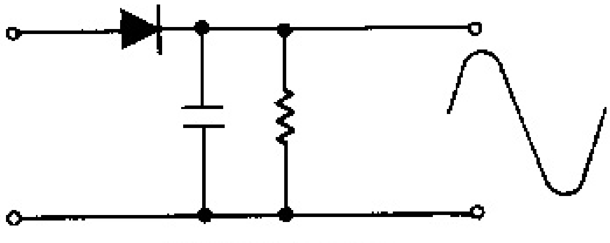

Figure 3-9C.—Slope detector. DIODE DETECTOR.

Q-21. What is the simplest form of fm detector?

Q-22. What is the function of an fm detector?

FOSTER-SEELEY DISCRIMINATOR

The FOSTER-SEELEY DISCRIMINATOR is also known as the PHASE-SHIFT DISCRIMINATOR. It uses a double-tuned rf transformer to convert frequency variations in the received fm signal to amplitude variations. These amplitude variations are then rectified and filtered to provide a dc output voltage. This voltage varies in both amplitude and polarity as the input signal varies in frequency. A typical discriminator response curve is shown in figure 3-10. The output voltage is 0 when the input frequency is equal to the carrier frequency (f_r). When the input frequency rises above the center frequency, the output increases in the positive direction. When the input frequency drops below the center frequency, the output increases in the negative direction.

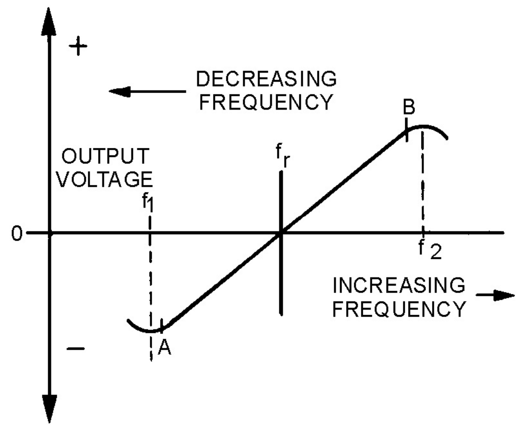

Figure 3-10.—Discriminator response curve.

The output of the Foster-Seeley discriminator is affected not only by the input frequency, but also to a certain extent by the input amplitude. Therefore, using limiter stages before the detector is necessary.

Circuit Operation of a Foster-Seeley Discriminator

View (A) of figure 3-11 shows a typical Foster-Seeley discriminator. The collector circuit of the preceding limiter/amplifier circuit (Q1) is shown. The limiter/amplifier circuit is a special amplifier circuit which limits the amplitude of the signal. This limiting keeps interfering noise low by removing excessive amplitude variations from signals. The collector circuit tank consists of C1 and L1. C2 and L2 form the secondary tank circuit. Both tank circuits are tuned to the center frequency of the incoming fm signal. Choke L3 is the dc return path for diode rectifiers CR1 and CR2. R1 and R2 are not always necessary but are usually used when the back (reverse bias) resistance of the two diodes is different. Resistors R3 and R4 are the load resistors and are bypassed by C3 and C4 to remove rf. C5 is the output coupling capacitor.

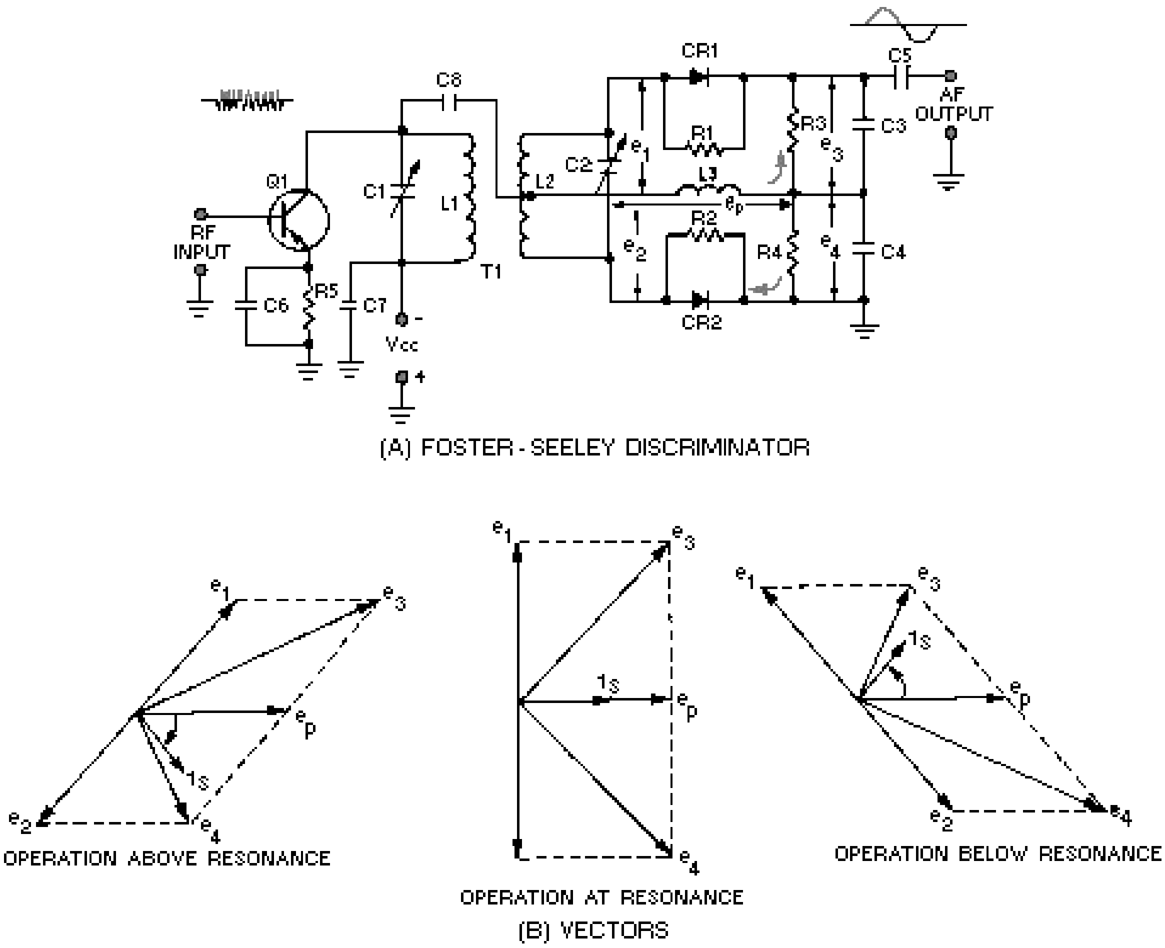

Figure 3-11.—Foster-Seeley discriminator. FOSTER-SEELEY DISCRIMINATOR.

CIRCUIT OPERATION AT RESONANCE.—The operation of the Foster-Seeley discriminator can best be explained using vector diagrams [figure 3-11, view (B)] that show phase relationships between the voltages and currents in the circuit. Let's look at the phase relationships when the *input frequency is equal to the center frequency* of the resonant tank circuit.

The input signal applied to the primary tank circuit is shown as vector e_p. Since coupling capacitor C8 has negligible reactance at the input frequency, rf choke L3 is effectively in parallel with the primary tank circuit. Also, because L3 is effectively in parallel with the primary tank circuit, input voltage e_p also appears across L3. With voltage e_p applied to the primary of T1, a voltage is induced in the secondary which causes current to flow in the secondary tank circuit. When the input frequency is equal to the center frequency, the tank is at resonance and acts resistive. Current and voltage are in phase in a resistance circuit, as shown by is and e_p. The current flowing in the tank causes voltage drops across each half of the balanced secondary winding of transformer T1. These voltage drops are of equal amplitude and opposite polarity with respect to the center tap of the winding. Because the winding is inductive, the voltage across it is 90 degrees out of phase with the current through it. Because of the center-tap arrangement, the voltages at each end of the secondary winding of T1 are 180 degrees out of phase and are shown as e_1 and e_2 on the vector diagram.

The voltage applied to the anode of CR1 is the vector sum of voltages e_p and e_1, shown as e_3 on the diagram. Likewise, the voltage applied to the anode of CR2 is the vector sum of voltages e_p and e_2, shown as e_4 on the diagram. At resonance e_3 and e_4 are equal, as shown by vectors of the same length. Equal anode voltages on diodes CR1 and CR2 produce equal currents and, with equal load resistors, equal and opposite voltages will be developed across R3 and R4. The output is taken across R3 and R4 and will be 0 at resonance since these voltages are equal and of appositive polarity.

The diodes conduct on opposite half cycles of the input waveform and produce a series of dc pulses at the rf rate. This rf ripple is filtered out by capacitors C3 and C4.

OPERATION ABOVE RESONANCE.—A phase shift occurs when an *input frequency higher than the center frequency* is applied to the discriminator circuit and the current and voltage phase relationships change. When a series-tuned circuit operates at a frequency above resonance, the inductive reactance of the coil increases and the capacitive reactance of the capacitor decreases. Above resonance the tank circuit acts like an inductor. Secondary current lags the primary tank voltage, e_p. Notice that secondary voltages e_1 and e_2 are still 180 degrees out of phase with the current (i_S) that produces them. The change to a lagging secondary current rotates the vectors in a clockwise direction. This causes el to become more in phase with e_p while e_2 is shifted further out of phase with e_p. The vector sum of e_p and e_2 is less than that of e_p and e_1. Above the center frequency, diode CR1 conducts more than diode CR2. Because of this heavier conduction, the voltage developed across R3 is greater than the voltage developed across R4; the output voltage is positive.

OPERATION BELOW RESONANCE.—When the *input frequency is lower than the center frequency*, the current and voltage phase relationships change. When the tuned circuit is operated at a frequency lower than resonance, the capacitive reactance increases and the inductive reactance decreases. Below resonance the tank acts like a capacitor and the secondary current leads primary tank voltage e_p. This change to a leading secondary current rotates the vectors in a *counterclockwise* direction. From the vector diagram you should see that e_2 is brought nearer in phase with e_p, while el is shifted further out of phase with e_p. The vector sum of e_p and e_2 is larger than that of e and e_1. Diode CR2 conducts more than diode CR1 below the center frequency. The voltage drop across R4 is larger than that across R3 and the output across both is negative.

Disadvantages

These voltage outputs can be plotted to show the response curve of the discriminator discussed earlier (figure 3-10). When weak AM signals (too small in amplitude to reach the circuit limiting level) pass through the limiter stages, they can appear in the output. These unwanted amplitude variations will cause primary voltage e_p [view (A) of figure 3-11] to fluctuate with the modulation and to induce a similar voltage in the secondary of T1. Since the diodes are connected as half-wave rectifiers, these small AM signals will be detected as they would be in a diode detector and will appear in the output. This unwanted AM interference is cancelled out in the ratio detector (to be studied next in this chapter) and is the main disadvantage of the Foster-Seeley circuit.

Q-23. What type of tank circuit is used in the Foster-Seeley discriminator?

Q-24. What is the purpose of CR1 and CR2 in the Foster-Seeley discriminator?

Q-25. What type of impedance does the tank circuit have above resonance?

RATIO DETECTOR

The RATIO DETECTOR uses a double-tuned transformer to convert the instantaneous frequency variations of the fm input signal to instantaneous amplitude variations. These amplitude variations are then rectified to provide a dc output voltage which varies in amplitude and polarity with the input signal frequency. This detector demodulates fm signals and suppresses amplitude noise without the need of limiter stages.

Circuit Operation

Figure 3-12 shows a typical ratio detector. The input tank capacitor (C1) and the primary of transformer T1 (L1) are tuned to the center frequency of the fm signal to be demodulated. The secondary winding of T1 (L2) and capacitor C2 also form a tank circuit tuned to the center frequency. Tertiary (third) winding L3 provides additional inductive coupling which reduces the loading effect of the secondary on the primary circuit. Diodes CR1 and CR2 rectify the signal from the secondary tank. Capacitor C5 and resistors R1 and R2 set the operating level of the detector. Capacitors C3 and C4 determine the amplitude and polarity of the output. Resistor R3 limits the peak diode current and furnishes a dc return path for the rectified signal. The output of the detector is taken from the common connection between C3 and C4. Resistor R_L is the load resistor. R5, C6, and C7 form a low-pass filter to the output.

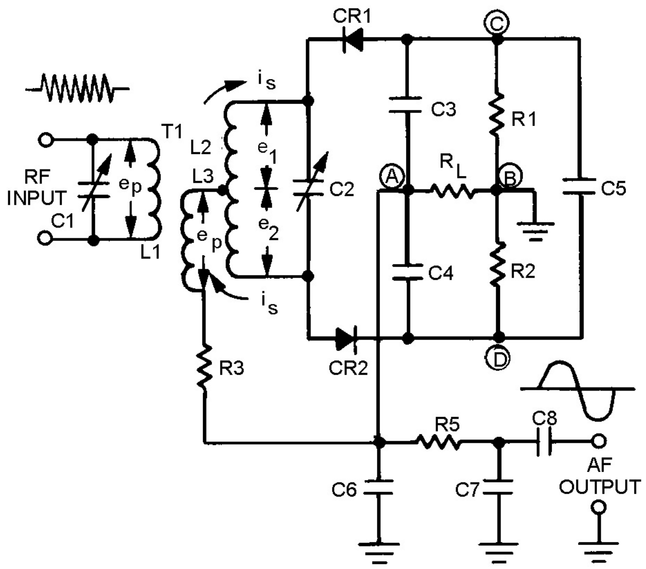

Figure 3-12.—Ratio detector.

This circuit operates on the same principles of phase shifting as did the Foster-Seeley discriminator. In that discussion, vector diagrams were used to illustrate the voltage amplitudes and polarities for conditions at resonance, above resonance, and below resonance. The same vector diagrams apply to the ratio detector but will not be discussed here. Instead, you will study the resulting current flows and polarities on simplified schematic diagrams of the detector circuit.

OPERATION AT RESONANCE.—When the input voltage e_p is applied to the primary in figure 3-12 it also appears across L3 because, by inductive coupling, it is effectively connected in parallel with the primary tank circuit. At the same time, a voltage is induced in the secondary winding and causes current to flow around the secondary tank circuit. At resonance the tank acts like a resistive circuit; that is,