CHAPTER 3

DEMODULATION

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. Describe cw detector circuit operations for the heterodyne and regenerative detectors.
2. Discuss the requirements for recovery of intelligence from an AM signal and describe the theory of operation of the following AM demodulators: series-diode, shunt-diode, common-emitter, and common-base.
3. Describe fm demodulation circuit operation for the phase-shift and gated-beam discriminators and the ratio-detector demodulator.
4. Describe phase demodulation circuit operation for the peak, low-pass filter, and conversion detectors.

INTRODUCTION

In chapters 1 and 2 you studied how to apply intelligence (modulation) to an rf-carrier wave. Carrier modulation allows the transmission of modulating frequencies without the use of transmission wire as a medium. However, for the communication process to be completed or to be useful, the intelligence must be recovered in its original form at the receiving site. The process of re-creating original modulating frequencies (intelligence) from the rf carrier is referred to as DEMODULATION or DETECTION. Each type of modulation is different and requires different techniques to recover (demodulate) the intelligence. In this chapter we will discuss ways of demodulating AM, cw, fm, phase, and pulse modulation.

The circuit in which restoration is achieved is called the DETECTOR or DEMODULATOR (both of these terms are used in *NEETS*). The term demodulator is used because the demodulation process is considered to be the opposite of modulation. The output of an ideal detector must be an exact reproduction of the modulation existing on the rf wave. Failure to accurately recover this intelligence will result in distortion and degradation of the demodulated signal and intelligence will be lost. The distortion may be in amplitude, frequency, or phase, depending on the nature of the demodulator. A nonlinear device is required for demodulation. This nonlinear device is required to recover the modulating frequencies from the rf envelope. Solid-state detector circuits may be either a pn junction diode or the input junction of a transistor. In electron-tube circuits, either a diode or the grid or plate circuits of a triode electron tube may be used as the nonlinear device.

Q-1. What is demodulation?

Q-2. What is a demodulator?

CONTINUOUS-WAVE DEMODULATION

Continuous-wave (cw) modulation consists of on-off keying of a carrier wave. To recover on-off keyed information, we need a method of detecting the *presence or absence of rf oscillations*. The CW DEMODULATOR detects the presence of rf oscillations and converts them into a recognizable form. Figure 3-1 illustrates the received cw in view (A), the rectified cw from a diode detector in view (B), and the dc output from a filter that can be used to control a relay or light indicator in view (C).

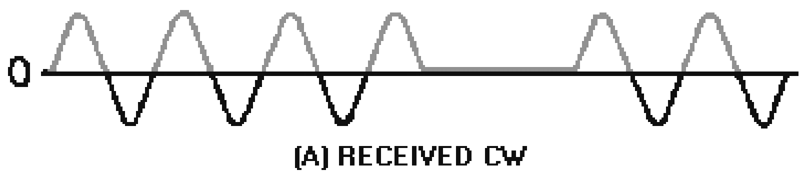


Figure 3-1A.—Cw demodulation. RECEIVED CW.

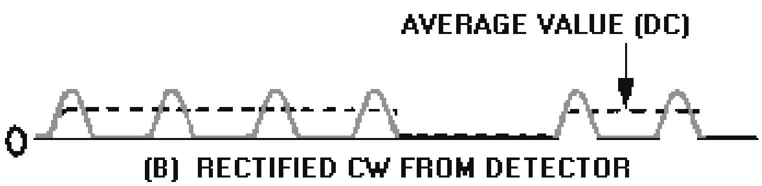


Figure 3-1B.—Cw demodulation. RECTIFIED CW FROM DETECTOR.

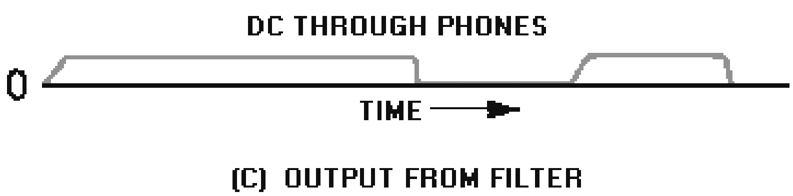


Figure 3-1C.—Cw demodulation. OUTPUT FROM FILTER.

Figure 3-2 is a, simplified circuit that could be used as a cw demodulator. The antenna receives the rf oscillations from the transmitter. The tank circuit, L and C1, acts as a frequency-selective network that is tuned to the desired rf carrier frequency. The diode rectifies the oscillations and C2 provides filtering to provide a constant dc output to control the headset. This demodulator circuit is the equivalent of a wire telegraphy circuit but it has certain disadvantages. For example, if two transmitters are very close in frequency, distinguishing which transmitting station you are receiving is often impossible without a method of fine tuning the desired frequency. Also, if the stations are within the frequency bandpass of the input tank circuit, the tank output will contain a mixture of both signals. Therefore, a method, such as HETERODYNE DETECTION, must be used which provides more than just the information on the presence or absence of a signal.

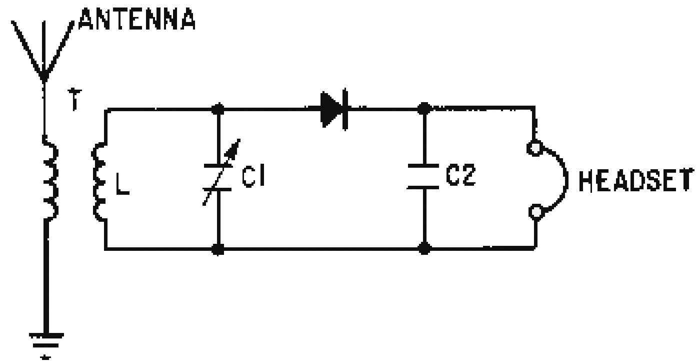


Figure 3-2.—Cw demodulator.

HETERODYNE DETECTION

The use of an af voltage in the detector aids the operator in distinguishing between various signals. Since the carrier is unmodulated, the af voltage can be developed by using the heterodyne procedure discussed in chapter 1. The procedure is to mix the incoming cw signal with locally generated oscillations. This provides a convenient difference frequency in the af range, such as 1,000 hertz. The af difference frequency then is rectified and smoothed by a detector. The af voltage is reproduced by a telephone headset or a loudspeaker.

Consider the heterodyne reception of the code letter **A**, as shown in figure 3-3, view (A). The code consists of a short burst of cw energy (dot) followed by a longer burst (dash). Assume that the frequency of the received cw signal is 500 kilohertz. The locally generated oscillations are adjusted to a frequency which is higher or lower than the incoming rf signal (501 kilohertz in this case), as shown in view (B). The voltage resulting from the heterodyning action between the cw signal [view (A)] and the local oscillator signal [view (B)] is shown in view (C) as the mixed-frequency signal. ENVELOPE (intelligence) amplitude varies at the BEAT (difference) frequency of 1,000 hertz (501,000 – 500,000). The negative half cycles of the mixed frequency are rectified, as shown in view (D). The peaks of the positive half cycles follow the 1,000-hertz beat frequency.

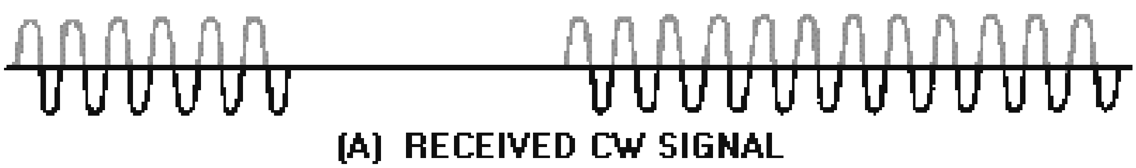


Figure 3-3A.—Heterodyne detection. RECEIVED CW SIGNAL.

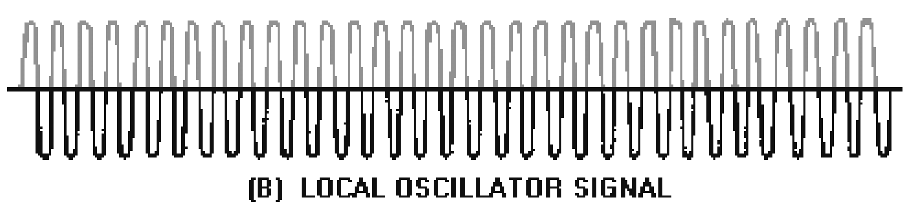


Figure 3-3B.—Heterodyne detection. LOCAL OSCILLATOR SIGNAL.

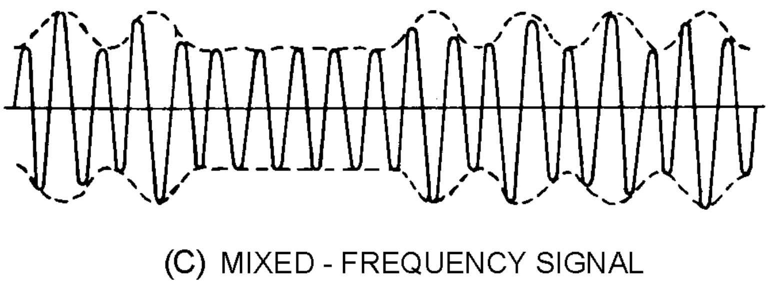


Figure 3-3C.—Heterodyne detection. MIXED-FREQUENCY SIGNAL.

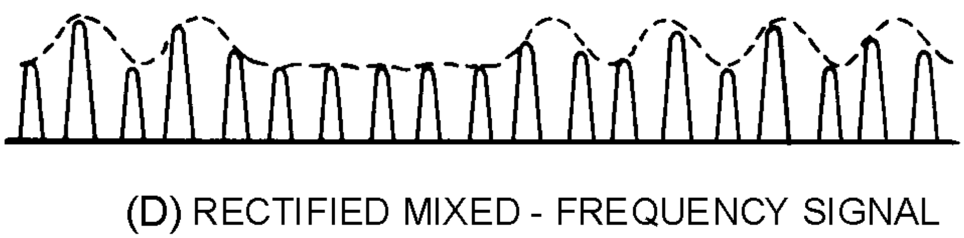


Figure 3-3D.—Heterodyne detection. RECTIFIED MIXED-FREQUENCY SIGNAL.

Figure 3-3E.—Heterodyne detection. AUDIO-BEAT NOTE FROM FILTER.

The cw signal pulsations are removed by the rf filter in the detector output and only the envelope of the rectified pulses remains. The envelope, shown in view (E), is a 1,000-hertz audio-beat note. This 1,000 hertz, dot-dash tone may be heard in a speaker or headphone and identified as the letter **A** by the operator.

The heterodyne method of reception is highly selective and allows little interference from adjacent cw stations. If a cw signal from a radiotelegraph station is operating at 10,000,000 hertz and at the same time an adjacent station is operating at 10,000,300 hertz, a simple detector cannot clearly discriminate between the two stations because the signals are just 300 hertz apart. This is because the bandpass of the tuning circuits is too wide and allows some of the other signal to interfere. The two carrier frequencies differ by only 0.003 percent and a tuned tank circuit cannot easily discriminate between them. However, if a heterodyne detector with a local-oscillator frequency of 10,001,000 hertz is used, then beat notes of 1,000 and 700 hertz are produced by the two signals. These are audio frequencies, which can be distinguished easily by a selective circuit because they differ by 30 percent (compared to the 0.003 percent above).

Even if two stations produce identical beat frequencies, they can be separated by adjusting the local-oscillator or BEAT-FREQUENCY OSCILLATOR (bfo) frequency. For example, if the second station in the previous example had been operating at 10,002,000 hertz, then both stations would have produced a 1,000-hertz beat frequency and interference would have occurred. Adjusting the local-oscillator frequency to 9,999,000 hertz would have caused the desired station at 10,000,000 hertz to produce a 1,000-hertz beat frequency. The other station, at 10,002,000 hertz, would have produced a beat frequency of 3,000 hertz. Either selective circuits or the operator can easily distinguish between these widely differing tones. A trained operator can use the variable local oscillator to distinguish between stations that vary in frequency by only a few hundred hertz.

Q-3. What is the simplest form of cw detector?

Q-4. What are the essential components of a cw receiver system?

Q-5. What principle is used to help distinguish between two cw signals that are close in frequency?

Q-6. How does heterodyning distinguish between cw signals?

REGENERATIVE DETECTOR

A simple, one-transistor REGENERATIVE DETECTOR circuit that uses the heterodyning principle for cw operation is shown in figure 3-4. The circuit can be made to oscillate by increasing the amount of energy fed back to the tank circuit from the collector-output circuit (by physically moving tickler coil L2 closer to L1 using the regeneration control). This feedback overcomes losses in the base-input circuit and causes self-oscillations which are controlled by tuning capacitor C1. The received signal from the antenna and the oscillating frequency are both present at the base of transistor Q1. These two frequencies are heterodyned by the nonlinearity of the transistor. The resulting beat frequencies are then rectified by the emitter-base junction and produce a beat note which is amplified in the collector-output circuit. The af currents in the collector circuit actuate the phones. The REGENERATIVE DETECTOR (figure 3-4) produces its own oscillations, heterodynes them with an incoming signal, and rectifies or detects them.

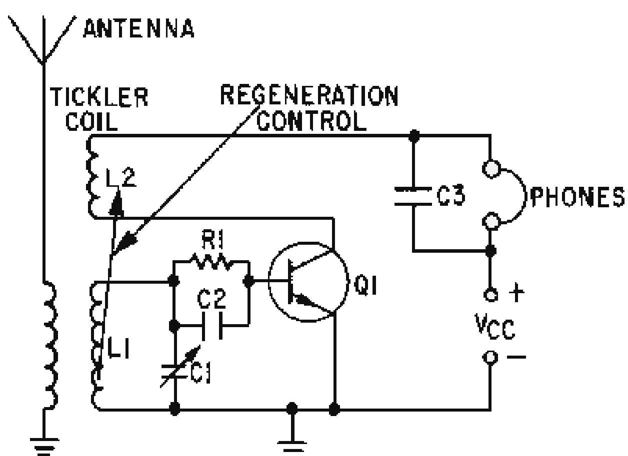


Figure 3-4.—Regenerative detector.

The regenerative detector is used to receive short-wave code signals because it is easy to adjust and has high sensitivity and good selectivity. At high frequencies, the amount of signal detuning necessary to produce an audio-beat note is a small percentage of the signal frequency and causes no trouble. The use of the regenerative detector for low-frequency code reception, however, is usually avoided. At low frequencies the detuning required to produce the proper audio-beat frequency is a considerable percentage of the signal frequency. Although this type detector may be used for AM signals, it has high distortion and is not often used.

Q-7. What simple, one-transistor detector circuit uses the heterodyne principle?

Q-8. What three functions does the transistor in a regenerative detector serve?

AM DEMODULATION

Amplitude modulation refers to any method of modulating an electromagnetic carrier frequency by varying its amplitude in accordance with the message intelligence that is to be transmitted. This is accomplished by heterodyning the intelligence frequency with the carrier frequency. The vector summation of the carrier, sum, and difference frequencies causes the modulation envelope to vary in amplitude at the intelligence frequency, as discussed in chapter 1. In this section we will discuss several circuits that can be used to recover this intelligence from the variations in the modulation envelope.

DIODE DETECTORS

The detection of AM signals ordinarily is accomplished by means of a diode rectifier, which may be either a vacuum tube or a semiconductor diode. The basic detector circuit is shown in its simplest form in view (A) of figure 3-5. Views (B), (C), and (D) show the circuit waveforms. The demodulator must meet three requirements: (1) It must be sensitive to the type of modulation applied at the input, (2) it must be nonlinear, and (3) it must provide filtering. Remember that the AM waveform appears like the diagram of view (B) and the *amplitude* variations of the peaks represent the original audio signal, but *no modulating signal frequencies* exist in this waveform. The waveform contains only three rf frequencies: (1) the *carrier* frequency, (2) the *sum* frequency, and (3) the *difference* frequency. The modulating intelligence is contained in the *difference* between these frequencies. The vector addition of these frequencies provides the modulation envelope which approximates the original modulating waveform. It is this modulation envelope that the DIODE DETECTORS use to reproduce the original modulating frequencies.

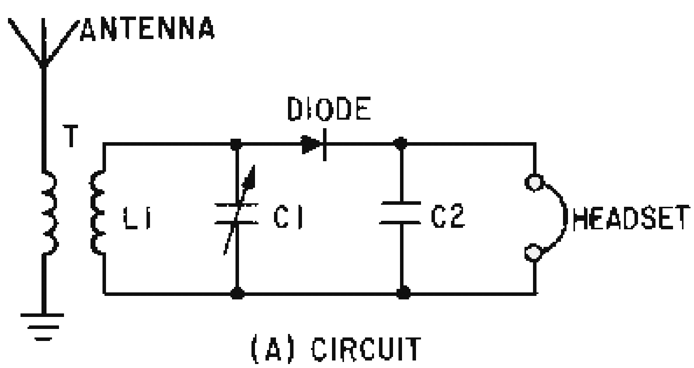


Figure 3-5A.—Series-diode detector and wave shapes. CIRCUIT.

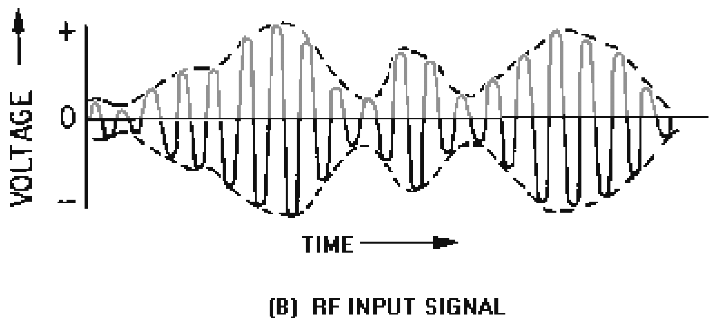


Figure 3-5B.—Series-diode detector and wave shapes. RF INPUT SIGNAL.

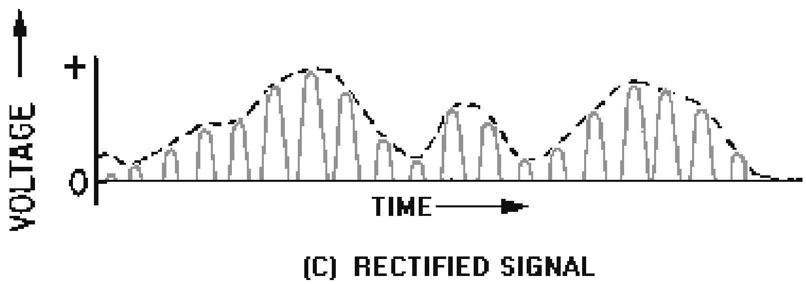


Figure 3-5C.—Series-diode detector and wave shapes. RECTIFIED SIGNAL.

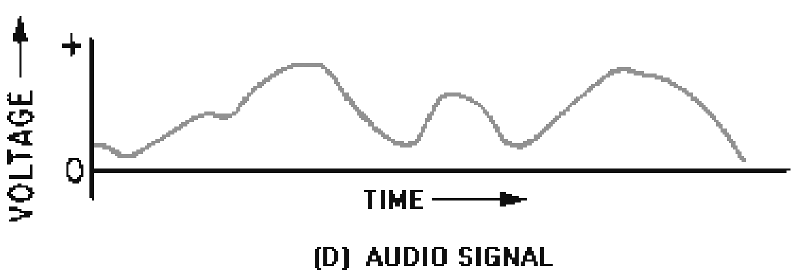


Figure 3-5D.—Series-diode detector and wave shapes. AUDIO SIGNAL.

Series-Diode Detector

Let's analyze the operation of the circuit shown in view (A) of figure 3-5. This circuit is the basic type of diode receiver and is known as a SERIES-DIODE DETECTOR. The circuit consists of an antenna, a tuned LC tank circuit, a semiconductor diode detector, and a headset which is bypassed by capacitor C2. The antenna receives the transmitted rf energy and feeds it to the tuned tank circuit. This tank circuit (L1 and C1) selects which rf signal will be detected. As the tank resonates at the selected frequency, the wave shape in view (B) is developed across the tank circuit. Because the semiconductor is a nonlinear device, it conducts in only one direction. This eliminates the negative portion of the rf carrier and produces the signal shown in view (C). The current in the circuit must be smoothed before the headphones can reproduce the af intelligence. This action is achieved by C2 which acts as a filter to provide an output that is proportional to the peak rf pulses. The filter offers a low impedance to rf and a relatively high impedance to af. (Filters were discussed in *NEETS*, Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits*.) This action causes C2 to develop the waveform in view (D). This varying af voltage is applied to the headset which then reproduces the original modulating frequency. This circuit is called a series-diode detector (sometimes referred to as a VOLTAGE-DIODE DETECTOR) because the semiconductor diode is in series with both the input voltage and the load impedance. Voltages in the circuit cause an output voltage to develop across the load impedance that is proportional to the input voltage peaks of the modulation envelope.

Q-9. What are the three requirements for an AM demodulator?

Q-10. What does the simplest diode detector use to reproduce the modulating frequency?

Q-11. What is the function of the diode in a series-diode detector?

Q-12. In figure 3-5, what is the function of C2?

Shunt-Diode Detector

The SHUNT-DIODE DETECTOR (figure 3-6) is similar to the series-diode detector except that the output variations are current pulses rather than voltage pulses. Passing this current through a shunt resistor develops the voltage output. The input is an rf modulated envelope. On the negative half cycles of the rf, diode CR1 is forward biased and shunts the signal to ground. On the positive half cycles, current flows from the output through L1 to the input. A field is built up around L1 that tends to keep the current flowing. This action integrates the rf current pulses and causes the output to follow the modulation envelope (intelligence) closely. (Integration was discussed in *NEETS*, Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits*.) Shunt resistor R1 develops the output voltage from this current flow. Although the shunt detector operates on the principle of current flow, it is the output voltage across the shunt resistor that is used to reproduce the original modulation signal. The shunt-diode detector is easily identified by noting that the detector diode is in parallel with both the input and load impedance. The waveforms associated with this detector are identical to those shown in views (B), (C), and (D) of figure 3-5.

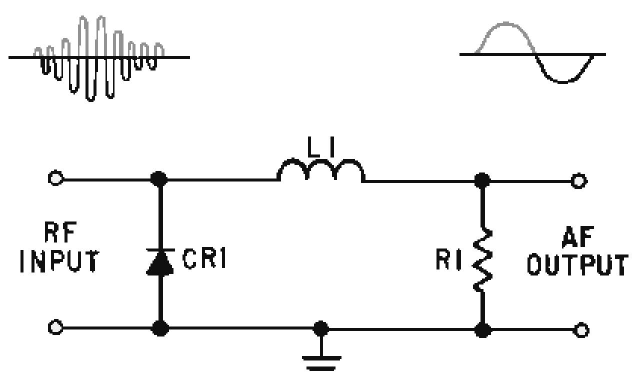


Figure 3-6.—Shunt-diode detector.

The series-diode detector is normally used where large input signals are supplied and a linear output is required. The shunt-diode detector is used where the voltage variations are too small to produce a full output from audio amplifier stages. Additional current amplifiers are required to bring the output to a usable level. Other methods of detection and amplification have been developed which will detect low-level signals. The next sections will discuss two of these circuits, the common-emitter and common-base detectors.

Q-13. How does the current-diode detector differ from the voltage-diode detector?

Q-14. Under what circuit conditions would the shunt detector be used?

COMMON-EMITTER DETECTOR

The COMMON-EMITTER DETECTOR is often used in receivers to supply an amplified detected output. The schematic for a typical transistor common-emitter detector is shown in figure 3-7. Input transformer T1 has a tuned primary that acts as a frequency-selective device. L2 inductively couples the input modulation envelope to the base of transistor Q1. Resistors R1 and R2 are fixed-bias voltage dividers that set the bias levels for Q1. Resistor R1 is bypassed by C2 to eliminate rf. This RC combination also acts as the load for the diode detector (emitter-base junction of Q1). The detected audio is in series with the biasing voltage and controls collector current. The output is developed across R4 which is also bypassed to remove rf by C4. R3 is a temperature stabilization resistor and C3 bypasses it for both rf and af.

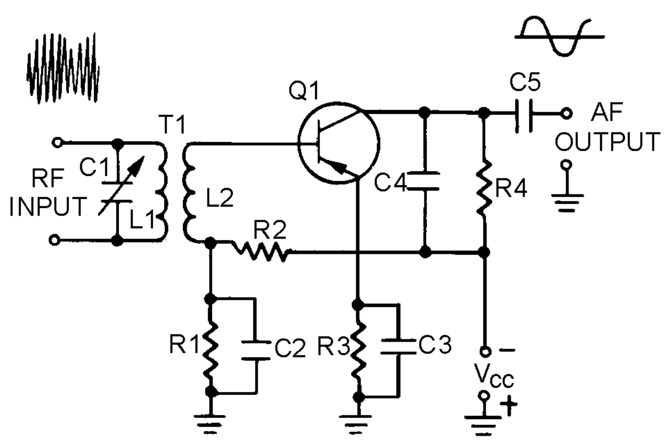


Figure 3-7.—Common-emitter detector.

Q1 is biased for slight conduction with no input signal applied. When an input signal appears on the base of Q1, it is rectified by the emitter-base junction (operating as a diode) and is developed across R1 as a dc bias voltage with a varying af component. This voltage controls bias and collector current for Q1. The output is developed by collector current flow through R4. Any rf ripple in the output is bypassed across the collector load resistor by capacitor C4. The af variations are not bypassed. After the modulation envelope is detected in the base circuit, it is amplified in the output circuit to provide suitable af output. The output of this circuit is higher than is possible with a simple detector. Because of the amplification in this circuit, weaker signals can be detected than with a simple detector. A higher, more usable output is thus developed.

Q-15. Which junction of the transistor in the common-emitter detector detects the modulation envelope?

Q-16. Which component in figure 3-7 develops the af signal at the input?

Q-17. How is the output signal developed in the common-emitter detector?

COMMON-BASE DETECTOR

Another amplifying detector that is used in portable receivers is the COMMON-BASE DETECTOR. In this circuit detection occurs in the emitter-base junction and amplification occurs at the output of the collector junction. The output developed is the equivalent of a diode detector which is followed by a stage of audio amplification, but with more distortion. Figure 3-8 is a schematic of a typical common-base detector. Transformer T1 is tuned by capacitor C3 to the frequency of the incoming modulated envelope. Resistor R1 and capacitor C1 form a self-biasing network which sets the dc operating point of the emitter junction. The af output is taken from the collector circuit through audio transformer T2. The primary of T2 forms the detector output load and is bypassed for rf by capacitor C2.

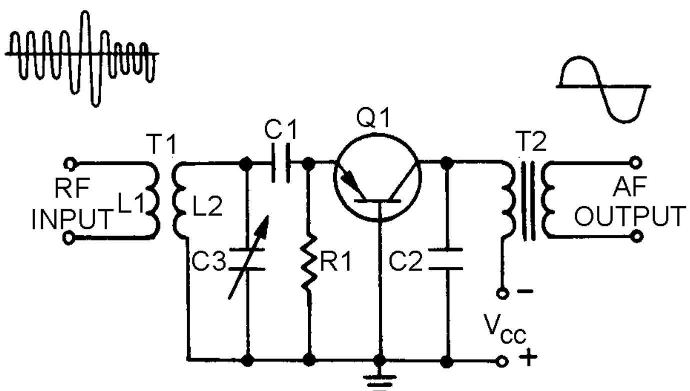


Figure 3-8.—Common-base detector.

The input signal is coupled through T1. When capacitor C3 is tuned to the proper frequency, the signal is passed to the emitter of Q1. When no input signal is present, bias is determined by resistor R1. When the input signal becomes positive, current flows through the emitter-base junction causing it to be forward biased. C1 and R1 establish the dc operating point by acting as a filter network. This action provides a varying dc voltage that follows the peaks of the rf modulated envelope. This action is identical to the diode detector with the emitter-base junction doing the detecting. The varying dc voltage on the emitter changes the bias on Q1 and causes collector current to vary in accordance with the detected voltage. Transformer T2 couples these af current changes to the output. Thus, Q1 detects the AM wave and then provides amplification for the detected waveform.

The four AM detectors just discussed are not the only types that you will encounter. However, they are representative of most AM detectors and the same characteristics will be found in all AM detectors. Now let's study some ways of demodulating frequency-modulated (fm) signals.

Q-18. Which junction acts as the detector in a common-base detector?

Q-19. To what circuit arrangement is a common-base detector equivalent?

Q-20. In figure 3-8, which components act as the filter network in the diode detector?

FM DEMODULATION

In fm demodulators, the intelligence to be recovered is not in amplitude variations; it is in the *variation of the instantaneous frequency* of the carrier, either above or below the center frequency. The detecting device must be constructed so that its output amplitude will vary linearly according to the instantaneous frequency of the incoming signal.

Several types of fm detectors have been developed and are in use, but in this section you will study three of the most common: (1) the phase-shift detector, (2) the ratio detector, and (3) the gated-beam detector.

SLOPE DETECTION

To be able to understand the principles of operation for fm detectors, you need to first study the simplest form of frequency-modulation detector, the SLOPE DETECTOR. The slope detector is essentially a tank circuit which is tuned to a frequency either slightly above or below the fm carrier frequency. View (A) of figure 3-9 is a plot of voltage versus frequency for a tank circuit. The resonant frequency of the tank is the frequency at point 4. Components are selected so that the resonant frequency is higher than the frequency of the fm carrier signal at point 2. The entire frequency deviation for the fm signal falls on the lower slope of the bandpass curve between points 1 and 3. As the fm signal is applied to the tank circuit in view (B), the output amplitude of the signal varies as its frequency swings closer to, or further from, the resonant frequency of the tank. Frequency variations will still be present in this waveform, but it will also develop amplitude variations, as shown in view (B). This is because of the response of the tank circuit as it varies with the input frequency. This signal is then applied to the diode detector in view (C) and the detected waveform is the output. This circuit has the major disadvantage that any amplitude variations in the rf waveform will pass through the tank circuit and be detected. This disadvantage can be eliminated by placing a limiter circuit before the tank input. (Limiter circuits were discussed in *NEETS*, Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits*.) This circuit is basically the same as an AM detector with the tank tuned to a higher or lower frequency than the received carrier.

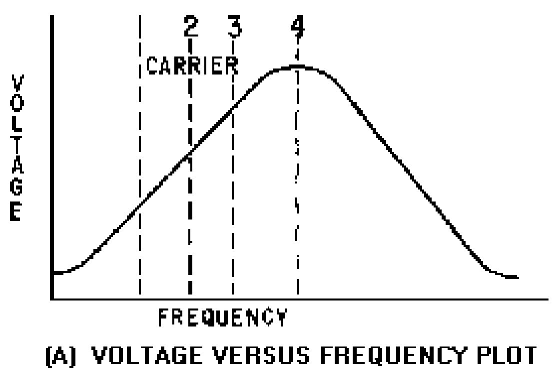


Figure 3-9A.—Slope detector. VOLTAGE VERSUS FREQUENCY PLOT.

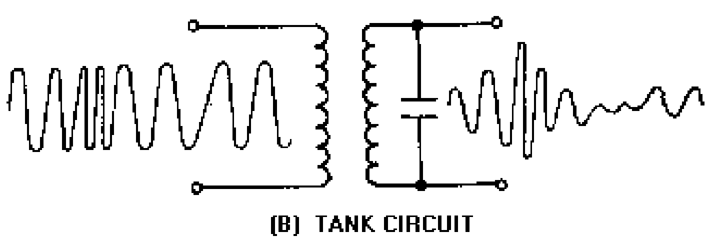


Figure 3-9B.—Slope detector. TANK CIRCUIT.

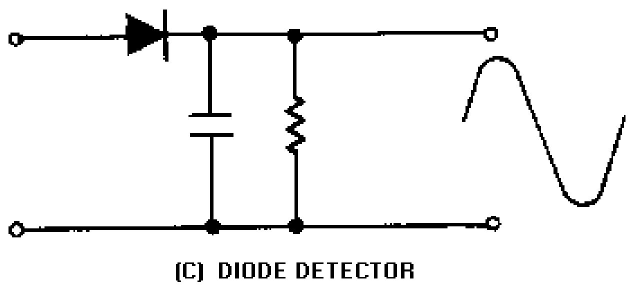


Figure 3-9C.—Slope detector. DIODE DETECTOR.

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.

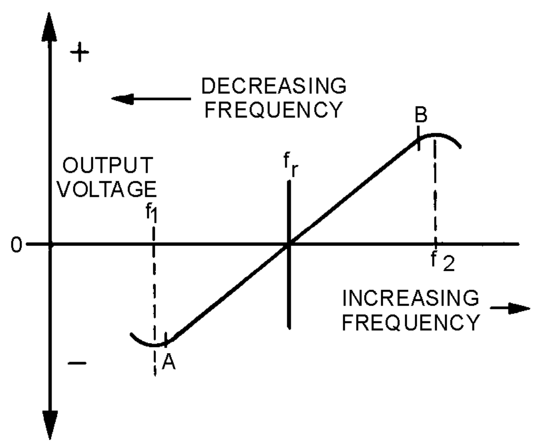


Figure 3-10.—Discriminator response curve.

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.

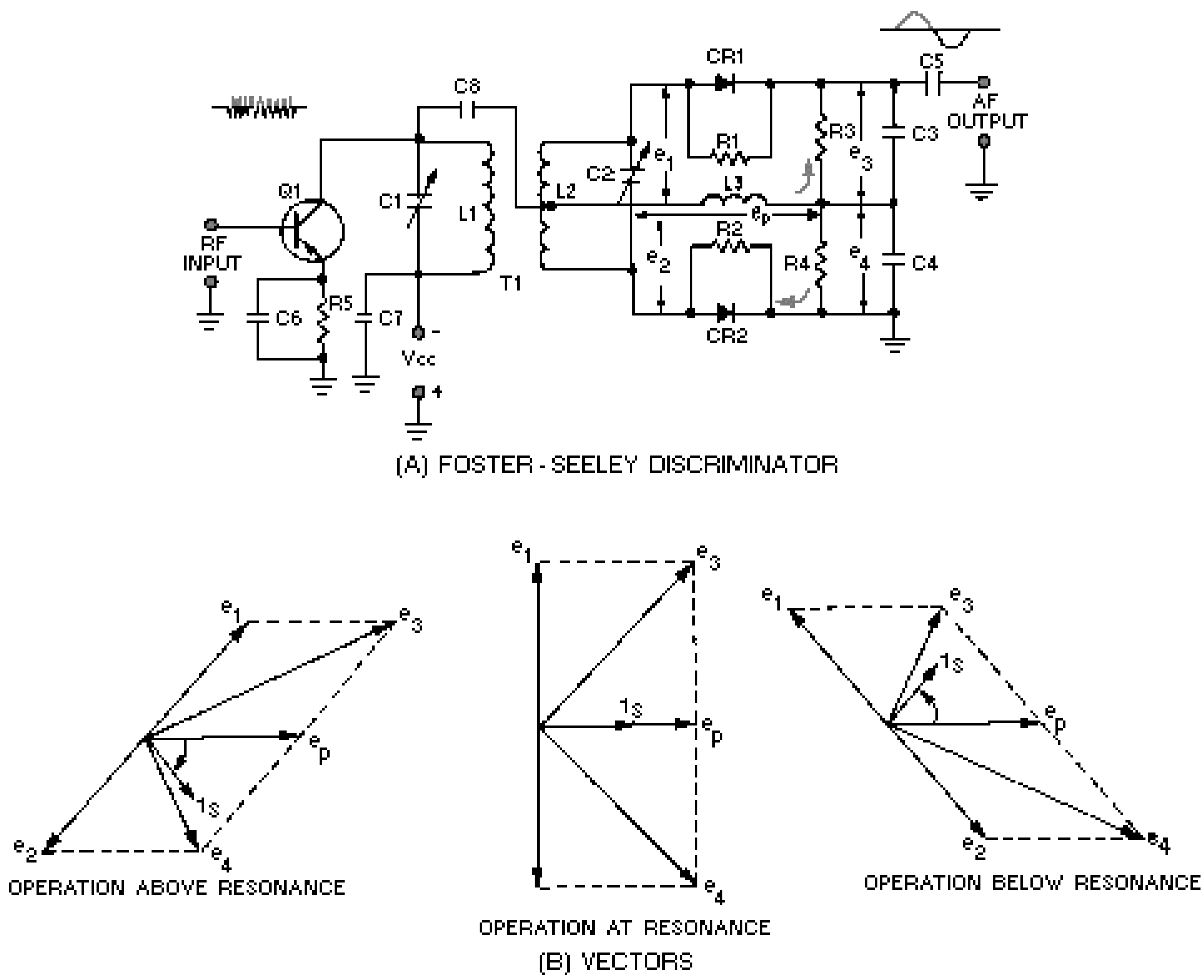


Figure 3-11.—Foster-Seeley discriminator. FOSTER-SEELEY DISCRIMINATOR.

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.

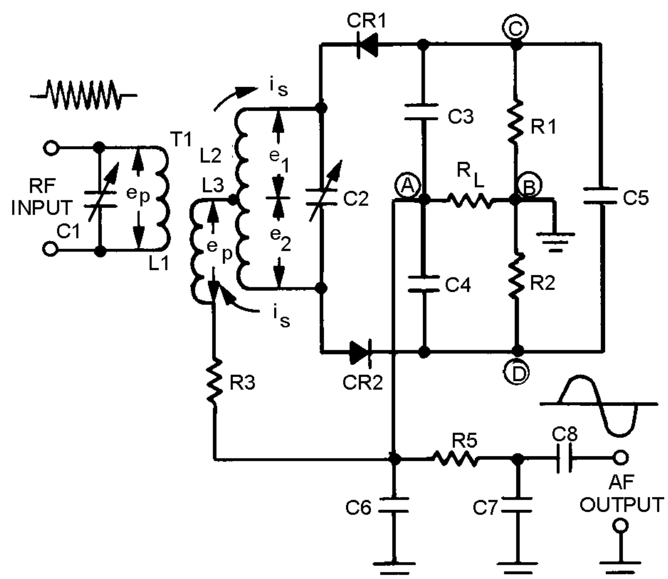


Figure 3-12.—Ratio detector.

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, the tank current is in phase with the primary voltage e_p. The current flowing in the tank circuit causes voltages e_1 and e_2 to be developed in the secondary winding of T1. These voltages are of equal magnitude and of opposite polarity with respect to the center tap of the winding. Since the winding is inductive, the voltage drop across it is 90 degrees out of phase with the current through it.

Figure 3-13 is a simplified schematic diagram of a ratio detector at resonance. The voltage applied to the cathode of CR1 is the vector sum of e_1 and e_p. Likewise, the voltage applied to the anode of CR2 is the vector sum of e_2 and e_p. No phase shift occurs at resonance and both voltages are equal. Both diodes conduct equally. This equal current flow causes the same voltage drop across both R1 and R2. C3 and C4 will charge to equal voltages with opposite polarities. Let's assume that the voltages across C3 and C4 are equal in amplitude (5 volts) and of opposite polarity and the total charge across C5 is 10 volts. R1 and R2 will each have 5 volts dropped across them because they are of equal values. The output is taken between points **A** and **B**. To find the output voltage, you algebraically add the voltages between points **A** and **B** (loop **ACB** or **ADB**). Point **A** to point **D** is −5 volts. Point **D** to point **B** is + 5 volts. Their algebraic sum is 0 volts and the output voltage is 0 at resonance. If the voltages on branch **ACB** were figured, the same output would be found because the circuit branches are in parallel.

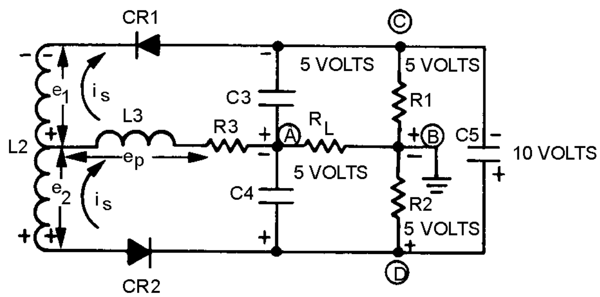


Figure 3-13.—Current flow and polarities at resonance.

When the input signal reverses polarity, the secondary voltage across L2 also reverses. The diodes will be reverse biased and no current will flow. Meanwhile, C5 retains most of its charge because of the long time constant offered in combination with R1 and R2. This slow discharge helps to maintain the output.

OPERATION ABOVE RESONANCE.—When a tuned circuit (figure 3-14) operates at a frequency higher than resonance, the tank is inductive. The secondary current i lags the primary voltage e_p. Secondary voltage e_1 is nearer in phase with primary voltage e, while e_2 is shifted further out of phase with e_p. The vector sum of e_1 and e_p is larger than that of e_2 and e_p. Therefore, the voltage applied to the cathode of CR1 is greater than the voltage applied to the anode of CR2 above resonance.

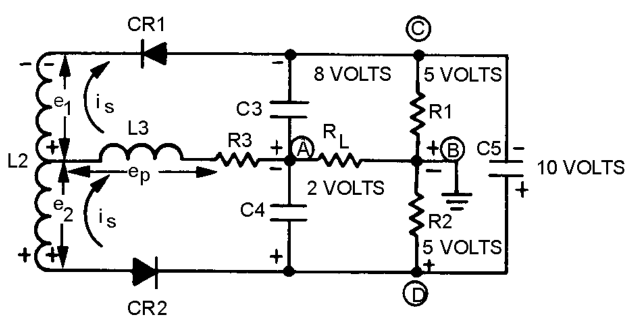


Figure 3-14.—Current flow and polarities above resonance.

Assume that the voltages developed above resonance are such that the higher voltage on the cathode of CR1 causes C3 to charge to 8 volts. The lower voltage on the anode of CR2 causes C4 to charge to 2 volts. Capacitor C5 remains charged to the sum of these two voltages, 10 volts. Again, by adding the voltages in loop **ACB** or **ADB** between points **A** and **B**, you can find the output voltage. Point **A** to point **D** equals -2 volts. Point **D** to point **B** equals +5 volts. Their algebraic sum, and the output, equals +3 volts when tuned above resonance. During the negative half cycle of the input signal, the diodes are reverse biased and C5 helps maintain a constant output.

OPERATION BELOW RESONANCE.—When a tuned circuit operates below resonance (figure 3-15), it is capacitive. Secondary current $_{is}$ leads the primary voltage e_p and secondary voltage e_2 is nearer in phase with primary voltage e_p. The vector sum of e_2 and e_p is larger than the sum of e_1 and e_p. The voltage applied to the anode of CR2 becomes greater than the voltage applied to the cathode of CR1 below resonance.

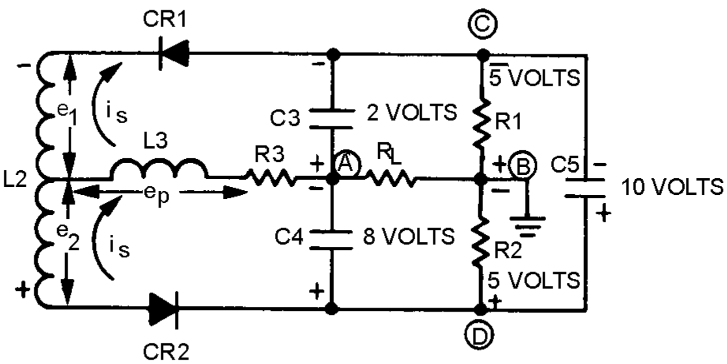


Figure 3-15.—Current flow and polarities below resonance.

Assume that the voltages developed below resonance are such that the higher voltage on the anode of CR2 causes C4 to charge to 8 volts. The lower voltage on the cathode of CR1 causes C3 to charge to 2 volts. Capacitor C5 remains charged to the sum of these two voltages, 10 volts. The output voltage equals –8 volts plus +5 volts, or –3 volts, when tuned below resonance. During the negative half cycle of the input signal, the diodes are reverse biased and C5 helps maintain a constant output.

Advantage of a Ratio Detector

The ratio detector is not affected by amplitude variations on the fm wave. The output of the detector adjusts itself automatically to the average amplitude of the input signal. C5 charges to the sum of the voltages across R1 and R2 and, because of its time constant, tends to filter out any noise impulses. Before C5 can charge or discharge to the higher or lower potential, the noise disappears. The difference in charge across C5 is so slight that it is not discernible in the output. Ratio detectors can operate with as little as 100 millivolts of input. This is much lower than that required for limiter saturation and less gain is required from preceding stages.

Q-26. What is the primary advantage of a ratio detector?

Q-27. What is the purpose of C5 in figure 3-12?

GATED-BEAM DETECTOR

An fm demodulator employing a completely different detection principle is the GATED-BEAM DETECTOR (sometimes referred to as the QUADRATURE DETECTOR). A simplified diagram of a gated-beam detector is shown in figure 3-16. It uses a gated-beam tube to limit, detect, and amplify the received fm signal. The output voltage is 0 when the input frequency is *equal to the center frequency*. When the input frequency rises *above the center frequency*, the output voltage goes positive. When the input frequency drops *below the center frequency*, the output voltage goes negative.

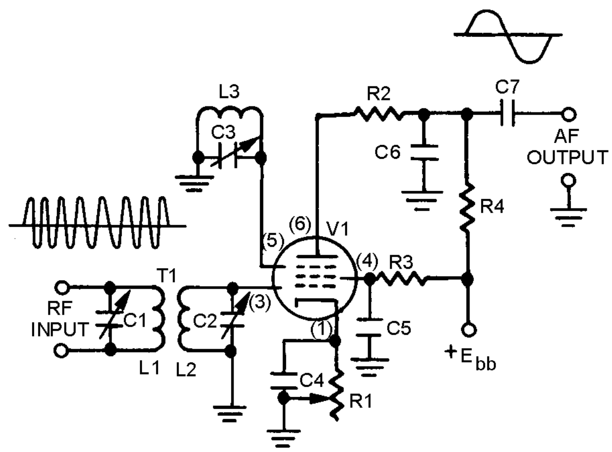


Figure 3-16.—Gated-beam detector.

Circuit Operation

The gated-beam detector employs a specially designed gated-beam tube. The elements of this tube are shown in figure 3-17. The focus electrode forms a shield around the tube cathode except for a narrow slot through which the electron beam flows. The beam of electrons flows toward the limiter grid which acts like a gate. When the gate is open, the electron beam flows through to the next grid. When closed, the gate completely stops the beam.

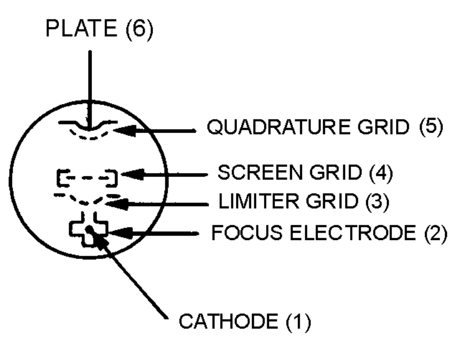


Figure 3-17.—Gated-beam tube physical layout.

After the electron beam passes the limiter grid, the screen grid refocuses the beam toward the quadrature grid. The quadrature grid acts much the same as the limiter grid; it either opens or closes the passage for electrons. These two grids act similar to an AND gate in digital devices; both gates must be open for the passage of electrons to the plate. Either grid can cut off plate current. AND gates were presented in *NEETS*, Module 13, *Introduction to Number Systems, Boolean Algebra, and Logic Circuits*.

Look again at the circuit in figure 3-16. With no signal applied to the limiter grid (3), the tube conducts. The electron beam moving near the quadrature grid (5) induces a current into the grid which develops a voltage across the high-Q tank circuit (L3 and C3). C3 charges until it becomes sufficiently negative to cut off the current flow. L3 tends to keep the current moving and, as its field collapses, discharges C3. When C3 discharges sufficiently, the quadrature grid becomes positive, grid current flows, and the cycle repeats itself. This tank circuit (L3 and C3) is tuned to the center frequency of the received fm signal so that it will oscillate at that frequency.

The waveforms for the circuit are shown in figure 3-18. View (A) is the fm input signal. The limiter-grid gate action creates a wave shape like view (B) because the tube is either cut off or saturated very quickly by the input wave. Note that this is a square wave and is the current waveform passing the limiter grid.

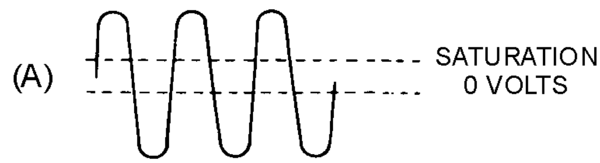


Figure 3-18A.—Gated-beam detector waveforms.

Figure 3-18B.—Gated-beam detector waveforms.

At the quadrature grid the voltage across C3 lags the current which produces it [view (C)]. The result is a series of pulses, shown in view (D), appearing on the quadrature grid at the center frequency, but lagging the limiter-grid voltage by 90 degrees. Because the quadrature grid has the same conduction and cutoff levels as the limiter grid, the resultant current waveform will be transformed into a square wave.

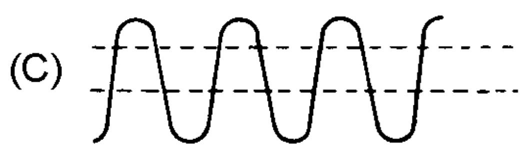


Figure 3-18C.—Gated-beam detector waveforms.

Figure 3-18D.—Gated-beam detector waveforms.

Both the limiter and quadrature grids must be positive at the same time to have plate current. You can see how much conduction time occurs for each cycle of the input by overlaying the current waveforms in views (B) and (D), as shown in view (E). The times when both grids are positive are shown by the shaded area of view (E). These plate current pulses are shown for operation at resonance in view (F).

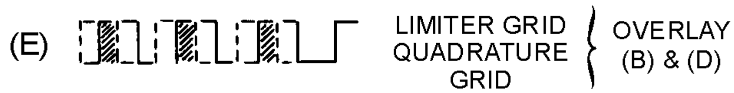


Figure 3-18E.—Gated-beam detector waveforms.

Figure 3-18F.—Gated-beam detector waveforms.

Now consider what happens with a deviation in frequency at the input. If the frequency increases, the frequency across the quadrature tank also increases. Above resonance, the tank appears capacitive to the induced current; voltage then lags the applied voltage by more than 90 degrees, as shown in view (G). Note in view (H) that the two grid signals have moved more out of phase and the average plate current level has decreased.

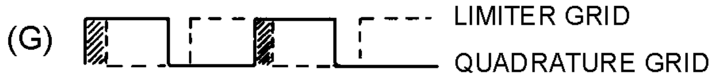


Figure 3-18G.—Gated-beam detector waveforms.

Figure 3-18H.—Gated-beam detector waveforms.

As the input frequency decreases, the opposite action takes place. The two grid signals move more in phase, as shown in view (I), and the average plate current increases, as shown in view (J).

Figure 3-18I.—Gated-beam detector waveforms.

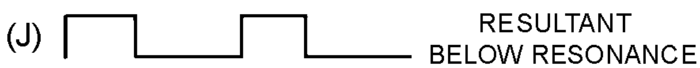


Figure 3-18J.—Gated-beam detector waveforms.

View (K) shows the resultant plate-current pulses when an fm signal is applied to a gated-beam detector. Plate load resistor R4 and capacitor C6 form an integrating network which filters these pulses to form the sine-wave output.

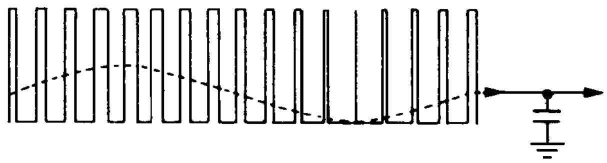


Figure 3-18K.—Gated-beam detector waveforms.

Advantages of the Gated-Beam Detector

The primary advantage of the gated-beam detector lies in its extreme simplicity. It employs only one tube, yet provides a very effective limiter with linear detection. It requires relatively few components and is very easily adjusted.

There are more than the three types of fm demodulators presented in this chapter. However, these are representative of the types with which you will be working. The principles involved in their operation are similar to the other types. You will now briefly study PHASE DEMODULATION which uses the same basic circuitry as fm demodulators.

Q-28. What circuit functions does the tube in a gated-beam detector serve?

Q-29. What condition must exist on both the limiter and quadrature grids for current to flow in a gated-beam detector?

Q-30. Name two advantages of the gated-beam detector.

PHASE DEMODULATION

In phase modulation (pm) the intelligence is contained in the *amount and rate of phase shift* in a carrier wave. You should recall from your study of pm that there is an incidental shift in frequency as the phase of the carrier is shifted. Because of this incidental frequency shift, fm demodulators, such as the Foster-Seeley discriminator and the ratio detector, can also be used to demodulate phase-shift signals.

Another circuit that may be used is the gated-beam (quadrature) detector. Remember that the fm phase detector output was determined by the phase of the signals present at the grids. A QUADRATURE DETECTOR FOR PHASE DEMODULATION works in the same manner.

A basic schematic is shown in figure 3-19. The quadrature-grid signal is excited by a reference from the transmitter. This may be a sample of the unmodulated master oscillator providing a phase reference for the detector.

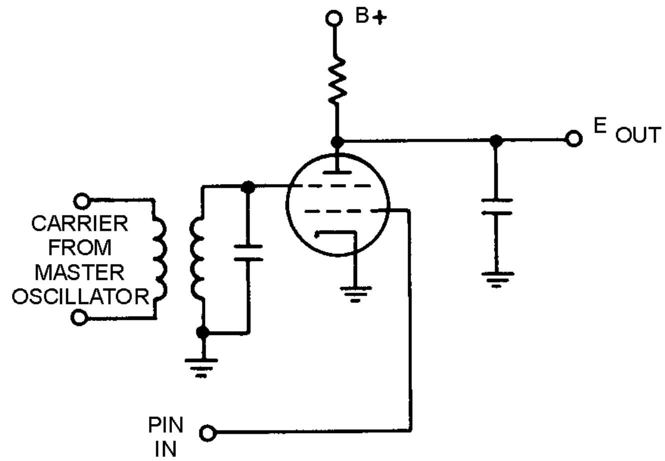


Figure 3-19.—Phase detector.

The modulated waveform is applied to the limiter grid. Gating action in the tube will occur as the phase shifts between the input waveform and the reference. The combined output current from the gated-beam tube will be a series of current pulses. These pulses will vary in width as shown in figure 3-20. The width of these pulses will vary in accordance with the phase difference between the carrier and the modulated wave.

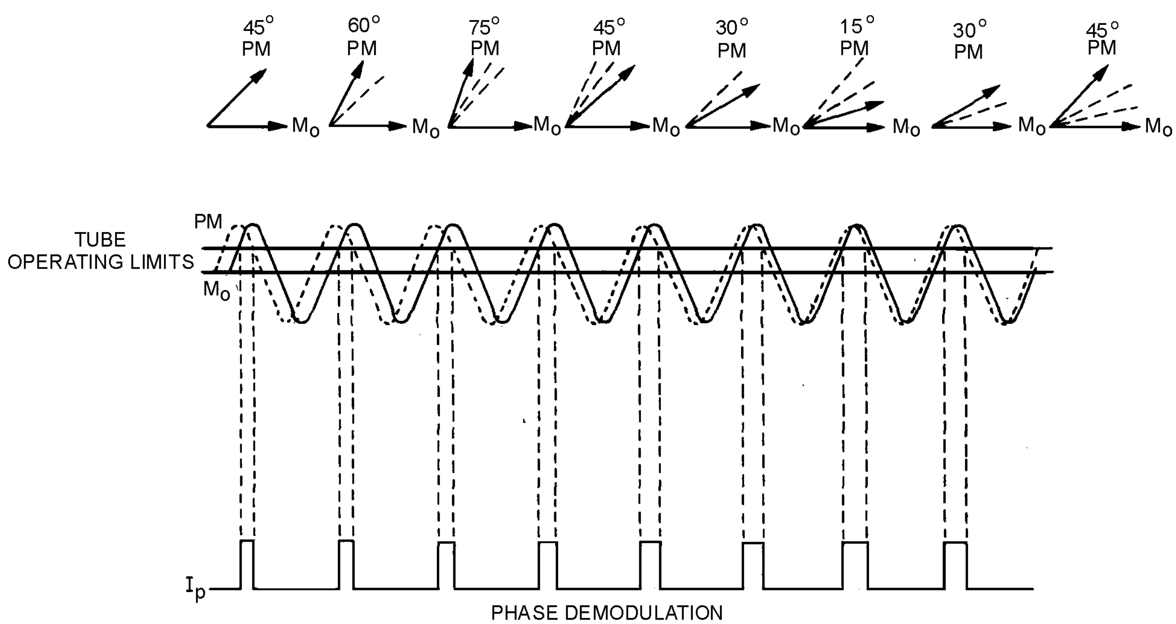


Figure 3-20.—Phase-detector waveforms.

Q-31. Where is the intelligence contained in a phase-modulated signal?

Q-32. Why can phase-modulated signals be detected by fm detectors?

Q-33. How is a quadrature detector changed when used for phase demodulation?

PULSE DEMODULATION

Pulse modulation is used in radar circuits as well as communications circuits, as discussed in chapter 2. A pulse-modulated signal in radar may be detected by a simple circuit that detects the presence of rf energy. Circuits that are capable of this were covered in this chapter in the cw detection discussion; therefore, the information will not be repeated here. A RADAR DETECTOR, in its simplest form, must be capable of producing an output when rf energy (reflected from a target) is present at its input.

In COMMUNICATIONS PULSE DETECTORS the modulated waveform must be restored to its original form. In this chapter you will study three basic methods of pulse demodulation: PEAK, LOW-PASS FILTER, and CONVERSION.

PEAK DETECTION

Peak detection uses the amplitude of a pulse-amplitude modulated (pam) signal or the duration of a pulse-duration modulated (pdm) signal to charge a holding capacitor and restore the original waveform. This demodulated waveform will contain some distortion because the output wave is not a pure sine wave. However, this distortion is not serious enough to prevent the use of peak detection.

Pulse-Amplitude Demodulation

Peak detection is used to detect pam. Figure 3-21 includes a simplified circuit [view (A)] for this demodulator and its waveforms [views (B) and (C)]. CR1 is the input diode which allows capacitor C1 to charge to the peak value of the pam input pulse. Pam input pulses are shown in view (B). CR1 is reverse biased between input pulses to isolate the detector circuit from the input. CR2 and CR3 are biased so that they are normally nonconducting. The discharge path for the capacitor is through the resistor (R1). These components are chosen so that their time constant is at least 10 times the interpulse period (time between pulses). This maintains the charge on C1 between pulses by allowing only a small discharge before the next pulse is applied. The capacitor is discharged just prior to each input pulse to allow the output voltage to follow the peak value of the input pulses. This discharge is through CR2 and CR3. These diodes are turned on by a negative pulse from a source that is time-synchronous with the timing-pulse train at the transmitter. Diode CR3 ensures that the output voltage is near 0 during this discharge period. View (C) shows the output wave shape from this circuit. The peaks of the output signal follow very closely the original modulating wave, as shown by the dotted line. With additional filtering this stepped waveform closely approximates its original shape.

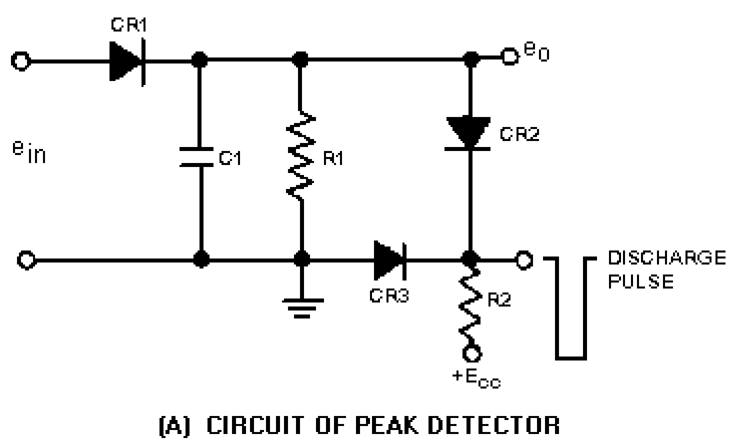


Figure 3-21A.—Peak detector. CIRCUIT OF PEAK DETECTOR.

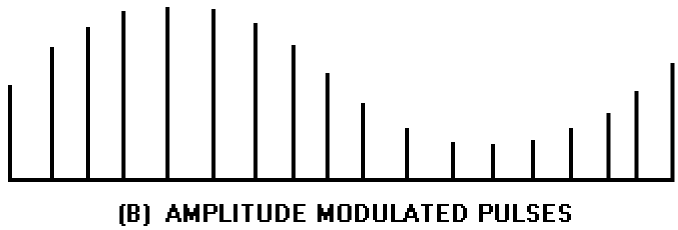


Figure 3-21B.—Peak detector. AMPLITUDE MODULATED PULSES.

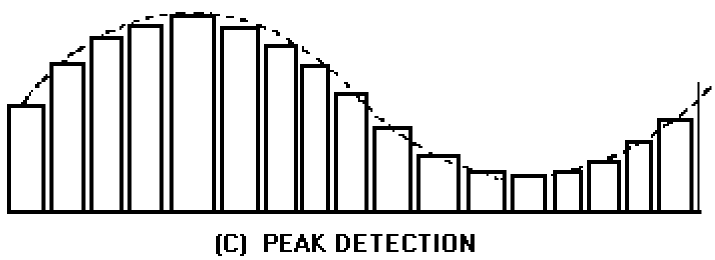


Figure 3-21C.—Peak detector. PEAK DETECTION.

Pulse-Duration Modulation

The peak detector circuit may also be used for pdm. To detect pdm, you must modify view (A) of figure 3-21 so that the time constant for charging C1 through CR1 is at least 10 times the maximum received pulse width. This may be done by adding a resistor in series with the cathode or anode circuit of CR1. The amplitude of the voltage to which C1 charges, before being discharged by the negative pulse, will be directly proportional to the input pulse width. A longer pulse width allows C1 to charge to a higher potential than a short pulse. This charge is held, because of the long time constant of R1 and C1, until the discharge pulse is applied to diodes CR2 and CR3 just prior to the next incoming pulse. These charges across C1 result in a wave shape similar to the output shown for pam detection in view (C) of figure 3-21.

Q-34. In its simplest form, what functions must a radar detector be capable of performing?

Q-35. What characteristic of a pulse does a peak detector sample?

Q-36. What is the time constant of the resistor and capacitor in a peak detector for pam?

Q-37. How can a peak detector for pam be modified to detect pdm?

LOW-PASS FILTER

Another method of demodulating pdm is by the use of a low-pass filter. If the voltage of a pulse waveform is averaged over both the pulse and no-pulse time, average voltage is the result. Since the amplitude of pdm pulses is constant, average voltage is directly proportional to pulse width. The pulse width varies with the modulation (intelligence) in pdm. Because the average value of the pulse train varies in accordance with the modulation, the intelligence may be extracted by passing the width-modulated pulses through a low-pass filter. The components of such a filter must be selected so that the filter passes only the desired modulation frequencies. As the varying-width pulses are applied to the low-pass filter, the average voltage across the filter will vary in the same way as the original modulating voltage. This varying voltage will closely approximate the original modulating voltage.

CONVERSION

Pulse-position modulation (ppm), pulse-frequency modulation (pfm), and pulse-code modulation (pcm) are most easily demodulated by first converting them to either pdm or pam. After conversion these pulses are demodulated using either peak detection or a low-pass filter. This conversion may be done in many ways, but your study will be limited to the simpler methods.

Pulse-Position Modulation

Ppm can be converted to pdm by using a flip-flop circuit. (Flip flops were discussed in *NEETS*, Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits*.) Figure 3-22 shows the waveforms for conversion of ppm to pdm. View (A) is the pulse-modulated pulse train and view (B) is a series of reset trigger pulses. The trigger pulses must be synchronized with the unmodulated position of the ppm pulses, but with a fixed time delay from these pulses. As the position-modulated pulse is applied to the flip-flop, the output is driven positive, as shown in view (C). After a period of time, the trigger pulse is again generated and drives the flip-flop output negative and the pulse ends. Because the ppm pulses are constantly varying in position with reference to the unmodulated pulses, the output of the flip-flop also varies in duration or width. This pdm signal can now be applied to one of the circuits that has already been discussed for demodulation.

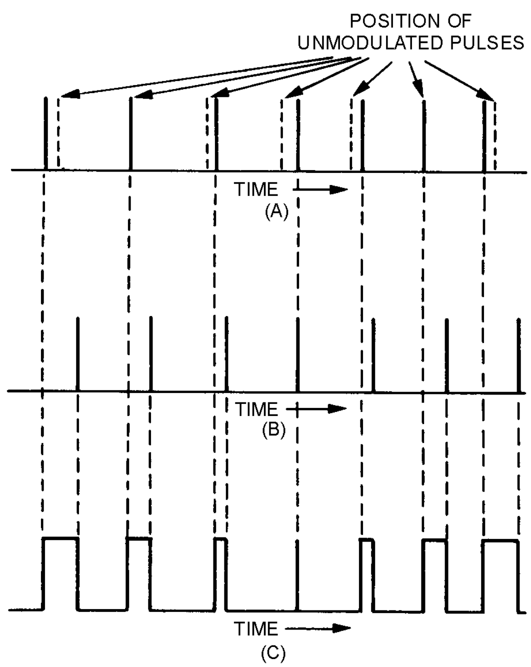


Figure 3-22.—Conversion of ppm to pdm.

Pulse-frequency modulation is a variation of ppm and may be converted by the same method.

Pulse-Code Modulation

Pulse-code modulation can easily be decoded, provided the pulse-code groups have been transmitted in reverse order; that is, if the pulse with the lowest value is transmitted first, the pulse with the highest value is transmitted last. A circuit that will provide a constant value of current without regard to its load is known as a current source. A current source is used to apply the pcm pulses to an RC circuit, such as that shown in figure 3-23, view (A). The current source must be capable of supplying a linear charge to C1 that will increase each time a pulse is applied if C1 is not allowed to discharge between pulses. In other words, if C1 charges to 16 volts during the period of one pulse, then each additional pulse increases the charge by 16 volts. Thus, the cumulative value increases by 16 volts for each received pulse. This does not provide a usable output unless a resistor is chosen that allows C1 to discharge to one-half its value between pulses. If only one pulse is received at T1, C1 charges to 16 volts and then begins to discharge. At T2 the charge has decayed to 8 volts and continues to decay unless another pulse is received. At T3 it has a 4-volt charge and at T4 it only has a 2-volt charge. At the sampling time, a 1-volt charge remains; this charge corresponds to the binary-weighted pulse train of 0001. Now we will apply a pcm signal which corresponds to the binary-coded equivalent of 7 volts (0111) in figure 3-23, view (A). View (B) is the pulse code that is received. Remember that the pulses are transmitted in reverse order. View (C) is the response curve of the circuit. At T1 the pulse corresponding to the least significant digit is applied and C1 charges to 16 volts. C1 discharges between pulses until it reaches 8 volts at T2. At T2 another pulse charges it to 24 volts. At T3, C1 has discharged through R1 to a value of 12 volts. The pulse at T3 increases the charge on C1 by 16 volts to a total charge of 28 volts. At T4, C1 has discharged to one-half its value and is at 14 volts. No pulse is present at T4 so C1 will not receive an additional charge. C1 continues to discharge until T5 when it has reached 7 volts and is sampled to provide a pam pulse which can be peak detected. This sampled output corresponds to the original sampling of the analog voltage in the modulation.

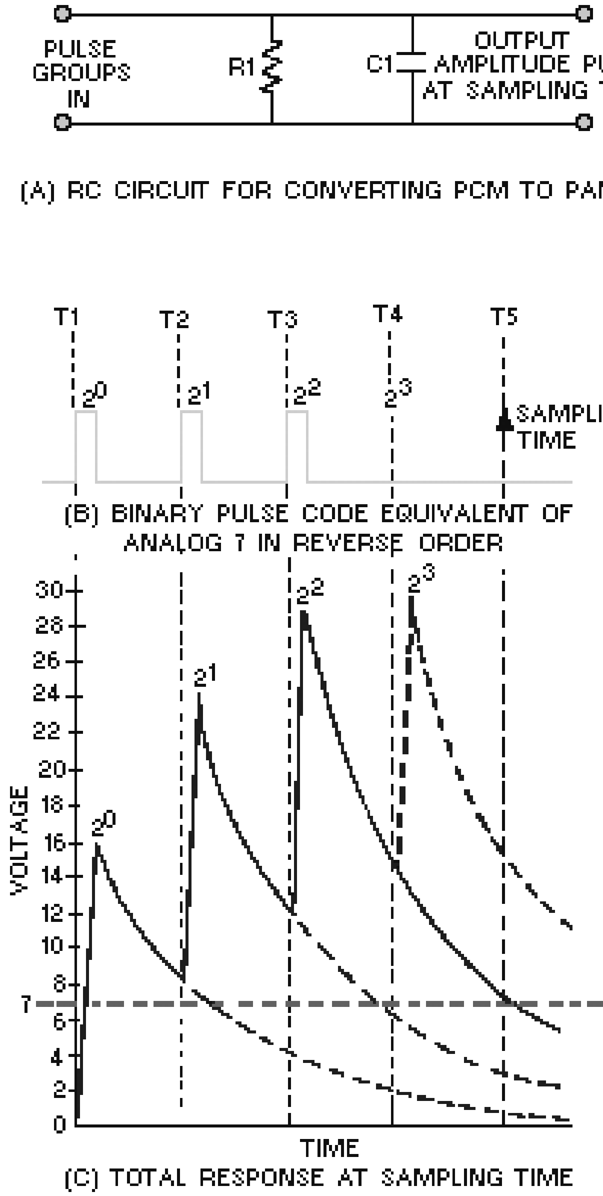


Figure 3-23.—Pcm conversion.

When the pcm demodulator recognizes the presence or absence of pulses in each position, it reproduces the correct standard amplitude represented by the pulse code group. For this reason, noise introduces no error if the largest peaks of noise are not mistaken for pulses. The pcm signal can be retransmitted as many times as desired without the introduction of additional noise effects so long as the signal-to-noise ratio is maintained at a level where noise pulses are not mistaken for a signal pulse. This is not the only method for demodulating pcm, but it is one of the simplest.

This completes your study of demodulation. You should remember that this module has been a basic introduction to the principles of modulation and demodulation. With the advent of solid-state electronics, integrated circuits have replaced discrete components. Although you cannot trace the signal flow through these circuits, the end result of the electronic action within the integrated circuit is the same as it would be with discrete components.

Q-38. *How does a low-pass filter detect pdm?*

Q-39. How is conversion used in pulse demodulation?

Q-40. What is the discharge rate for the capacitor in a pcm converter?

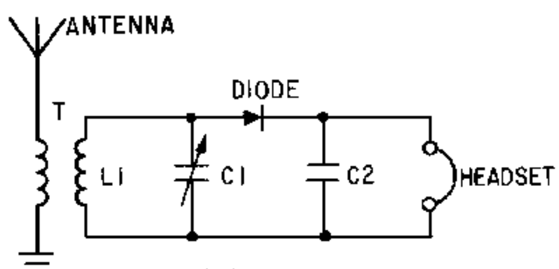
SUMMARY

Now that you have completed this chapter, a short review of what you have learned is in order. The following summary will refresh your memory of demodulation, its basic principles, and typical circuitry required to accomplish this task.

DEMODULATION, also called DETECTION, is the process of re-creating original modulating frequencies (intelligence) from radio frequencies.

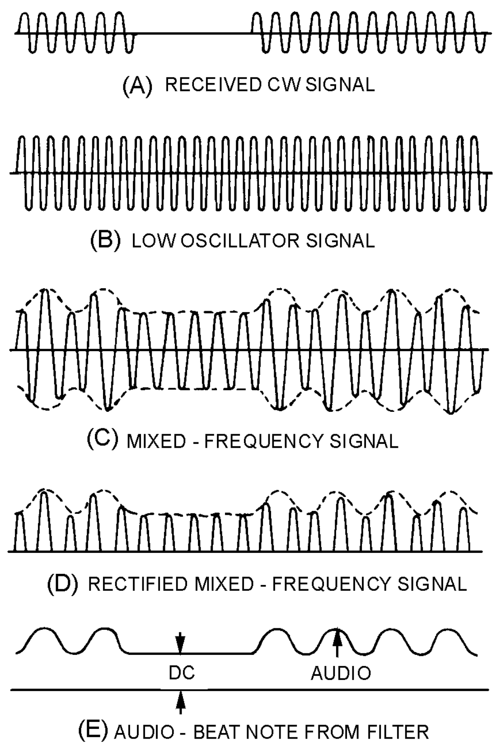
The **DEMODULATOR**, or DETECTOR, is the circuit in which the original modulating frequencies are restored.

A **CW DEMODULATOR** is a circuit that is capable of detecting the presence of rf energy.

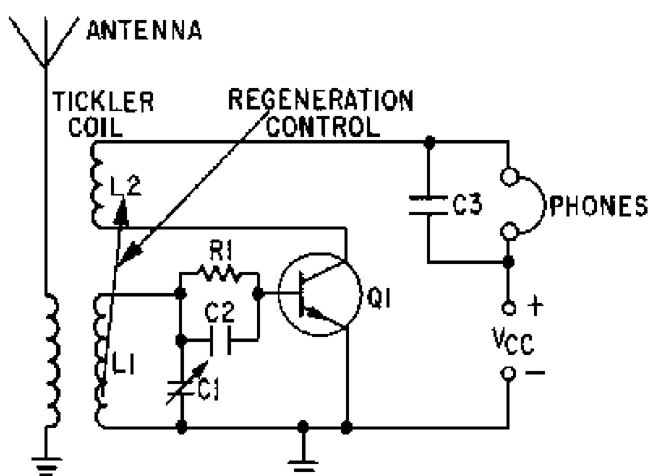


(A) CIRCUIT

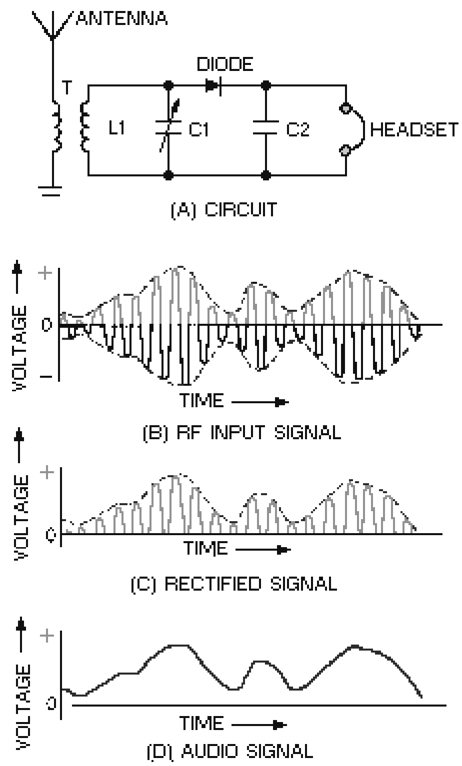
HETERODYNE DETECTION uses a locally generated frequency to beat with the cw carrier frequency to provide an audio output.



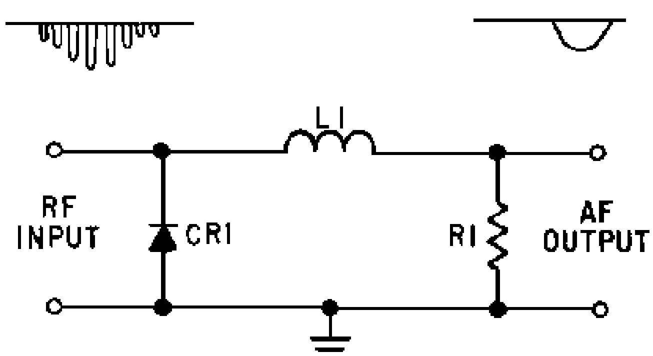
The **REGENERATIVE DETECTOR** produces its own oscillations, heterodynes them with an incoming signal, and detects them.



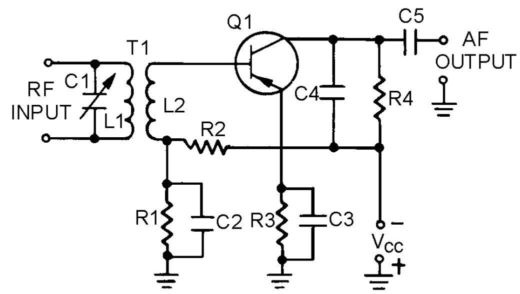
The **SERIES- (VOLTAGE-) DIODE DETECTOR** has a rectifier diode that is in series with the input voltage and the load impedance.



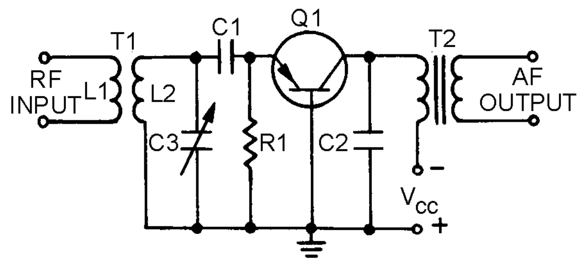
SHUNT- (CURRENT-) DIODE DETECTOR is characterized by a rectifier diode in parallel with the input and load impedance.



The **COMMON-EMITTER DETECTOR** is usually used in receivers to supply a detected and amplified output.

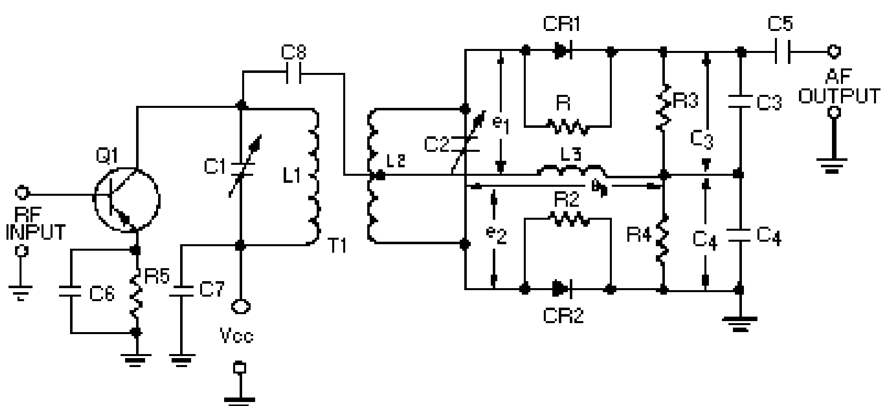


The **COMMON-BASE DETECTOR** is an amplifying detector that is used in portable receivers.

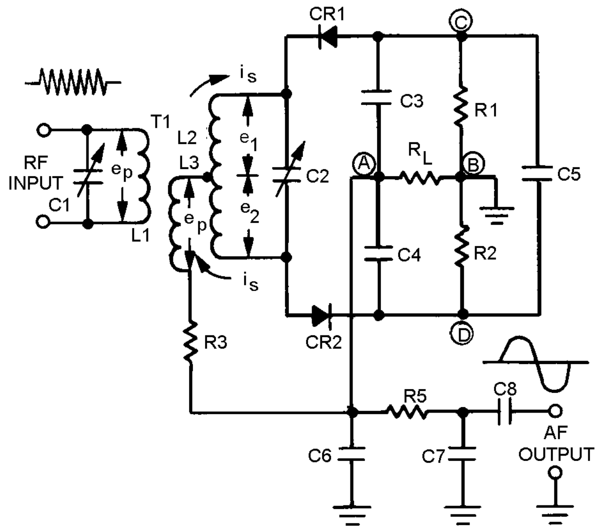


The **SLOPE DETECTOR** is the simplest form of frequency detector. It is essentially a tank circuit tuned slightly away from the desired fm carrier.

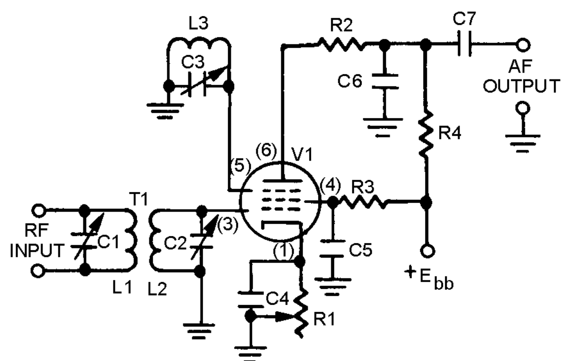
The **FOSTER-SEELEY DISCRIMINATOR** uses a double tuned rf transformer to convert frequency changes of the received fm signal into amplitude variations of the rf wave.



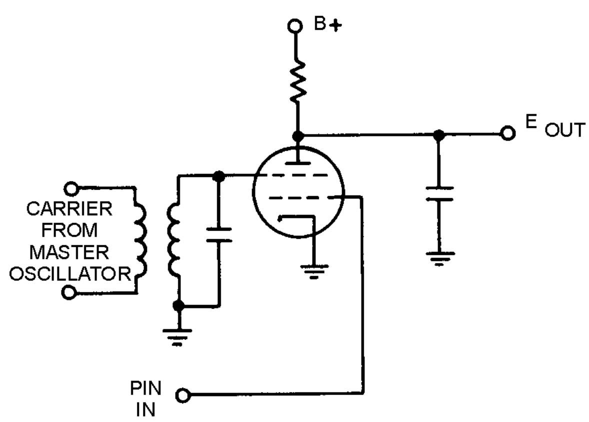
The **RATIO DETECTOR** uses a double-tuned transformer connected so that the instantaneous frequency variations of the fm input signal are converted into instantaneous amplitude variations.



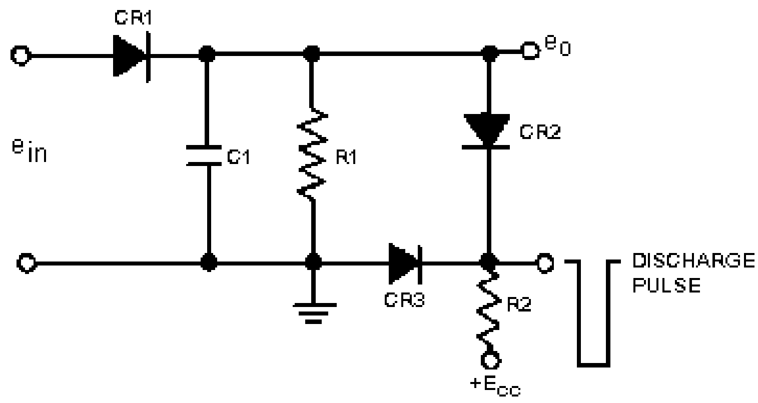
The **GATED-BEAM DETECTOR** uses a specially-designed tube to limit, detect, and amplify the received fm signal.



PHASE DEMODULATION may be accomplished using a frequency discriminator or a quadrature detector.



PEAK DETECTION uses the amplitude, or duration, of a pulse to charge a holding capacitor and restore the modulating waveform.



(A) CIRCUIT OF PEAK DETECTOR

A **LOW-PASS FILTER** is used to demodulate pdm by averaging the pulse amplitude over the entire period between pulses.

PULSE CONVERSION is used to convert ppm, pdm, or pcm to pdm or pam for demodulation.

ANSWERS TO QUESTIONS Q1. THROUGH Q40.

A-1. Re-creating original modulating frequencies (intelligence) from radio frequencies.

A-2. Circuit in which intelligence restoration is achieved.

A-3. A circuit that can detect the presence or absence of rf energy.

A-4. An antenna, tank circuit for tuning, rectifier for detection, filter to give constant output, and an indicator device.

A-5. Heterodyning.

A-6. By giving a different beat frequency for each signal.

A-7. Regenerative detector.

A-8. Oscillator, mixer, and detector.

A-9. (1) Sensitive to the type of modulation applied, (2) nonlinear, and (3) provide filtering.

A-10. The modulation envelope.

A-11. Rectifies the rf pulses in the received signal.

A-12. To filter the rf pulses and develop the modulating wave (intelligence) from the modulation envelope.

A-13. The current-diode detector is in parallel with the input and load.

A-14. When the input voltage variations are too small to give a usable output from a series detector.

A-15. Emitter-base junction.

A-16. R1.

A-17. By the collector current flow through R4.

A-18. Emitter-base junction.

A-19. A diode detector followed by a stage of audio amplification.

A-20. C1 and R1.

A-21. Slope detector.

A-22. Converting frequency variations of received fm signals to amplitude variations.

A-23. A double-tuned tank circuit.

A-24. Rectify the rf voltage from the discriminator.

A-25. Inductive.

A-26. Suppresses amplitude noise without limiter stages.

A-27. It helps to maintain a constant circuit voltage to prevent noise fluctuations from interfering with the output.

A-28. Limits, detects, and amplifies.

A-29. Both grids must be positively biased.

A-30. Extreme simplicity, few components, and ease of adjustment.

A-31. In the amount and rate of phase shift of the carrier wave.

A-32. Because of the incidental frequency shift that is caused while phase-shifting a carrier wave that is similar to fm modulation.

A-33. The quadrature grid signal is excited by a reference from the transmitter.

A-34. Detecting the presence of rf energy.

A-35. Pulse amplitude or pulse duration.

A-36. At least 10 times the interpulse period.

A-37. By making the time constant for charging the capacitor at least 10 times the maximum received pulse width.

A-38. By averaging the value of the pulses over the period of the pulse-repetition rate.

A-39. Ppm, pfm, and pcm are converted to either pdm or pam for demodulation.

A-40. It will discharge to one-half its value between pulses.