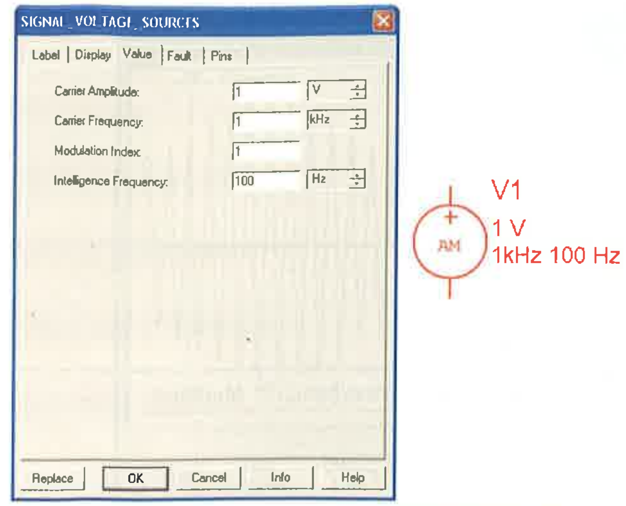

FIGURE 2-37 The AM Source and the menu for setting its parameters.

by selecting the source and clicking the OK button. The image will open behind the Sources menu. Use your mouse to drag the source to the desired location on the circuit diagram. The parameters for the AM signal can be set by double-clicking on the AM Source. The AM Source and its menu are both shown in Figure 2-37.

The AM Source menu allows you to set the carrier amplitude, frequency, modulation index, and modulation frequency. Refer to Sections 2-2, 2-3, and 2-4 for a review of amplitude modulation fundamentals. In this case, the carrier amplitude is set to 1 V, the carrier frequency is 1000 Hz, the modulation index is 1, and the modulation frequency is 100 Hz. The AM waveform produced by the source is shown in Figure 2-38. The AM Source is used in the Electronics Workbench exercises that follow this section.

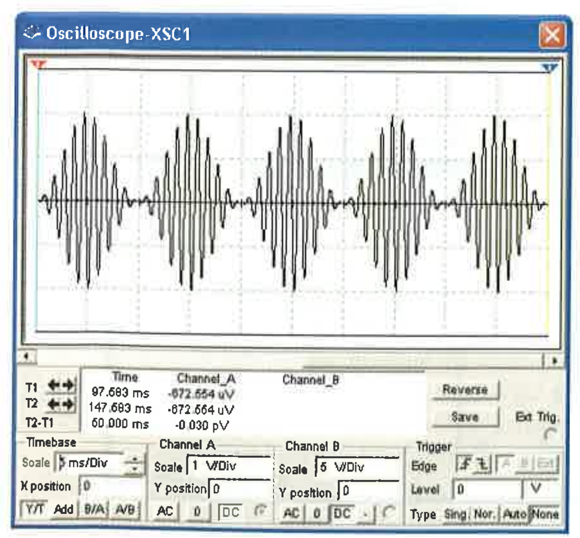

FIGURE 2-38 The output of the AM Source.

Electronics Workbench™ Exercises

1. Open **FigE2-1** on your EWB CD. Determine the modulation index.
2. Open **FigE2-2** on your EWB CD. Use the cursors on the oscilloscope to verify that the carrier frequency is 15 kHz.
3. Open **FigE2-3** on your EWB CD. Add the display of the input signals of the modulating circuit to the channel B input of your oscilloscope so that both the AM signal and the intelligence signal are displayed. Use the scale controls and the Y position so that both traces are easily viewed. Print out the traces displayed on the oscilloscope.

Summary

In Chapter 2 we studied the concept of amplitude modulation as it is specifically utilized in a transmitter. The major topics you should now understand include the following:

- the fundamental concept of amplitude modulation
- the meaning of modulation index and its use in AM calculations
- the cause of overmodulation and why it must be avoided
- the mathematical analysis of AM and the effect of modulation index on sideband amplitude
- the elements of a simple transistor AM generator and the analysis of its operation
- the understanding of high- and low-level modulation
- the analysis of a high-level transistor modulator
- the analysis and operation of various linear integrated circuit modulators
- the caution necessary when working with high-powered transmitters

Questions and Problems

Section 2-2

1. A 1500-kHz carrier and 2-kHz intelligence signal are combined in a *nonlinear* device. List *all* the frequency components produced.

*2. If a 1500-kHz radio wave is modulated by a 2-kHz sine-wave tone, what frequencies are contained in the modulated wave (the actual AM signal)?

*3. If a carrier is amplitude-modulated, what causes the sideband frequencies?

*4. What determines the bandwidth of emission for an AM transmission?

5. Explain the difference between a sideband and a side frequency.
6. What does the phasor at point 6 in Figure 2-7 imply about the modulation signal?
7. Explain how the phasor representation can describe the formation of an AM signal.
8. Construct phasor diagrams for the AM signal in Figure 2-7 midway between points 1 and 2, 3 and 4, and 5 and 6.

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

Section 2-3

*9. Draw a diagram of a carrier wave envelope when modulated 50 percent by a sinusoidal wave. Indicate on the diagram the dimensions from which the percentage of modulation is determined.

*10. What are some of the possible results of overmodulation?

*11. An unmodulated carrier is 300 V p-p. Calculate $\%m$ when its maximum p-p value reaches 400, 500, and 600 V. (33.3%, 66.7%, 100%)

12. If $A = 60$ V and $B = 200$ V as shown in Figure 2-8, determine $\%m$. (53.85%)

13. Determine E_c and E_m from Problem 12. ($E_c = 65$ Vpk, $E_m = 35$ Vpk)

Section 2-4

14. Given that the amplitude of an AM waveform can be expressed as the sum of the carrier peak amplitude and intelligence signal, derive the expression for an AM signal that shows the existence of carrier and side frequencies.

15. A 100-V carrier is modulated by a 1-kHz sine wave. Determine the side-frequency amplitudes when $m = 0.75$. (37.5 V)

16. A 1-MHz, 40-V peak carrier is modulated by a 5-kHz intelligence signal so that $m = 0.7$. This AM signal is fed to a 50-Ω antenna. Calculate the power of each spectral component fed to the antenna. ($P_c = 16$ W, $P_{usb} = P_{lsb} = 1.96$ W)

17. Calculate the carrier and sideband power if the total transmitted power is 500 W in Problem 15. (390 W, 110 W)

18. The ac rms antenna current of an AM transmitter is 6.2 A when unmodulated and rises to 6.7 A when modulated. Calculate $\%m$. (57.9%)

*19. Why is a high percentage of modulation desirable?

*20. During 100 percent modulation, what percentage of the average output power is in the sidebands? (33.3%)

21. An AM transmitter has a 1-kW carrier and is modulated by three different sine waves having equal amplitudes. If $m_{eff} = 0.8$, calculate the individual values of m and the total transmitted power. (0.462, 1.32 kW)

22. A 50-V rms carrier is modulated by a square wave as shown in Table 1-4(c). If only the first four harmonics are considered and $V = 20$ V, calculate m_{eff}. (0.77)

Section 2-5

23. Describe two possible ways that a transistor can be used to generate an AM signal.

*24. What is *low-level modulation*?

*25. What is *high-level modulation*?

26. Explain the relative merits of high- and low-level modulation schemes.

*27. Why must some radio-frequency amplifiers be neutralized?

28. Describe the difference in effect of self-oscillations at a circuit's tuned frequency and parasitic oscillations.

29. Define *parasitic oscillation.*

30. How does self-oscillation occur?

31. Draw a schematic of a class C transistor modulator and explain its operation.

*32. What is the principal advantage of a class C amplifier?

33. Explain the circuit operation of the PIN diode modulator in Figure 2-15. What type of AM transmitters are likely to use this method of AM generation?

*34. What is the function of a quartz crystal in a radio transmitter?

Section 2-6

*35. Draw a block diagram of an AM transmitter.

*36. What is the purpose of a buffer amplifier stage in a transmitter?

37. Describe the means by which the transmitter shown in Figure 2-19 is modulated.

*38. Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power amplifier stage of a transmitter to an antenna.

39. Describe the functions of an antenna coupler.

*40. A ship radio-telephone transmitter operates on 2738 kHz. At a certain point distant from the transmitter the 2738-kHz signal has a measured field of 147 mV/m. The second harmonic field at the same point is measured as 405 μV/m. To the nearest whole unit in decibels, how much has the harmonic emission been attenuated below the 2738-kHz fundamental? (51.2 dB)

41. What is a *tune-up procedure*?

Section 2-7

*42. Draw a sample sketch of the trapezoidal pattern on a cathode-ray oscilloscope screen indicating low percentage modulation without distortion.

43. Explain the advantages of the trapezoidal display over a standard oscilloscope display of AM signals.

44. A spectrum analyzer display shows that a signal is made up of three components only: 960 kHz at 1 V, 962 kHz at $\frac{1}{2}$ V, 958 kHz at $\frac{1}{2}$ V. What is the signal and how was it generated?

45. Define *spur*.

46. Provide a sketch of the display of a spectrum analyzer for the AM signal described in Problem 63 at both 20 percent and 90 percent modulation. Label the amplitudes in dBm.

47. The spectrum analyzer display shown in Figure 2-25 is calibrated at 10 dB/vertical division and 5 kHz/horizontal division. The 50.0034-MHz carrier is shown riding on a −20-dBm noise floor. Calculate the carrier power, the frequency, and the power of the spurs. (2.51 W, 50.0149 MHz, 49.9919 MHz, 50.0264 MHz, 49.9804 MHz, 6.3 mW, 1 mW)

*48. What is the purpose of a *dummy antenna*?

49. An amplifier has a spectrally pure sine-wave input of 50 mV. It has a voltage gain of 60. A spectrum analyzer shows harmonics of 0.035 V, 0.027 V, 0.019 V, 0.011 V, and 0.005 V. Calculate the total harmonic distortion (THD) and the relative harmonic distortion. (2.864%, 38.66 dB)

50. An additional harmonic ($V_6 = 0.01$ V) was neglected in the THD calculation shown in Example 2-9. Determine the percentage error introduced by this omission. (0.91%)

Section 2-8

51. When troubleshooting, what is the purpose of inspection? Describe the various steps involved in this process.

52. After a repair has been made, how is a hot check accomplished?

53. Discuss the function of C_1 in Figure 2-28 and explain the effect if it should fail by either shorting or becoming an open circuit.

54. Explain the dangers of working on high-power transmitters and describe the precautions that should be taken.

55. Describe why and how a dummy load is used in checking the output of a transmitter. Why is the impedance of the dummy load an important consideration?
56. There is no output from Q_1 in Figure 2-28. Briefly describe a plan to isolate the problem.
57. Describe the output of the amplifier in Figure 2-28 if R_1 is open.
58. Explain the advantages of using a spectrum analyzer.
59. If the inductor L_2 in Figure 2-30 is shorted, describe its output. Assume the load is an antenna that is not grounded.
60. Describe some of the physical defects of a system that are obvious to the eye.

Questions for Critical Thinking

61. Would the *linear* combination of a low-frequency intelligence signal and a high-frequency carrier signal be effective as a radio transmission? Why or why not?
62. You are analyzing an AM waveform. What significance do the upper and lower envelopes have?
63. An AM transmitter at 27 MHz develops 10 W of carrier power into a 50-Ω load. It is modulated by a 2-kHz sine wave between 20 and 90 percent modulation. Determine:
    (a) Component frequencies in the AM signal.
    (b) Maximum and minimum waveform voltage of the AM signal at 20 percent and 90 percent modulation. (25.3 to 37.9 V peak, 3.14 to 60.1 V peak)
    (c) Sideband signal voltage and power at 20 percent and 90 percent modulation. (2.24 V, 0.1 W, 10.06 V, 2.025 W)
    (d) Load current at 20 percent and 90 percent modulation. (0.451A, 0.530A)
64. Compare the display of an oscilloscope to that of a spectrum analyzer.