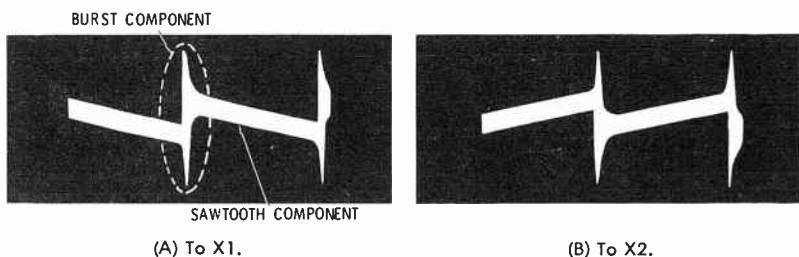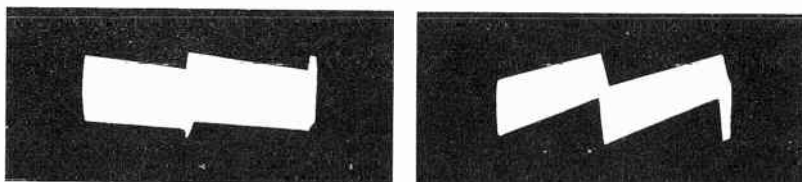(A) To X1.   (B) To X2.

Fig. 4-16. Input waveforms.

Note in Fig. 4-16 that the input waveforms normally have the same shape, except that they are reversed in polarity. If abnormal wave-forms are observed, we know that the trouble is not in the oscillator and control section, but that the fault will be found in the preceding burst-amplifier section. Conversely, if the input waveforms are normal, we will proceed to make systematic waveform checks through the os-cillator and control section. There is one exception, however, to be kept in mind. That is, in case X1 or X2 is defective in Fig. 4-15, an abnormal load will be placed on the burst transformer, and the input waveforms will be distorted to some extent. Let us see how loading affects these waveforms.

Diodes X1 and X2 in Fig. 4-15 are a matched pair. If either of the diodes develops a poor front-to-back ratio, the phase-detector system becomes unbalanced. This unbalanced loading causes the input to be-come unsymmetrical, as seen in Fig. 4-17. These distorted waveforms do not have the same shape, compared with normal operational wave-

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forms. Unbalanced loading also causes an increase in crosstalk from the subcarrier oscillator. Thus, the distorted waveforms in Fig. 4-17 are considerably broader than the normal waveforms in Fig. 4-16. With this large unbalance in the phase-detector circuit, no color is reproduced in the picture because the bandpass amplifier remans cut off by the color killer.

WAVEFORMS ARE NOT MIRROR IMAGES OF EACH OTHER

Fig. 4-17. Waveforms showing defective diode.

CHROMA HUNTING

Next, let us consider the cause and effect of *hunting* in the phase-detector and subcarrier-oscillator system. We know that when hunting occurs in the afc section of a black and white receiver, the result is a pie crust symptom, as shown in Fig. 4-18. Pie crust distortion is caused by over-correction in the high-frequency direction, followed by over-correction in the low-frequency direction. Defective capacitors are the most common troublemakers in this situation. When hunting occurs in the phase-detector and subcarrier-oscillator system, the result is barber-pole interference in the color picture, without loss of color sync lock.

For example, suppose that C2 is open in Fig. 4-15. This defect causes a hunting symptom in the color picture. Since the hunting waveform is applied to the phase-detector diodes, the input waveforms

Fig. 4-18. Pie crust symptoms.

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become broader than normal—compare Fig. 4-19 with Fig. 4-16. Normally, the combined filtering action of C2 and C1 in Fig. 4-15 is sufficiently complete and practically no 3.58-MHz voltage is present at TP-1. However, if C2 is open, the filtering action is incomplete, and a scope test at TP-1 shows a 3.58-MHz waveform (Fig. 4-20) with an amplitude of 0.5 volt pk-pk. The most prominent waveform clue to the trouble is this appearance of a 3.58-MHz waveform at TP-1.

BURST COMPONENT NORMAL

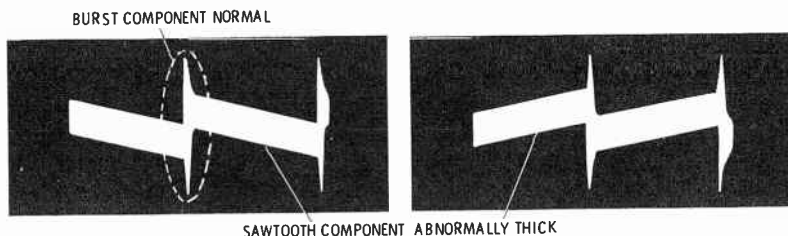SAWTOOTH COMPONENT ABNORMALLY THICK

Fig. 4-19. Input waveforms are thickened when the color-sync section is hunting.

In case the picture has weak color and unstable color sync lock, C9 may be open in Fig. 4-15. Let us see why this result occurs. In normal operation, 3.58-MHz voltages are applied to the X and Z demodulators. However, if C9 is poen, the 3.58-MHz voltage across the primary of L3 is reduced by lack of bypassing around R10. In turn, the amplitude of the X and Z output waveforms is reduced from the normal value of 23 volts pk-pk to 7 volts pk-pk. Note Fig. 4-20A, that normally, a scope check shows no 3.58-MHz voltage across C9. On the other hand, Fig. 4-20B, when C9 is open, we find a 3.58-MHz waveform present at an amplitude of 130 volts pk-pk.

(A) No subcarrier voltage feeds out in normal operation.

(B) Subcarrier voltage is fed out when filtering action is defective.

Fig. 4-20. Waveforms across C9 in Fig. 4-15.

Color reproduction is weak when C9 is open, because insufficient subcarrier voltage is being injected into the X and Z demodulators to obtain normal output. That is, the chroma demodulators are driven into conduction on the peaks of the injected subcarrier voltage in normal operation, but when C9 is open, the reduced injection voltage causes marginal demodulator action. Unstable color sync lock also occurs, because subnormal comparison voltage is fed back to the

phase-detector diodes in Fig. 4-15 when C9 is open. In turn, insufficient control voltage is fed to V1 and the pull-in range of color-sync action is greatly reduced.

BURST-AMPLIFIER TROUBLES

Thus far, we have assumed that the input waveforms have a normal burst component (see Fig. 4-16). Now, let us consider the situation in which the sawtooth component is present, but the burst component is absent. This waveform clue points to a defect in the burst amplifier. A typical burst-amplifier circuit was shown in Fig. 4-9B. If C1 opens up, or if C5 shorts, the burst signal disappears. Misalignment of T1 causes either a weakened burst signal, or complete absence of output signal. If C6 opens up, the burst output is greatly weakened. A short circuit in C4 increases the amplitude of the burst output, and also permits random chroma signal to enter the color-sync section. The result is that color sync lock becomes erratic.

However, we must not assume that a weak output from the burst amplifier is always due to a defective component in the burst-amplifier circuit. Poor alignment in the i-f amplifier can weaken both the burst signal and the chroma signal. In turn, color sync range is impaired, and color reproduction is weak, even though the color-intensity control is advanced to maximum. It follows that if color reproduction is normal, but the burst output from the burst amplifier is weak, we will look for the trouble in the burst-amplifier circuit. Otherwise, we will suspect that the i-f amplifier is supplying a subnormal chroma signal.

SUMMARY

Color-sync waveforms are not the same in theory and practice; circuit action causes practical waveforms to have sloping sides and rounded corners.

When a horizontal sync pulse passes through a circuit that has limited bandwidth, the sync pulse becomes partially integrated, or "feathered."

A differentiated pulse can acquire a broadened peak excursion by means of subsequent integrating circuit action.

Good color sync lock requires that the burst-keying pulse be correctly timed to coincide with the color burst.

The output waveform from a burst amplifier has sloping sides and pointed peaks.

A burst waveform can be expanded by means of a triggered-sweep scope in order to inspect the waveform details.

Color receivers often use a crystal ringing circuit followed by a limiter to reconstitute the color-subcarrier signal.

The output waveform from a ringing crystal decays slowly between color bursts, but the amplitude of the output waveform is maintained constant by a limiter circuit.

Strong noise pulses can ring a quartz crystal, and may cause touchy color-sync action.

Some color receivers use a reactance tube to control the frequency and phase of the subcarrier oscillator.

Waveform analysis at the input of a phase-detector circuit will show the presence of a defective diode.

Color-sync hunting can be compared with hunting in the black-and-white horizontal afc circuit.

Hunting in the color-sync section produces barber-pole interference in the picture, without loss of color sync lock.

Open capacitors in the color-sync section can often be pinpointed by waveform analysis.

Apparent burst-amplifier trouble is sometimes due to i-f misalignment.

REVIEW QUESTIONS

1. If the horizontal-hold control is set near one end of its range, what effect would you expect with regard to color-sync action?
2. Why does the output waveform from the burst amplifier have sloping sides and pointed peaks?
3. With reference to Fig. 4-13A, estimate the percentage of decay of a crystal ringing waveform from one color burst to the next.
4. Why does the input waveform to the burst phase-detector circuit have both a sawtooth component and a burst component?
5. Explain why the input waveform becomes thickened when the color-sync section is *hunting*.
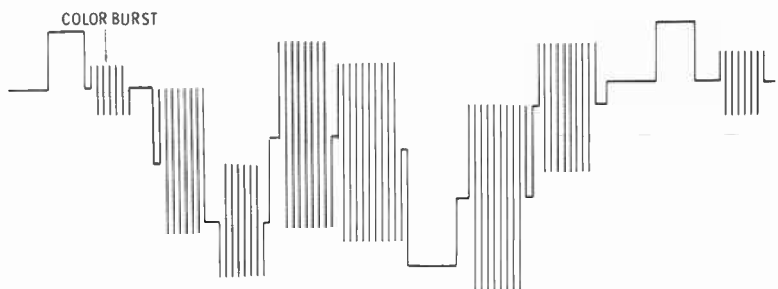
5

Scoping the
Bandpass Amplifier and
Chroma Demodulators

Waveform checks in the bandpass-amplifier section include peak-to-peak voltage measurements of chroma waveforms, observation of waveshapes, and the checking of frequency-response curves. The basic procedure is to make an evaluation of chroma waveforms; if waveform distortion is present, we follow up by checking the bandpass frequency response. In case the bandpass amplifier cannot be aligned correctly, or if the bandpass gain is subnormal, we know that a component defect is responsible. Waveform analysis usually serves to localize the faulty circuit, and will sometimes pinpoint the defective component. If necessary, dc voltage and resistance measurements are made to locate the defective component.

BANDPASS-AMPLIFIER CIRCUIT ACTION

The function of the bandpass amplifier is to separate the chroma signal from the complete color signal, as shown in Fig. 5-1. The Y signal is rejected, and the chroma signal is passed. Since the horizontal sync pulse is a part of the Y signal, the sync pulse is rejected. Some bandpass amplifiers have an output waveform which contains the color burst, as seen in Fig. 1; other bandpass amplifiers blank out the color burst and pass the chroma-bar signals only. Since the input and output waveform amplitudes are different in various receivers, it is necessary to check the service data for the particular receiver in question.
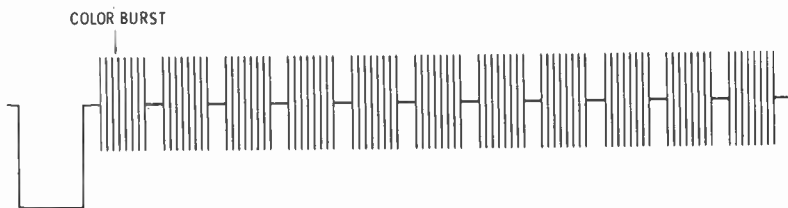
The waveforms depicted in Fig. 5-1 are idealized. In practice, we find that the chroma waveforms are not perfectly rectangular. This
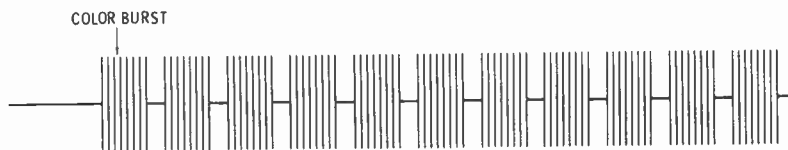
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(A) Complete color-signal input (NTSC generator).

(B) Bandpass amplifier output.

(C) Keyed rainbow signal input.

(D) Bandpass amplifier output.

Fig. 5-1. Color signal waveforms.

change in waveshape is caused chiefly by the limited bandwidth of the bandpass amplifier. Fig. 5-2A shows a typical bandpass-amplifier circuit, and its normal frequency-response curve is seen in Fig. 5-2B. Since the chroma signal has upper and lower sidebands centered on 3.58-MHz, the bandwidth of this circuit is approximately 0.5 MHz. Therefore, the rise time of the bandpass amplifier is about 0.6 microsecond. The result of limited bandwidth is to produce sloping sides

and rounded corners in the output waveform, as illustrated in Fig. 5-3. Remember that the bandwidth (in MHz) times the rise time (in μs) is approximately equal to unity for good pulse reproduction.

We will also find that limited bandwidth causes the output pulses to have a greater width than input pulses. That is, the bandpass amplifier tends to "stretch" the input pulses as a result of the sloping sides

(A) Circuit.

(B) Frequency response.

Fig. 5-2. Typical bandpass amplifier.

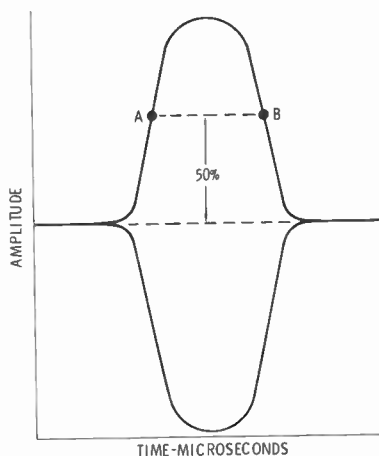that are introduced. With reference to Fig. 5-4, pulse width is measured at the 50-percent points on the pulse. If the bandpass amplifier has subnormal bandwidth, the width of the output pulses is increased. Although pulse widths can be measured easily with a triggered-sweep scope, most shops use service-type scopes. Therefore, it is general practice to evaluate pulse widths indirectly by means of vectorgrams, as explained later in the chapters.

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Fig. 5-3. Bandpass-amplifier output waveform has sloping sides and rounded corners.

CHROMA–DEMODULATOR CIRCUIT ACTION

The output from the bandpass amplifier is fed to the chroma demodulators (chroma detectors, color detectors). At least two chroma demodulators are provided, and sometimes three. Fig. 5-5 shows various demodulator arrangements in present use. Most configurations provide color-difference outputs $(R - Y, B - Y,$ or $G - Y)$. However, some receivers provide complete color-signal outputs (red, blue, and green signals). If a demodulator configuration develops two color-difference signals, the third color-difference signal is usually produced by a matrix. However, there is one common exception. Let us briefly review the basic circuit actions in Fig. 5-5.

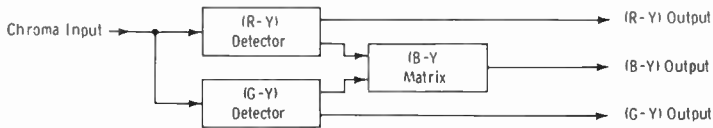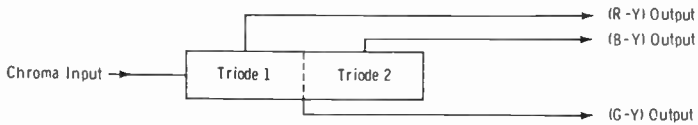1. $R - Y$ and $B - Y$ signals are demodulated; the $G - Y$ signal is matrixed.
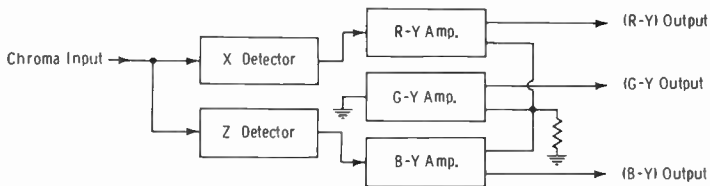

Fig. 5-4. Pulse width is measured from A to B.

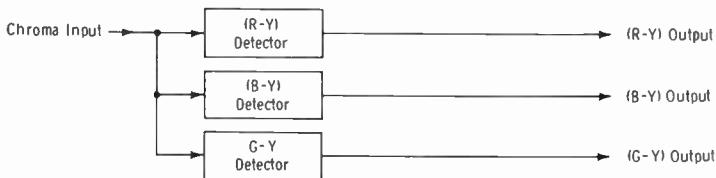(A) R — Y and B — Y demodulated; G — Y matrixed.
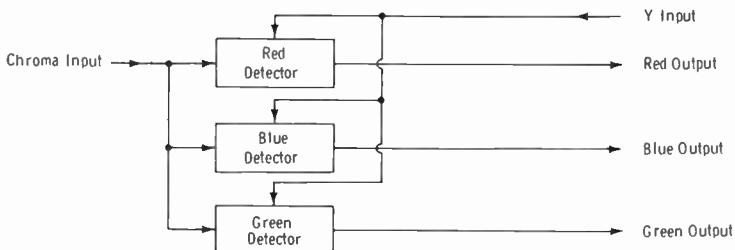

(B) R — Y and G — Y demodulated, B — Y matrixed.

(C) R — Y and B — Y demodulated; G — Y bootstrap matrixed.

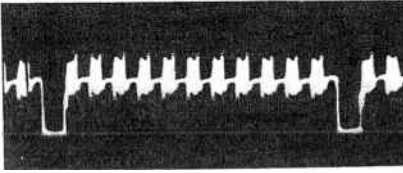
(D) X and Z demodulated; R — Y, B — Y, and G — Y matrixed.

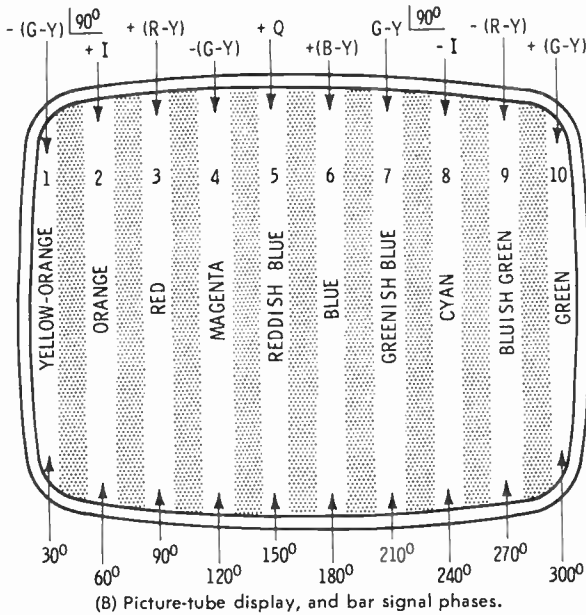(E) R — Y, B — Y, and G — Y demodulated.

(F) R, G, and B demodulated; Y and chroma matrixed.

Fig. 5-5. Chroma demodulator configurations.

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(A) Input waveform to bandpass amplifier.

(B) Picture-tube display, and bar signal phases.

Fig. 5-6. Keyed rainbow signal.

2. $R - Y$ and $G - Y$ signals are demodulated; the $B - Y$ signal is matrixed.
3. $R - Y$ and $B - Y$ signals are demodulated; the $G - Y$ signal is matrixed in a common-cathode circuit.
4. X and Z signals are demodulated; $R - Y$, $B - Y$, and $G - Y$ signals are matrixed.
5. $R - Y$, $B - Y$, and $G - Y$ signals are demodulated.
6. Red, blue, and green signals are demodulated; the chroma detectors do double duty as RGB matrixes.

Note in Fig. 5-5 that the end result is the same in diagrams A through E. That is, each system produces $R - Y$, $B - Y$, and $G - Y$ signals, which are applied to the grids in the color picture tube. In turn, the Y signal is applied to the cathodes of the picture tube, and RGB matrixing occurs in the picture tube. However, there is a basic difference in the arrangement of Fig. 5-5F. The end result is the de-

velopment of R, G, and B signals which are applied to the cathodes in the picture tube; no signal input is applied to the grids. That is, the picture tube does not operate as a matrix in this arrangement. We will analyze matrix operation in greater detail in the next chapter.

It is helpful at this point to briefly review the chroma phases in a keyed rainbow signal. Normally, $R - Y$ is represented by the third bar, $B - Y$ is represented by the sixth bar, and $G - Y$ is represented by the tenth bar. Note that $R - Y$ and $B - Y$ are quadrature signals,
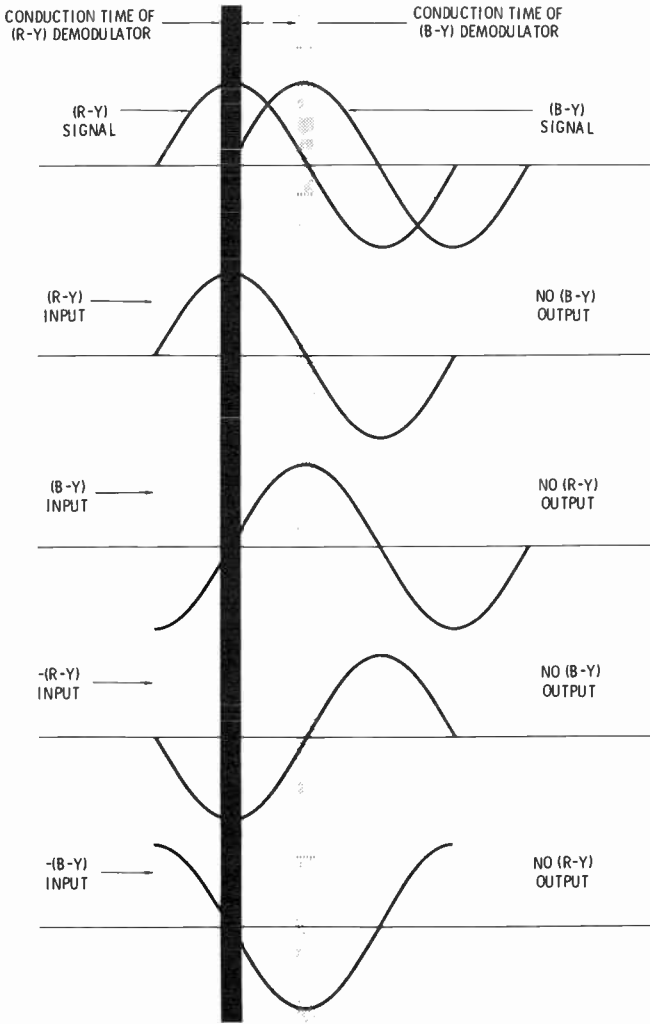

Fig. 5-7. Examples of signal sampling by R — Y and B — Y demodulators.

since they have a 90° phase difference. Similarly, $G - Y$ and $G - Y$ /90° are quadrature signals, and are separated by 90°. Also, I and Q are quadrature signals. With reference to Fig. 5-5, the $R - Y$ and $B - Y$ detectors are quadrature demodulators. As shown in Fig. 5-7, the incoming signals are sampled. As the $R - Y$ signal goes through its peak, the $B - Y$ signal is going through zero. Thereby, the $R - Y$ and $B - Y$ signals are separated by the demodulators.
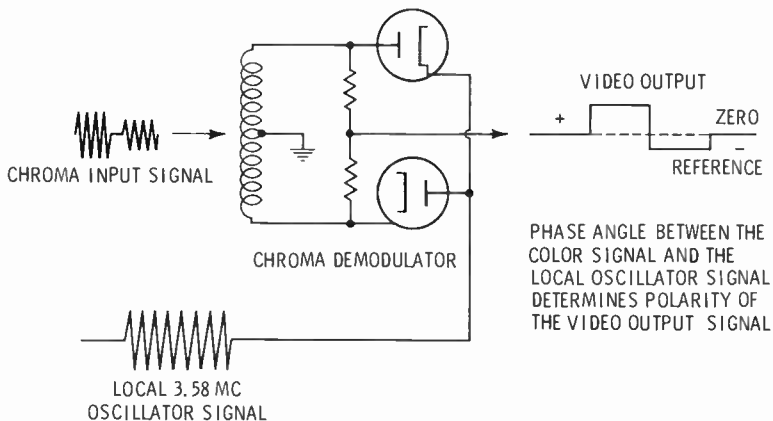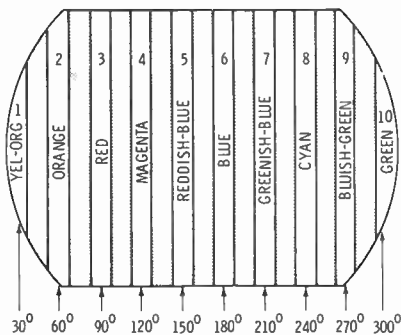

Fig. 5-8. A basic chroma-demodulator circuit.

The conduction time (sampling time) of each chroma demodulator is determined by the injected 3.58-MHz oscillator signal, as depicted in Fig. 5-8. That is, a demodulator diode conducts only on the peak of the injected oscillator signal. It is obvious from Fig. 7 that correct chroma demodulation depends on the correct phase of the injected oscillator signal. If there is a component defect in the circuitry between the 3.58-MHz oscillator and a chroma demodulator, distortion will occur in the demodulator output waveform. In turn, incorrect colors will be displayed on the picture-tube screen. Let us now consider the analysis of normal and abnormal demodulator waveforms.
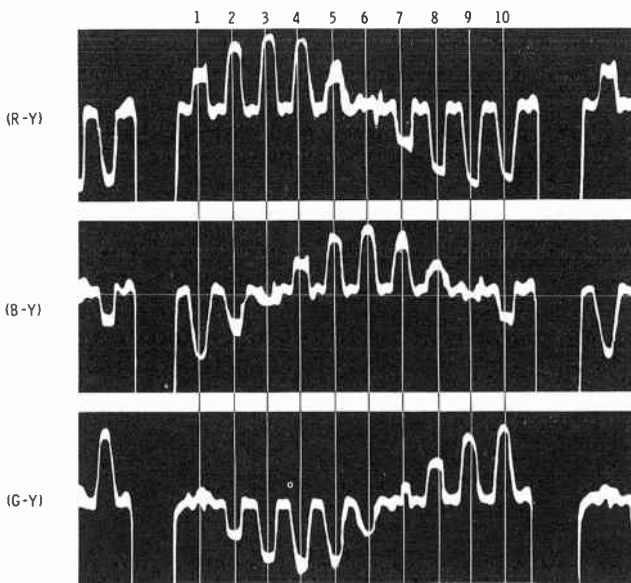
CHROMA-DEMODULATOR WAVEFORM ANALYSIS

The input waveform to the bandpass amplifier is illustrated in Fig. 5-6A. We know that the output waveform is modified somewhat, and has sloping sides and rounded corners, as is illustrated in Fig. 5-3. We will find that the chroma demodulators also have limited bandwidth (approximately 0.5 MHz), which further modifies the pulse shapes that we observe at the outputs of the chroma demodulators. Fig. 5-9 shows a keyed rainbow color-bar pattern, with the ideal $R - Y$, $B - Y$, and $G - Y$ demodulator output waveforms. However, due to

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(A) Picture tube display of color-bar signal.

(B) Ideal signals at red, blue, and green guns with bar pattern input to receiver.

(C) Practical waveforms displayed on scope screen.

Fig. 5-9. Demodulated chroma waveforms.

limited bandwidth in the bandpass amplifier and in the chroma demodulators, the actual waveforms display rounded pulses.
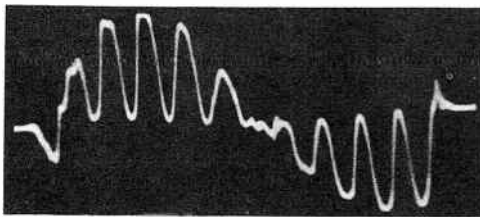
In normal operation, the $R - Y$ waveform nulls on the sixth bar; the $B - Y$ signal nulls on the third and ninth bar; the $G - Y$ signal nulls on the first and seventh bars. If one of the waveforms displays incorrect nulls, a component defect or misalignment will be found in the associated circuit. Of course, a defective component that is common to both the $R - Y$ and $B - Y$ demodulator sections will cause

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incorrect nulls in both the $R - Y$ and $B - Y$ output waveforms. In addition to having incorrect nulls, a distorted waveform often has incorrect amplitude also. Some defects (such as weak diodes) will cause subnormal waveform amplitude, although the nulls will appear to be correct.
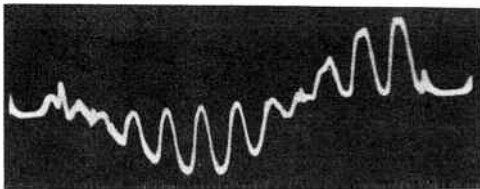
Next, we will find that the baseline in a demodulated waveform changes when the circuit bandwidth is subnormal. The normal situation is seen in Fig. 5-9C; each pulse in the waveforms rests on a horizontal baseline. If you observe carefully, you will note that the pulse baseline is not perfectly straight, but is slightly curved. This is least evident in the $R - Y$ waveform, but is noticeable in the $B - Y$ and $G - Y$ waveforms. Now, let us consider the waveform distortion produced by subnormal bandwidth. With reference to Fig. 5-10, we observe:

1. The $B - Y$ waveform has a large curvature in the baseline; therefore, the bandwidth of the $B - Y$ channel is subnormal.
2. There is a small amount of curvature in the baseline of the $G - Y$ waveform; this curvature is within normal circuit tolerance, and the bandwidth of the $G - Y$ channel is acceptable.
3. There is only a slight amount of curvature in the baseline of the $R - Y$ waveform; therefore, the bandwidth of the $R - Y$ channel is acceptable.
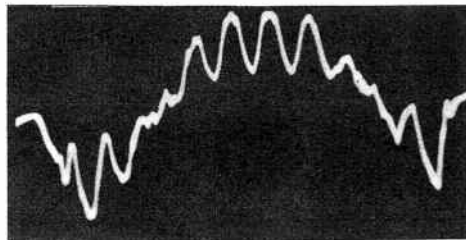
Let us see why subnormal bandwidth causes baseline curvature in a keyed rainbow waveform. In our analysis of bandpass-amplifier circuit action, it was noted in Fig. 5-4 that limited bandwidth causes the pulse
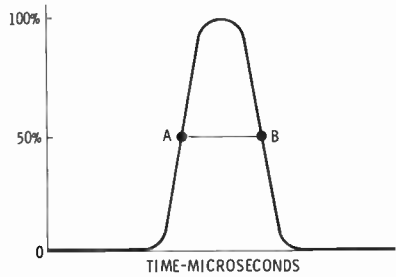

(A) R — Y waveform.

(B) G — Y waveform.

(C) B — Y waveform.

Fig. 5-10. The B — Y channel has subnormal bandwidth.

Fig. 5-11. Pulse width is measured from A to B.

width to increase. The same principle applies to demodulator-circuit action. That is, the width of the demodulated pulse (Fig. 5-11) increases when the demodulator bandwidth becomes narrower. Since the pulses in a keyed rainbow waveform follow one another rapidly, a straight baseline can occur only if one pulse decays to zero before the next pulse starts. In other words, if the first pulse is not completed before the next pulse starts the baseline is effectively displaced.

We can now understand why it is unnecessary to measure pulse widths when checking demodulator output waveforms. Excessive pulse width shows up clearly as a baseline curvature, and this is the bandwidth clue that we look for. With reference to Fig. 5-12, component
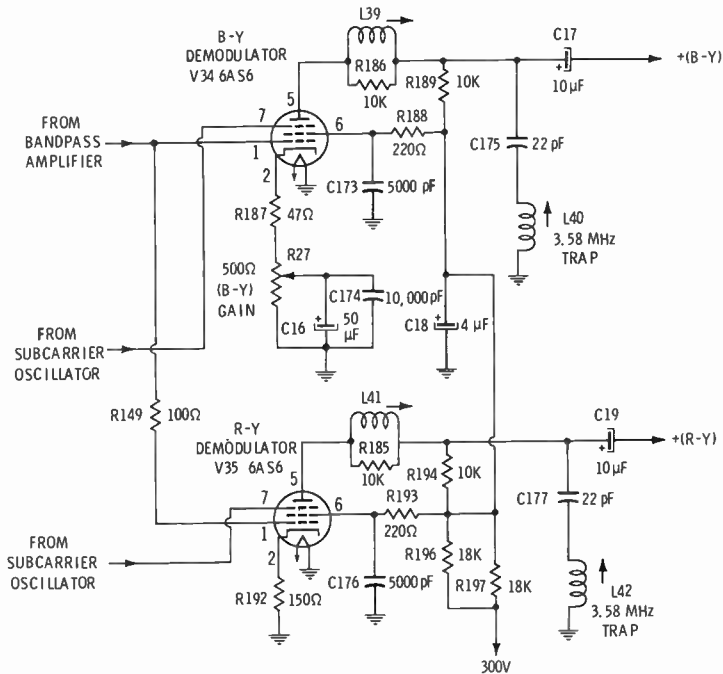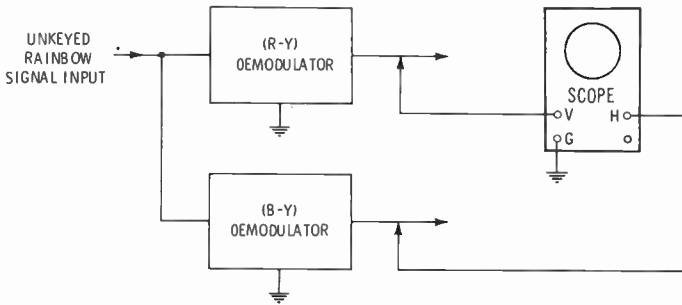

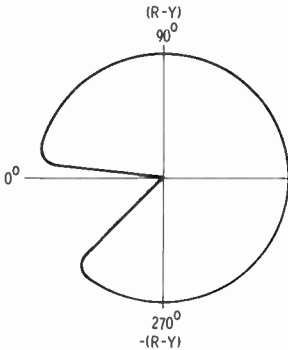Fig. 5-12. An R — Y and B — Y demodulator circuit.

defects that can cause subnormal bandwidth are off-value plate-load resistors, defective plate-bypass capacitor, misaligned subcarrier traps, or misaligned plate inductors. Since the demodulators are driven by the bandpass amplifier, curved baselines in demodulator waveforms can also be caused by misalignment (or a component defect) in the bandpass amplifier.

VECTORSCOPE PRINCIPLES AND APPLICATIONS

A vectorscope operates from a pair of demodulator-output waveforms, such as the $R - Y$ and $B - Y$ signals. Its advantage is that a vectorgram shows the over-all action of two chroma channels simultaneously, and saves time. The basic operation of a vectorscope is depicted in Fig. 5-13. This is the simplest arrangement, in which the color receiver is driven by an unkeyed rainbow signal. There are several facts to be noted, as follows:
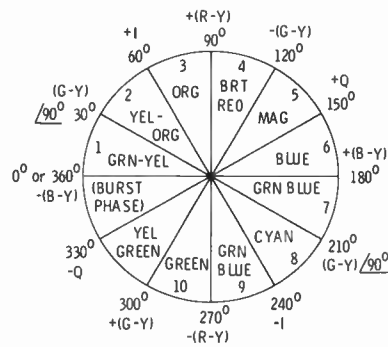

(A) Vectorgram test setup.

CIRCLE WAVEFORM AS SEEN WITH OSCILLOSCOPE
IN PROPERLY ADJUSTED (R-Y), (B-Y) DEMODULATORS

(B) Normal pattern.

(C) Chroma phases in the vectorgram pattern.

Fig. 5-13. Basic vectorscope connections and normal vectorgram.

1. An ellipse will usually be displayed on the screen, instead of a circle. In normal operation of the chroma circuits, we can change the ellipse into a circular vectorgram by adjustment of the vertical or horizontal gain controls of the scope.
2. A "pie cut" normally appears in the vectorgram pattern. This is produced by the horizontal blanking pulse.
3. If the hue control of the receiver is turned, the vectorgram is rotated, but its shape is not changed.
4. When the hue control is adjusted correctly, the $-(B - Y)$ and $-Q$ points are absent in the vectorgram, due to the "pie cut."
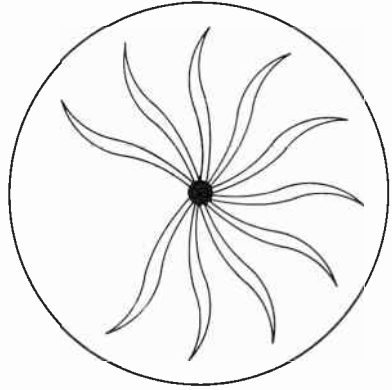

Fig. 5-14. Keyed rainbow vectorgram.

Next, if we apply a keyed rainbow signal to the color receiver, the basic vectorgram normally appears as shown in Fig. 5-14. This pattern is easier to evaluate than the circular vectorgram in Fig. 5-13, because each "petal" indicates a particular chroma phase. We observe that the third petal (pointing straight up in Fig. 5-14) represents the $R - Y$ phase; the sixth petal (pointing to the right) represents the $B - Y$ phase, and so on. It is helpful to start by considering the development of an ideal vectorgram, as shown in Fig. 5-15. Note that the ideal pattern has perfectly straight sides, and that the top of each "petal" is a circular arc.

In practice, the "petal" shapes are not ideal. The reason for this is seen in Fig. 5-9. That is, the demodulator output waveforms do not have perfectly straight sides and tops that are sectors of a sine wave. Instead, the sides of the pulses are actually curved; the sides of the pulses slope, and the tops are rounded off, as seen in Fig. 5-9C. The practical result is that the "petals" are curved and have more or less pointed peaks, as depicted in Fig. 5-14. We will find that vectorgram waveshapes are different in various color receivers. In normal operation, circuit tolerances produce small pattern variations. We are not concerned with normal tolerances—however, if a vectorgram shows

distortions that are out of normal tolerance, we know that a circuit defect is present.

With reference to Fig. 5-13, the demodulator output signals are being applied to the vertical and horizontal input terminals of the scope. This is a useful method, provided that the scope amplifiers have frequency response up to 1.5 MHz. However, since most service-type scopes have limited horizontal-amplifier bandwidth, we must often use another test method. That is, if the demodulator signal is passed through a horizontal amplifier that has limited bandwidth, the vector-gram will be distorted, and the distortion will be falsely charged to the receiver.

Therefore, service-type scopes that are designed for use as a vector-scope usually provide for coupling the $R - Y$ and $B - Y$ signals directly to the deflection plates in the CRT. For example, a terminal board is commonly mounted on the rear of the scope case for this purpose. When we couple the test signals directly to the deflection plates in the CRT, there is an important requirement that we must keep in
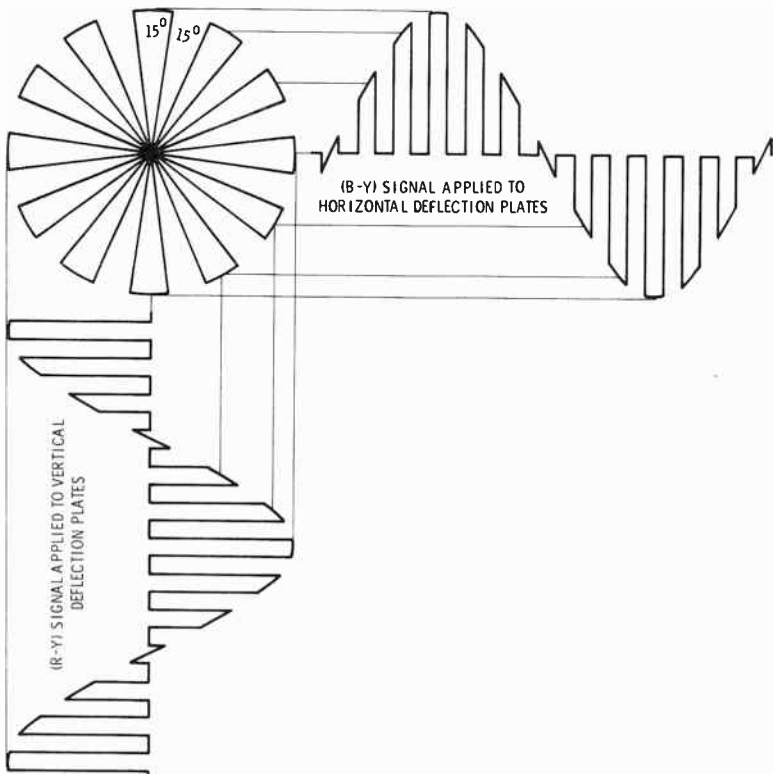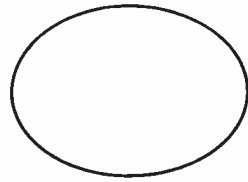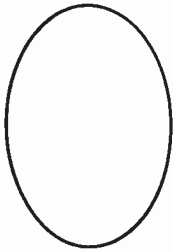

Fig. 5-15. Development of an ideal vectorgram.

(A) R — Y signal greater than B — Y signal.   (B) B — Y signal greater than R — Y signal.

Fig. 5-16. Basic elliptical vectorgrams.

mind. That is, at least 100 volts pk-pk must be applied to obtain a pattern of useful size. This means that we cannot use the output signals from the chroma demodulators, but must employ the high-level signals that are present at the red and blue grids (red and blue leads) to the color picture tube.

We know that when test signals are coupled directly to the deflection plates in the CRT, that the vertical and horizontal gain controls of the scope are inoperative. Otherwise stated, we then have no control over horizontal and vertical gain in the vectorgram. Since the R — Y and B — Y channel gains are normally somewhat different in a color receiver, we must work with elliptical patterns instead of circular patterns. The basic elliptical vectorgram outlines are shown in Fig. 5-16. In most color receivers, the R — Y signal is somewhat greater than the B — Y signal. Therefore, we will usually observe an elliptical envelope such as shown in Fig. 5-16A.

Fig. 5-17 shows a typical vectorgram for a color receiver in normal operation. In this example, the outline is nearly circular. If the hue control of the receiver is turned, the vectorgram will be rotated, but its shape will remain unchanged. We adjust the hue control to place the third "petal" at the R — Y position on the graticule. Then, the sixth "petal" normally falls at B — Y position on the graticule. The following facts should be noted:
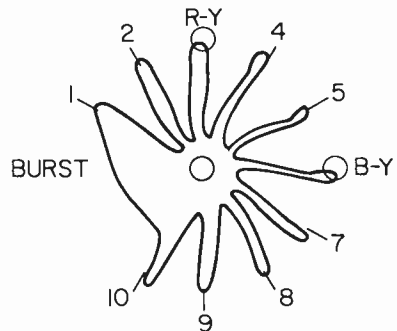
Fig. 5-17. Normal vectorgram for a Zenith receiver.

1. Since the pattern in Fig. 5-17 is practically circular, each "petal" can be checked with respect to the graticule phase calibrations.
2. Although the fourth, sixth, seventh, and tenth "petals" are not in exactly correct positions, the displacement is within normal circuit tolerances.
3. The "petals" do not extend into the center of the screen. However, their approach to center-screen is sufficient to indicate normal bandwidth of the $R - Y$ and $B - Y$ signal channels.
4. The essentially correct placement of the third and sixth "petals" at their tips ($R - Y$ and $B - Y$ positions) shows that the subcarrier voltage is being injected correctly at practically 90° phase difference into the $R - Y$ and $B - Y$ demodulators.

ANALYSIS OF INCORRECT DEMODULATOR PHASES

Next, let us consider the symptoms of a demodulator phase error. As before, the output signal from the $R - Y$ channel is being applied to the vertical-deflection plates, and the output signal from the $B - Y$ channel is being applied to the horizontal-deflection plates in the vectorscope CRT. If the subcarrier voltage is injected into the demodulators with incorrect phase (more or less than a 90° phase difference), we observe an inclined ellipse on the vectorscope screen, such as depicted in Fig. 5-18. Therefore, we must look for a defective component or misadjustment in the $R - Y$ and $B - Y$ demodulator circuits.
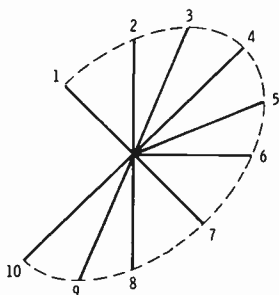

Fig. 5-18. Inclined ellipse indicates a demodulation phase error.

After the defect is corrected, and the subcarrier voltage is injected into the $R - Y$ and $B - Y$ demodulators with a 90° phase difference, the inclined ellipse will have vertical and horizontal axes, as shown in Fig. 5-16A. There is a basic difference between an inclined ellipse (Fig. 5-18) and a vertical or horizontal ellipse (Fig. 5-16). A vertical or horizontal ellipse can be changed into a circle by adjustment of gain; on the other hand, an inclined ellipse cannot be changed into a circle by adjustment of gain. For example, suppose that an inclined ellipse is displayed when using the test method shown in Fig. 5-13A.
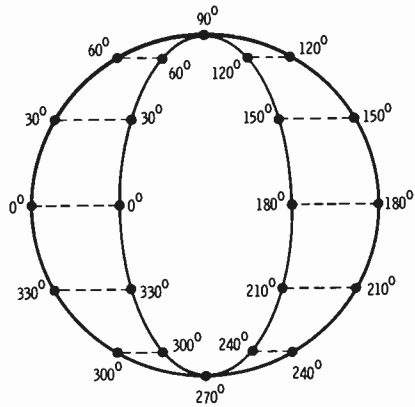
Fig. 5-19. Locating phase angles on an ellipse.

We will find that no adjustment of the vertical and horizontal gain controls can change the inclined ellipse into a circle, because a phase error exists in the subcarrier voltages.

Another important fact is illustrated in Fig. 5-19. When we are evaluating an ellipse, as shown in the diagram, the phase angles on the ellipse are found by projecting across from the calibrated circle on the vectorscope graticule. For example, the 30° point on the ellipse is on a horizontal line from the 30° point on the circle. Similarly, the 60° point on the ellipse is on a horizontal line from the 60° point on the circle. The 90° points coincide on both the ellipse and the circle, because the major axis of the ellipse passes through the 90° point of the circle. Unless the method of locating phase angles on an ellipse is kept in mind, we can easily make an incorrect measurement.

We know that the demodulation angles are correct in Fig. 5-19, and are 90° different in phase because the major and minor axes of the ellipse fall along the vertical and horizontal axes of the vectorscope screen. Next, let us suppose that the demodulation angles are incorrect, and that we wish to measure the phase difference between them. In this case, the vectorgram will have the outline of an inclined ellipse, as depicted in Fig. 5-18. To measure the phase angle between the injected subcarrier voltages, we use the method shown in Fig. 5-20. The ellipse must be carefully centered on the vectorscope screen. Then, we calculate the ratio of the distances M and N. In this example, M/N = 0.75; we consult a table of sines, and find that the demodulation angle is approximately 49°.

Returning to Fig. 5-17, it is helpful to repeat a basic point which applies to any vectorgram. Note that the "petals" approach the center of the screen and form an inner pattern outline that has roughly a circular form. The outline of this inner pattern is not a true circle, because the R − Y and B − Y channels have somewhat different bandwidths. From a practical standpoint, the main requirement is that the

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inner pattern should not have an excessive diameter. If its diameter is substantially greater than shown in Fig. 5-17, we know that the system bandwidth is subnormal. This symptom is accompanied by an abnormal width of some or all of the "petals."

We should also note that if the gain of the R − Y channel is subnormal, the vectorgram will have an outline as shown in Fig. 5-16B. When the gain of the B − Y channel is subnormal, the vectorgram will have an outline as shown in Fig. 5-16A. To repeat an important point, the R − Y deflection will usually be a little greater than the B − Y deflection in normal operation. However, color receivers differ in this respect, and the receiver service data must be consulted to determine the peak-to-peak voltages that are normally applied to the red and blue grids of the color picture tube.
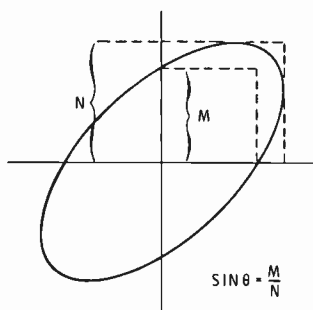

Fig. 5-20. Measuring the demodulation phase separation from an inclined ellipse.

$$SIN\theta = \frac{M}{N}$$

SUMMARY

Peak-to-peak voltage measurements of bandpass-amplifier and chroma-demodulator waveforms are as important as checks of waveshapes.

Typical bandpass amplifiers have a bandwidth of approximately 0.5 MHz.

Limited bandwidth causes an increase in pulse width.

Each bar in a keyed rainbow signal corresponds to a certain chroma phase.

Chroma-demodulator action can be checked by noting the nulls in the output waveform when the receiver is driven by a keyed rainbow signal.

Baseline curvature in a chroma-demodulator waveform indicates subnormal bandwidth in the demodulator circuit, or in the bandpass-amplifier circuit.

Waveforms observed in practice are not perfect; the basic requirement is that any distortion is within normal circuit tolerances.

A vectorscope is usually driven by the signal outputs from the R − Y and B − Y channels.
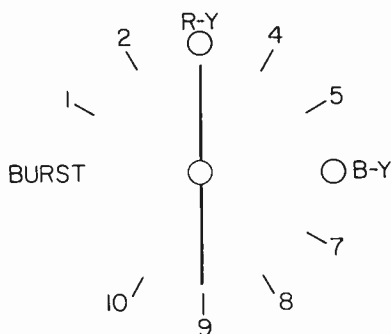
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Fig. 5-21. A vectorgram in which only a vertical trace is displayed.
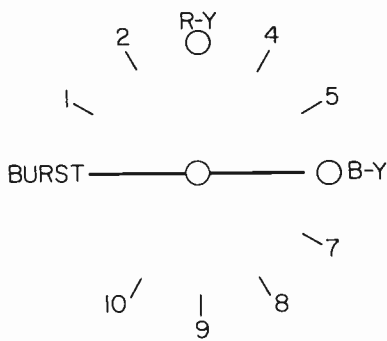

Fig. 5-22. A vectorgram in which only a horizontal trace is displayed.

Vectorgrams generally have more or less of an elliptical outline.

A vectorgram normally displays 10 "petals" when the receiver is driven by a keyed rainbow generator.

The major and minor axes of a vectorgram fall along the vertical and horizontal axes of the vectorscope graticule when the R − Y and B − Y demodulators are operating correctly.

Phase angles on the elliptical vectorgram must be located by projecting across to the phase calibrations on the vectorscope graticule.

An inclined elliptical vectorgram indicates that there is a phase error in the subcarrier voltages being injected into the R − Y and B − Y demodulators.

REVIEW QUESTIONS

1. Fig. 5-21 shows a vectorgram trouble situation wherein only a vertical trace is displayed. What conclusion do you draw in view of the fact that there is no deflection along the B − Y axis?
2. Fig. 5-22 shows a vectorgram trouble symptom wherein only a horizontal trace is displayed. What conclusion do you draw in view of the fact that there is no deflection along the R − Y axis?
3. If the keyed rainbow waveform at the output of a chroma demodulator has a large curvature in the baseline, what is the cause of the trouble?
4. If a vectorgram has shortened "petals" (excessively large circle in the inner portion of the pattern), what is the cause of the trouble?
5. Why is it usually impractical to feed a keyed rainbow signal through the horizontal amplifier of a service-type scope?
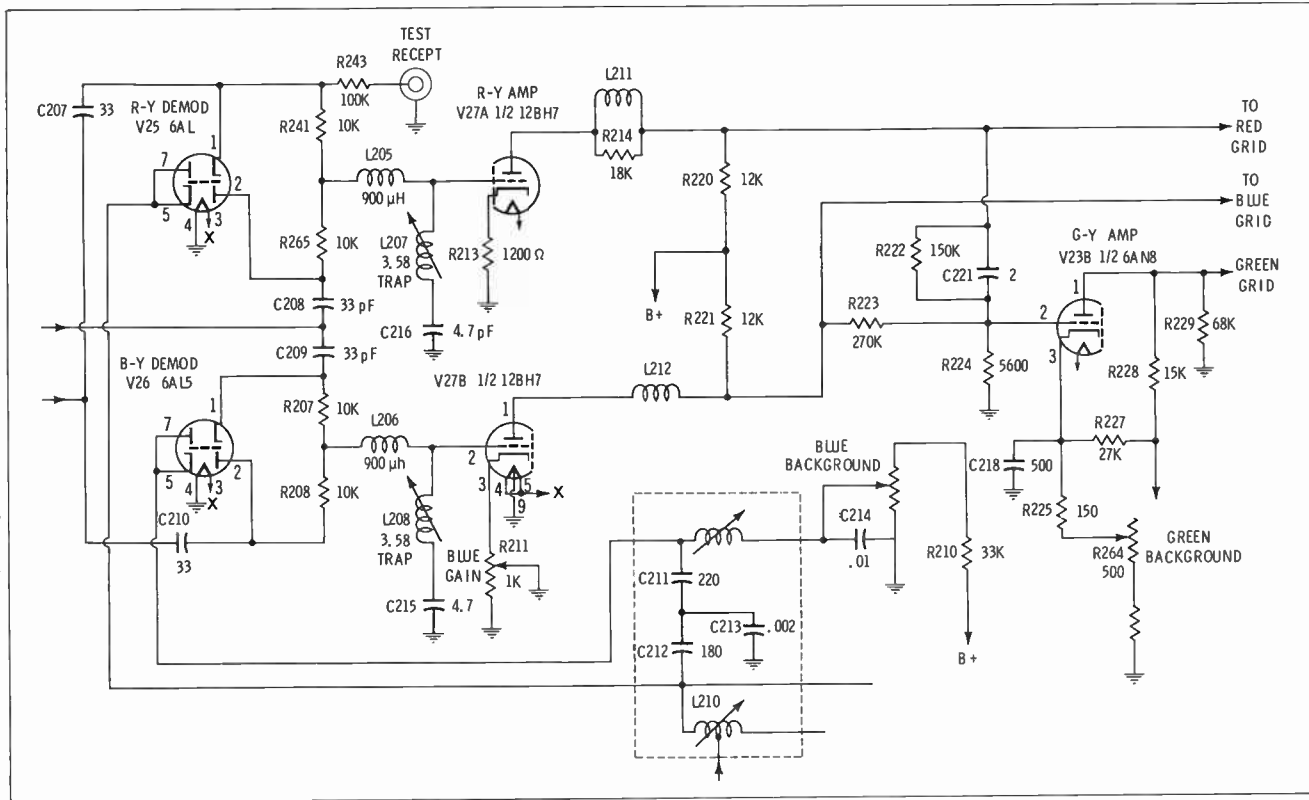
6

Matrix
Waveforms and Tests

Matrix waveforms are the same as chroma-demodulator waveforms in most cases. Evaluation of matrix waveforms is not as simple, however, because a matrix is driven by a pair of chroma demodulators. Incorrect nulls in a matrix waveform can be caused by a defect in one of the chroma demodulators, or by a fault in the matrix circuit. If the demodulators have been checked and are known to be operating normally, distortion or incorrect amplitude of a matrix waveform localizes the trouble to the matrix circuit. The result of most matrix defects is a distorted output waveform that has incorrect amplitude. However, a few components can cause only an abnormal amplitude if they develop faults.

G − Y MATRIX ANALYSIS

The G − Y matrix exemplified in Fig. 6-1 is the most basic type of chroma matrix. In normal operation, a scope check at the output of each section will display waveforms having the nulls shown in Fig. 6-2. Let us see how the G − Y waveform is produced by the matrix; and in turn, we will find how distorted waveforms are evaluated. With reference to Fig. 6-1, the output from the R − Y amplifier is the R − Y waveform depicted in Fig. 6-2. Similarly, the output from the B − Y amplifier is the B − Y waveform. These R − Y and B − Y waveforms are fed to the G − Y amplifier through resistive voltage dividers. In turn, the mixed waveforms appear as the G − Y waveform (Fig. 6-2) at the output of the G − Y amplifier.

Note in Fig. 6-1 that the voltage dividers in the G − Y matrix reduce the B − Y signal amplitude more than the R − Y signal ampli-

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Fig. 6-1. Typical G — Y matrix configuration.

tude. That is, the input signals to the G − Y matrix have the amplitudes shown in Fig. 6-3. These R − Y and B − Y input waveforms are 90° out of phase, and they add and subtract to produce the G − Y waveform shown in Fig. 6-3. This G − Y waveform is applied to the grid of the G − Y amplifier in Fig. 6-1. In turn, the plate output is inverted in polarity. The end result is to develop a +(G − Y) signal. Note in Fig. 6-3 that the resistive matrix produces a −(G − Y) signal; by polarity inversion through the G − Y amplifier, a +(G − Y) signal output is provided.

The waveform relations depicted in Fig. 6-3 are those found in normal operation of the G − Y matrix. Waveform analysis involves the following factors:
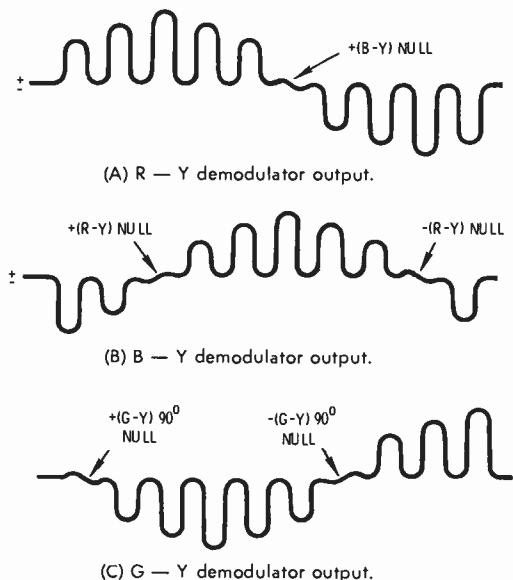

(A) R — Y demodulator output.

(B) B — Y demodulator output.

(C) G — Y demodulator output.

Fig. 6-2. Correct nulls for a standard 10-bar keyed rainbow signal.

1. Above normal R − Y amplitude causes above normal G − Y amplitude, and makes the G − Y null occur too early.
2. Subnormal R − Y amplitude causes subnormal G − Y amplitude, and makes the G − Y null occur too late.
3. Above normal B − Y amplitude causes above normal G − Y amplitude, and makes the G − Y null occur too late.
4. Subnormal B − Y amplitude causes subnormal G − Y amplitude, and makes the G − Y null occur too early.
5. Phase errors in R − Y or B − Y chroma demodulation produce phase errors in the G − Y matrix output.

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A set of normal $R - Y$, $B - Y$, and $G - Y$ waveforms are illustrated in Fig. 6-4. Note that there is a small amount of baseline curvature in each waveform; this is due to the limited bandwidth of the chroma circuits. However, the baseline curvature is not excessive in this example, and is within normal tolerances. Note also in this example that the amplitude of the $B - Y$ signal is slightly greater than the
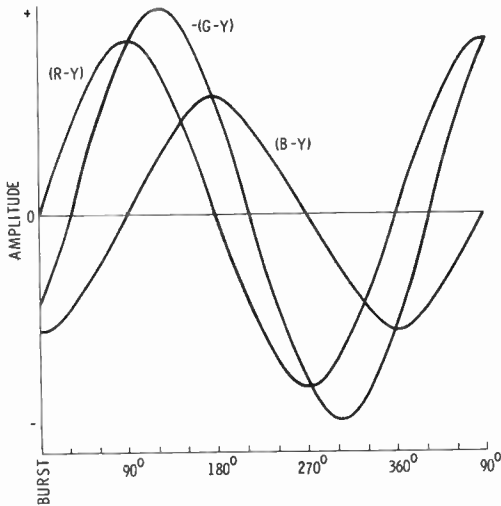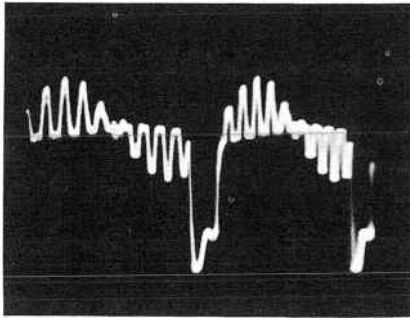

Fig. 6-3. Combination of $R - Y$ and $B - Y$ waveforms in a $G - Y$ matrix to form a $-(G - Y)$ signal.
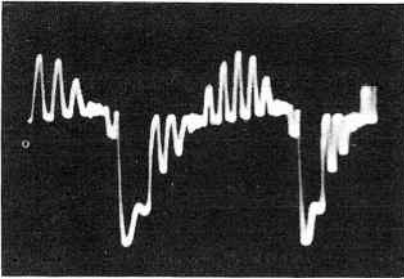
amplitude of the $R - Y$ signal. The $G - Y$ signal amplitude is substantially less. We will find that the waveform amplitudes applied to the red, blue, and green grids in the color picture tube are not the same in all receivers. That is, the amplitudes of the driving waveforms must accommodate the phosphors used in the particular type of color picture tube.
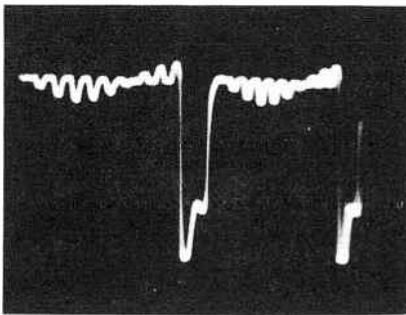
B − Y MATRIX ANALYSIS

We encounter various chroma matrix arrangements other than the $G - Y$ configuration. For example, Fig. 6-5 shows a $B - Y$ matrix circuit. The demodulated $R - Y$ and $G - Y$ signals are mixed in a resistive matrix, and applied to the grid of the $B - Y$ amplifier tube. Observe the waveform relations that are shown in Fig. 6-6. We see that the $R - Y$ and $G - Y$ signals add and subtract to form a $-(B - Y)$ signal. After passing through the $B - Y$ amplifier, the $-(B - Y)$ signal becomes a $+(B - Y)$ signal. Note that the same waveform amplitudes are employed as in Fig. 6-3; only the relative

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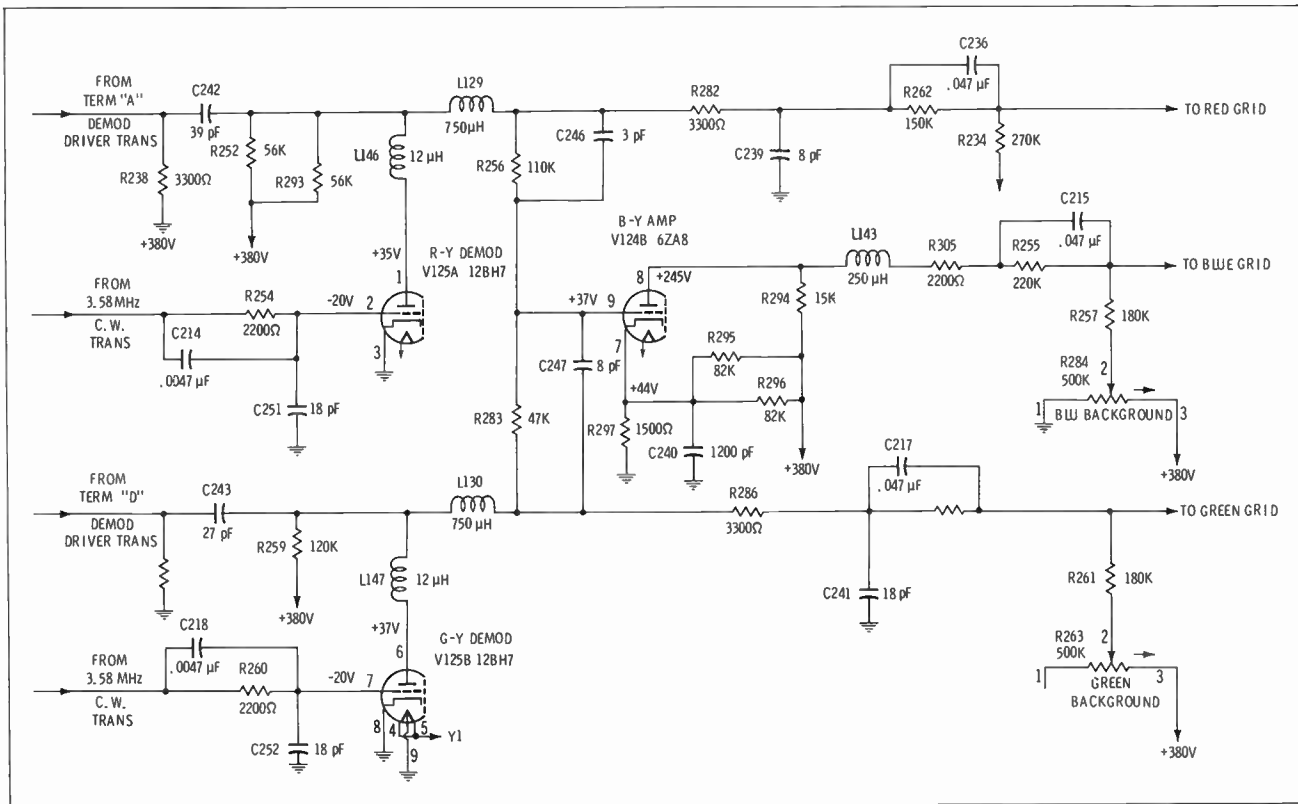
(A) R — Y signal.

(B) B — Y signal.

(C) G — Y signal.

Fig. 6-4. Normal keyed-rainbow signals from R — Y, B — Y, and G — Y circuits.

polarities of the signals are different in a B — Y matrix. Waveform analysis involves the following factors:

1. Above normal R — Y amplitude causes above normal B — Y amplitude, and makes the B — Y null occur too early.
2. Subnormal R — Y amplitude causes subnormal B — Y amplitude, and makes the B — Y null occur too late.
3. Above normal G — Y amplitude causes above normal B — Y amplitude, and makes the B — Y null occur too early.
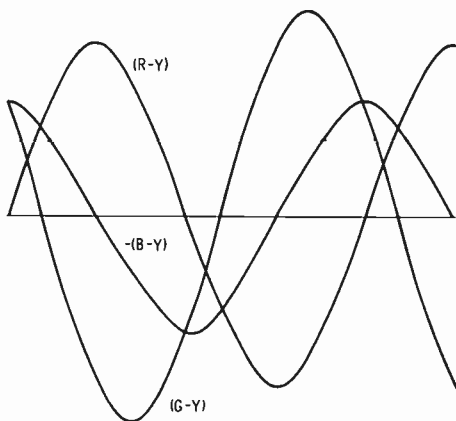
Fig. 6-5. Typical B — Y matrix configuration.

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Fig. 6-6. Matrixing of B — Y from R — Y and G — Y.

4. Subnormal $G - Y$ amplitude causes subnormal $B - Y$ amplitude, and makes the $B - Y$ null occur too late.
5. Phase errors in $R - Y$ or $G - Y$ chroma demodulation produce phase errors in the $B - Y$ matrix output.
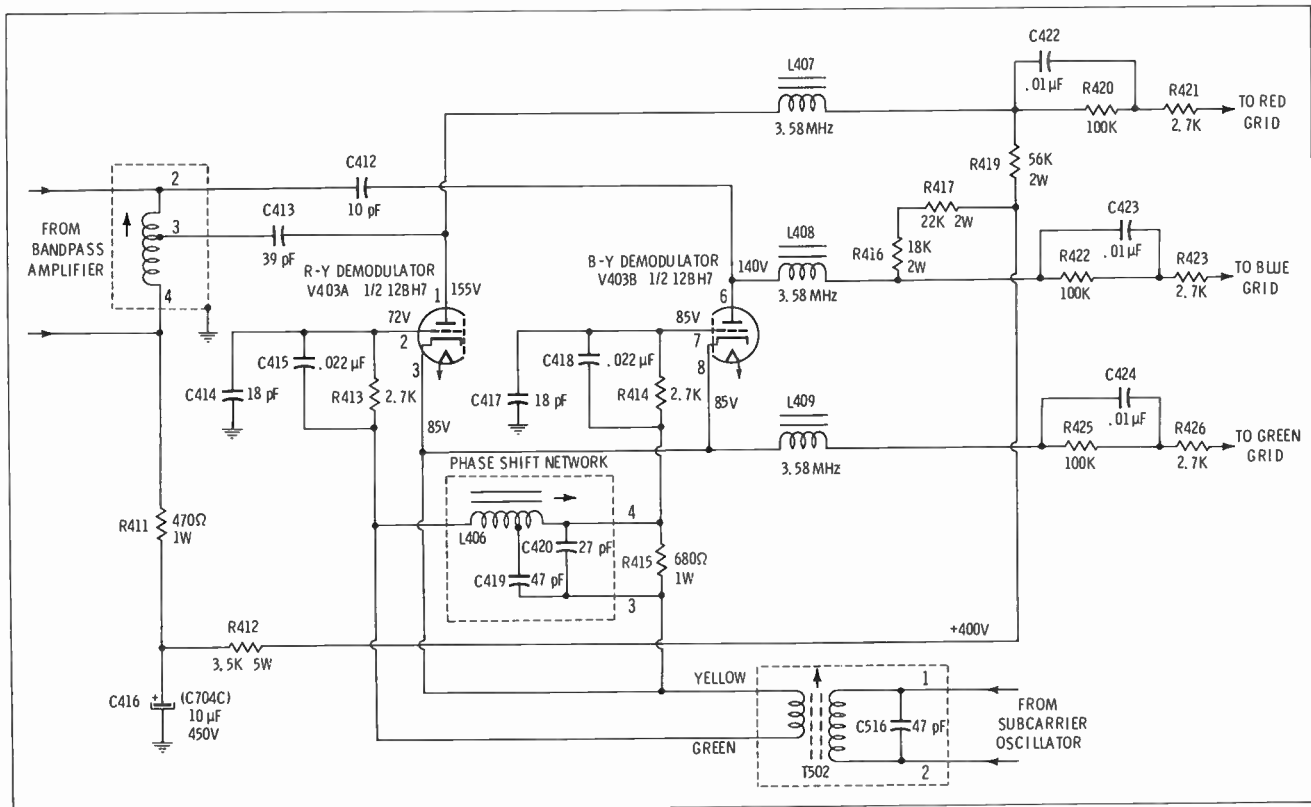
Note C246 and C247 in the $B - Y$ matrix circuit of Fig. 6-5. These capacitors serve the same purpose as C221 in the $G - Y$ matrix circuit of Fig. 6-1. That is, a small capacitance in shunt with a matrix resistance provides for passage of high frequencies, and increases the bandwidth of the matrix circuit. If a matrix capacitor opens up, the bandwidth of the matrix is decreased, and the corresponding symptom is excessive baseline curvature in the matrix output waveform. In other words, the operation of a matrix capacitor can be compared with the action of a peaking coil in a wide band amplifier.

BOOTSTRAP MATRIX ANALYSIS

We find bootstrap matrix circuits used in some color receivers. A typical example is shown in Fig. 6-7. In this arrangement, demodulated $R - Y$ and $B - Y$ signals are obtained at the plates of the triodes, and the $G - Y$ signal is matrixed in the common cathode circuit. That is, the demodulated $R - Y$ and $B - Y$ signals mix in R415 and form the $G - Y$ signal. Phase inversion occurs in the triodes; therefore, the signals applied to R415 are $-(R - Y)$ and $-(B - Y)$ phases. In turn, the cathode output is a $+(G - Y)$ waveform.

Although $R - Y$ and $B - Y$ outputs appear at the plates of the triodes in Fig. 6-7, the tubes do not demodulate on the $R - Y$ and $B - Y$ axes. The reason for this is that the $R - Y$ output is the result-

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Fig. 6-7. A typical bootstrap matrix circuit.

ant of the plate signal and the cathode signal. Similarly, the $B - Y$ output is the resultant of the plate signal and the cathode signal. Therefore, to obtain $R - Y$ and $B - Y$ outputs, the subcarrier must be injected into the demodulators with the phases shown in Fig. 6-8. Then, the resultant of the plate signal and the cathode signal is the $R - Y$ signal in the first triode. Also, the resultant of the plate signal and the cathode signal is a $B - Y$ signal in the second triode. As we shall see, the cathode signal is a $G - Y$ signal.
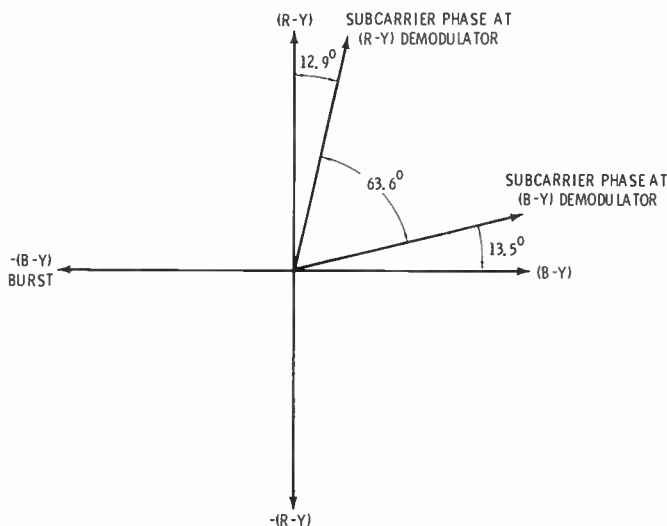

Fig. 6-8. Subcarrier phases used in the bootstrap matrix system.

To matrix $G - Y$ from $R - Y$ and $B - Y$, the signal proportions shown in Fig. 6-3 must be present in the cathode resistor. That is, the $R - Y$ signal must have 1.4 times the amplitude of the $B - Y$ signal. This is accomplished by use of suitable drive voltages and plate-load resistance values in Fig. 6-7. The signals in the cathode circuit have the $-(R - Y)$ and $-(B - Y)$ phases, and combine to form the $G - Y$ signal as shown in Fig. 6-9. Analysis of distorted waveforms is somewhat complicated in a bootstrap matrix arrangement, because of the circuit interactions. In other words, a component defect that distorts the $R - Y$ signal, for example, will usually distort the $B - Y$ and $G - Y$ signals also.

However, there are certain exceptions. For example, if C423 (Fig. 6-7) opens up, only the waveform at the blue grid is distorted; waveforms at the red and green grids remain normal. The $B - Y$ signal will be normal at the left-hand end of C423. The same observations apply to C422 and C424. In case one of the remaining capacitors in the matrix or demodulator circuits becomes defective, it can sometimes be

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pinpointed by dc voltage measurements. A leaky capacitor often changes the dc voltage distribution in its circuit. However, an open capacitor can be localized only by systematic tests. One lead of the capacitor can be opened for test, or a suspected open capacitor can be bridged by a good capacitor. If the output waveforms then become normal, correction of the trouble is verified.
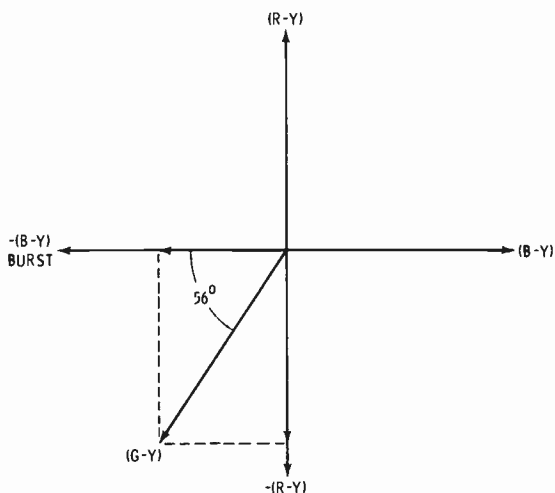

Fig. 6-9. Matrixing the G — Y signal from R — Y and B — Y signals.

X AND Z MATRIX ANALYSIS

The X and Z demodulator-matrix system shown in Fig. 6-10 is in wide use. It can be compared with the bootstrap arrangement in Fig. 6-7, in that G — Y is matrixed in a common-cathode circuit. Another similarity is that quadrature demodulation is not used. However, there are practical differences present in the X and Z system, inasmuch as the matrix function is separate from the demodulation function. That is, the pentodes in Fig. 6-10 operate as demodulators, and the triodes operate as matrixes. In turn, matrix waveform analysis in the X and Z system is different in some respects, compared with the bootstrap system.

In the configuration of Fig. 6-10, the phases of the injected subcarrier voltages are the same as depicted in Fig. 6-8. These subcarrier phases correspond to the basic X and Z waveforms shown in Fig. 6-11. The X waveform nulls between the sixth and seventh pulses; the Z waveform nulls between the second and third pulses and also between the eighth and ninth pulses. Since polarity reversal occurs between grids and plate of each demodulator tube, the waveforms that we normally observe at the plates of the X and Z demodulator tubes
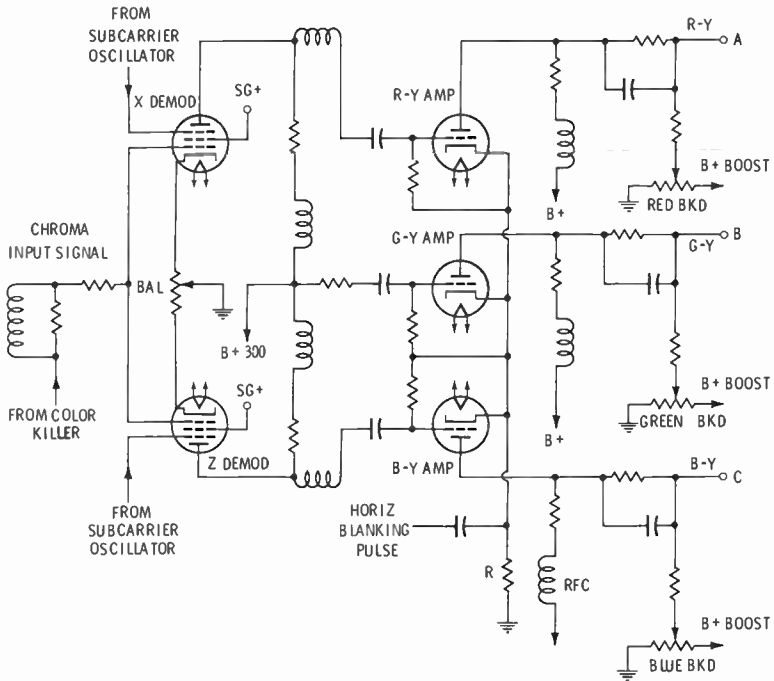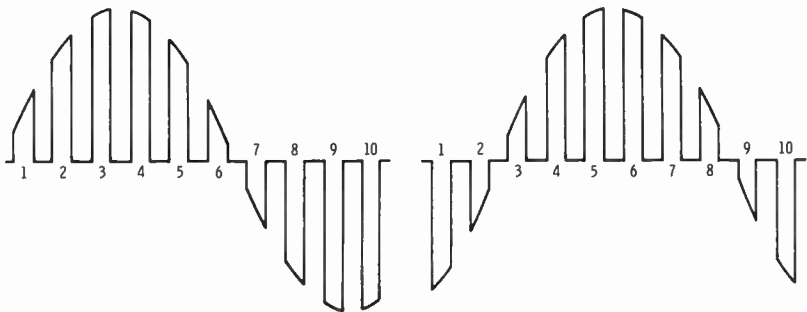
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Fig. 6-10. Basic X and Z matrix configuration.

are the same as shown in Fig. 6-11, except that each of the waveforms is turned upside down.

To put it another way, the result of demodulator-circuit action is to apply $-X$ and $-Z$ signals to the grids of the triodes in Fig. 6-10. Since the cathode signal follows the grid signal, the $-X$ and $-Z$ signals are matrixed in the common cathode resistor R. The relative amplitudes

(A) Normal X waveform produced by X subcarrier.

(B) Normal Z waveform produced by Z subcarrier.

Fig. 6-11. Subcarrier waveforms.

of the −X and −Z signals are determined by the adjustment of the balance potentiometer in Fig. 6-10. In normal operation, these amplitudes are such that their resultant forms the G − Y signal, as shown in Fig. 6-12. Note that this is a positive G − Y signal which drives the cathode of the G − Y amplifier tube. In turn, an amplified positive G − Y signal is found at the plate of the tube.

Next, let us follow the operation of the R − Y and B − Y amplifier tubes. The cathode of the R − Y amplifier tube is driven by a G − Y signal. However, the grid of the tube is driven by a −X signal. At the plate, the −X signal becomes a +X signal; on the other hand, the positive G − Y signal at the cathode remains a positive G − Y signal at the plate. The result is that the +X and +(G − Y) signals are matrixed in the plate circuit to form the R − Y signal. In the same way, the +Y and +(G − Y) signals are matrixed in the plate circuit of the B − Y amplifier to form the B − Y signal. Therefore, we observe the waveforms shown in Fig. 6-4 at A, B, and in C in Fig. 6-10.
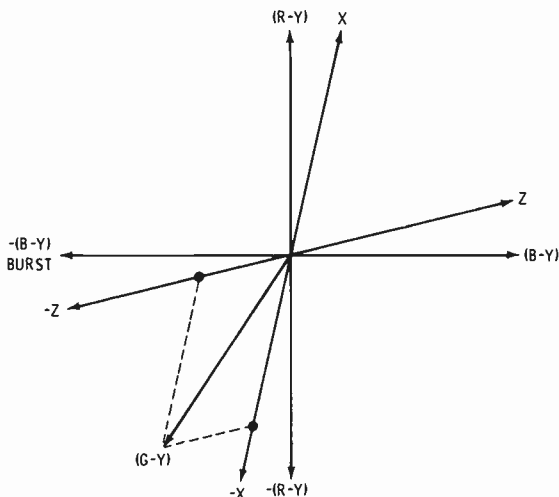

Fig. 6-12. Matrixing of −X and −Z signals to form the G − Y signal.

Troubleshooting the X and Z matrix system is not unduly difficult, although there is interaction among the three matrix sections. When abnormal waveforms are observad at points A, B, and C in Fig. 6-10, the first step is to check the grid-driving waveforms of the matrix tubes. In normal operation, the nulls should appear as shown in Fig. 6-11; as noted previously, these waveforms are displayed upside down at the grids of the R − Y and B − Y amplifier tubes. Since we are concerned chiefly with matrix action, we will assume here that the driving waveforms are normal, and that the trouble is consequently in the matrix section.

Capacitors are the most common troublemakers, and the capacitors in the matrix circuit are checked first for leakage or opens. If the capacitors are all right, resistance checks are then made. Values of the plate-load resistances and the common-cathode resistance are critical in the X and Z matrix system. An off-value resistor will cause incorrect nulls and incorrect amplitudes of all three output waveforms. If a plate or cathode resistor is off-value, it can be localized by dc voltage measurements. To verify that the resistor is off-value, disconnect one end and make an ohmmeter measurement.

RGB MATRIX ANALYSIS

The RGB matrix system is considerably different from a chroma-matrix arrangement because the Y signal is combined with the chroma signal in the demodulator- matrix circuits. As seen in Fig. 6-13, three separate demodulators are used, and no chroma matrixing is employed. Instead, the Y signal from the video amplifier is matrixed with the chroma signal in each demodulator. It is important to note the difference between RGB matrixing in Fig. 6-13, compared with matrixing in the color picture tube. Because of differences in signal processing, we will find that the demodulators do not operate on the $R - Y$, $B - Y$, and $G - Y$ axes, as in many of the older systems.
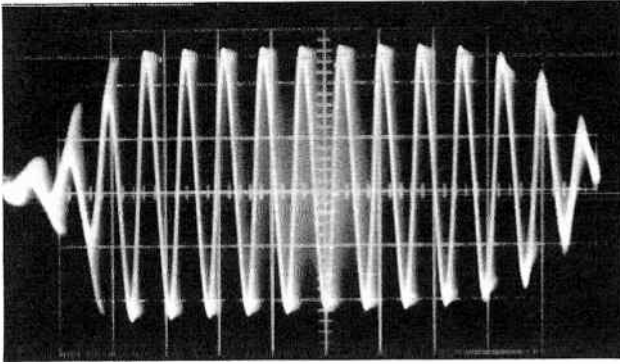
When the color picture tube is used as the RGB matrix, the Y signal is applied to all three cathodes, and the grids are driven by $R - Y$, $B - Y$, and $G - Y$ signals. If a fully saturated red hue is to be reproduced, the red gun is driven to full output. At the same time, while the red grid is being driven by the $R - Y$ signal, there is also a certain amount of output from the $B - Y$ and $G - Y$ sections. That is, a red signal has components on the $R - Y$, $B - Y$, and $G - Y$ axes. The $R - Y$ component on the grid, and the Y component on the cathode drive the red gun in the color picture tube to full output. At the same time, the $B - Y$ and $G - Y$ signals and the Y signal have polarities that cut off the blue and green guns.

Next, when RGB matrixing is completed in the chroma demodulator circuits (Fig. 6-13), the subcarrier voltages are injected with the red, blue, and green phases, as shown in Fig. 6-14B. We will find that when a fully saturated red signal is being reproduced, the red channel drives the red gun in the color picture tube to full output. The red signal has components on the blue and green axes with polarities that cause the blue and green channels to drive the blue and green guns to cutoff. Thus, although the end result is the same, the RGB matrix system operates on the primary color axes. The matrix waveforms are somewhat different from those found in the systems discussed.
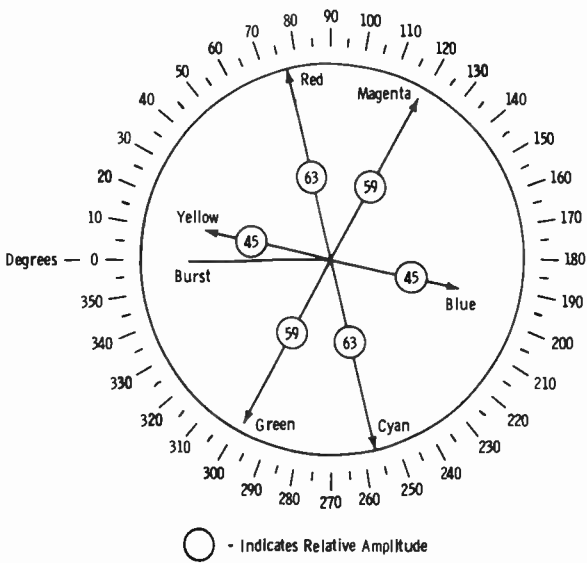
Fig. 6-15 shows the signal-processing circuitry for the RGB matrix system. Note that the brightness signal (Y signal) is fed into the center

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Fig. 6-13. Block diagram of a color receiver that uses RGB matrixing.

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(A) Waveform of the colors.

- Indicates Relative Amplitude

(B) Phase angles of the colors.

Fig. 6-14. Saturated primary and complementary colors.

tap on the secondary of the demodulator-driver transformer. Thus, the chroma signal is combined (matrixed) with the Y signal at the input of each demodulator. A technical point of interest to the technician is the polarization of the diodes in the demodulator circuits. Note that the diodes in the G demodulator section are polarized oppositely with respect to the diodes in the R and B demodulator sections. This is done to provide cancellation of spurious demodulator waveforms (blip waveforms).

Since the demodulator diodes have reversed polarities in the G demodulator section of Fig. 6-15, a green signal output is obtained by injecting the subcarrier voltage in the magenta phase, which is 120^c from burst, as seen in Fig. 6-14B. In other words, reversal of both the subcarrier phase and the diode polarities produces a green signal output, while also providing blip cancellation. After the R, G, and B color signals are formed in the diode sections, the signals are stepped up by video amplifiers and applied to the cathodes of the color picture tube. Fig. 6-16 shows the amplifier circuits for the green demodulator-matrix section. Similar amplifier circuits are used in the red and blue demodulator-matrix sections.

Waveforms in the RGB matrix circuits can be checked with a keyed rainbow signal, or with an NTSC signal. If a red bar signal from an NTSC generator is applied to the receiver, we normally observe a square-wave output from the red channel; on the other hand, we find no output (only a horizontal trace) from the blue and green channels. Or, if a green bar signal is applied, a square-wave output appears from the green channel—there is zero output from the red channel and the blue channel. Again, if a blue bar signal is applied, we find a square-wave output from the blue channel, but zero output from the red channel and the green channel. Thus, matrix checks with an NTSC signal are straightforward.

Next, let us consider the normal waveforms that are observed when a keyed-rainbow signal is applied. With reference to Fig. 6-17, we observe that the red matrix output waveforms nulls between the fifth and sixth pulses. The blue matrix output waveform nulls between the third and fourth pulses, and between the ninth and tenth pulses. The green matrix output waveform nulls on the first pulse and on the seventh pulse. If incorrect nulls are observed, the trouble is most likely to be found in the subcarrier-injection circuit. Defective capacitors are the most common culprits. Waveforms that have incorrect shapes and/or amplitudes are usually the result of poor front-to-back ratio in a demodulator diode.

Baseline distortion (excessive curvature in the matrix waveform baseline) is due to limited bandwidth, as explained previously. Check the alignment of the bandpass (color i-f) amplifier; it normally has full response from 3.1 to 4.1 MHz. Increased values of collector load re-
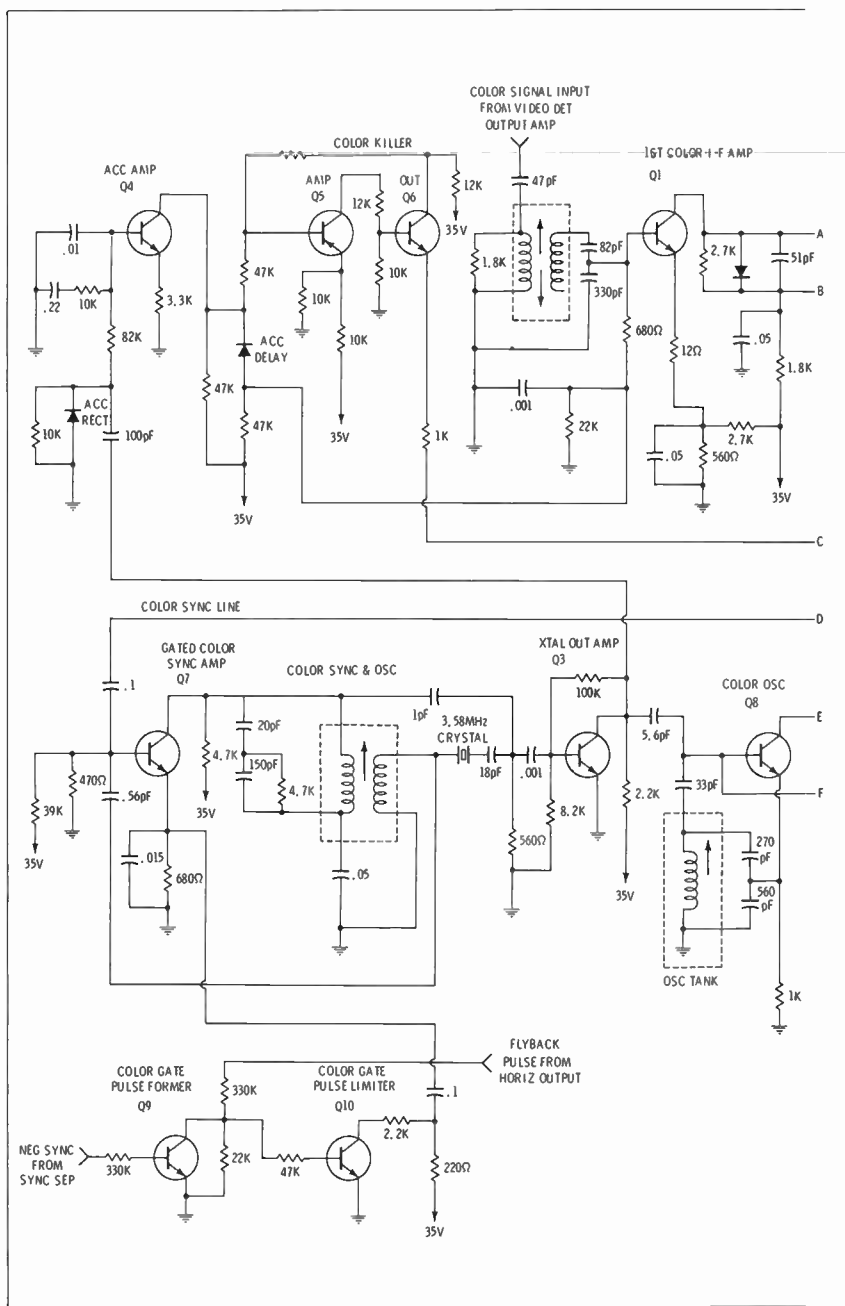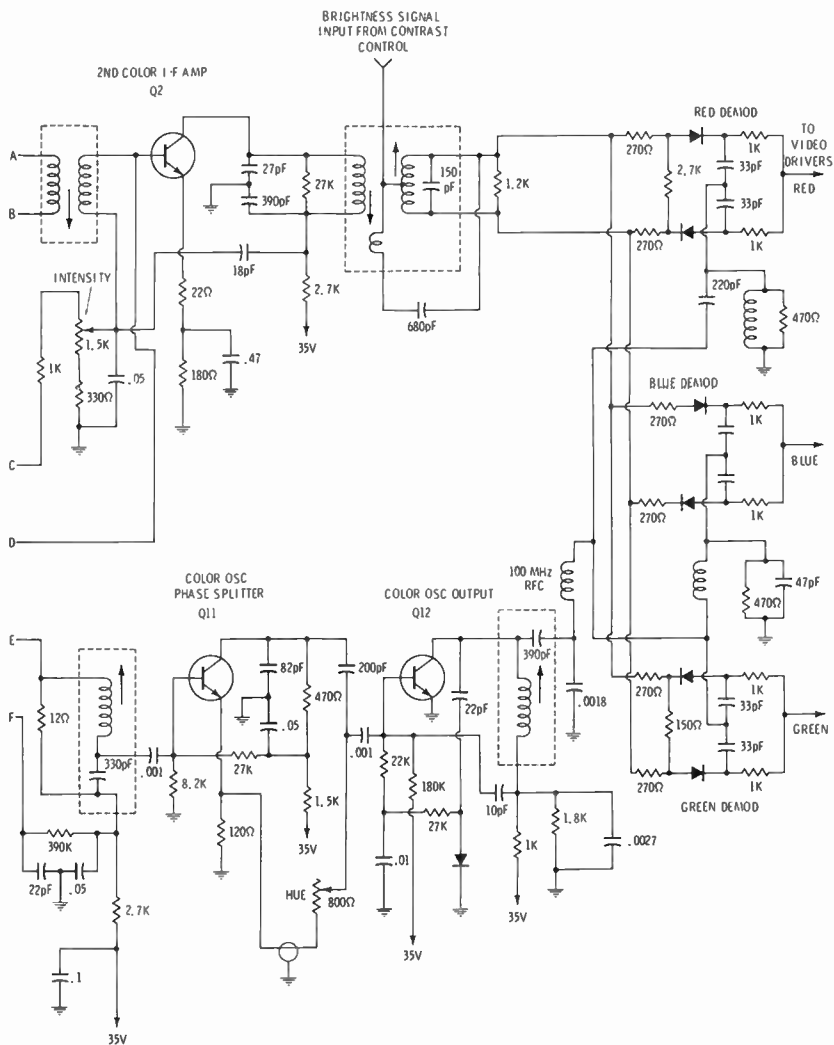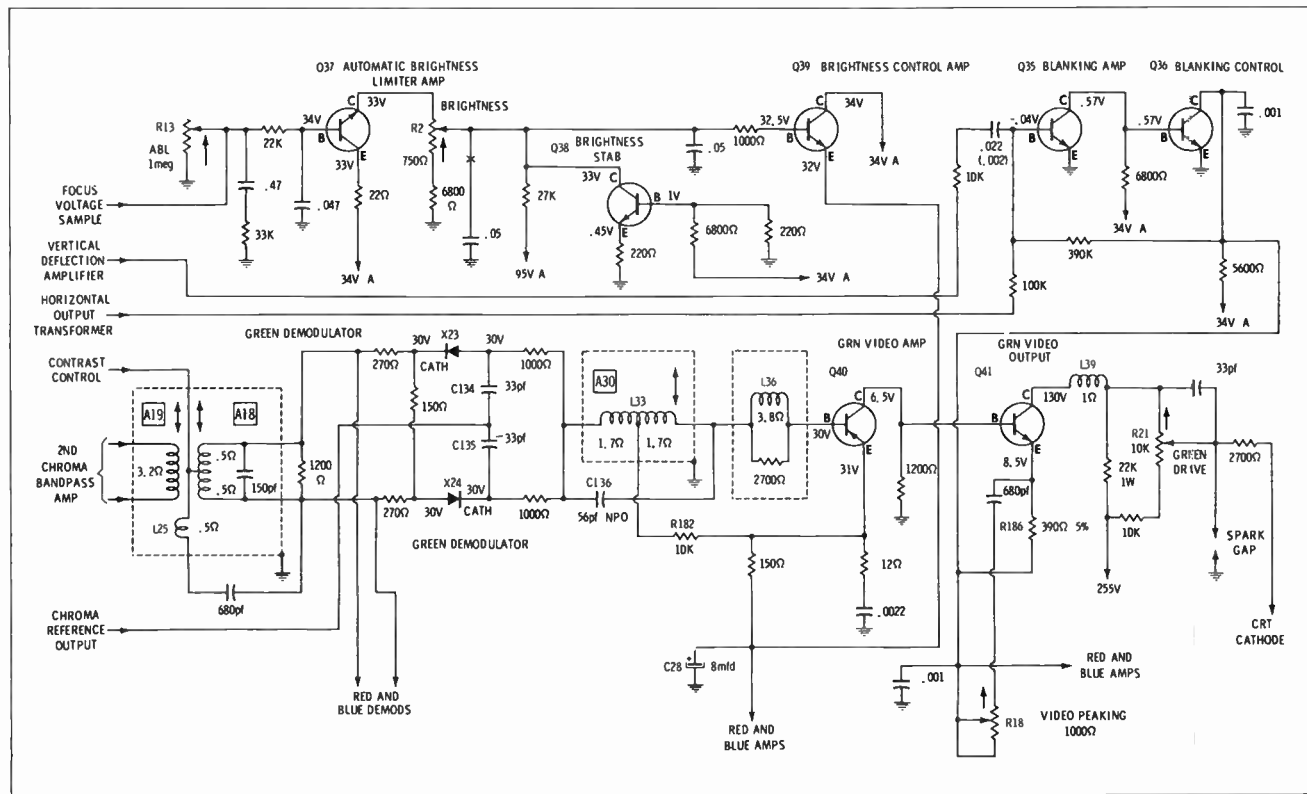
Fig. 6-15. Chroma signal processing

and color-sync configuration.

Fig. 6-16. Color processing circuitry in the RGB system.

sistors can also cause bandwidth reduction. Look for an open capacitor in the video-peaking circuit, if the control is inoperative. An open capacitor in the collector circuit of the output amplifier will cause bandwidth reduction, and also reduce the waveform amplitude. Misalignment of the video i-f amplifier can cause bandwidth reduction, as noted previously.
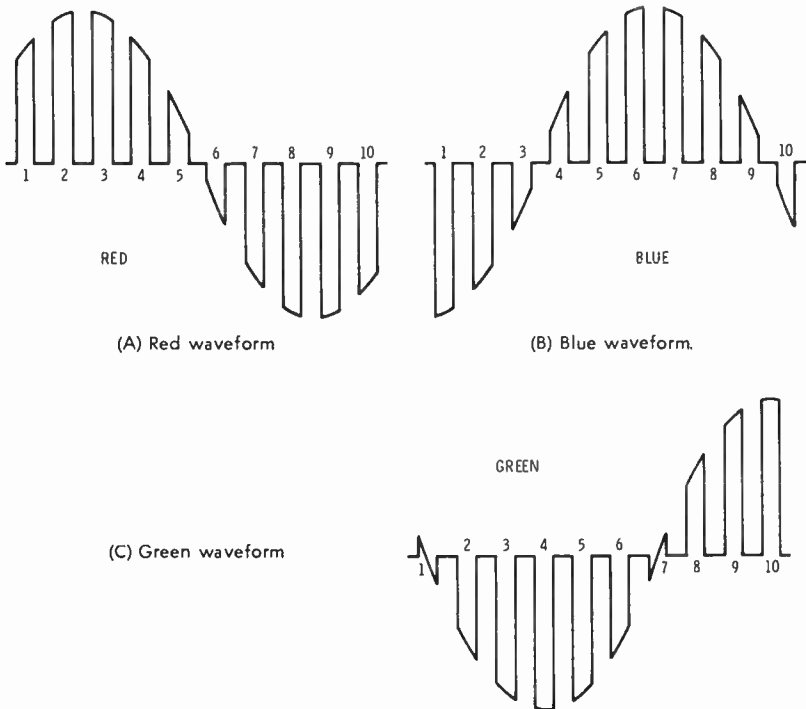

(A) Red waveform

(B) Blue waveform.

(C) Green waveform

Fig. 6-17. Keyed rainbow output waveforms from an RGB matrix.

WAVESHAPES OF VECTORGRAM PETALS

When a vectorscope is connected to the output terminals of the $R - Y$ and $B - Y$ matrixes, we know that the resulting vectorgram has petal-shaped excursions. Let us see why this is so. If the same waveform is applied to the vertical and horizontal input terminals of a vectorscope, the resulting pattern is always a straight line. For example, Fig. 6-18 shows how a straight-line pattern is formed when the same triangular pulse waveform is applied to the vertical and horizontal deflection plates of the CRT. Similarly, Fig. 6-19 shows how a straight-line pattern is formed when the same exponential pulse waveform is applied to both inputs of the vectorscope. This is another illus-
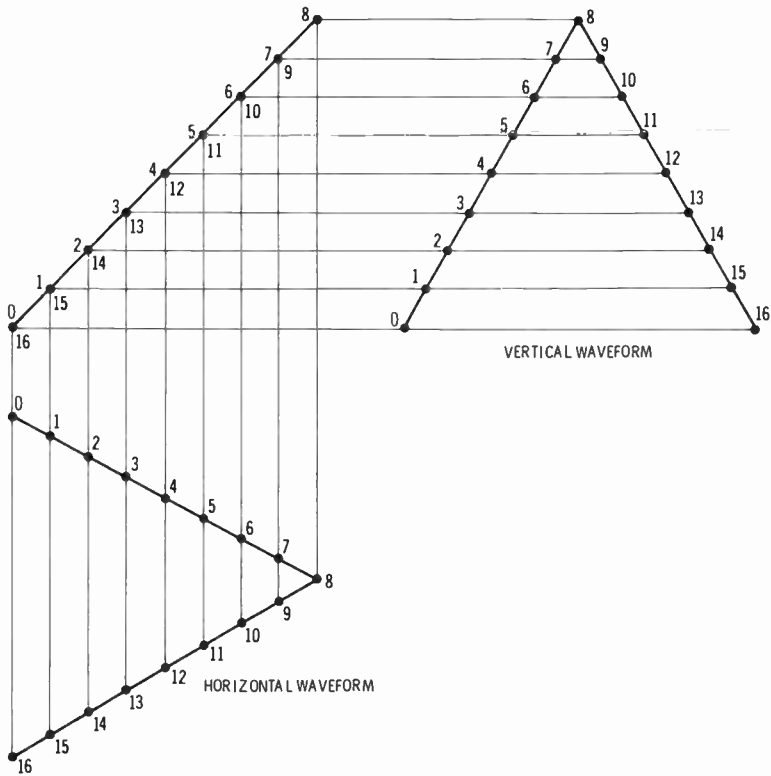
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Fig. 6-18. The vectorgram is a straight line, because the two triangular pulse waveforms are identical.

tration of the fact that a vectorgram is always a straight line if the V and H waveforms are identical.

In practice, the matrix output waveforms that we apply to a vector-scope do not have exactly the same waveshapes. There are several reasons for this; first, the time constants of the $R - Y$ and $B - Y$ channels are never exactly the same. An exponential waveform rises more slowly when the time constant is greater. Second, there is always a slight amount of nonlinearity in a chroma channel; this residual non-linearity is not exactly the same in the $R - Y$ and $B - Y$ channels. Therefore, the slightly different basic exponentials are individually modified further by the residual nonlinearities. Third, the $R - Y$ and $B - Y$ channels introduce a small amount of phase shift from input to output, and this residual phase difference is usually greater for the $B - Y$ channel than for the $R - Y$ channel.

When we look at the $R - Y$ and $B - Y$ waveforms in Fig. 6-20, the pulse shapes appear to be almost the same. However, if we observe
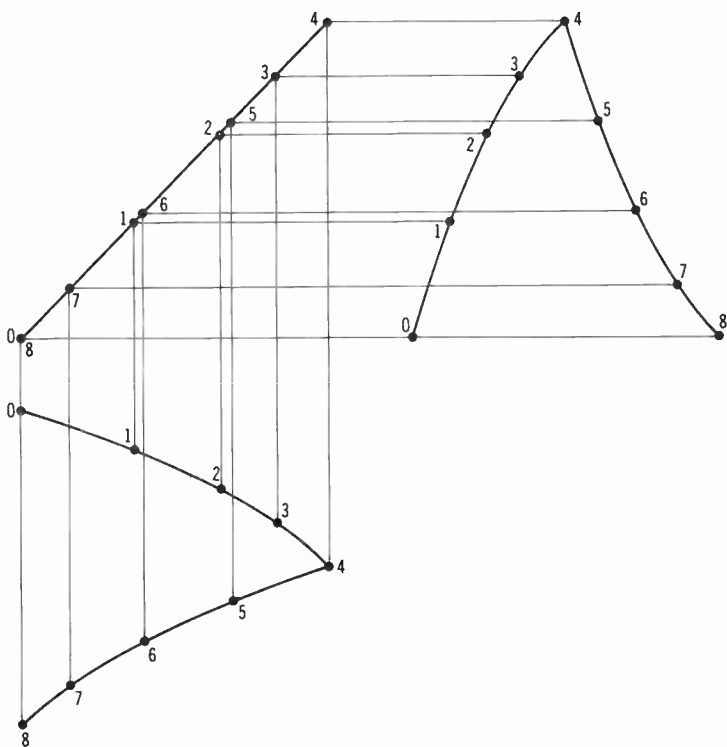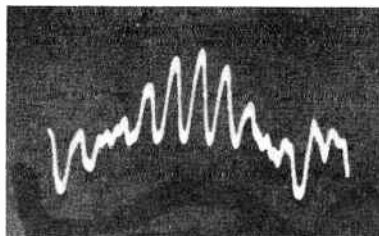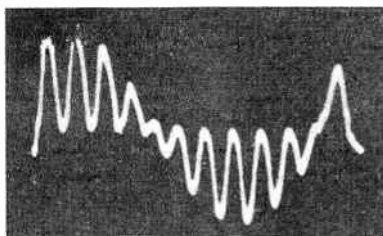
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Fig. 6-19. The vectorgram is a straight line, because the exponential pulses are the same.

very carefully, we will see that the pulse shapes are slightly different. It is this residual variation in waveshape that produces the petals in a vectorgram. For example, the pulse shapes in Fig. 6-21 are not quite the same; the diagram shows the development of a petal-shaped vectorgram from these pulse shapes. In practice, many variations in petal shapes are observed. The *shape* is less important than the *width* of the petal; that is, excessive petal width points to a component defect or a

(A) R — Y waveform.

(B) B — Y waveform.

Fig. 6-20. Actual waveforms.

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Fig. 6-21. Petal-shaped vectorgram produced by pulses with differently shaped waveforms.

tuned-circuit misadjustment that causes the $R - Y$ and $B - Y$ wave-forms to become distorted.

SUMMARY

A $G - Y$ matrix is basically a resistive mixer circuit, which combines $R - Y$ and $B - Y$ signals in suitable proportions.

A matrix circuit is usually followed by an amplifier to step up the signal amplitude; the matrix waveform is inverted by the amplifier.

Matrix waveforms are checked for correct nulls and correct amplitudes, as specified in receiver service data.

Baseline curvature in a matrix waveform is caused by limited bandwidth in the associated circuit, or in prior signal circuts.

Some receivers matrix the $B - Y$ signal from $R - Y$ and $G - Y$ signals.

The bandwidth of a resistive matrix is controlled by small capacitors shunting the resistive branches.

A bootstrap matrix develops the $G - Y$ signal in a common cathode circuit; the subcarriers are not injected in quadrature.

X and Z matrix systems have various similarities to a bootstrap matrix, but employ more tubes.

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The input waveforms to X and Z matrix tubes have shifted nulls, compared to quadrature systems.

An RGB matrix system has chroma demodulators that do double duty as matrix sections; the subcarriers are not injected in quadrature.

Complete color signals appear at the outputs of RGB matrixes, due to injection of the Y signal into the chroma demodulators.

The nulls in the output waveforms of an RGB matrix system are different from those found in any chroma-matrix system.

Vectorgrams produced by $R - Y$ and $B - Y$ matrixes are basically the same as vectorgrams produced by $R - Y$ and $B - Y$ chroma demodulators.

Petal formation in practical vectorgrams is the result of slightly different $R - Y$ and $B - Y$ waveshapes.

REVIEW QUESTIONS

1. With reference to Fig. 6-1, what type of distortion would you expect to find in the $G - Y$ output waveform if C221 opens?
2. If R220 (Fig. 6-1) increases in value, how will the $R - Y$ and $G - Y$ output waveforms be affected?
3. With reference to Fig. 6-5, what effect is produced on the $B - Y$ output waveform if C215 opens?
4. Why are $R - Y$ and $B - Y$ waveforms found at the plates of V403 in Fig. 6-7, although the subcarrier voltages are not injected in quadrature?
5. Explain why vectorgram petals become wider when the width of the $B - Y$ pulses is increased with respect to the width of the $R - Y$ pulses.

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Vectorgram Analysis

We have considered some of the basic characteristics of vector-grams in previous chapters. Experienced technicians are concerned with many of the fine points in waveform analysis. Therefore, this chapter presents a general survey of vectorgram patterns with expla-nations of the technical points that are involved. For the reader's con-venience, the basic development of a vectorgram envelope is repeated in Fig. 7-1. This waveform is classified as a *Lissajous figure*, and is the type of display produced by an unkeyed rainbow signal. A circular pattern indicates the following facts:

1. Both input signals are true sine waves (no harmonics are con-tained in the signals).
2. The input signals are 90° out of phase.
3. Both signals have the same amplitude.

EFFECT OF HARMONICS

In practical situations, the signals that produce a *Lissajous figure* or vectorgram usually have at least a small harmonic content. In trouble conditions, the harmonic content may be quite large. The most com-mon cause of harmonics is nonlinearity in the demodulator or matrix circuitry. For example, if a defective component causes a tube to be driven beyond cutoff, the output waveform will not be a true sine wave; it will be clipped, and the waveform will contain even harmon-ics. Fig. 7-2 shows a "flat" in a pattern, due to clipping of one of the input waveforms. The amount of flattening that is produced depends upon the amount of clipping.

Next, if the input waveforms are true sine waves, but their phase difference is less than 90°, an elliptical pattern is displayed. This is

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always an inclined ellipse. That is, the major and minor axes of the ellipse do not fall along the vertical and horizontal axes of the scope screen. Fig. 7-3 shows a pair of ellipses that are produced by input waveforms having 30° and 60° phase difference, respectively. The linear pattern is a special case that occurs when the input waveforms are exactly in phase with each other. To summarize briefly, an inclined ellipse always indicates that the input waveforms have a phase difference other than 90°.
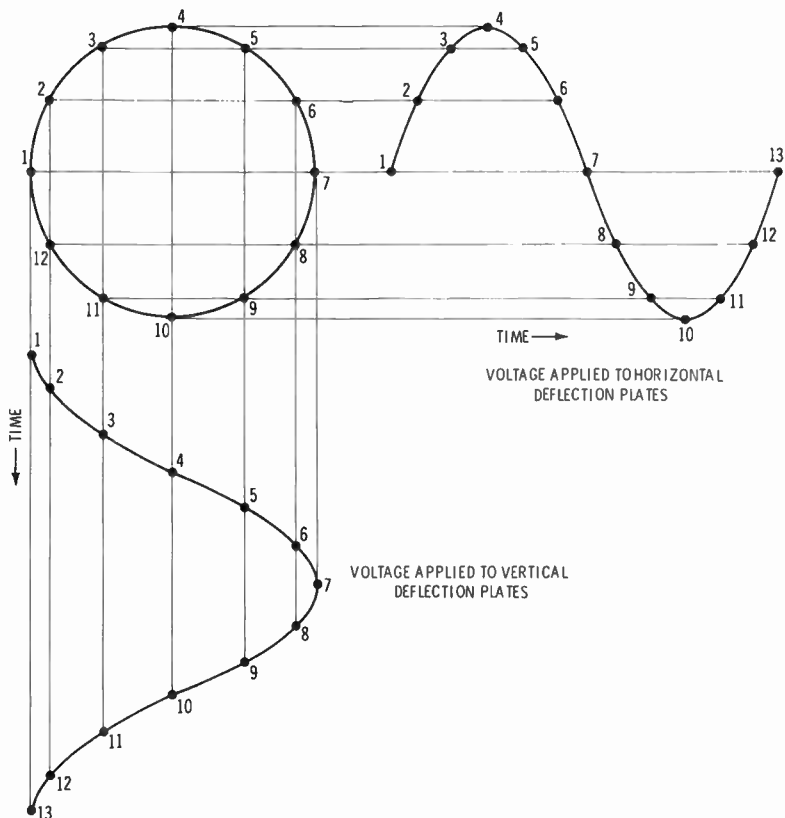

Fig. 7-1. Generation of circular pattern by two sine waves 90° out of phase.

Clipping of an input waveform, when the phase difference is other than 90°, produces a "flat" on the elliptical pattern. In other words, clipping distortion results in the same pattern symptom, regardless of its basic circularity or ellipticity. In the special case wherein the input waveforms are exactly in phase, clipping distortion produces a broken straight-line pattern, as depicted in Fig. 7-4. Note in Fig. 7-2 and Fig. 7-4A that a "flat" may appear at the bottom of the pattern, at the left

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side, or at the right side of the pattern. The location of a "flat" is determined by which input waveform is clipped, and whether the positive peak or negative peak is clipped.

If both input waveforms are clipped on their positive peaks, two "flats" will appear in the pattern. One "flat" will be located on top of the pattern, and the other will be located at the bottom. Or, if only one

Fig. 7-2. The pattern becomes flattened when one of the input waveforms is clipped.

of the input waveforms is clipped, and is clipped on both its positive and its negative peaks, a pair of "flats" will be displayed on opposite sides of the pattern. When we understand how the envelopes are developed, it is easy to evaluate a distorted pattern to determine whether one or both input waveforms are clipped, and whether positive-peak, negative-peak, or both positive-peak and negative-peak clipping are occurring.

In practical situations, an input waveform may be distorted by peak compression instead of peak clipping. Compression distortion is simi-

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lar to clipping distortion in a vectorgram, except that the flattening of the pattern is not as abrupt. This type of distortion occurs if the color-intensity control of the receiver is advanced to maximum. If clipping or compression is present at a normal setting of the color-intensity control, the most likely cause is a defective component in the matrix circuit. For example, if the plate voltage on a matrix tube, or the col-
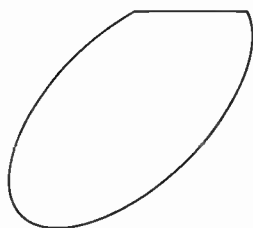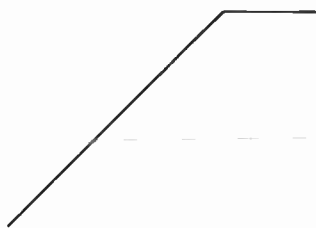

Fig. 7-3. Generation of linear and elliptical patterns by two sine waves which are less than 90° out of phase.

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(A) Elliptical pattern with a "flat".   (B) Broken straight-line pattern.

Fig. 7-4. Clipped input waveform with phase difference other than 90°.

lector voltage on a matrix transistor is lower than normal, this type of distortion will occur.

EQUALIZATION OF VERTICAL AND HORIZONTAL DEFLECTION

In normal operation, the $R - Y$ signal is usually somewhat greater in amplitude than the $B - Y$ signal. Depending upon the $R - Y/B - Y$ amplitude ratio, the proportions of the resulting vectorgram envelope will vary as depicted in Fig. 7-5. In practical procedures, it is helpful to equalize the vertical and horizontal deflection. Fig. 7-6 shows how a service-type scope can be connected to change elliptical patterns such as is shown in Fig. 7-5 into circular patterns. The $B - Y$

Fig. 7-5. Input signals 90° out of phase, but with different amplitude ratios.

signal is coupled directly to the horizontal-deflection plates of the CRT, while the $R - Y$ signal is passed through the vertical amplifier in the scope.

Because the vertical amplifier is employed in the test setup of Fig. 7-6, the vertical-gain controls of the scope can be adjusted to equalize the vertical and horizontal deflection. However, since a vectorgram display is quite sensitive to small phase errors, it is necessary that the vertical-input step attenuator be carefully adjusted for exact high-frequency compensation. Fig. 7-7 shows a typical vertical-amplifier cir-

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cuit. C2 and C3 are high-frequency compensating capacitors. To determine whether the step attenuator has good high-frequency compensation, simply feed the $R - Y$ signal into the vertical-input terminal, with the $R - Y$ signal also coupled directly to the horizontal-deflection plates in the CRT.

With reference to Fig. 7-6, we can check the attenuator compensation by temporarily using the $R - Y$ signal instead of the $B - Y$ signal to drive the horizontal deflection plates. If a straight diagonal line is displayed on the scope screen, we know that the step attenuator is properly compensated. Conversely, if an ellipse is displayed, we know that the compensating capacitors are not in exact adjustment. We will then adjust C2 or C3, or both, (Fig. 7-7) to obtain a straight-line

Fig. 7-6. Scope connections used to obtain equalized vertical and horizontal deflection.

NOTE: X_C AND Y_C CONNECT TO THE CENTERING CONTROLS

display. Then, the scope is in proper adjustment for application of the $B - Y$ signal to the horizontal deflection plates, as depicted in Fig. 7-6.

When a keyed rainbow signal is applied to the receiver, a vectorgram is displayed. The ideal initial pattern is repeated for reference in Fig. 7-8. In this example, the $R - Y$ signal has a greater amplitude than the $B - Y$ signal. By adjustment of the vernier vertical-gain control in the scope, the elliptical pattern can next be changed into the basic circular pattern, as shown in Fig. 7-9. Of course, we know that ideal petal shapes are not produced in practice, due to limited chroma bandwidth and residual circuit nonlinearities. That is, the petal waveshape in a practical situation might appear as shown in Fig. 7-10. Nevertheless, if the $R - Y$ and $B - Y$ signals are separated by a 90° phase difference, an elliptical vectorgram can always be changed into a circular vectorgram by adjustment of the vertical-gain control of the scope.

The result of suitable vertical-gain control adjustment is shown in Fig. 7-11(A). Each petal represents a vector, and although the petals
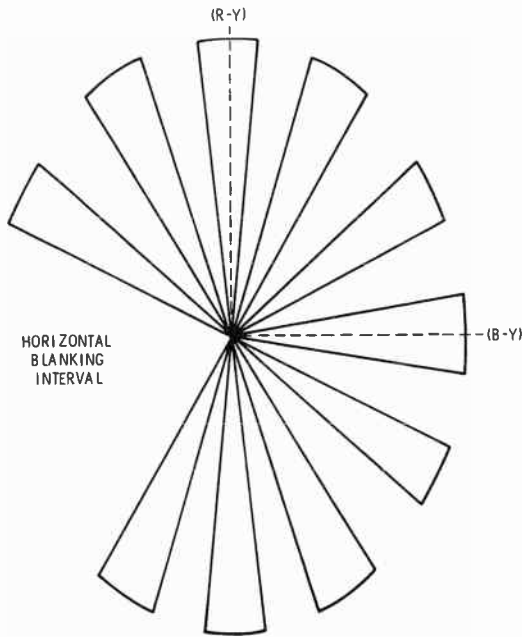
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Fig. 7-7. Typical vertical-amplifier circuit.

Fig. 7-8. Ideal keyed rainbow vectorgram, with the R — Y signal amplitude greater than the B — Y signal amplitude.

have curved sides, the points of the petals normally form a circular envelope. The tip of each petal indicates the phase angle of the vector. That is, the tip of each petal normally falls on the calibration marks of the vectorscope graticule shown in Fig. 7-11B. We will find it helpful to employ a circular pattern to check the individual phases of the petal tips, because no projection or calculation is required to make the phase determinations. Of course, circuit action cannot be perfect, and small phase errors that are within normal tolerances are disregarded in practical work.

Fig. 7-9. Vertical-gain control adjusted to display a circular pattern.

Fig. 7-10. Waveshape of a typical
vectorgram petal.

FORMATION OF INNER CIRCLE OR ELLIPSE

When the demodulator output waveforms both have curved base-
lines, the vectorgram has an inner circle, or an inner ellipse. If the
waveform amplitudes are the same, and the baseline curvature is the
same in both, an inner circle is formed, as shown in Fig. 7-12. In case
the $R - Y$ signal is greater than the $B - Y$ signal, an inner ellipse is
formed in the vectorgram. Or, if the signal amplitudes are the same,
but with more baseline curvature in one waveform than the other, an
inner ellipse is formed. Note that baseline curvature can be caused by
a defective diode in a duo-diode chroma-demodulator circuit, so
baseline curvature is not always a symptom of subnormal bandwidth.

Fig. 7-13 shows the appearance of a vectorgram in which the $B - Y$
signal has much more baseline curvature than the $R - Y$ signal. In
this example, the inner ellipse is so narrow that it is almost a straight
line. Note that the inner excursion of a vectorgram will be a straight
horizontal line segment in case that the $R - Y$ waveform has no base-

(A) The petals have curved sides, but their
tips form a circular envelope.

(B) Layout of a vectorscope graticule.

Fig. 7-11. Correct vertical gain control setting.

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B-Y SIGNAL APPLIED TO
HORIZONTAL DEFLECTION PLATES

R-Y SIGNAL APPLIED TO
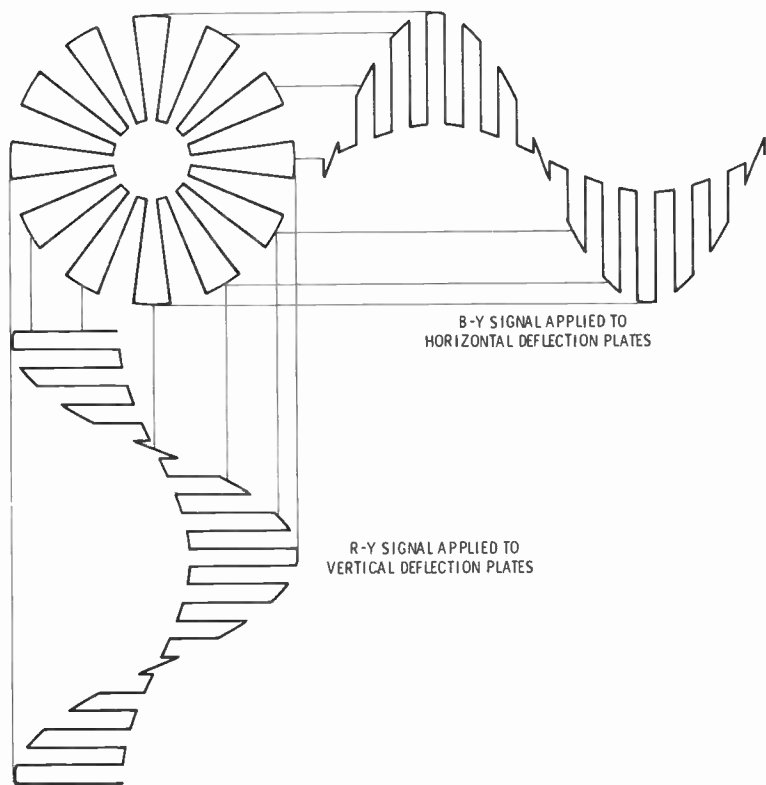VERTICAL DEFLECTION PLATES

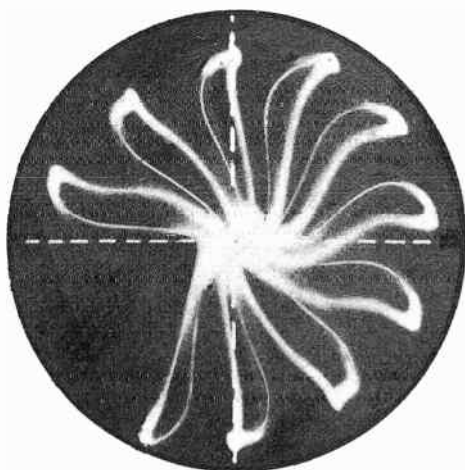Fig. 7-12. Formation of an inner circle in a vectorgram.

Fig. 7-13. Vectorgram indicates that the B — Y signal has much more baseline
curvature than the R — Y signal.

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line curvature, while the B — Y waveform has a curved baseline. The basic principles that are involved are as follows:

1. In an ideal vectorgram, the petals come to a point in the center of the pattern.
2. The central portion of a vectorgram is a circle, ellipse, or occasionally a straight-line segment in practical situations.
3. Inner circles or ellipses result from baseline curvature in the R — Y and B — Y waveforms.
4. Baseline curvature is caused by subnormal bandwidth in a chroma channel, or by a defective diode in a chroma demodulator.
5. Subnormal bandwidth can be caused by an open high-frequency compensating capacitor, or by misalignment of the chroma circuits.

NTSC VECTORGRAMS

An NTSC signal is different from a keyed rainbow signal, in that it is not a linear phase sweep. Instead, the NTSC color-bar signal "jumps" abruptly from one phase to the next. In turn, it produces a vectorgram that has a distinctive form. That is, petals are absent in an NTSC vectorgram pattern. Let us consider the development of the pattern. Fig. 7-14 shows the chroma signal phases and amplitudes that we are concerned with. This "kite-shaped" vector pattern is basically an ideal NTSC vectorgram. Each vector starts at the center of the pattern and ends at one of the arrowheads. Of course, theory and practice are not quite the same, for the following reasons.
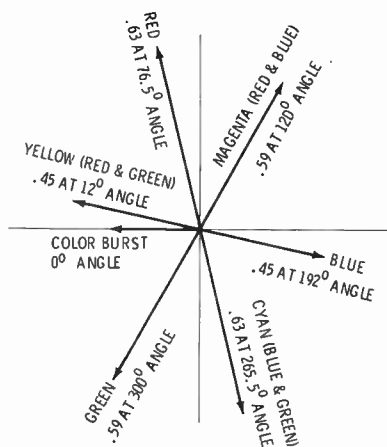

Fig. 7-14. NTSC chroma signal phases and amplitudes.

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With reference to Fig. 7-15, the basic test setup is employed, in which the $R - Y$ signal is fed to the vertical channel of the scope, and the $B - Y$ signal is fed to the horizontal channel. As noted previously, the $B - Y$ signal will have to be coupled directly to the horizontal-deflection plates in the CRT, in case the horizontal amplifier of the scope has inadequate bandwidth. An NTSC color-bar signal is employed, which has the sequence G, Y, R, M, C, and B; however, the sequence of colors is arbitrary and it makes no difference insofar as the pattern shape is concerned. Note that white and black are not colors, and are disregarded in the analysis.

In Fig. 7-15, the green bar makes an abrupt transition to the yellow bar, the yellow bar makes an abrupt transition to the red bar, and so on. Unlike a keyed rainbow signal, there is no black bar between each pair of chroma signals. Therefore, the vectorgram has excursions through the center of the pattern only between the magenta and cyan bars, and between the blue and green bars, in this example. The horizontal-blanking interval (not shown in Fig. 7-15) occurs between the black and green bars. The spot travel in the vectorgram is indicated by arrows. That is, the spot travels via (1), (2), (3), and so on.

A vectorscope graticule for an NTSC signal is not the same as a graticule for a keyed rainbow signal. Fig. 7-16 shows an NTSC graticule. The vectorgram pattern is characterized by bright spots and faint lines from one spot to the next. In normal operation, the bright spots fall within the small circles on the graticule. A typical NTSC vectorgram display is illustrated in Fig. 7-17. Demodulation phase errors show up as displacement of the bright spots (vector tips) from the graticule calibration circles. Note that the entire vectorgram rotates when the color-phasing control of the receiver is adjusted.

To position the vectorgram pattern in reference position, we proceed as follows:

1. Adjust the vertical and horizontal gain controls (Fig. 7-15) to obtain vertical and horizontal pattern proportions indicated by the calibration circles on the graticule (Fig. 7-16).
2. Adjust the color-phasing control of the receiver to move the red vector into the corresponding circle on the graticule. (Red is used as a reference because the receiver is ordinarily adjusted for optimum flesh tones).
3. Touch up the scope gain settings and the positioning controls to move the maximum number of vectors possible into the calibration circles.

We evaluate the vectorgram pattern by noting the various errors in amplitude and phase of the vectors. Since circuit action is not perfect, allowance is made for small errors due to component tolerances. It is
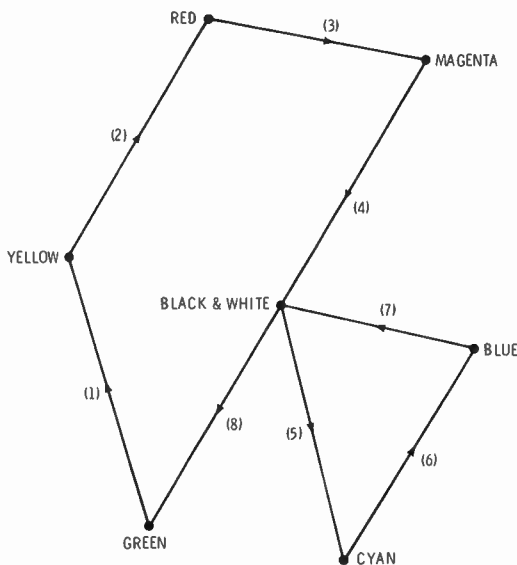
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assumed in this discussion that the color-bar generator is in good operating condition. We would otherwise misinterpret any generator defects to the receiver under test. Next, let us consider some useful fol-

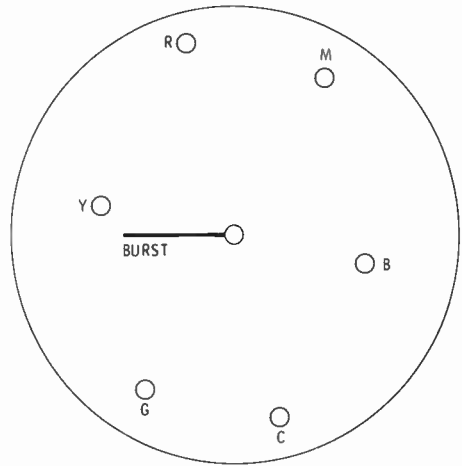(A) Block diagram.

(B) Color-bar sequence.

(C) Vectorgram.

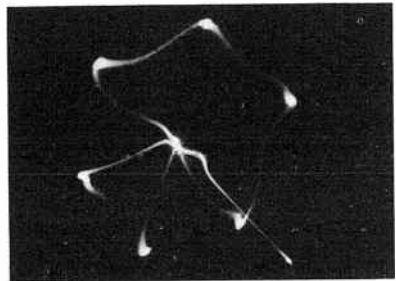Fig. 7-15. Display of chroma phases in a vectorgram pattern.

low-up tests that can be made to break down the analysis of the pattern, in case substantial distortion is present. Fig. 7-14 showed that the red phase is normally displayed $13.5°$ from the $R - Y$ phase, and that the blue phase is normally displayed $12°$ from the $B - Y$ phase. In turn, the following individual tests are helpful:

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Fig. 7-16. Vectorscope graticule
for NTSC signal.

1. Set the NTSC generator to R − Y output. Normally, a vertical trace is displayed on the vectorscope screen. If the trace slopes to the right or left, the R − Y signal is producing more or less output from the B − Y channel, and a phasing error is present.
2. Set the generator to B − Y output. Normally, a horizontal trace is displayed. If the trace slopes uphill or downhill, the B − Y signal is producing either more or less output from the R − Y channel, and a phasing error is present.
3. Most NTSC generators provide I and Q signals, also. When the generator is set for I and Q outputs, their vectors are normally displayed 90° apart, as shown in Fig. 7-18; also, the I vector is normally 33° left of the vertical axis on the graticule.
4. Some NTSC generators provide a $G − Y\underline{/90°}$ test signal. This vector normally appears as a diagonal trace which is practically at right angles to the green axis.
5. Switch the generator to its complete color-bar output, and observe the vectorgram as the Y signal is switched off and on. Normally, the vectorgram does not change shape. If the Y signal

Fig. 7-17. Typical NTSC vectorgram display.

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affects the vectorgram pattern shape, there is a receiver defect present that permits the Y signal to gain entry into the chroma channels.

If you are using a scope that has adequate horizontal-amplifier bandwidth, the vector pattern can be checked at the output of the chroma demodulators, as noted in Fig. 7-15. This test is useful to determine whether the pattern distortion is occurring in the demodulator section, or in the circuitry between the demodulators and the color picture tube. Note that $R - Y$ and $B - Y$ demodulators are depicted in Fig. 7-15. In case X and Z demodulators are used, this test will not be useful unless the demodulation angle is specified in the receiver service data. Various X and Z demodulators operate on an angle that may be less or greater than $90°$. It is necessary to know this angle to make an informative test of demodulator action.

Our first concern is to correct component defects (or circuit adjustments) that cause substantial errors in $R - Y$ and $B - Y$ signal relations at the color picture tube. The fault may occur in a chroma demodulator, matrix section, or amplifier. This is usually the most difficult part of the troubleshooting procedure. After the $R - Y$ and $B - Y$ channels are operating normally, it is comparatively easy to evaluate the operation of the $G - Y$ channel. Facility in vectorgram analysis requires both study and experience, as in any other field of sophisticated instrument application.

Fig. 7-18. $R - Y$, $B - Y$, I, and Q phases.

SUMMARY

True sine-wave signals that have the same amplitude with a $90°$ phase difference produce a circular vectorgram pattern.

Harmonics in chroma-demodulator output signals are usually caused by overload distortion.

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Clipped sine waves produce vectorgram patterns with one or more "flats" which may appear at the top, bottom, or either side of the pattern.

A diagonal ellipse indicates that the phase difference between the vectorscope input signals is an angle other than 90°.

Vertical or horizontal ellipses indicate that the vectorscope input signals do not have equal amplitudes.

Scope amplifiers may be used to process vectorgram signals, provided the amplifiers have adequate bandwidth (at least 1.5 MHz).

An inner circle of elliptical shape in a vectorgram indicates that the input signals have baseline curvature.

"Petals" are produced in a vectorgram because a keyed rainbow signal is a linear phase sweep.

Vectorgram "petals" are distorted in practice because chroma circuit action is not perfect.

An NTSC signal can be used to display a vectorgram; however, a different type of graticule is used on the vectorscope.

Individual vertical and horizontal gain controls are very desirable for good analysis of an NTSC vectorgram.

Troubleshooting is facilitated by use of the $R - Y$, $B - Y$, I, and Q signals provided by an NTSC generator.

It is often helpful to check the vectorgram at the chroma-demodulator output terminals, if the scope amplifiers have adequate bandwidth.

REVIEW QUESTIONS

1. With reference to Fig. 7-1, what type of pattern will be displayed if the amplitude of the vertical signal is increased? If the amplitude of the horizontal signal is increased?
2. If the clipped peak in Fig. 7-2 was occurring on the other input waveform, where would the "flat" appear on the vectorgram?
3. How would you proceed to correct a phase error in the vertical amplifier shown in Fig. 7-6?
4. If a vectorgram displays an abnormally large inner circle, what receiver defects would you look for?
5. Why are "petals" absent in an NTSC vectorgram pattern?

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Using SCOPES in
COLOR TV
BY ROBERT G. MIDDLETON

Scope applications in color-TV servicing include all the procedures used in black-and-white TV servicing, plus numerous tests that are unique to chroma circuitry.

This book concentrates on chroma-circuit waveform analysis and the interpretation of special patterns, such as vectorgrams. The first chapter deals with different types of scopes and their applications to color-TV circuitry. Another chapter deals with color waveforms with the distinction between ideal and practical waveforms.

Most scope applications in chroma circuits require the use of a color-bar generator; therefore, there is a comprehensive discussion of the operation and maintenance of this piece of test equipment. A generator malfunction can cause misleading symptoms and a waste of time.

The uses of a scope in checking bandpass amplifiers, chroma demodulators, various types of matrixing circuitry, and the practical use of vectorgrams are thoroughly discussed.

Professional technicians will find this book an extremely helpful supplement to generalized books on color-TV troubleshooting. It will prove invaluable in coping with the problems that arise during the successful servicing of color-TV sets.

ABOUT THE AUTHOR

Bob Middleton is one of the few full-time, professional freelance technical writers in the electronics field. His many books have proven invaluable to technicians and engineers because they are based on his own personal experience. His home workshop is filled with a wide variety of test instruments, receivers, and other equipment which he uses in preparing the factual and practical content of his many books.

Other SAMS books by Mr. Middleton include: ten volumes of his famous *101 Ways to Use Test Equipment* series, *Solving TV Tough-Dogs*, *Bench Servicing Made Easy* *Troubleshooting With the VOM & VTVM*, *Scope Waveform Analysis*, *Know Your Color-TV Test Equipment*, *Know Your Sweep Generators*, *Know Your Signal Generators*, *Color-TV Servicing Guide*, *Transistor-TV Servicing Guide*, *Transistor Color-TV Servicing Guide*, and *Using Scopes in Transistor Circuits*.

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