value of resistance (such as 270 or 330 ohms) and using the next stage as a wideband amplifier by using a plate load resistor of about 470 ohms. The method is illustrated in Fig. 16-48. The small plate load resistor in the output stage may be incorporated in the detector probe to avoid having to solder an extra resistor across the plate coil. Typical detector probe constants are shown in Fig. 16-49.

The resonant frequency and bandwidth of each side of a double-tuned transformer are measured by varying the frequency of a calibrated amplitude-modulated r-f generator until the maximum modulation voltage is indicated on the oscilloscope.

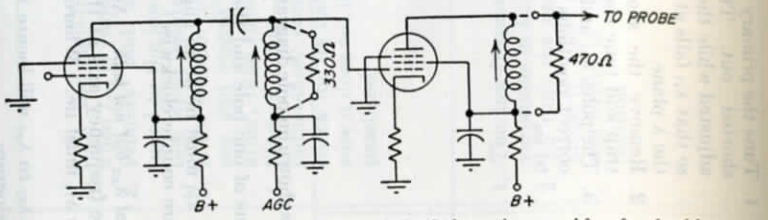


Fig. 16-48. Method of determining frequency and $Q$ of the primary side of a double-tuned transformer.

Care must be taken to avoid overload. With some standard deflection set on the oscilloscope at the frequency of maximum deflection, the generator output is increased by a factor of $\sqrt{2}$. Then the generator frequency is changed to one side of the resonance until the oscilloscope deflection falls to the previously set standard, and this frequency ($f_1$) is noted. Then the frequency is changed to the other side of the resonance until the oscilloscope deflection falls to the standard again, and this frequency ($f_2$) is noted. The circuit $Q$ then is

$$Q = \frac{f_0}{f_2 - f_1} \tag{16.61}$$

where $f_0$ = resonant frequency

If the designer wishes, an unmodulated signal may be used and a voltmeter utilized in place of the oscilloscope.

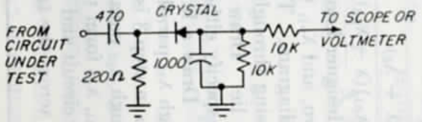


Fig. 16-49. Typical detector probe.

*Typical Amplifier Pole Patterns.* A properly designed television i-f amplifier possesses a pole diagram which is known and can be reproduced. After having first determined the gain required, the designer may choose a convenient number of poles and zeros to fit the number of stages required. By trial and error and a reasonable amount of engineering judgment, he may then arrive at a pole diagram which gives the desired amplitude and phase response. A typical pole diagram and amplitude characteristic for a competitive monochrome receiver is shown in Fig. 16-50. This diagram uses six poles and a zero, with a double pole at 43 mc. One of the poles at 43 mc moves to 41.25 mc, and the pole at 45.9 mc doubles in $Q$, as the signal level falls low enough to provide zero a-g-c bias voltage.

Figure 16-51 illustrates the amplitude response of a color receiver i-f amplifier of the type employing a combined chrominance-sound detector and a separate luminance detector. The poles and zeros are marked with the amplifier stage number in which they occur. The amplifier has four tubes in the luminance chain. The chrominance-sound chain includes the first three tubes and a separate stage which brings the gain to the chrominance-sound detector approximately up to the gain to the luminance detector. Stage 1 is the plate of the converter to the grid of the first i-f tube. This diagram shows that a large number of poles and zeros is needed to achieve the wide bandwidth necessary for color signal reception while providing the necessary attenuation of the sound carrier.

*Electrolytic Tank Measurements.* In place of the trial-and-error method of achieving a suitable pole diagram, other faster and more elegant methods are available. The most accurate technique employs an electrolytic tank. It can be shown[21-23] that

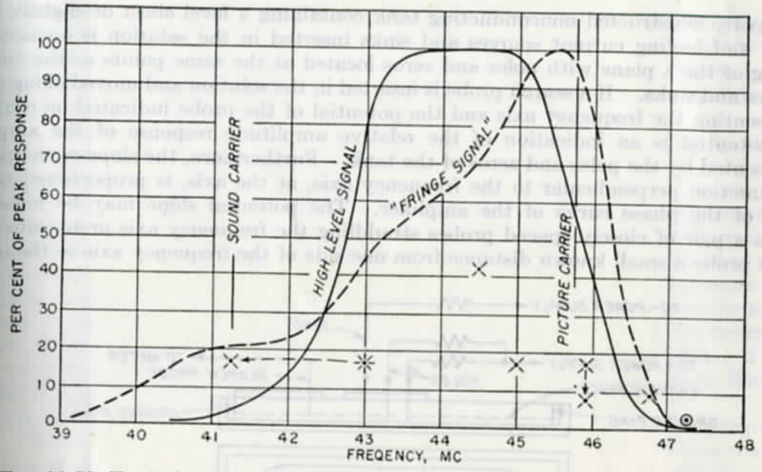
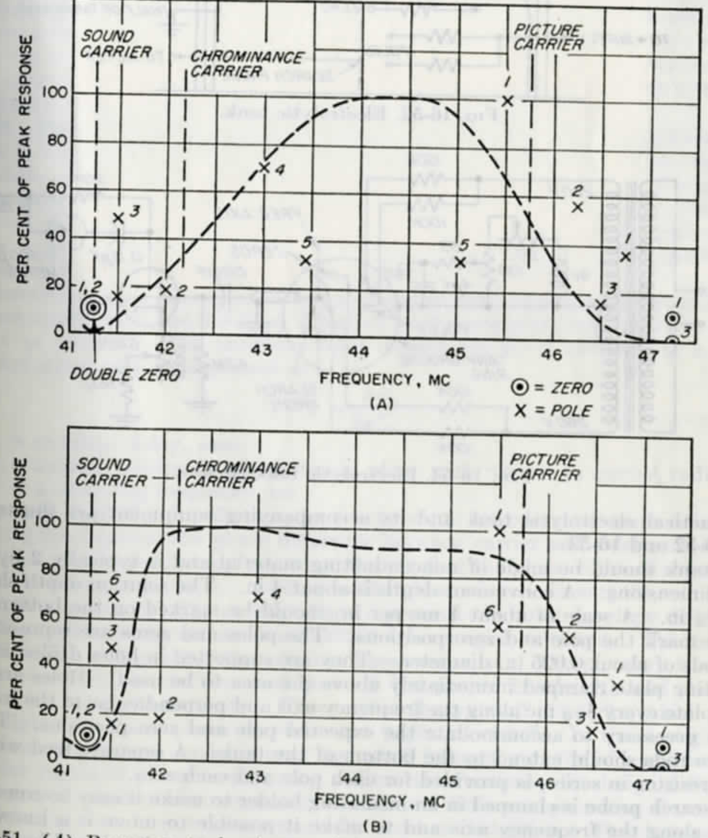


Fig. 16-50. Typical low-cost receiver i-f amplitude response with pole diagram.



(A)

(B)

Fig. 16-51. (*A*) Response to luminance detector; (*B*) response to chrominance-sound detector.

a properly constructed nonconducting tank containing a level sheet of slightly salty water and having current sources and sinks inserted in the solution is an accurate analog of the λ plane with poles and zeros located at the same points as the current sources and sinks. If a search probe is inserted in the solution and moved along a line representing the frequency axis and the potential of the probe indicated on a meter, the potential is an indication of the relative amplitude response of the amplifier represented by the poles and zeros of the tank. Furthermore, the slope of the potential function perpendicular to the frequency axis, at the axis, is proportional to the slope of the phase curve of the amplifier. The potential slope may be measured across a pair of closely spaced probes straddling the frequency axis or by moving a single probe a small known distance from one side of the frequency axis to the other.

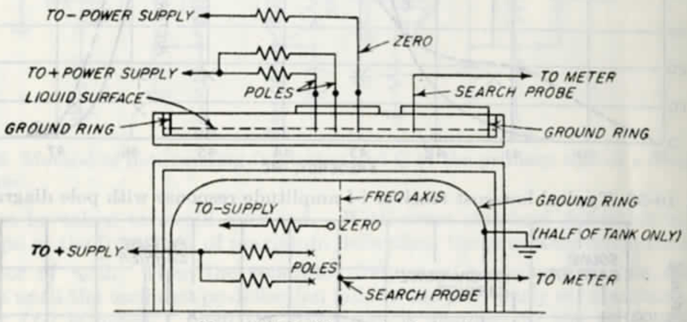


Fig. 16-52. Electrolytic tank.

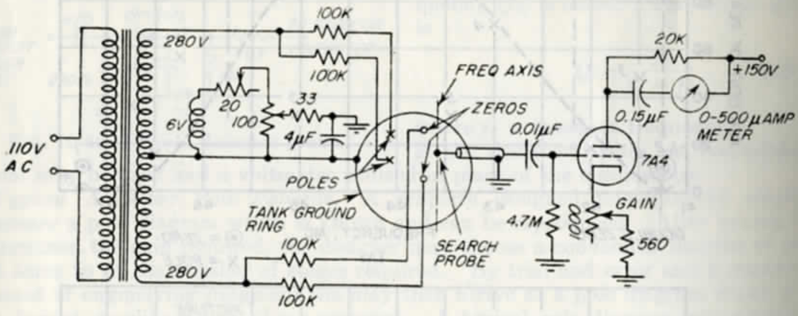


Fig. 16-53. Electrolytic tank circuits.

A practical electrolytic tank and its accompanying equipment are illustrated in Figs. 16-52 and 16-53.

The tank should be made of nonconducting material and is typically 2 by 4 ft in inside dimensions. A convenient depth is about 4 in. The solution depth should be about ¾ in. A scale of about 1 mc per in. should be marked on the bottom of the tank to mark the pole and zero positions. The poles and zeros are represented by brass rods of about 0.025 in. diameter. They are supported in holes drilled in a nonconducting plate clamped immediately above the area to be used. Holes are drilled in this plate every $\frac{1}{10}$ mc along the frequency axis and perpendicular to the frequency axis, as necessary to accommodate the expected pole and zero positions. The pole and zero rods should extend to the bottom of the tank. A separate feed wire, with a100K resistor in series, is provided for each pole and each zero.

The search probe is clamped in an insulating holder to make it easy to constrain its motion along the frequency axis and to make it possible to move it a known small distance perpendicular to the frequency axis. The search probe should be a fine rod which just penetrates the surface of the solution.

The ground ring is a thin conducting strip about 1 in. wide, bent to form an ellipse which just fits inside the tank walls, and is immersed to rest on the bottom of the tank. This ring should theoretically fall along an equipotential line in the solution. With most television i-f pole configurations the ground ring recommended here will be very close to the ideal.

An a-c supply is used for the pole and zero currents to avoid polarization effects. A balancing voltage and phase shift circuit is added to the ground side of the system. The balancing voltage is used to set the meter reading at a convenient low value. The phase shift circuit is used to compensate for the phase shift introduced by polarization.

The balance voltage is set by first moving the search probe to the point of maximum gain and then turning up the balance potentiometer *through* the balance point to make the meter read 100 μa. As the probe is moved away from the point of maximum gain, the meter reading should increase. Use a meter having 50 divisions and set the amplifier gain so that one division equals 1 db gain change. Full scale on the meter will then be 40 db below maximum, and a gain change of ¼ db is perceptible. If very great variations of gain are to be measured, the amplifier gain can be set so that one division is equivalent to 2 db change in gain.

When calibrating the meter, use a single pole only and place it on the frequency axis. Place the search probe 1 or 2 mc away from the pole and note the meter reading. Then double the distance between the pole and the search probe and note the meter reading again. The difference in the readings must be set to 6 db. To calibrate the phase slope probe, a pole is set 1 mc from the frequency axis. Then directly on the frequency axis, at the frequency of the pole, the phase slope is 1 radian per mc.

With the setup described, it is possible to move poles around in any manner necessary to achieve the gain and phase curves which the designer desires, within the realm of possibility.

**16.404 Phase Response.** *Envelope Delay.* The importance of correct amplitude response in a television receiver is obvious; the effect of variations in phase response is more subtle. Basically, it is required that the receiver reproduce rapid changes from black to white or from white to black with as little distortion as possible. This means that, from a design standpoint, the important characteristic of the receiver is its response to a step function. Phase distortion may be even more objectionable than amplitude distortion.

Fundamentally, the absolute time delay in a television receiver is immaterial. The important condition is that the delay imparted to all modulation frequencies shall be as constant as possible. The envelope delay introduced by a network to a steady modulated signal may be expressed as

$$\tau = \frac{\Delta\phi}{2\pi f_m} \tag{16.62}$$

where $\tau$ = envelope delay, μsec
$\Delta\phi$ = amount sidebands are shifted in phase with respect to carrier, radians
$f_m$ = modulating frequency, mc

It is apparent from Eq. (16.62) that, for a network to introduce the same delay to all modulating frequencies, the phase difference between carrier and sidebands must be proportional to the modulating frequency, that is, that the phase curve of the network be as nearly linear as possible. As long as the phase curve is linear, the value of the slope is not important. The average slope represents the total envelope delay.

Television picture signals are transmitted by vestigial sideband. This is unfortunate from the viewpoint of the receiver phase response. The picture i-f amplifier of a superheterodyne receiver must provide the proper bandwidth and the major portion of the receiver selectivity. This implies sharp cutoff networks, which tend to display highly nonlinear phase curves in the region of cutoff. In the vestigial sideband system the picture carrier is near the cutoff frequency of the i-f amplifier and is thus in the region of phase nonlinearity. Since this fundamental design difficulty is well recognized, transmitters normally introduce a little compensating distortion in the modulating waveform to compensate for receiver distortion. The designer must use great care in choosing a pole diagram which has as linear a phase curve as possible, especially in the region around picture carrier.

output with only noise present. That useful output is, then,

$$\eta(\sqrt{C^2 + E_n^2} - \sqrt{E_n^2}) \tag{16.92}$$

while the noise output is $\eta E_n$.

The ratio is

$$\frac{\text{Useful output}}{\text{Noise output}} = \sqrt{1 + \left(\frac{C}{E_n}\right)^2} - 1 \tag{16.93}$$

This relationship shows the magnitude of the phenomenon known as "signal suppression by noise."[31] If the case of $C/E_n \ll 1$ is considered,

$$\sqrt{1 + \left(\frac{C}{E_n}\right)^2} - 1 \approx \left[1 + \frac{1}{2}\left(\frac{C}{E_n}\right)^2 - 1\right] = \frac{1}{2}\left(\frac{C}{E_n}\right)^2 \tag{16.94}$$

Therefore, under very weak signal conditions, a signal $n$ db below noise becomes $2n + 6$ db below noise at the detector output. Equation (16.93) is plotted versus $C/E_n$ in Fig. 16.85.

**References** Secs. 16.401–16.409

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## 16.5 SOUND I-F SYSTEMS—*BY H. H. WILSON, JR.*

**16.501 Important Design Problems.** The two methods of designing television i-f amplifiers and the advantages and disadvantages of each have been discussed in Sec. 16.4. The conventional "split-sound" type of sound reception has been generally abandoned in favor of the intercarrier type. The factors which favor the intercarrier system are low cost, lack of microphonics, and the noncritical tuning characteristic.

In both types of receiver, the important design considerations are:

1. Separation of sound and the elimination of the various forms of intermodulation
2. The required gain of the sound system
3. The stability and bandwidth of the sound system
4. Proper limiter operation
5. Optimum design of the f-m detector

**16.502 Separation of Sound and Picture Signals.** It is desirable in a split-sound receiver to separate the sound and picture signals early in the i-f amplifier, so that the sound signal may be subsequently trapped out of the main intermediate frequency.