CHAPTER 16
TV Receiver

16.1 Monochrome Receiver:

Fig. 16.1 shows the block diagram of a monochrome receiver. The tuner (RF) section includes both the VHF and UHF tuners. The function of the tuner is to select the desired channel and amplify the RF signal. RF frequencies are changed to IF frequencies (41-47 MHz) by heterodyning against the local oscillator frequency. If the VHF/UHF selector is in the UHF position, the UHF oscillator and mixer convert the UHF signals to a lower frequency in the IF range. This IF signal is amplified in the VHF tuner and then fed to the IF amplifiers. Thus, the UHF tuner consists basically of a local oscillator and a mixer without an RF amplifier. The IF carrier is at a frequency of 45.75 MHz and the sound IF carrier is at 41.25 MHz. The fixed difference of 4.5 MHz is the FM sound IF frequency. The output of the IF amplifier is coupled to the video detector. The video detector can be either an envelope detector or a synchronous detector. In the latter, the video carrier is heterodyned against its sidebands to provide different frequencies that constitute the original modulating video frequencies, thus, recovering the original video information. Also, in the video detector, the video carrier is heterodyned against the sound carrier to produce the 4.5 MHz intercarrier sound IF frequency. The sound IF frequency is then applied to the sound IF amplifier, and the video signal is applied to the video amplifier.

A portion of the video information is also fed into the automatic gain control (AGC) and the sync pulse separator circuits. In color broadcasts for color TV receiver, the output video detector will also contain a 3.58 MHz color carrier and its sidebands. This signal is fed to special color circuits. In monochrome receivers, however, the demodulated color signals are not permitted to pass through the video amplifier. This is done to avoid an interference pattern on the monochrome receiver screen.

The FM sound is amplified in the 4.5 MHz sound IF amplifier, and is then fed into an FM detector. In some receivers, an FM discriminator is used as the FM detector. This circuit requires a limiter for noise reduction. The detected picture signal is fed into a video amplifier. The basic function of the video amplifier is to drive the picture tube. If the picture is negative, it is applied to the grid, and if it positive, it is applied to the cathode. The peak to peak signal is about 100V and the bandwidth is about 2.5 MHz-3.25MHz. The sync pulse separator removes the synchronizing pulses from the detected video signal, amplifies them to the proper level, and then feeds them into the vertical and horizontal deflection sections (prob. 11-5, 11-6, 11-7).

The amplified sync pulses are coupled through an integrator to the vertical oscillator. This integrator filters and shapes the pulses, so that only the vertical pulses affect the vertical oscillator. The vertical output amplifier is a power amplifier that drives the vertical windings of the deflection yoke which is mounted on the neck of the picture tube. This vertical magnetic field drive moves the electron beam in the picture tube from the top of the screen to the bottom. The output of the sync pulse separator is also applied to the horizontal deflection section.

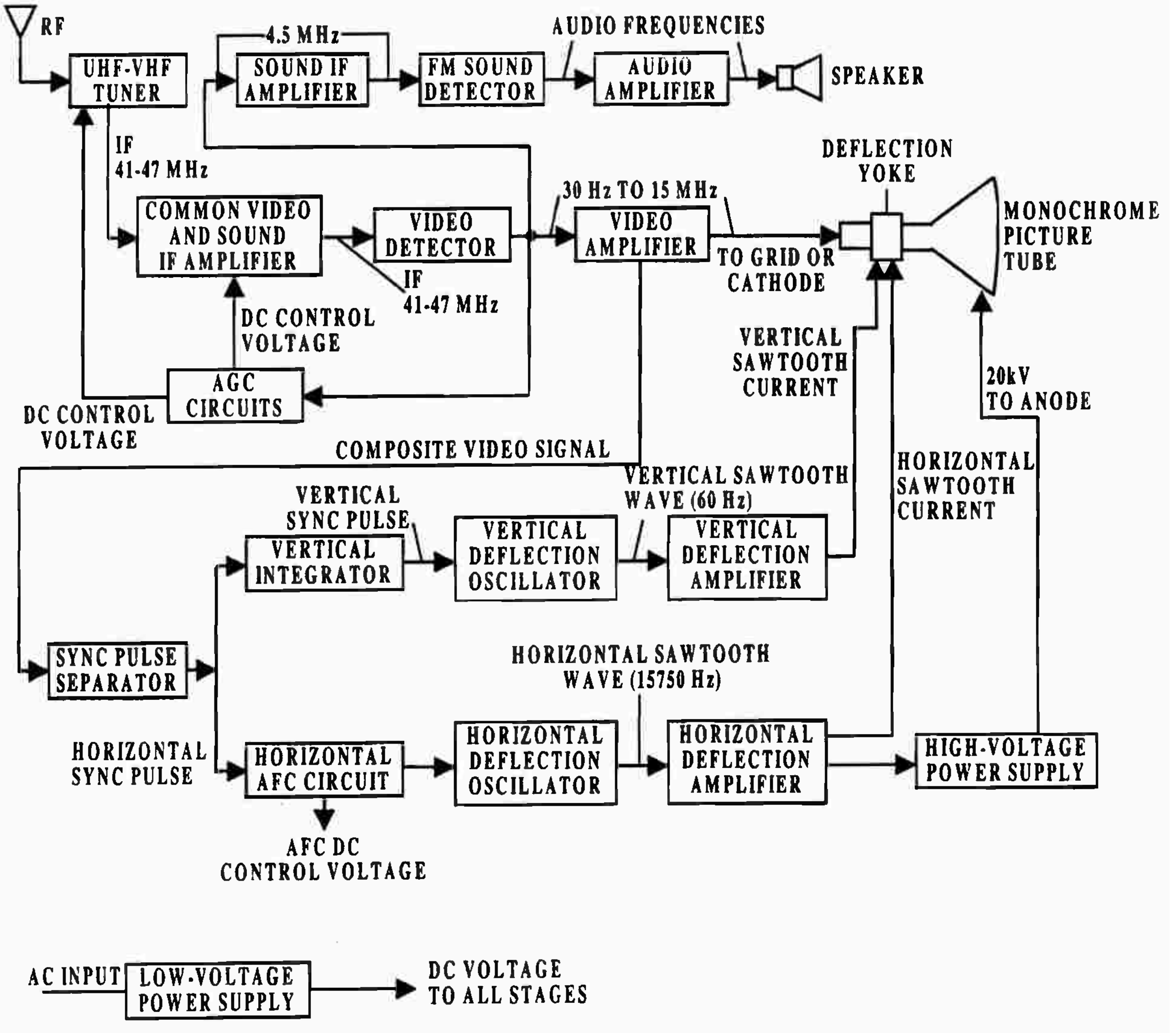


Fig. 16.1 Block diagram of a monochrome TV receiver

An automatic frequency control (AFC) circuit is used to prevent noise or other interference pulses from triggering the horizontal oscillator, and keeps the horizontal oscillator locked-in with the scanning beam in the TV camera. The horizontal oscillator generates a sawtooth waveform, which is coupled to the horizontal output amplifier. This power amplifier increases the level of the horizontal sawtooth wave, and shapes it for driving the horizontal windings of the deflection yoke on the neck of the picture tube.

At the end of each horizontal scanning line, the drive current in the horizontal windings of the yoke suddenly changes in order to retrace the scanning beam. This sudden current change produces a high voltage pulse across a winding of the horizontal output transformer. Here, by transformer action, the pulse is increased to about 20 kV. After this increase, the pulse is rectified, filtered and applied to the high voltage anode on the picture tube. This high voltage is called extra high tension (EHT). Finally, a low voltage power supply provides the necessary voltages for all of the circuits in the receiver.

16.2 Automatic Gain Control (AGC)

Superheterodyne AM radio receivers use a circuit to provide automatic adjustment of the output sound volume against variations in RF signal strength. This is called automatic volume control (AVC). In TV receivers, a similar circuit is used. It is called automatic gain control (AGC), since it deals with stabilizing against the picture and sound signal strength. The envelope detector detects the composite video signal. A smoothing filter produces a voltage proportional to the peak of the sync pulse. A simplified circuit (Fig. 16.2) illustrates this concept. This dc voltage is used to control the biasing, and hence, the transistor gain (β) of the RF and IF amplifiers. Since β is a function of the bias current, any change of this bias - either an increase or a decrease - will result in a change in amplifier current gain.

This characteristic leads to two methods of transistor AGC control, namely, forward AGC and reverse AGC (Fig. 16.3). With forward AGC in an npn transistor, a positive voltage increase will reduce the amplifier gain. For a pnp transistor with AGC voltage applied to the base circuit, a negative voltage increase will reduce the amplifier gain.

With reverse AGC, the gain of a transistor is reduced by decreasing the base to emitter bias. As the bias is decreased toward cut-off, the transistor gain decreases. For an npn transistor with AGC voltage applied to the base circuit, reducing the positive voltage at the base will reduce the amplifier gain. For a pnp transistor, a negative base voltage decrease will reduce the amplifier gain. Fig. 16.4 shows forward and reverse AGC circuits.

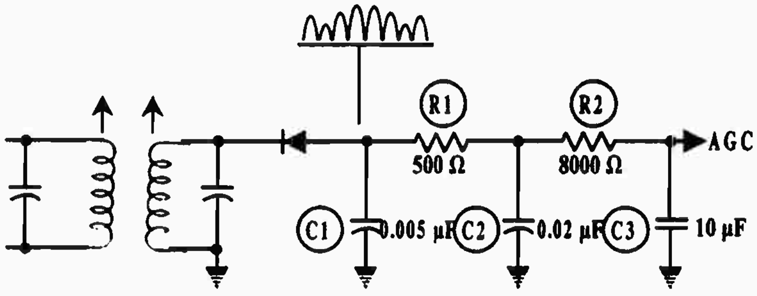


Fig. 16.2 Simplified AGC circuit

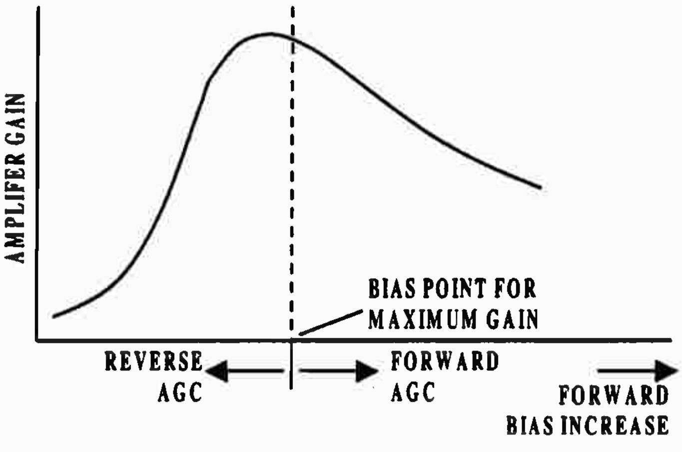


Fig. 16.3 Forward and reverse AGC

16.3 Synchronous Video Detector

Diode video detectors are simple, but have some important disadvantages:

1- Diodes have a barrier threshold voltage, which must be overcome before the diode conducts.
2- With low signal level diode operation, the diode operates in the nonlinear portion of its characteristic. A nonlinear device acts as a mixer, giving rise to sum and difference frequency components causing interference.
3- A diode detector has no gain, and in fact, introduces loss which has to be made up for.

The synchronous video detector requires two separate inputs. These inputs are the usual modulated IF signal and a reference signal at the picture IF carrier frequency and phase. A simplified block diagram of a synchronous video detector is shown (Fig.16.5a).

Basically, this diagram consists of two dual differential amplifiers and two modulator transistors. The reference picture IF carrier is fed in a push-pull fashion to the differential amplifier. The outputs of these amplifiers are connected in parallel. The result is a push-pull input and a parallel output.

The two modulator transistors have their inputs in a push-pull arrangement (Fig. 16.5b). As a result, they can vary the output currents of the differential amplifiers according to the modulation of the IF signal. These current variations represent the original video modulation. The IF picture carrier frequency is cancelled in the differential amplifiers, which act as balanced demodulators. The 45.75 MHz reference signal can be received by either one of two basic methods. One method is to pass the composite IF signal through a narrow BPF tuned to 45.75 MHz. The second method is to use a PLL (prob. 16.4).

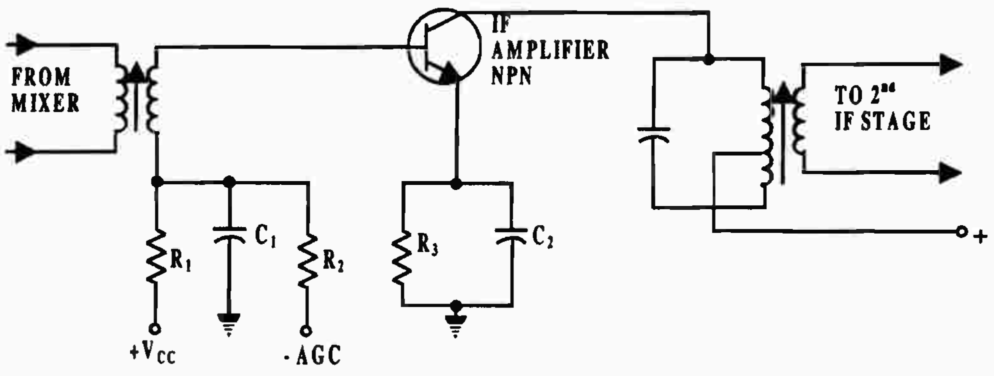
16.4 Automatic Frequency Control (AFC)

Automatic frequency control (AFC) - or automatic frequency tuning (AFT) - is used for proper picture, color and sound quality. AFT can also correct for the effect of cable loading leading to channel frequency offsets. The fine tuning control of a TV set adjusts the frequency of the local oscillator in the tuner. In color receivers, particularly, even a small deviation of the oscillator frequency from its correct setting may result in serious deterioration or a complete loss of color.

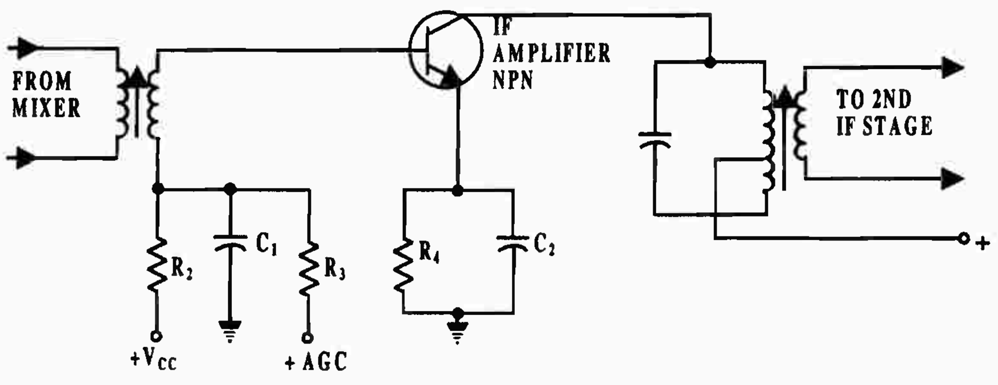
Oscillator drift may be caused by such factors as ambient temperature change, component aging and power supply fluctuations. The basic principle of AFT circuit is shown (Fig. 16.6).

When the tuner oscillator frequency is correct, the IF response is shown as the waveform (1) (Fig. 16.6a). This condition results in equal amplitude for the picture IF (45.75 MHz) and the color IF (42.17 MHz) carriers. These IF carrier frequencies are dependent upon the difference frequencies and the tuner oscillator frequency.

The difference frequencies should be above the picture RF carrier frequency by exactly 45.75 MHz. If the tuner oscillator frequency differs from this amount, either higher or lower, the frequency sensitive detector (discriminator) provides a dc output having either a positive or a negative polarity, depending upon whether the oscillator is above or below its required frequency. When the tuner oscillator is properly tuned (Fig. 16.6b), the picture IF carrier is at exactly 45.75 MHz. When this frequency is applied to the 45.75 MHz discriminator and differential amplifier, the outputs at W and R are equal dc voltages. The differential voltage applied to the varactor has a nominal value that is needed to produce the value required for biasing the varactor to give the capacitance which maintains the correct frequency. When the tuner oscillator frequency is too low (Fig.16.6c), the picture and color IF carrier frequencies are decreased. Note the unequal position of the IF response.



(a)



(b)

Fig. 16.4 Forward and reverse AGC circuits
a) reverse AGC b) forward AGC

The lower frequency picture IF carrier has moved to a higher amplitude point. The color IF carrier frequency has moved to a lower amplitude point. This condition causes weak color or loss of color. Because the picture IF carrier frequency is now lower than 45.75 MHz, the discriminator differential amplifier (or alternately PLL) increases the positive voltage at R and decreases it at W. This applies more reverse bias to the varactor - which reduces the capacitance in turn - and increases the oscillator frequency, and hence, compensates the original error (too low frequency). On the other hand, when the tuner oscillator frequency is too high (Fig. 16.6d), the picture and color IF carrier frequencies are increased. The picture IF carrier has moved to a low amplitude value.

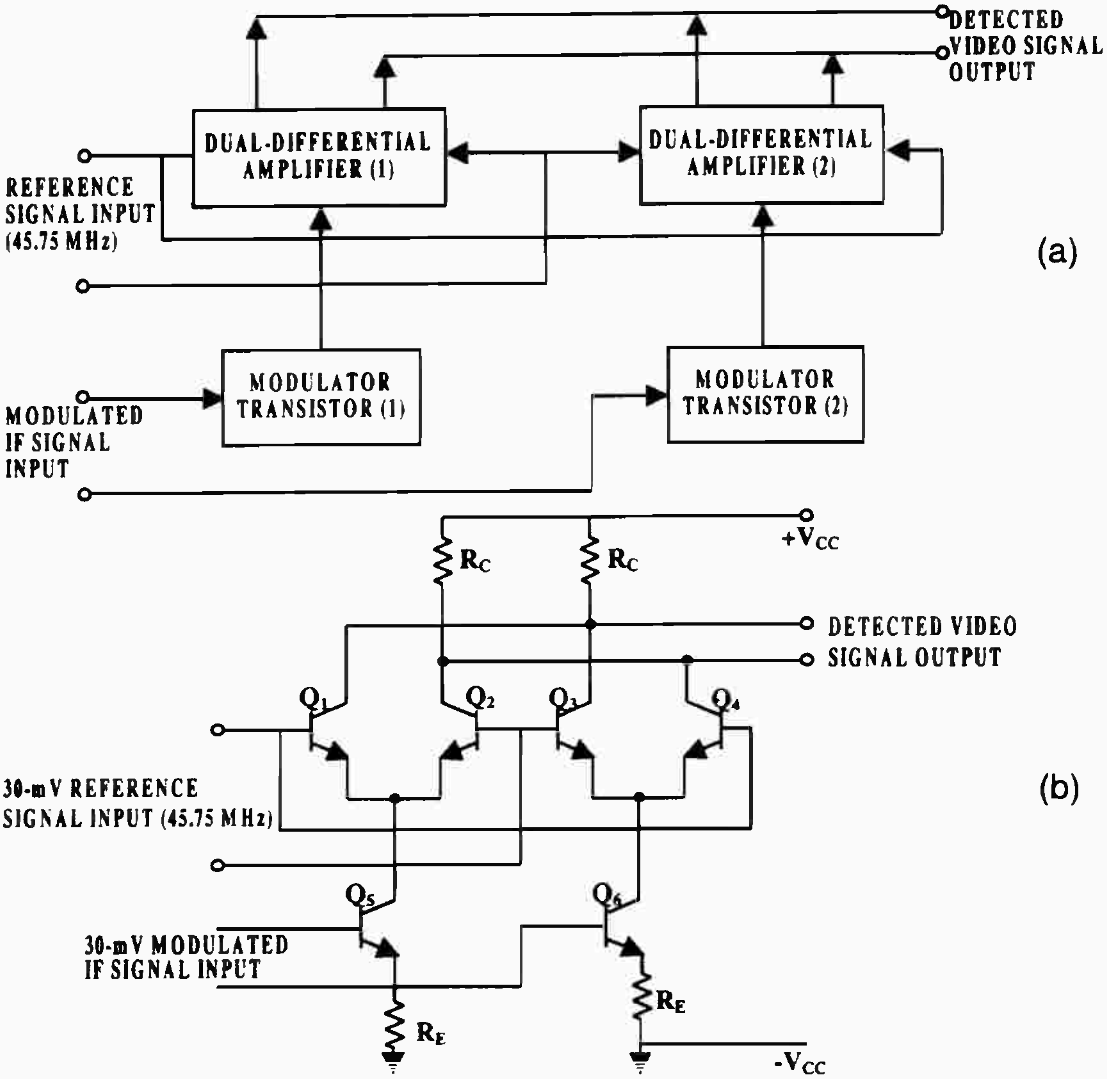


Fig. 16.5 Video detector
a) block diagram b) schematic diagram

This condition results in a weak picture perhaps with a loss of synchronization. The picture IF carrier frequency is now higher than 45.75 MHz, (noting the transposition after heterodyning). The output of the differential amplifier is such that the positive voltage at R decreases and that at W increases. This reduces the reverse bias across the varactor, which decreases its capacitance, and increases the tuner oscillator frequency, hence, canceling the error (too high frequency). The pull-in range for the system shown is usually ± 50 kHz, while the hold - in range is about ± 1 MHz.

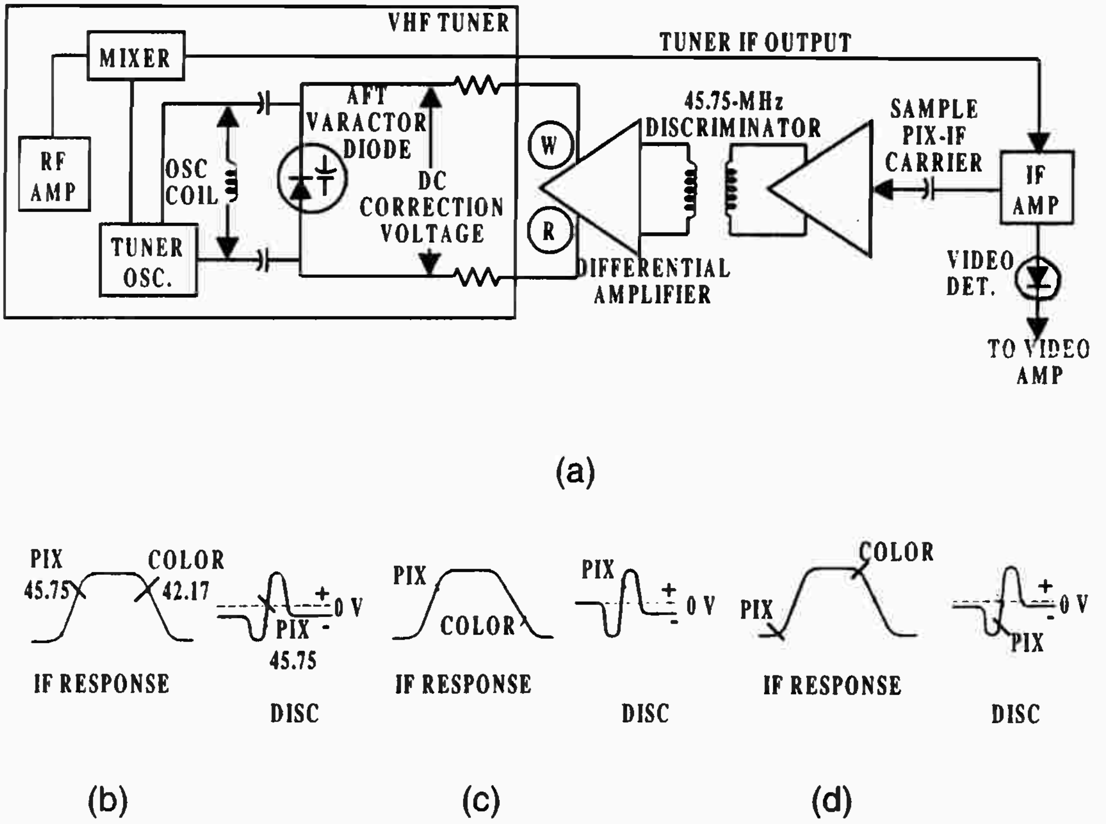


Fig. 16.6 AFT circuit

a) block diagram
b) correct local oscillator (nominal reverse voltage)
c) low local oscillator (more reverse bias)
d) high local oscillator (less reverse bias)

16.5 Color TV Receiver:

A color receiver must perform all the functions of a monochrome TV set with additional functions as well. These include the detection and processing of color signal sidebands and color synchronization. A crude block diagram of a color TV receiver is shown (Fig. 16.7). The RF, IF and audio sections resemble basically those for the monochrome receiver. A 920 kHz beat frequency results from the difference between the color subcarrier (3.58 MHz) and the sound carrier (4.5 MHz).

Therefore, in color TV receivers, the sound and video carriers are usually separated at the last IF stage to keep the 920 kHz beat interference voltage as small as possible.

The sound and video carriers are mixed together in a solid state diode to produce the 4.5 MHz sound IF signal. This signal is then amplified by a sound

IF amplifier, and applied to a sound detector stage, where the original audio signal is recovered. The audio signal is then amplified by an AF amplifier, and is then outputted to loudspeakers.

In the video detector, the signal is demodulated, giving back the 0 - 4.2 MHz monochrome (luminance) signal, and the color sidebands. The various synchronizing pulses plus the color burst are also present. At the output of the detector, the brightness must be fed to a separate amplifier.

The color sidebands are separated from the full signal and transferred to a separate chrominance section. The color burst must be made available to the color sync circuits. The signal from the video detector is fed to a video amplifier. Here, both chroma and monochrome signals are amplified.

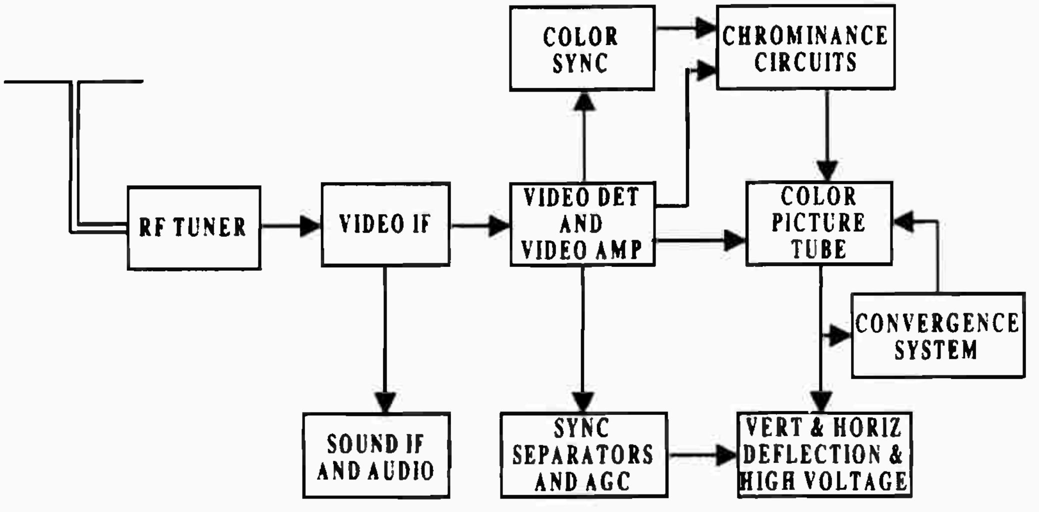


Fig. 16.7 A simplified block diagram of a color TV receiver

The monochrome signal is then transferred to a video amplifier. From this stage, it goes to a matrix network or to the cathode of the picture tube. The chroma signal is taken from the first video amplifier and coupled to a bandpass amplifier in the chrominance section. The burst amplifier separates the burst signal from the chroma signal. The stability of the 3.58 MHz carrier is important, since it must be reinserted into the chroma demodulators. The chrominance section separates and amplifies the chrominance section, and demodulates the individual red, green and blue signal components. Then, by a matrixing (or signal adding network) it couples the correct portions of these signal components to the tricolor picture tube.

The sync separators, AGC circuits, horizontal deflection, vertical deflection and EHT systems are essentially similar to those in monochrome receivers. Nevertheless, the color picture tube requires 30 kV and a special voltage regulation.

16.6 Color Processing:

From Fig.16.8, full color signal is obtained from the video detector and fed to a bandpass amplifier. Also applied to the bandpass amplifier is a gating pulse which keys off the amplifier by applying a pulse derived from the horizontal deflection output transformer. The pulse arrives only during the horizontal retrace interval when the color burst is passing through the system.

The bandpass amplifier also receives a dc biasing voltage from a stage known as color killer, which is located in the color sync section of the receiver. Its purpose is to bias the bandpass amplifier to cut-off in the absence of a color signal, i.e., when a monochrome program is transmitted. This circuit prevents random color caused by noise in the $I-Q$ demodulators. In the output circuit of the bandpass amplifier, there is a bandpass filter which permits signals from 2.1 to 4.2 MHz to pass, but strongly attenuates all others. This filter, thus, separates that portion of the signal containing only monochrome information. The color signal is fed to the I and Q color demodulators. Also, arriving at these demodulators is a 3.58 MHz signal, which represents the missing subcarrier. It must be recombined with the color signal of the demodulator, so that the original I and Q signals can be detected. The 3.58 MHz signals applied to the I and Q channels differ by 90°.

The outputs of the two demodulators represent the original I and Q color signals. The I signal then is passed through a 0-1.5 MHz BPF and a special 0.5 μs delay line. It may receive additional amplification before being made available to the adding or matrix network in positive and negative polarity. The double polarity $I-$ signals are required in the final mixing process from which red, green and blue voltages are recreated. A single phase splitter provides the positive and negative $I-$ signals. The use of a 0.5 μs delay network in the $I-$ channel is needed due to the use of the narrow 0-0.5 MHz BPF through which the $Q-$ signal is sent.

The $Y-$ signal had to be delayed 1 μs for the same reason. The difference in delay between the Y and $I-$ signals arises from the different characteristics of their respective networks. In the $Y-$ channel, the bandpass of the circuits extends from 0-3.5 MHz (or 4 MHz). In the $I-$ channel, the bandpass extends only from 0-1.5 MHz. The narrower bandpass introduces some delay to slow $I-$ signal down to the $Q-$ signal. In the $Q-$channel, a demodulated $Q-$signal passes through a 0-0.5 MHz BPF, and reaches a phase splitter from which positive and negative $Q-$ signals are made available to the matrix. We now have at the matrix the I , Q and $Y-$ signals.

By properly combining them, we can obtain red, green, and blue voltages. The addition is carried out in a simple fashion by using a series of resistors. At the output of the matrix section, each of the three color voltages is separately amplified, and then transferred - via separate dc restorers - to the appropriate control grid of the trigun picture tube.

There are other systems for color processing. One of these systems is the $R-Y$ and $B-Y$ system. In the $R-Y$, $B-Y$ system (Fig.16.9), both channels possess the same bandwidth (0-0.5 MHz). In this narrower system, only the larger objects are in color. Time delay networks in the chrominance section are, thus, eliminated. The $G-Y$ signal is formed in a cathode circuit which is common to both $R-Y$ and $B-Y$ demodulators. The detected $R-Y$, $B-Y$ and $G-Y$ color signals are then fed directly to the grid of the picture tube, at the same time the Y - signal is fed to the three cathodes of the picture tube. Thus, matrixing is performed within the tricolor tube itself. When the Y - signal is added to the $R-Y$ signal, a voltage representing R will appear on the red gun, and so on.

16.7 Tricolor Picture Tube:

Color receivers employ a tricolor picture tube. The tube possesses three electron beams. The screen of the tube possesses three different color emitting phosphors. These color emitting phosphors are arranged in a dot or line pattern on the picture tube screen. Convergence circuits and convergence magnets are required to ensure that the beams strike the proper points on the screen.

There are basically three structures (Fig. 16.10). The first is delta electron gun and color dot phosphor triads on the screen. The second is three guns in-line using vertical color stripes. The third structure is one gun (three beams) in-line with vertical color stripes.

In the dot triad structure, the color producing dots are arranged on the screen in an orderly array of small triangular groups (Fig. 16.11). The actual number of such dots for a 21-in screen is somewhere in the neighborhood of 1 million dots (or nearly 350000 triads). Each dot has a diameter of 16 mils (0.016 in). If all three dots in a group are bombarded at the same time, the combined red, green, and blue light outputs will present one mixed color to the observer's eyes.

Proper beam convergence is an important aspect of delta gun picture tube operation. Thus, to ensure that each beam strikes only one type phosphor dot, a mask (called shadow mask or aperture mask) is inserted between the electron guns and the phosphor dot screen.

The mask is positioned in front of and parallel to the screen. It contains circular holes equal in number to the dot triads. Each hole is so aligned with respect to its group that any one of the approaching beam can strike only one phosphor dot. The remaining two dots of the triad are hidden (or shadowed) by the mask opening. This way we can minimize color contamination which occurs when a beam either hits the wrong dot or overlaps several dots at the same time (Fig. 16.12).

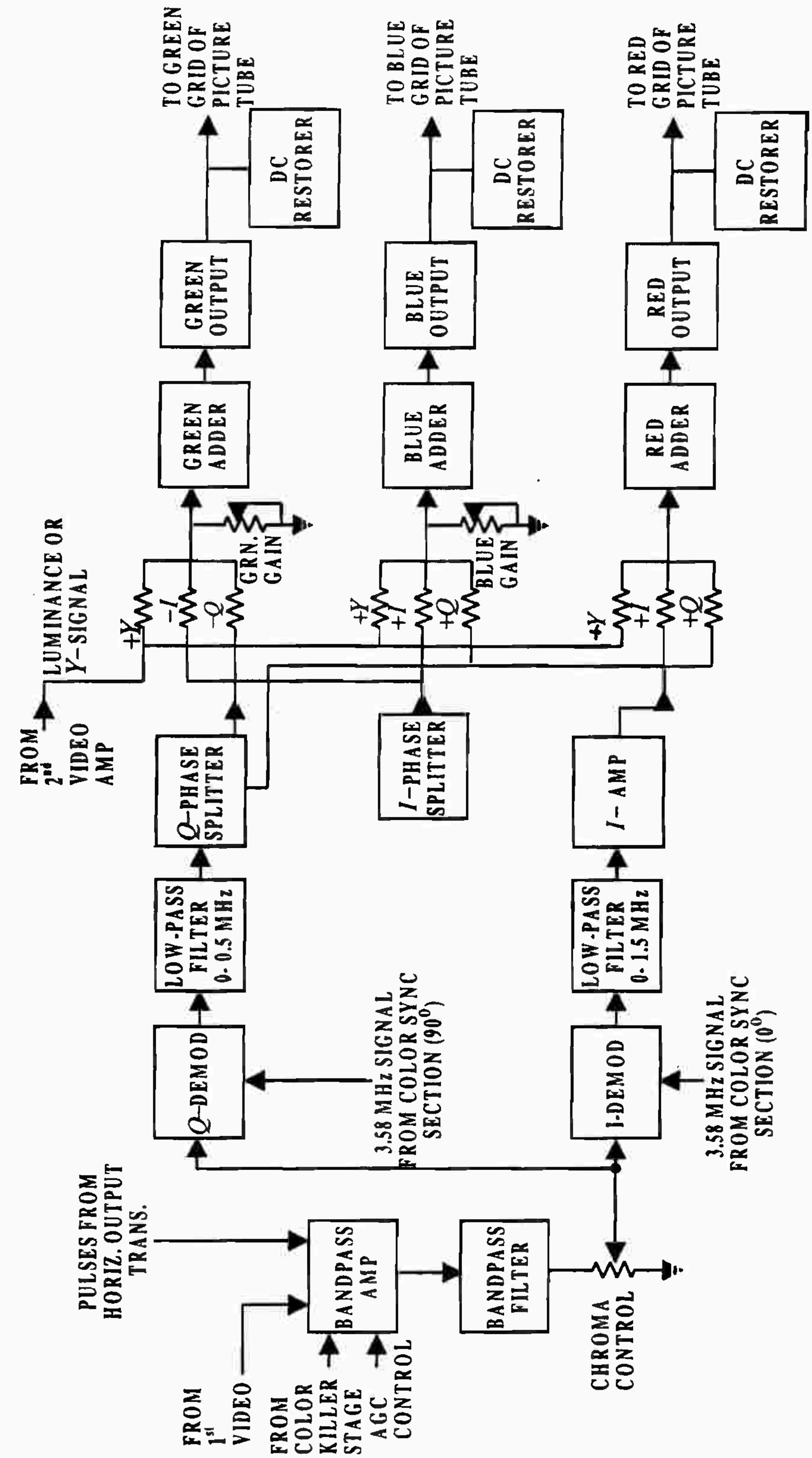


Fig. 16.8 Chrominance section employing *I-Q* demodulators

There are two types of convergence: static convergence and dynamic convergence. In static convergence, the positions of the beams are adjusted by sing either fixed dc voltages or fixed magnetic fields. Since the screen and the shadow mask are not spherical, convergence may not be achieved away from the center.

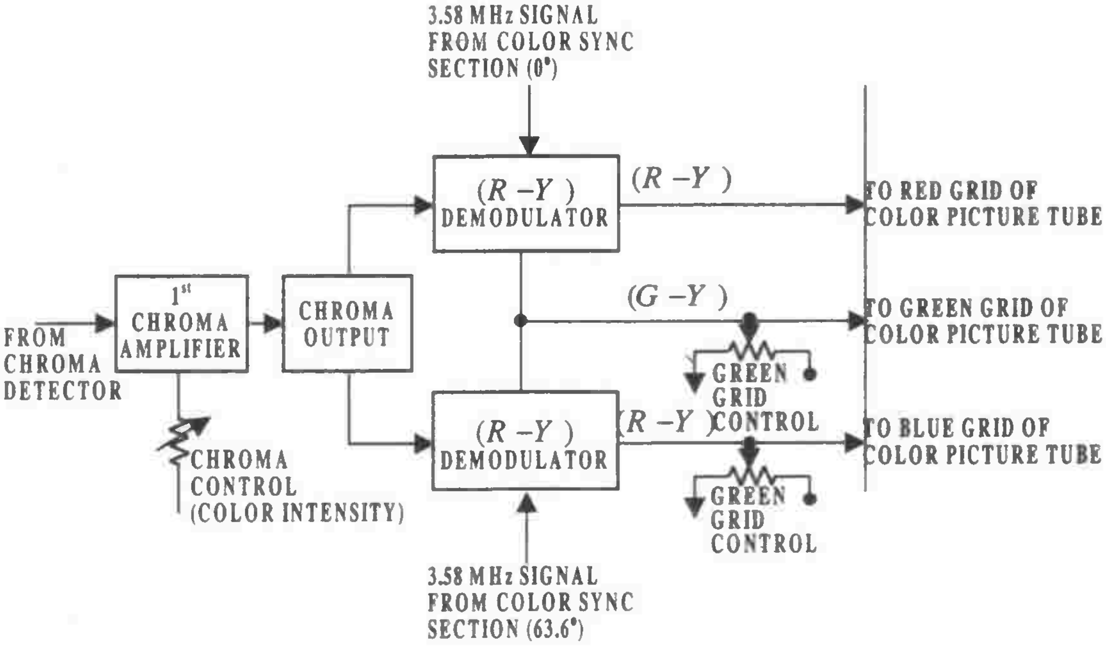


Fig. 16.9 $R-Y$, $B-Y$ **system**

Color Sync signals are separated by 63.6° to eliminate crosstalk

This converged condition of the beams - as they swing away from the center - is necessary. This is called dynamic convergence. It is accomplished by dynamic convergence currents which are correction currents needed for the vertical and horizontal deflection systems. When the three beams are in the center of the screen, the correction current is zero. On either side of the center, however, the current varies. The combined effect of the correction (dynamic and static fields) is to keep the beams properly converged at every point of the screen (Fig.16.13).

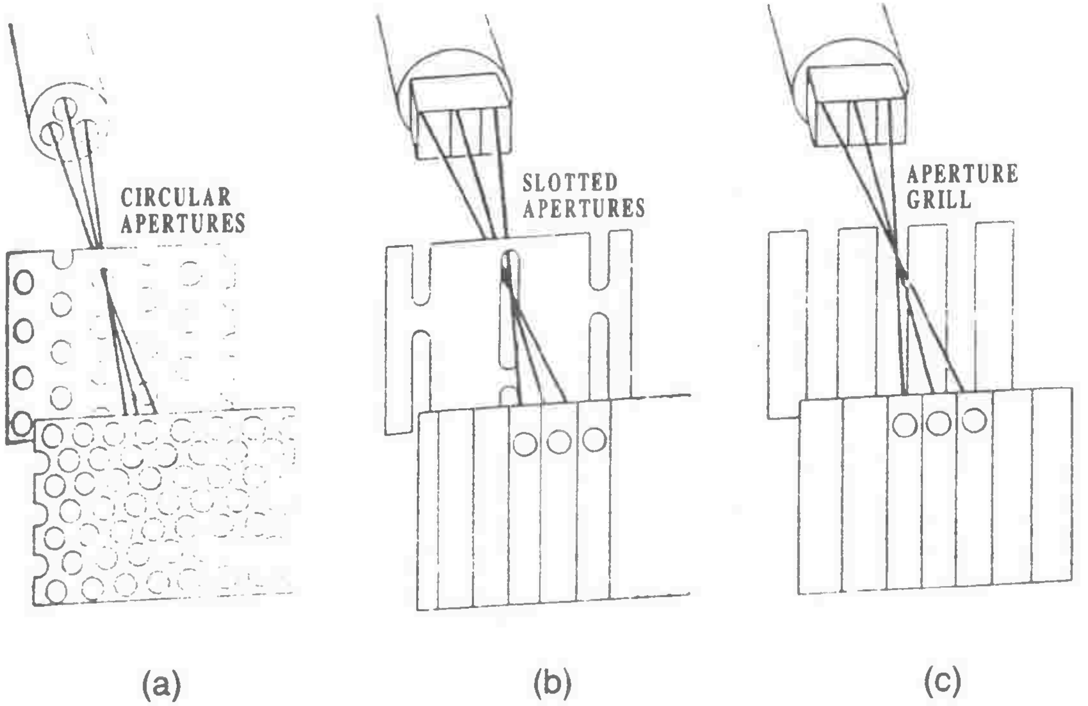


Fig. 16.10 Three basic types of color picture tubes

a) delta electron gun with circular aperture mask and color phosphor dot triads
b) RCA in-line gun with slotted aperture mask and vertical color stripe triads
c) Sony Trinitron in-line gun with aperture grill mask and vertical color stripe triads.

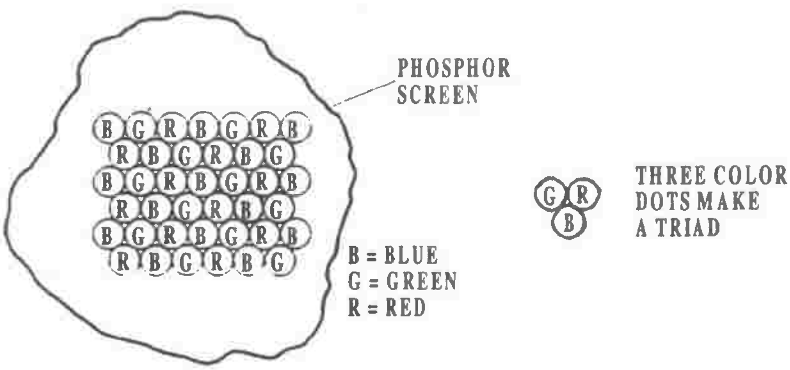


Fig. 16.11 Triad structure in a delta gun

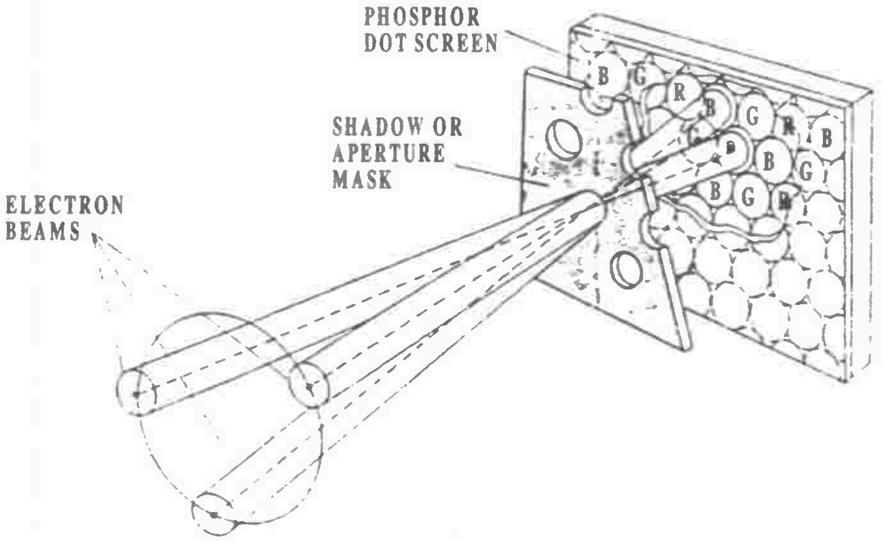
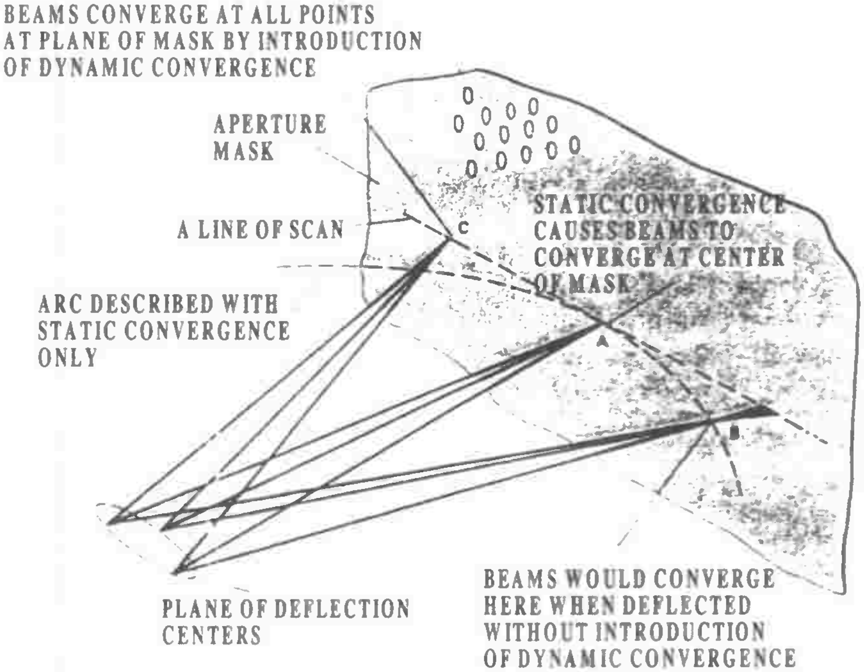


Fig. 16.12 Convergence of the three beams at a single hole in the shadow mask



(a)

Fig. 16.13 Need for dynamic convergence

a) static versus dynamic convergence
b) dynamic convergence currents (parabolic)

Ex. 16.1:
Describe the operation of the blocking oscillator used for vertical deflection (Fig. 16.14).

Solution:

The tightly coupled windings on transformer T_1 provides positive feedback from collector to base of transistor Q_1 (which is operated as class C and is turned on for brief intervals). When the supply voltage is applied, a negative forward bias voltage appears at the base of Q_1 (pnp transistor) due to the voltage divider R_1-R_3. Capacitor C_2 is not charged. Transistor Q_1 conducts, and C_2 starts to charge in the negative direction. As the collector current increases in the primary of T_1, a voltage is induced in the secondary winding, which is connected to the base of Q_1 with the polarity shown.

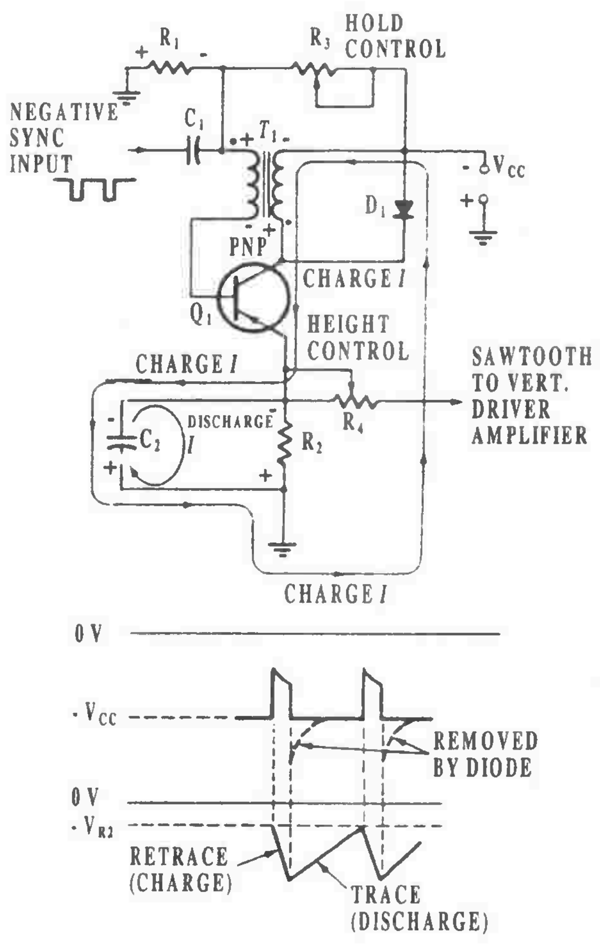


Fig. 16.14 Vertical deflection sawtooth generator using a blocking oscillator

The base voltage now consists of two voltages in series to ground: the voltage across R_1 and the T_1 secondary voltage. Both voltages are series aiding, and force the base to a higher negative voltage (more forward bias). Transistor Q_1, thus, conducts even more strongly, and C_2 charges rapidly and linearly to produce the retrace portion of the sawtooth wave. The regenerative cycle - in which C_2 continues to charge to a higher negative voltage - goes on, until Q_1 saturates. Saturation causes the collector current in Q_1 to level off at the saturation level. T_1 now has a strong but steady magnetic field built up in the primary winding. No voltage is induced in the T_1 secondary winding at the moment the collector current saturates. The base voltage drops to the value developed across R_1. At this time, the C_2 voltage (reverse bias) exceeds the base voltage (forward bias), and transistor Q_1 cuts off. The steady magnetic field in T_1 now collapses, and induces a voltage pulse in both windings, with opposite polarity. The negative collector pulse is clipped, because of diode D_1 becoming forward biased. With Q_1 now cut off, C_2 begins to discharge through R_2, producing the trace portion of the waveform in the positive going direction.

Transistor Q_1 remains cut off until the voltage across C_2-R_2 decreases to the same value as the forward bias voltage across R_1. When this happens, the base to emitter junction again becomes forward biased, transistor Q_1 conducts, and the charging cycle begins again. The relatively slow discharge of C_2 through R_2 develops the trace portion of the sawtooth, and establishes the tracing time interval. Lock-in (or synchronization) is accomplished by applying negative going synchronizing pulses to the base. The sync pulse frequency must be slightly higher than the blocking oscillator natural frequency. Notice that during discharge, transistor Q_1 is cut off and the R_2-C_2 network is isolated from the remainder of the circuitry. This helps provide excellent frequency stability. R_3 provides hold-in control, and R_4 provides height control (prob. 16.8).

At the time Q_1 cuts off, the voltage transient pulses appearing across the T_1 secondary and primary might cause the collector base breakdown. Such transients are removed by connecting a diode across the primary winding. The diode conducts when the T1 voltage polarities are opposite those shown, and the magnetic field energy is then dissipated harmlessly through the diode.

Ex. 16.2:
Deduce the waveforms needed to drive vertical and horizontal yokes

Solution:

In electromagnetic deflection systems, the driving force in the picture tube is a magnetic field. Sawtooth deflection current is required. To develop such a current, a voltage waveform must be shaped - as in Fig. 16.14 - for resistor, inductor and a coil (L, R), respectively. In vertical deflection circuits, the resistance is an appreciable part of the L, R impedance. A trapezoidal wave is required across the vertical yoke in this case.

In horizontal deflection circuits, due to much higher deflection frequency, the reactance of the horizontal yoke is much higher than its resistance. The horizontal yoke looks almost like a pure inductance. A square wave is needed in this case. However, in a horizontal output amplifier, a trapezoidal waveform is needed to ensure sharp cut off of the output. Hence, a flyback transformer may be used to generate EHT (prob. 16.9).

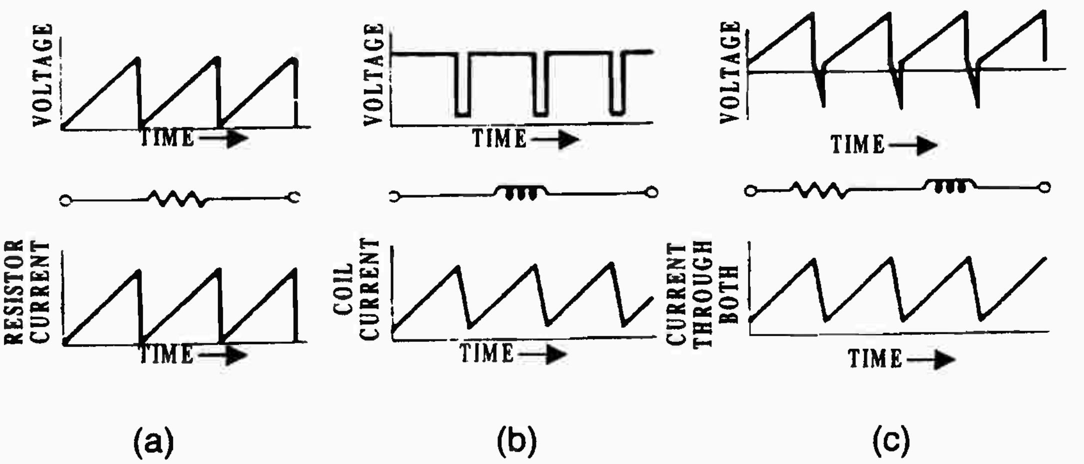


Fig. 16.15 Waveforms producing a sawtooth current drive for different loads
a) R b) L c) R,L

Problems:

1- Analyze the AGC circuit given (Fig. 16.4), and show how forward or reverse AGC is achieved.
2- Find the beat frequencies due to a nonlinear video detector.
3- Analyze the synchronous video detector circuit shown in Fig.16.5.
4- Design a PLL circuit for the generation of a picture carrier for synchronous video detector.
5- Propose a circuit for a sync pulse separator.
6- Analyze the AFT circuit shown in Fig. 16.6.
7- In Ex. 16.1, obtain an expression for the blocking oscillator frequency.
8- Discuss the function of the hold-in control and the height control in the circuit of Ex 16.1.
9- Using a simple model for a horizontal oscillator, show how EHT may be generated at its output, with the aid of an autotransformer (flyback transformer).
10- Discuss the operation of the circuits of the chrominance sections of Figs. 16.8 and 16.9.

References:

1- "Television Electronics", M. Kiver and M. Kaufman, 8th ed., Van Nostrand, Reinhold, N. Y., 1983.

2- "Basic Television and Video Systems", B. Grob and C. Herndon, 6th ed., Glencoe-McGraw Hill, N. Y., 1999.

3- "This is Electronics, circuits and applications", W. Burke, D. Irvin, G. Mann, Bobbs-Merrill, Indianapolis, 1981.

4- "Color Television", G. Hutson, P. Shepherd and J. Brice, 2nd ed., McGraw Hill, N.Y., 1990.

5- "Guide to TV and Video Technology", 2nd ed., E. Trundle, Newnes, Oxford, 1996.

6- "Television Engineering Handbook", K. Benson, McGraw Hill, N. Y., 1986.