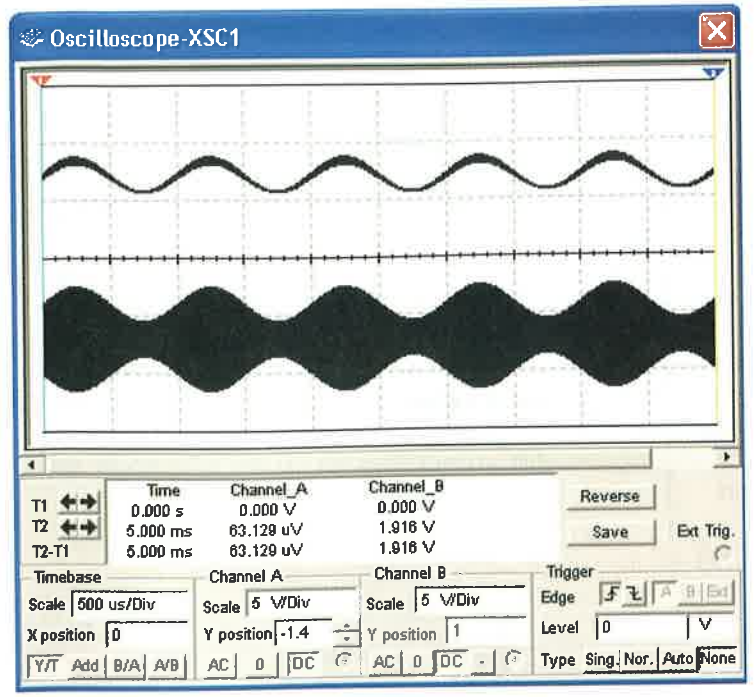

FIGURE 3-33 Oscilloscope output traces from the diode detector.

Next, open **FigE3-1.** This circuit looks the same as **Fig3-32** except that this circuit contains a fault. Use the oscilloscope to view the traces in the circuit. Good troubleshooting practice says: *Always perform a visual check of the circuit and check the vital signs. Checking vital signs implies that you must check power-supply voltages and also examine the input signals.*

Start the simulation of the circuit and view the output and input traces. Notice that the input AM envelope looks the same, whereas the output is significantly different. This circuit does not show a power supply, but just in case, visually check that the ground connections are in place. The input signal (the AM envelope) and the ground connections are good, so the problem rests with a component. Verify that the output coupling capacitor is allowing the signal to pass properly from the detector to the output. Do this by connecting the oscilloscope A and B channels to each side of C3. You will notice that the signal is the same on both sides, which indicates that C3 is good. Electronics Workbench Multisim provides a feature that allows for the addition of a component fault in a circuit. Double-click on each of the components and check the setting under the **Fault** tab. You will discover that R1 is shorted. Change the fault setting back to **none,** which means no fault, and simulate the circuit again. The circuit should now be operational.

Additional insight into troubleshooting with Electronics Workbench™ Multisim is provided in the EWB exercises below.

Electronics Workbench™ Exercises

1. Open **FigE3-2** found on your EWB CD. Determine if this circuit is working properly. If it is not, find the fault. Describe why this fault would have caused the output waveform you observed.

2. Open **FigE3-3** found on your EWB CD. Determine if this circuit is working properly. If it is not, find the fault. Describe why this fault would have caused the output waveform you observed.
3. Open **FigE3-4** found on your EWB CD. Adjust the virtual capacitors C1 and C3 to provide an output waveform that contains minimal RF noise. This process requires that you adjust C1 and then C3 and keep repeating this sequence until an optimized output is obtained (C1 = 50%, C3 = 70%).

Summary

In Chapter 3 the basics of AM receivers were introduced. The development of receivers from the simplest to superheterodyne systems was discussed. The major topics you should now understand include:

- the basics of a simple radio receiver
- the fundamental concepts of sensitivity and selectivity
- the functional blocks of a tuned radio frequency (TRF) receiver
- the input/output characteristics of a nonlinear device used as an AM detector
- the characteristics, operation, types, and design considerations of diode detectors
- the advantages of synchronous detection over the basic diode detector
- a complete analysis of superheterodyne receiver operation
- the tuning and tracking of a superheterodyne receiver
- an analysis of image frequency and methods for its attenuation
- the operation and typical circuits of the functional blocks in a superheterodyne receiver
- the need for automatic gain control (AGC) in a receiver and the description of a typical circuit and its operation
- the description of various superheterodyne receiver systems with power gain analysis

Questions and Problems

Section 3-1

*1. Draw a diagram of a tuned radio-frequency (TRF) radio receiver.

*2. Explain the following: sensitivity of a receiver; selectivity of a receiver. Why are these important characteristics? In what units are they usually expressed?

3. Explain why a receiver can be overly selective.

4. A TRF receiver is to be tuned over the range 550 to 1550 kHz with a 25-μH inductor. Calculate the required capacitance range. Determine the tuned circuit's necessary Q if a 10-kHz bandwidth is desired at 1000 kHz. Calculate the receiver's selectivity at 550 and 1550 kHz. (0.422 to 3.35 nF, 100, 5.5 kHz, 15.5 kHz)

*An asterisk preceding a number indicates a question that has been provided by the FCC as a study aid for licensing examinations.

SECTION 3-2

*5. Explain the operation of a diode detector.
6. Describe the advantages and disadvantages of a diode detector.
7. Describe diagonal clipping.
8. What association does diagonal clipping have with modulation index?
9. Explain how diagonal clipping occurs in a diode detector.
10. Provide the advantages of a synchronous detector compared to a diode detector. Explain its principle of operation.

SECTION 3-3

*11. Draw a block diagram of a superheterodyne AM receiver. Assume an incident signal, and explain briefly what occurs in each stage.
*12. What type of radio receivers contains intermediate-frequency transformers?
13. The AM signal into a mixer is a 1.1-MHz carrier that was modulated by a 2-kHz sine wave. The local oscillator is at 1.555 MHz. List all mixer output components and indicate those accepted by the IF amplifier stage.
*14. Explain the purpose and operation of the first detector in a superhet receiver.
15. Explain how the variable tuned circuits in a superheterodyne receiver are adjusted with a single control.

SECTION 3-4

16. Provide an adjustment procedure whereby adequate tracking characteristics are obtained in a superheterodyne receiver.
17. Draw a schematic that illustrates *electronic* tuning using a varactor diode.
18. A silicon varactor diode exhibits a capacitance of 200 pF at zero bias. If it is in parallel with a 60-pF capacitor and 200-μH inductor, calculate the range of resonant frequency as the diode varies through a reverse bias of 3–15 V. (966 kHz, 1.15 MHz)
19. A varactor diode has C_0 equal to 320 pF. Plot a curve of capacitance versus V_R from 0 to 20 V. The diode is used with a 200-μH coil. Plot the resonant frequency versus V_R from 0 to 20 V and suggest how the response could be linearized.

SECTION 3-5

*20. If a superheterodyne receiver is tuned to a desired signal at 1000 kHz and its conversion (local) oscillator is operating at 1300 kHz, what would be the frequency of an incoming signal that would possibly cause *image* reception? (1600 kHz)
21. A receiver tunes from 20 to 30 MHz using a 10.7-MHz IF. Calculate the required range of oscillator frequencies and the range of image frequencies.
22. Show why image frequency rejection is not a major problem for the standard AM broadcast band.
*23. What are the advantages to be obtained from adding a tuned radio-frequency amplifier stage ahead of the first detector (converter) stage of a superheterodyne receiver?
*24. If a transistor in the only radio-frequency stage of your receiver shorted out, how could temporary repairs or modifications be made?
25. What advantages do dual-gate MOSFETs have over BJTs for use as RF amplifiers?

*26. What is the *mixer* in a superheterodyne receiver?
27. Describe the advantage of an autodyne mixer over a standard mixer.
28. Why is the bulk of a receiver's gain and selectivity obtained in the IF amplifier stages?

SECTION 3-6

29. Describe the difficulties in listening to a receiver without AGC.
*30. How is *automatic volume control* accomplished in a radio receiver?
31. Explain how the ac gain of a transistor can be controlled by a dc AGC level.
32. The IF/AGC system in Figure. 3-20 has an AGC level of 5.5 V ($V_{AGC} = 5.5$ V). Determine the rms output voltage and the gain of the A1, A2 amplifier combination. Calculate the rms input voltage. (1.4 V rms, 20.5 dB, 0.132 V rms)

SECTION 3-7

33. Describe the function of auxiliary AGC.
34. What is the major limiting function with respect to manufacturing a complete superheterodyne receiver on an LIC chip?
35. A superhet receiver tuned to 1 MHz has the following specifications:
    RF amplifier: $P_G = 6.5$ dB, $R_{in} = 50\ \Omega$ *Detector:* 4-dB attenuation
    Mixer: $P_G = 3$ dB *Audio amplifier:* $P_G = 13$ dB
    3 IFs: $P_G = 24$ dB each at 455 kHz
    The antenna delivers a 21-μV signal to the RF amplifier. Calculate the receiver's image frequency and input/output power in watts and dBm. Draw a block diagram of the receiver and label dBm power throughout. (1.91 MHz, 8.82 pW, −80.5 dBm, 10 mW, 10 dBm)
36. A receiver has a dynamic range of 81 dB. It has 0.55 nW sensitivity. Determine the maximum allowable input signal. (0.0692 W)
37. Define *dynamic range.*
38. Describe the C-Quam system of generating broadcast AM stereo. Explain why it hasn't met with widespread acceptance like FM stereo has.
39. Define a *quadrature signal* and explain its use in AM stereo.

SECTION 3-8

40. You are troubleshooting an AM receiver. You have determined that the RF signal is not reaching Q1's base in the self-excited mixer of Figure 3-27. Explain possible causes and a procedure to pinpoint the problem.
41. Describe possible problems after it is determined that voltage measurements taken on the emitter of Q1 in Figure 3-27 show a zero volt reading.
42. Describe operation of the mixer in Figure 3-27 if the local oscillator stops functioning.
43. Assume the output of the first IF amplifier in Figure 3-27 is 2455 kHz. What is a probable cause?
44. The regulated power supply in Figure 3-28 has no output. Describe how you would troubleshoot this circuit.
45. The power supply in Figure 3-28 provides a 12-V output. Calculate the voltage at point C if $R_2 = 330\ \Omega$ and $R_3 = 470\ \Omega$. (7.05 V)
46. In Figure 3-28, suppose the 15,000 μfd capacitor was open. Describe the output voltage.

47. Using the block diagram of a receiver (Figure 3-26), explain how to isolate methodically a problem that lies in the detector stage of the receiver.
48. Describe how a receiver's volume control can be used to determine problems with the audio amplifier.

Questions for Critical Thinking

49. Which of the factors that determine a receiver's sensitivity is more important? Defend your judgment.
50. Would passing an AM signal through a nonlinear device allow recovery of the low-frequency intelligence signal when the AM signal contains only high frequencies? Why or why not?
51. Justify in detail the choice of a superheterodyne receiver in an application that requires constant selectivity for received frequencies.
52. A superheterodyne receiver tunes the band of frequencies from 4 to 10 MHz with an IF of 1.8 MHz. The double-ganged capacitor used has a 325 pF maximum capacitance per section. The tuning capacitors are at the maximum value (325 pF) when the RF frequency is 4 MHz. Calculate the required RF and local oscillator coil inductance and the required tuning capacitor values when the receiver is tuned to receive 4 MHz and 10 MHz. (4.87 μH, 2.32 μH, 52 pF, 78.5 pF)