Electronic-Circuit II
Chap 4. Communication Systems

Foster Seeley Discriminator

Ratio Detector

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Course Homepage

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FM Detectors

- Slope Detector (refer to your class notes)
- Balanced Slope Detector (refer to your class notes)
- PLL (refer to your class notes)
- Foster Seeley Discriminator
- Ratio Detector
- Quadrature Detector

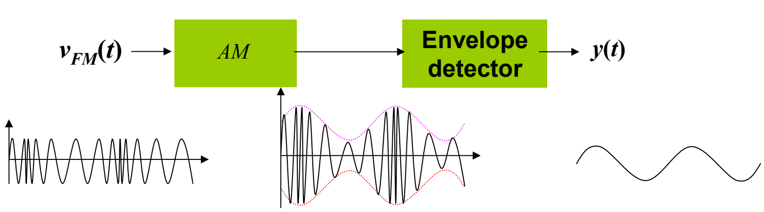
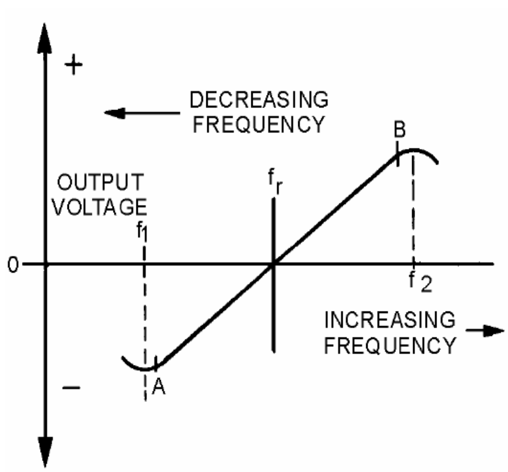


Fig. Basic Principle of Slope Detector

Foster Seeley Discriminator

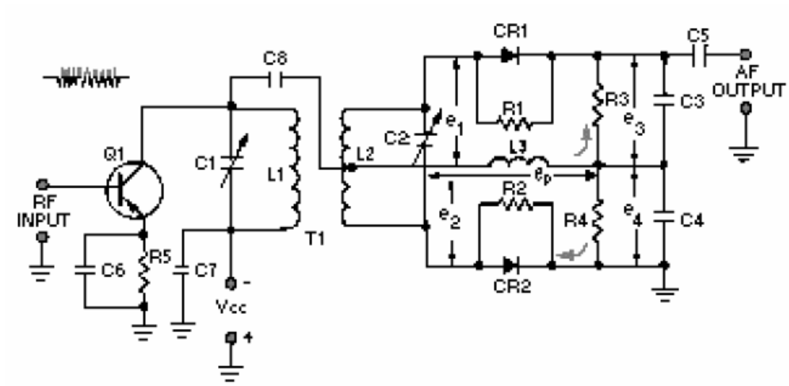
- A discriminator is a circuit or a device in which amplitude variations are derived from frequency or phase variations
- Foster Seeley Discriminator is also known as Phase Shift Discriminator
- Uses a double tuned RF transformer to convert frequency variations in the received signal to amplitude variations
- The amplitude variations are then rectified and filtered to provide a dc output voltage
- This output voltage varies both in amplitude polarity as the input signal varies in frequency

Discriminator Response Curve



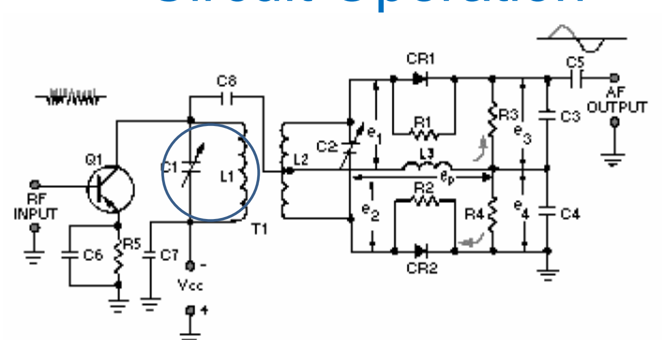
- When input frequency equals carrier frequency (f_r), output voltage = zero
- When input frequency rises above f_r, output increases in positive direction
- When input frequency drops below f_r, output increases in negative direction

Circuit Diagram of Foster Seeley Discriminator



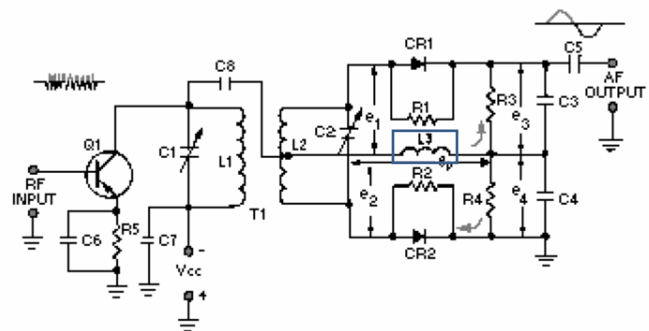
• The output of the Foster-Seeley discriminator is affected not only by the input frequency, but also to a certain extent by the input amplitude
• Therefore, using limiter stages before the detector is necessary.

Circuit Operation



- The collector circuit of the preceding limiter/amplifier circuit (Q1) is shown.
- 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. Tank circuits are tuned to incoming FM signal

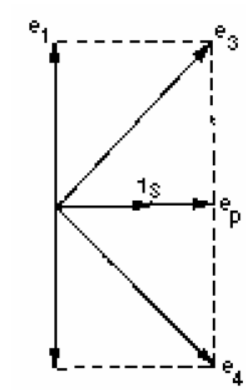
Circuit Operation



- 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
- R3 and R4 are the load resistors and are bypassed by C3 and C4 to remove RF
- C5 is the output coupling capacitor

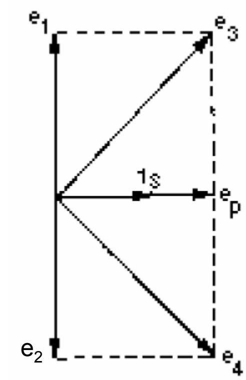
Circuit Operation at Resonance

- The operation of the Foster-Seeley discriminator can best be explained using vector diagrams
- At resonance, 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
- RF choke L3 is effectively in parallel with the primary tank circuit
- L3 is effectively in parallel with the primary tank circuit, input voltage e_p also appears across L3



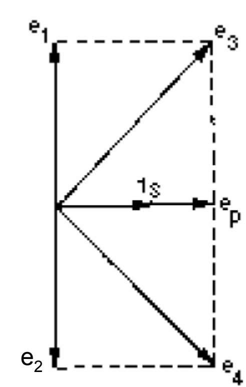
Circuit Operation at Resonance contd.

- With voltage e_p applied to the primary of T1, a voltage is induced in the secondary. This causes the 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 i_s and e_p
- The current flowing in the tank causes voltage drops across each half of the balanced secondary winding of transformer T1.



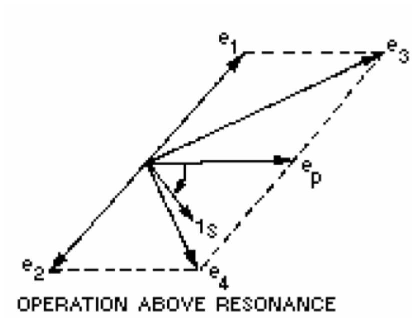
Circuit Operation at Resonance contd.

- These voltage drops are of equal amplitude and opposite polarity with respect to the center tap of the winding
- As 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
- e_3 is the vector sum of e_p and e_1 wherease e_4 is the vector sum of e_p and e_2



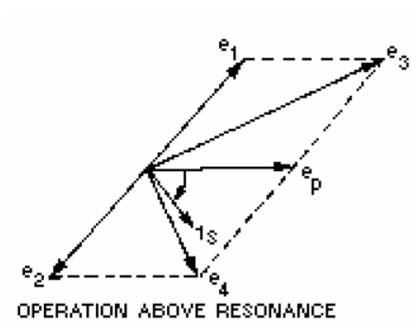
Circuit Operation above Resonance

- A phase shift occurs when an input frequency higher than the center frequency is applied to the discriminator circuit
- 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, ep.



Circuit Operation above Resonance contd..

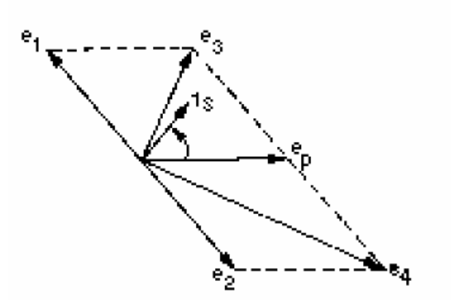
- Secondary voltages e1 and e2 are still 180 degrees out of phase with the current (i_s) that produces them
- The change to a lagging secondary current rotates the vectors in a clockwise direction.
- This causes e1 to become more in phase with e_p while e2 is shifted further out of phase with e_p
- The vector sum of ep and e2 is less than that of ep and e1
- Above the center frequency, diode CR1 conducts more than diode CR2



The voltage developed across R3 is greater than the voltage developed across R4, the output voltage is positive

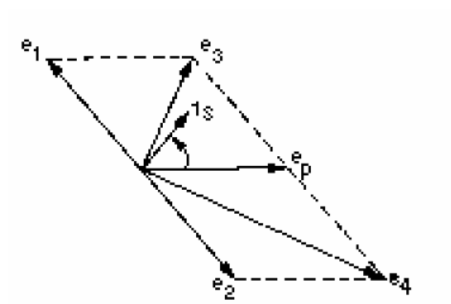
Circuit Operation below Resonance

- 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.*
- e_2 is brought nearer in phase with e_p, while e_1 is shifted further out of phase with ep



Circuit Operation below Resonance contd…

- The vector sum of ep and e2 is larger than that of ep and e1. Below resonance the tank acts like a capacitor and the secondary current leads primary tank voltage e_p
- 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.



Conclusion

- At resonance, the tank circuit of Foster Seeley Discriminator has a resistive impedance
- Above resonance, the tank circuit of Foster Seeley Discriminator has an inductive impedance
- Below resonance, the tank circuit of Foster Seeley Discriminator has a capacitive impedance

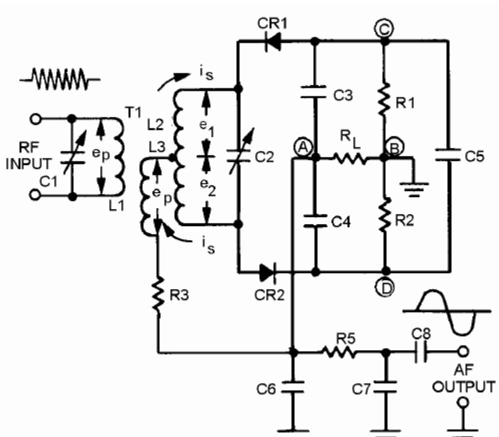
Disadvantage of Foster Seeley Discriminator

- 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 ep 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.

Ratio Detector

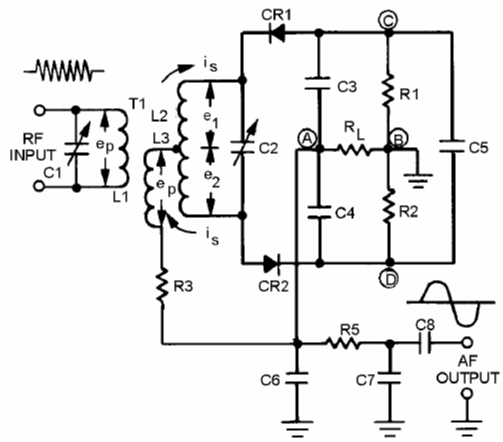
- By making a few changes in the Foster-Seely discriminator, it is possible to have a demodulator circuit which has built in capability to handle the amplitude changes of the input FM signal
- This obviates the need for an amplitude limiter
- This resulting circuit is called the *ratio detector*
- The same vector diagram of Foster Seeley discriminator applies for ratio detector

Circuit Operation



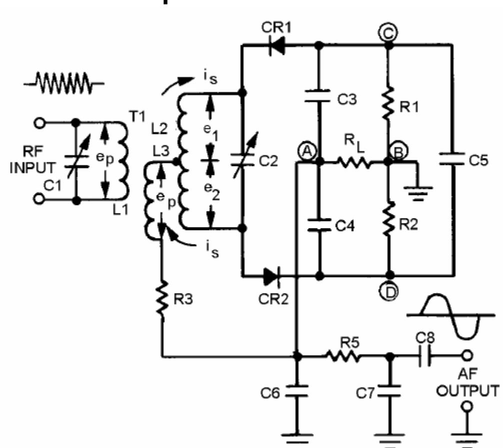
- The direction of diode CR1 is reversed
- The input tank capacitor (C1) and the primary of transformer T1 (L1) are tuned to the center frequency of the FM signal to be demodulated
- The secondary winding of T1 (L2) and capacitor C2 also form a tank circuit tuned to the center frequency

Circuit Operation contd



- 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

Circuit Operation contd



- 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 RL is the load resistor. R5, C6, and C7 form a low-pass filter to the output

Conclusion

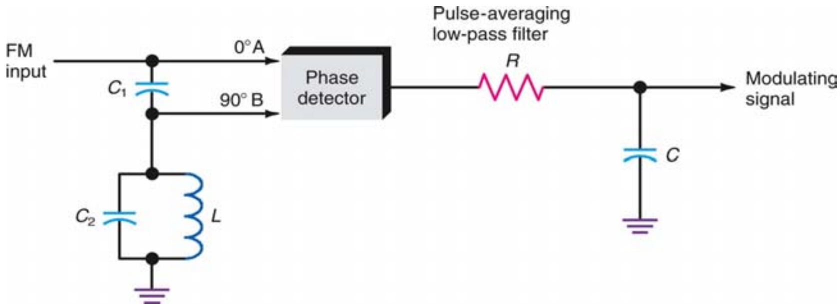
- For a large number of years, the Foster-Seely discriminator and the ratio detector have been the work horses of the FM industry
- As these circuit configurations are not very convenient from the point of view of IC fabrication, of late, their utility has come down
- Companies such as Motorola have built high quality FM receivers using the Foster-Seeley discriminator and the ratio detector.

Qudrature Detector

Quadrature Detector

- The **quadrature detector** is probably the single most widely used FM demodulator.
- The quadrature detector is primarily used in TV demodulation.
- This detector is used in some FM radio stations.
- The quadrature detector uses a phase-shift circuit to produce a phase shift of 90 degrees at the unmodulated carrier frequency.

Quadrature Detector circuit



- The signal is split into two components
- Phase detector produces a voltage output that is proportional to the phase difference and hence to the level of deviation on the signal
- able to operate with relatively low input levels
- provides good linearity enabling very low levels of distortion

End of Slides