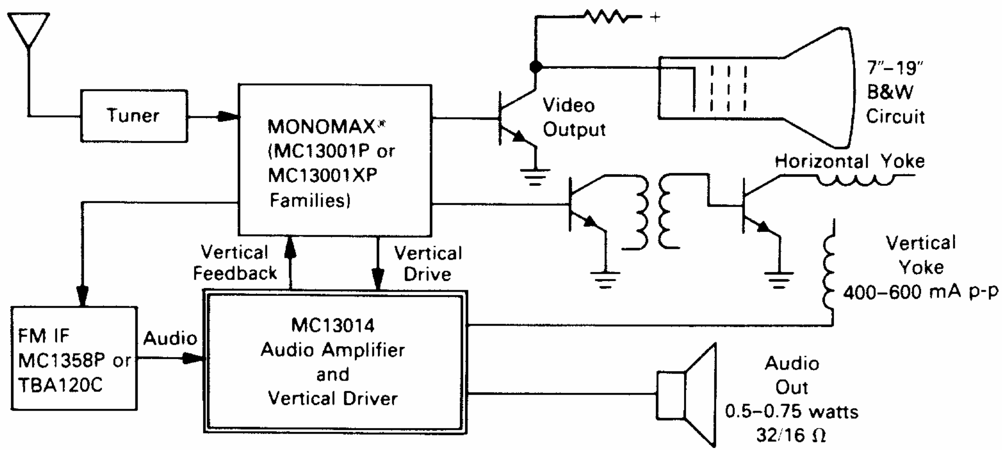
A8 Television Receivers

Many receiver subsystems are being integrated into a single chip, thus allowing the receiver size to shrink dramatically.

Integrated Monochrome TV Receiver[1]



Most TV sets today make use of highly integrated circuits. A partial list of these can be found in Appendix 1.

A8.1 Antennas

The purpose of an antenna is to collect and convert electromagnetic waves to electronic signals. These are then guided by transmission lines to the receiver front end.

In order for a picture to be usable, a high signal to nose ratio must be achieved. A video signal with an S/N of 10 dB is not usable whereas a S/N of 40 dB results in an excellent picture.

Although most TV receiving antennas are simply a piece of bent wire, their interaction with electromagnetic fields is quite complex, and a whole array of terms is needed to characterize them:

Beamwidth: the angle defines by the radiation pattern where the signal strength drops 3 dB of its maximum value in a given plane.

Polarization: the plane of electric field polarization with respect to the earth.

Gain: a figure of merit used to quantify the signal capturing ability of the antenna. It is closely related to *directivity* and *beamwidth*.

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1 Motorola Linear/Interfaces Databook

_____ Notes _____

Effective area: a measure of the antenna's ability to collect energy. It is related to gain by the expression: $A = G\lambda^2/4\pi$.

Input impedance: The impedance that is necessary in the receiver for maximum power transfer to occur.

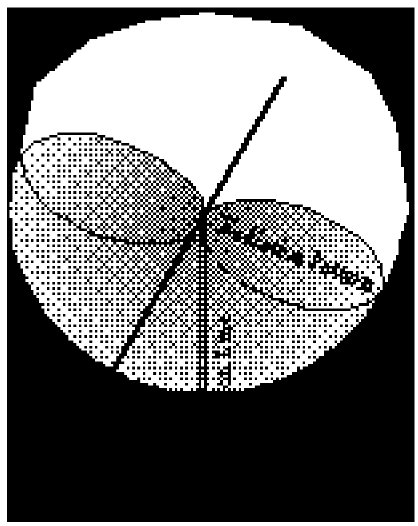
Radiation resistance: the ratio of the power driving the antenna to the square of the current driving its terminals.

Bandwidth: the usable frequency band associated with the antenna.

Dipole Antenna

A dipole is sometimes referred to as a Hertzian dipole. Since it has a relatively simple construction and it's radiation characteristics are well defined, it is often used as the standard to which all other antennas are compared.

The dipole radiation pattern is shaped like a donut.



The simplest antenna is the dipole. The relationship between the current in the antenna and electric field is given by:[2]

$$E_\theta = j\eta \frac{e^{-j\beta r}}{2\pi r} I \frac{\cos\left[\frac{\beta L \cos\theta}{2}\right] - \cos\left(\frac{\beta L}{2}\right)}{\sin\theta}$$

where $E =$ electric field strength

$\theta =$ angle from antenna axis (radians)

$I =$ antenna current (rms)

$\eta =$ intrinsic impedance (377Ω)

$L =$ antenna length

$r =$ distance

A 1/2 λ dipole has an impedance of about 70 Ω. To increase this impedance and more closely match the characteristics of a twin lead cable, the dipole may

2 Antenna Theory & Design, Stutzmann & Thiele, eq. 5-6

be folded. A 1/2 λ folded dipole has an impedance of about 280 Ω, and is used as the driving element in many other types of antennas.

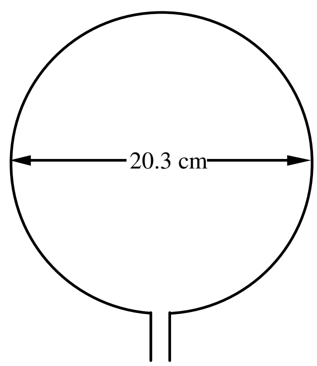
Most TV receivers are equipped with two indoor antennas, one to cover the VHF band and the other the UHF band.

The most common VHF antennas are the extendible monopole and vee dipole colloquially known as the rabbit ears. These are available with either a 75 Ω or 300 Ω impedance and have a typical gain of -4 dB with respect to a half wave dipole. The vee dipole has a lower input impedance than a straight dipole of the same length, but under some conditions, it can exhibit a higher directivity due to the reduction of sidelobes.

The common UHF antennas are the circular loop and triangular dipole. They typically have a 300 Ω impedance. The dipole version sometimes has a reflecting screen to improve the gain and directivity.

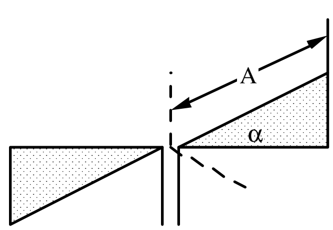
Loop Antenna

The entire UHF band can be received on a single 20.3 cm diameter loop. The circumference varies from one wavelength at 470 MHz to 1.7 wavelengths at 806 MHz. The directivity is about 3.5 dB. The mid band gain is 3 dB higher than a 1/2 wave dipole, but falls off to about 1 dB at either end.



Loop antennas which are much smaller than wavelength they are attempting to catch, exhibit a null in the direction of the loop axis. This makes it suitable for radio direction finding equipment. If the loop size is increased, it begins to generate a lobe across the axis and in line with the feed.

Triangular Dipole [Bowtie]



_____ Notes _____

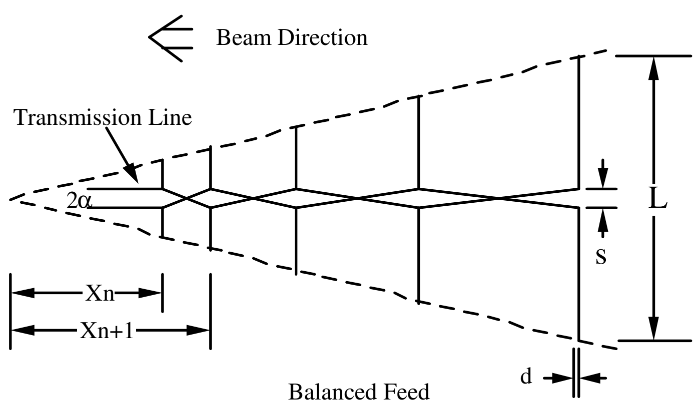
The bowtie antenna is formed of two triangular sheets connected to a transmission line and provides a 3 dB gain over a simple dipole. It can also be constructed of a wire mesh if the spacing is less than 1/10 wavelength. the input impedance is a function of length and flare angle. For television applications, the flare angle α is between 60^o and 80^o. If the antenna is mounted 1/4 wavelength in front of a reflecting surface, the gain increases to approximately 9 dB. Stacking two of them vertically one wavelength apart increases the overall gain to about 12 dB.

If the receiver is located at a great distance from the broadcast tower, it is often necessary to use an outdoor antenna. These often have a gain of 15 dB. Placing the antenna on a tall mast also increases the received signal strength by as much as an additional 14 dB. A further improvement occurs because these antennas have a greater immunity to interference, due to their complex structure.

Most outdoor antennas are a combination of two antennas [UHF and VHF] in a single structure. The VHF antenna is generally a log-periodic dipole array [LPDA]. The UHF antenna may be an LPDA, Yagi-Uda [yagi], corner reflector, parabolic reflector, or triangular dipole array with reflecting screen.

Log Periodic Dipole Array [LPDA]

This antenna is called a log periodic array because the impedance variations across the usable band are periodic functions of frequency. The high impedance version is mounted on an insulated boom and feed by a balanced cable. The average domestic antenna of this type has a gain of about 4.5 dB in the low VHF band, rising to 7 dB in the high VHF band.



Basic Design Formulas

$$\tau = \frac{X_n}{X_{n+1}} = \frac{L_n}{L_{n+1}} = \frac{s_n}{s_{n+1}} = \frac{d_n}{d_{n+1}}$$

typically $.7 \le \tau \le .95$

$$\alpha = \tan^{-1}\left[\frac{1-\tau}{4\sigma}\right]$$

typically $10^o \le \alpha \le 45^o$

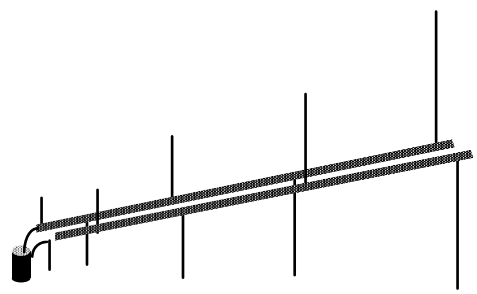
_____ Notes _____

$$\sigma = \frac{d_n}{2L_n}$$

$$\text{Bandwidth} = B = \frac{f_{high}}{f_{low}}\left[1 + 7.7(1-\tau)^2 \cot\alpha\right]$$

$$\text{Number of dipoles} = N = 1 + \frac{\ln B}{\ln\frac{1}{\tau}}$$

Most CATV applications use a 75Ω unbalanced configuration, because it is more compatible with their cable feeds and equipment.

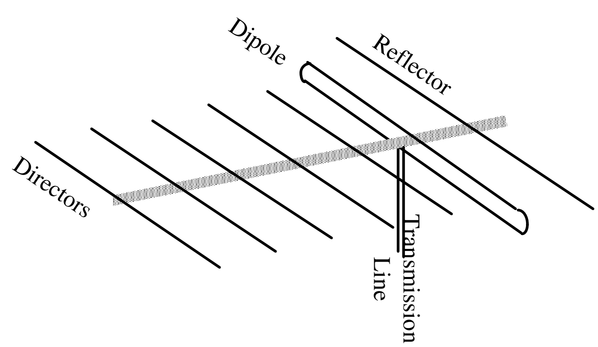


Unbalanced Coax Feed

Two parallel conducting booms form a low impedance transmission line. Phase reversal between dipoles is obtained by alternate attachment to the booms.

A UHF LPDA can be constructed from V-shaped dipoles. The dipoles are used in their 1/2 λ and 3/2 λ modes and eliminate the need for higher frequency dipoles.

Yagi Uda Antenna



The dipole is typically .45 to .49 wavelengths long. The reflector is normally .55 wavelengths long and place anywhere from .1 to .25 wavelengths behind the dipole. The reflector spacing has no affect on the forward gain, but does influence the front to back ratio and input impedance.

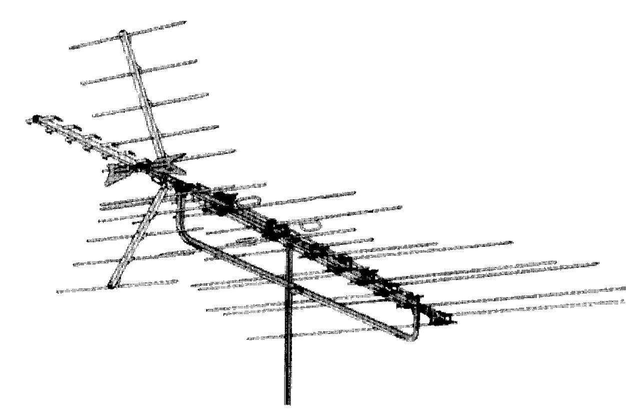
_____ Notes _____

The directors are normally .4 to .45 wavelengths long and are spaced at .3 to .4 wavelengths in front of the dipole. An antenna will usually have 6 to 12 directors.

Antenna transmission lines may be either 75 Ω unbalanced or 300 Ω balance cable. A baluns transformer is needed to match to a 75 Ω cable to a 300 Ω input. They have an insertion loss of about 1 or 2 dB.

Most modern receivers have to inputs; one accepts a 300 Ω twin lead cable on a screw terminal and the other accepts a 75 Ω coax cable on a type F connector.

Combined Yagi-Uda & Corner Reflector Antenna[3]



In order to increase the reception bandwidth, more than one antenna may be combined on a single mast. Separate transmission lines may be run to the receiver, or the signals may be combined though a transformer.

Transmission Line Loss for 100 ft Lengths at Different Channels[4]

		Channel Loss									
Cable	**Ω**	**4**	**9**	**14**	**24**	**34**	**44**	**54**	**64**	**74**	**83**
RG-58 U	75	2.4	4.1	6.8	7.2	8.0	8.5	8.8	8.8	9.2	9.5
RG-6U	75	1.7	3.0	5.1	5.5	5.8	6.1	6.5	6.8	7.1	7.4
Flat Twin Lead	300	0.9	1.6	3.0	3.3	3.5	3.8	4.0	4.2	4.4	4.6
Foam Twin Lead	300	1.0	1.9	3.5	3.8	4.1	4.3	4.6	4.8	5.0	5.3
Tube Twin Lead	300	0.9	1.7	3.2	3.5	3.7	4.0	4.2	4.5	4.7	5.0
Shielded Twin Lead	300	2.7	4.9	8.3	9.0	9.5	10.5	11.5	12.8	13.5	15.3

The above table represents average values. The loss can dramatically increase if the cable is in close proximity to metal or is wet.

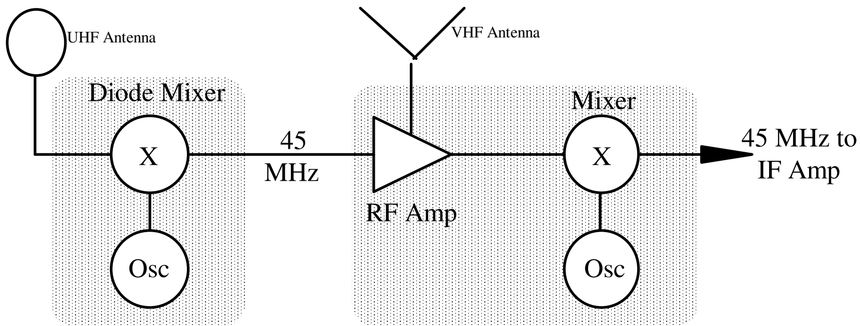
3 Color Television Theory & Troubleshooting, Stan Prentiss, FIG. 1-4

4 Antenna Engineering Handbook, 2nd ed., Richard C. Johnson & Henry Jask, Table 29-3

_____ Notes _____

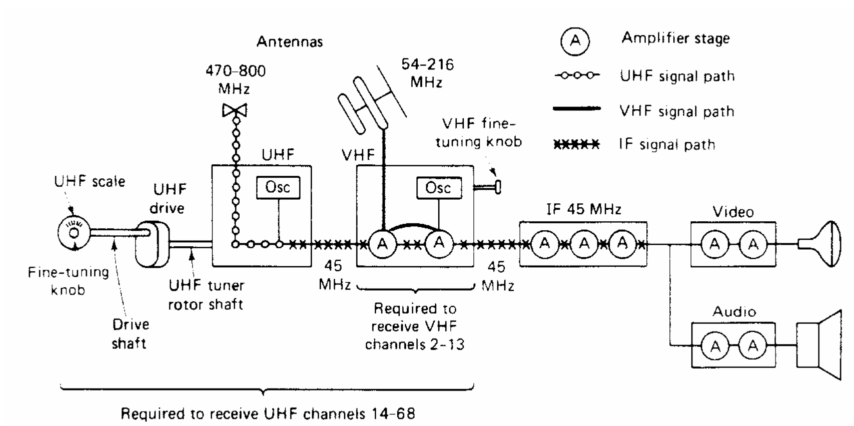
A8.2 Front End

- Selects the desired station
- Amplifies the signal
- Prevents reradiation
- Heterodynes the RF signal down to IF
- Provides impedance matching to the antenna
  Maximum power transfer
  Maximum signal to noise ratio



UHF Tuner VHF Tuner

UHF VHF Tuners[5]



UHF Tuner

When the UHF tuner is selected:

- The VHF oscillator is disabled
- The UHF oscillator is tuned to 45 MHz below the desired station frequency
- The antenna and oscillator signals are mixed through a diode

5 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-9

_____ Notes _____

- The desired station is heterodyned down to the 45 MHz IF frequency in one step
- The RF amplifier provides additional gain at the IF frequency

VHF Tuner

Must tune from 54 - 216 MHz.

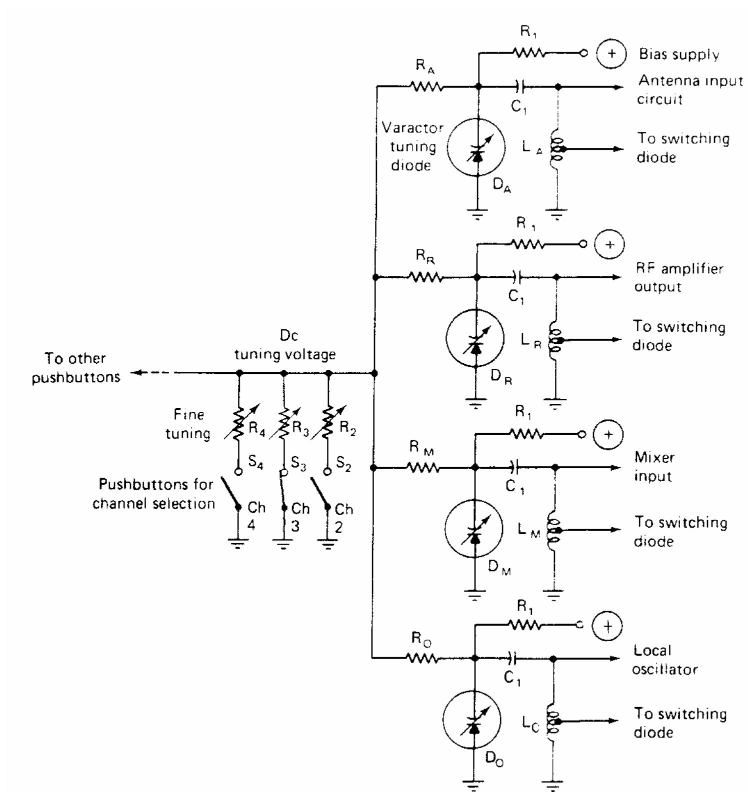
Turret or Drum Tuner

- When a station is selected, the required coils for the RF amp, mixer and local oscillator are connected into their respective circuits

Wafer switch type
  - The coils are wound on the outer rim of the switch and contain several turns for channels 2 to 6, and single or partial turns for channels 7 to 13

Electronic types
  - Phase locked loop frequency synthesizer
  - Varactor tuners

Varactor Tuner[6]



6 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-10

Notes

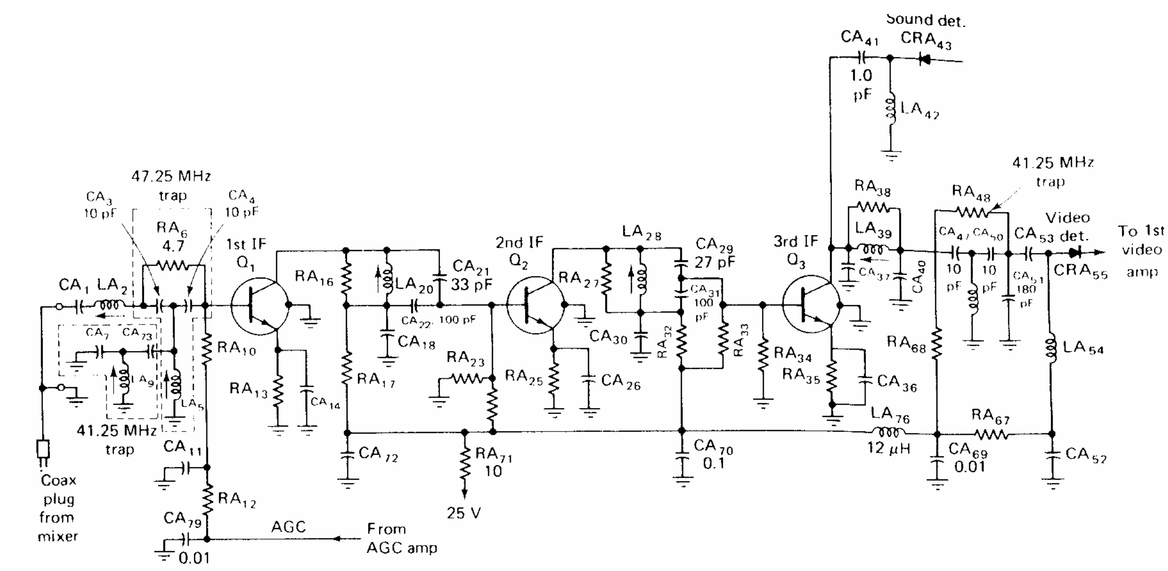
Circuit description:

- The reverse bias applied to the varactor diode controls its junction capacitance
- A switchable voltage divider simultaneously adjusts the bias on all controlling diodes
- The capacitance tuning range is limited to channels 2 to 6
- To adjust for channels 7 to 13, a switching diode shorts part of the tuning coils to ground

A8.3 IF Section

- Provides selectivity & gain
- Since the LO frequency is < IF, the video signal gets frequency inverted
- Generally 3 - 5 stage stagger tuning is employed
- The gain around the video carrier is somewhat reduced to overcome the enhancement to low frequencies by vestigial sideband
- The audio signal has comparatively little gain to minimize audio effects on the picture

Discrete IF Amplifier Schematic[7]



Circuit Description:

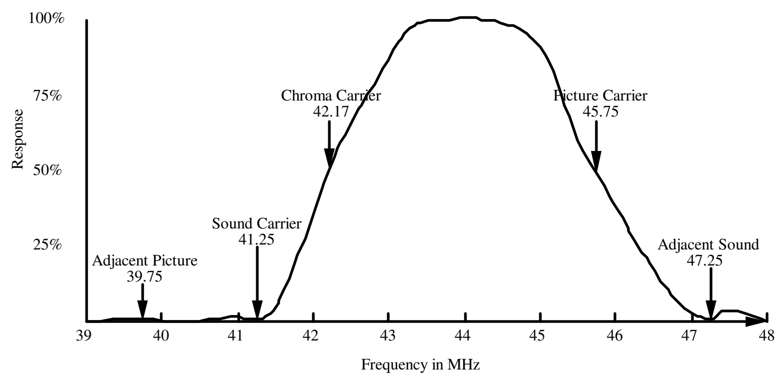
- Input traps are at 41.25 & 47.25 MHz
  The 41.25 MHz trap reduces the gain of the sound carrier
  The 47.25 MHz trap eliminates the adjacent channel sound carrier

7 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-16

_____ Notes _____

- Q1 is a high voltage gain, bypassed common emitter amplifier whose gain is adjusted by an AGC signal injected at the base
- Q2 & Q3 are similar stages but without AGC
- The three tank circuits in the collectors are staggered tuned at slightly different frequencies to provide the overall passband
- A 41.25 MHz trap is provided prior to video detection to completely remove the sound signal from the picture
- The AM video signal is passed through an envelope detector, thus recreating the original 4 MHz baseband video signal

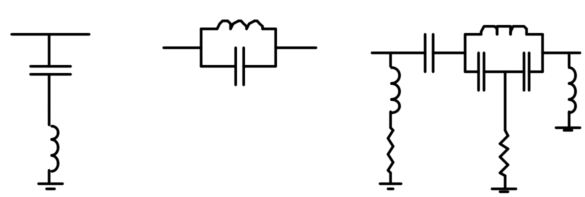
Typical Color TV IF Response[8]



Wavetraps

Wavetraps are high Q band stop circuits placed in the IF section to block adjacent channel signals, and reduce the amplitude of the sound carrier.

Typical Wavetraps[9]



- All sets have a 41.25 MHz trap to prevent the sound carrier from getting into the picture
- Some sets have one at 39.75 MHz to eliminate the video carrier of the upper adjacent channel (adjacent channels are generally not assigned for aerial broadcast in the same city)
- Some sets may have a 47.25 MHz trap to eliminate the sound carrier of the lower adjacent channel

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8 Based on fig. 13-17, Television Engineering Handbook, Benson

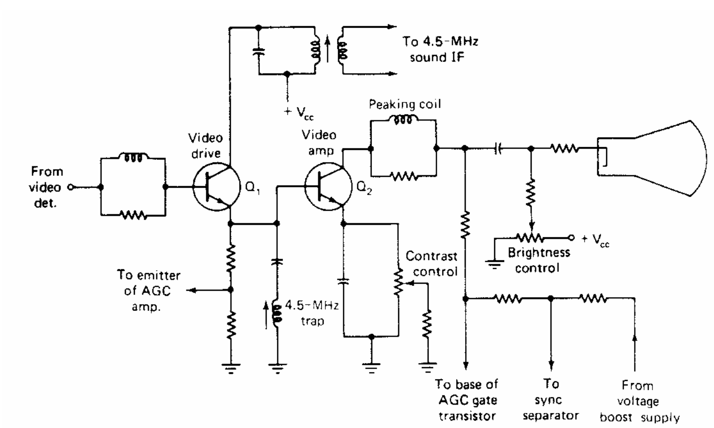
9 Based on fig 7-15, Modern Electronic Communication, 3rd ed, Gary M. Miller

_____ Notes _____

A8.4 Video Section

- Amplifies the video signal which ultimately modulates the beam intensity
- Contrast - varies the amplitude of the signal applied to the CRT
- Generally the video amplifiers are AC coupled. Therefore a DC level must be restored to provide a background reference level
- Brightness control - controls the overall brightness by biasing the beam or restoring the DC level
- Sound takeoff may occur anywhere in the video section except in color sets where the sound is taken off before the video detector
- Provides a takeoff for AGC, to control the gain in the RF and IF stages. This helps create a constant video level somewhat independent of the broadcast signal strength

Discrete Video Section Schematic[10]



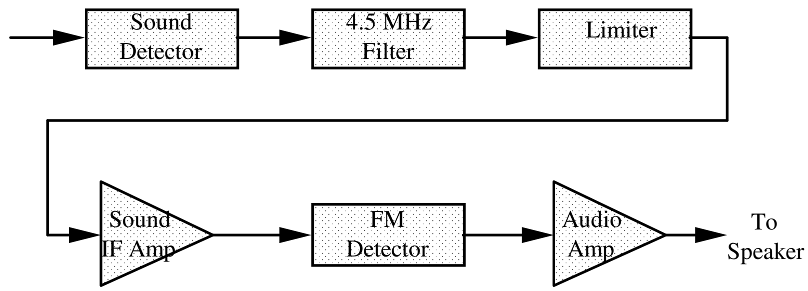
Circuit description:

- The peaking coil in the collector of Q2 improves the high frequency response by increasing the collector impedance
- The 4.5 MHz trap removes the audio carrier, thus preventing it from appearing in the picture
- The collector of Q1 is tuned to pick off the 4.5 MHz audio IF
- The brightness control provides DC restoration
- The video signal amplitude or contrast is governed by the emitter resistance in Q2
- The circuit is powered from a boost supply, several 100 volts

10 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-19

_____ Notes _____

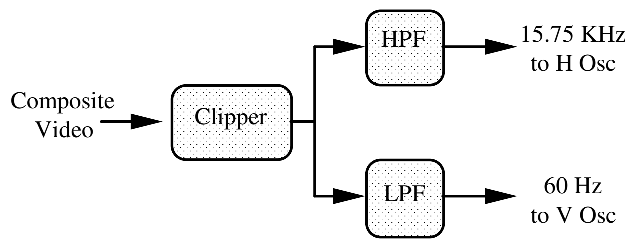
A8.5 Audio Section



- The 45.75 MHz IF picture carrier at is mixed with the 41.25 MHz IF sound carrier
  - This heterodynes the audio carrier to 4.5 MHz
  - The sound IF stays at exactly 4.5 MHz, even if the local RF oscillator drifts
- Any form of FM detection may be used
  - PLL and quadrature detection are becoming more popular since they can be integrated and do not need tuned circuits at 4.5 MHz
  - The audio amplifier may be integrated onto the same IC

A8.6 Raster Generation

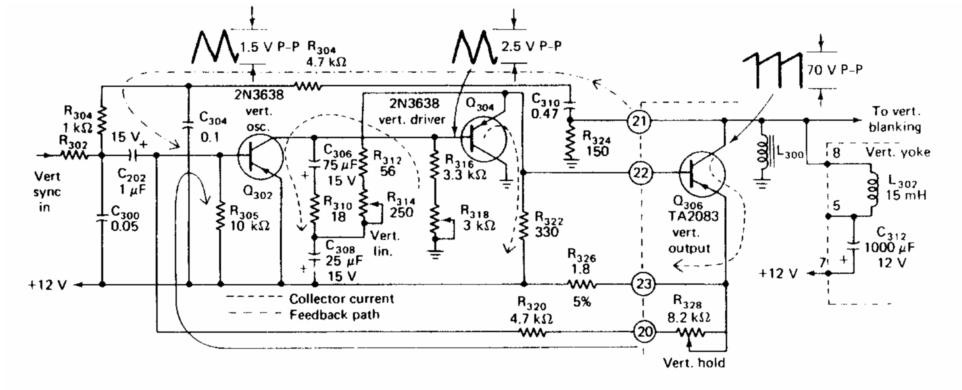
Sync Separator



- Clips the sync pulses from the composite video
- Each oscillator is free running at just below the correct rate
- A control is provided to adjust the free running rate
- The sync pulse, frequency locks the oscillator

_____ Notes _____

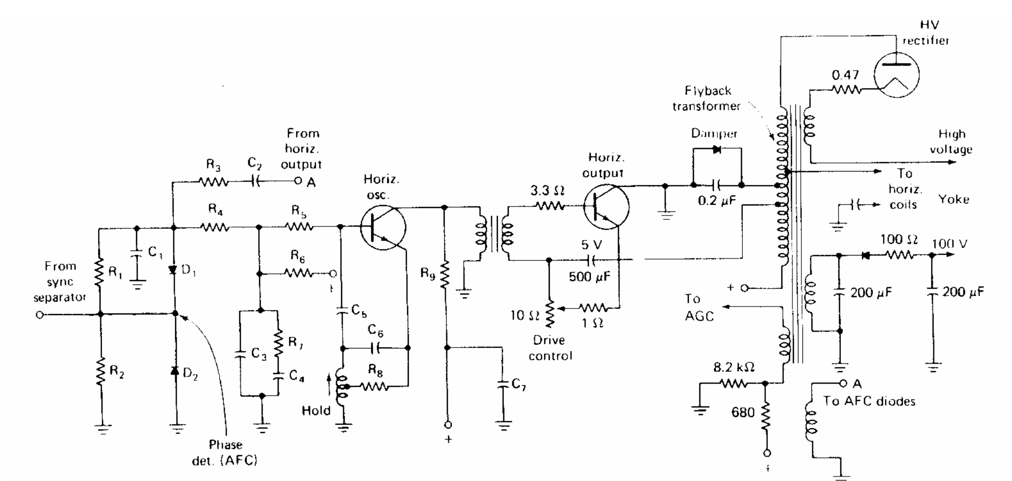
Discrete Vertical Deflection Schematic[11]



Circuit description

- Q302 & Q306 form the 60 Hz oscillator
- R328 adjusts the free running frequency (vertical hold)
- The vertical sync pulses are detected by the integrator formed by R302 & C300
- During the vertical scanning period, Q302 is cut off
- The sawtooth forming capacitors C306 & 308 discharge through R316 & R318
- R318 controls the sawtooth amplitude (picture height)
- R314 controls the ramp linearity
- The ramp o/p from Q306 drives the vertical yoke coil
- An o/p is also provided to the CRT to guarantee blanking during vertical retrace

Discrete Horizontal Defection and High Voltage Sections[12]



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11 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-21

12 Modern Electronic Communication, 3rd ed, Gary M. Miller, FIG. 7-24

_____ Notes _____

Circuit description:

- Synchronization is achieved by comparing the phase of the incoming H sync pulse and the horizontal output
  - A dc level is generated controlling the oscillator frequency
  - Some circuits may use a phase locked loop IC
- The H hold normally adjusts an inductor to set the free running frequency
- During the scanning interval, the collector current in the horizontal output increases linearly
- During retrace this current abruptly drops to zero
  - This induces a high amplitude flyback EMF across the transformer primary and secondary as the horizontal yoke field collapses
- The EMF built up on the secondary is rectified and applied to the CRT [thousands of volts]
- The EMF built up on the primary is conducted to ground through a damping diode
  - This eliminates the possibility of ringing when the next ramp waveform is generated
- An auxiliary secondary winding provides the boost voltages [hundreds of volts]

Delay Line

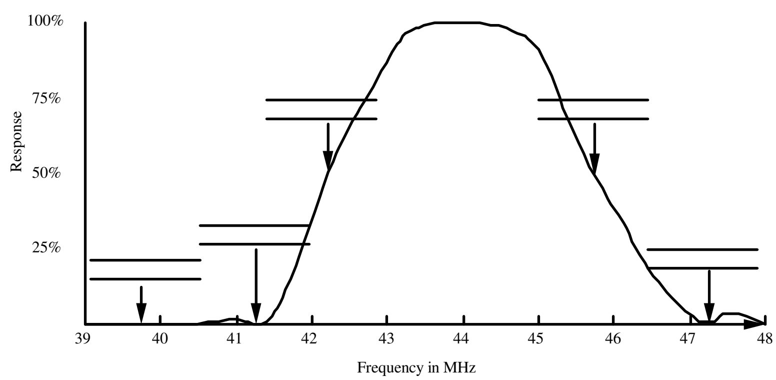
Both the chroma and luminance signals must be applied to the receiver CRT at the same instant. Consequently, a delay line is introduced into the Y signal path because:

- The chroma signals are band limited, hence delayed with respect to the luminance signal, and
- The chroma circuits require processing time to decode the colors prior to application to the CRT

_____ Notes _____

Assignment Questions

1. What faults in a TV set could cause the screen to go completely black?
2. What would cause a picture to "tear" diagonally?
3. How does the brightness control modify the video signal?
4. List the two principle methods of FM detection in a TV set.
5. Explain in detail what happens to the signals and components in a TV set, when the UHF tuner is selected.
6. Label the following drawing.



7. Explain the operation of a varactor tuner.
8. Why is the IF amplifier gain in a television set reduced by 50% at the picture carrier frequency of 45.75 MHz?
9. Why do some TV sets have a 47.25 MHz trap?
10. What is the purpose of the DC restorer?
11. Which sync pulse is integrated before detection, and which one is differentiated before detection?

For Further Reading

Grob, Bernard, Basic Television 4th ed., McGraw Hill,

Herrick, N. Clyde, Color Television: Theory and Servicing, Reston, 1977

Miller, Gary M., Modern Electronic Communication 3rd ed., 1988

Prentiss, Stan, Color Television Theory & Troubleshooting, Reston, 1979