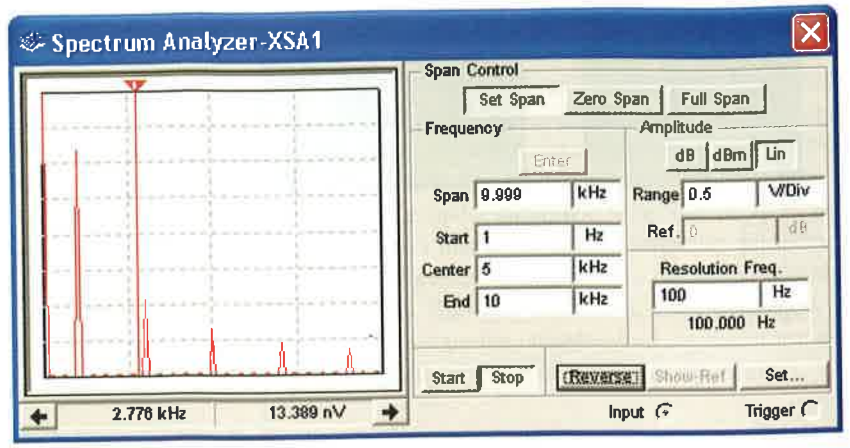

FIGURE 1-37 The Multisim spectrum analyzer view of a 1-kHz square wave.

The spectrum analyzer provides a cursor that can be positioned to measure the frequency of each component. In this case, the cursor has been positioned next to the 3-kHz spike, which is the third harmonic of a 1-kHz square wave. The spectrum analyzer provides settings for the frequency span, start, center, and end frequencies. These adjustments provide the user with the capability of selecting the frequency range for conducting a measurement. Additional experiments are presented in the text that demonstrate additional features of the Electronics Workbench tools. Three exercises requiring the use of Electronics Workbench™ Multisim are provided below.

Electronics Workbench™ Exercises

1. Use the cursor on the spectrum analyzer to identify the seventh and ninth harmonics for the circuit provided in **Fig1-35.**
2. The circuit provided in **FigE1-1** on your CD can be used to demonstrate the effect a bandlimited channel has on the spectral content of a square wave. Discuss the observed changes in the circuit as compared to the circuit provided in **Fig1-35.**
3. The circuit provided in **FigE1-2** on your CD contains a 100-kHz square wave. Change the settings on the spectrum analyzer so that the first, third, fifth, seventh, and ninth harmonics are displayed on the screen. The solution is provided on your EWB **FigE1-2-solution.**

Summary

In Chapter 1 the concept of a communication system was introduced. Decibels and the effects of electrical noise were explained, and *LC* circuits and oscillators were discussed. The major topics you should now understand include:

- the use of the decibel in communications
- the function and basic building blocks of a communication system

- the need for modulation/demodulation in a communications system
- the difference between the carrier wave and intelligence wave and their importance
- the effects and analysis of electrical noise in a communications system
- the performance of signal-to-noise ratio and noise figure calculations
- the performance of electrical noise measurements on a communications system
- the makeup of nonsinusoidal waveforms
- the mathematical analysis of waveforms using Fourier analysis
- the analysis of *LC* filters
- the understanding of common oscillator types, including Hartley, Colpitts, Clapp, and crystal varieties

Questions and Problems

Section 1-1

1. Define *modulation.*

*2. What is *carrier frequency*?

3. Describe the two reasons that modulation is used for communications transmissions.
4. List the three parameters of a high-frequency carrier that may be varied by a low-frequency intelligence signal.
5. What are the frequency ranges included in the following frequency subdivisions: MF (medium frequency), HF (high frequency), VHF (very high frequency), UHF (ultra high frequency), and SHF (super high frequency)?

Section 1-2

6. A signal level of 0.4 μV is measured on the input to a satellite receiver. Express this voltage in terms of dBμV. Assume a 50-Ω system. (-7.95 dB$_\mu$V)
7. A microwave transmitter typically requires a +8-dBm audio level to drive the input fully. If a +10-dBm level is measured, what is the actual voltage level measured? Assume a 600-Ω system. (2.45 V)
8. If an impedance matched amplifier has a power gain (P_{out}/P_{in}) of 15, what is the value for the voltage gain (V_{out}/V_{in})? (3.87)
9. Convert the following powers to their dBm equivalents:
   (a) $p = 1$ W (30 dBm)
   (b) $p = 0.001$ W (0 dBm)
   (c) $p = 0.0001$ W (-10 dBm)
   (d) $p = 25$ μW (-16 dBm)
10. The output power for an audio amplifier is specified to be 38 dBm. Convert this value to (a) watts and (b) dBW. (6.3 W, 8 dBW)
11. A 600-Ω microphone outputs a -70-dBm level. Calculate the equivalent output voltage for the -70-dBm level. (0.245 mV)
12. Convert 50-μV to a dBμV equivalent. (34 dBμV)

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

13. A 2.15-V rms signal is measured across a 600-Ω load. Convert this measured value to its dBm equivalent. (8.86 dBm (600))
14. A 2.15-V rms signal is measured across a 50-Ω load. Convert this measured value to its dBm(50) equivalent. (19.66 dBm(50))

Section 1-3

15. Define *electrical noise*, and explain why it is so troublesome to a communications receiver.
16. Explain the difference between external and internal noise.
17. List and briefly explain the various types of external noise.
18. Provide two other names for Johnson noise and calculate the noise voltage output of a 1-MΩ resistor at 27°C over a 1-MHz frequency range. (128.7 μV)
19. The noise produced by a resistor is to be amplified by a noiseless amplifier having a voltage gain of 75 and a bandwidth of 100 kHz. A sensitive meter at the output reads 240 μV rms. Assuming operation at 37°C, calculate the resistor's resistance. If the bandwidth were cut to 25 kHz, determine the expected output meter reading. (5.985 kΩ, 120 μV)
20. Explain the term *low-noise resistor.*
21. Determine the noise current for the resistor in Problem 18. What happens to this noise current when the temperature increases? (129 pA)
22. The noise spectral density is given by $e_n^2/\Delta f = 4kTR$. Determine the bandwidth Δf of a system in which the noise voltage generated by a 20-kΩ resistor is 20 μV rms at room temperature. (1.25 MHz)

Section 1-4

23. Calculate the *S/N* ratio for a receiver output of 4 V signal and 0.48 V noise both as a ratio and in decibel form. (69.44, 18.42 dB)
24. The receiver in Problem 23 has an *S/N* ratio of 110 at its input. Calculate the receiver's noise figure (NF) and noise ratio (NR). (1.998 dB, 1.584)
25. An amplifier with NF = 6 dB has S_i/N_i of 25 dB. Calculate the S_o/N_o in dB and as a ratio. (19 dB, 79.4)
26. A three-stage amplifier has an input stage with noise ratio (NR) = 5 and power gain (P_G) = 50. Stages 2 and 3 have NR = 10 and P_G = 1000. Calculate the NF for the overall system. (7.143 dB)
27. A two-stage amplifier has a 3-dB bandwidth of 150 kHz determined by an *LC* circuit at its input and operates at 27°C. The first stage has P_G = 8 dB and NF = 2.4 dB. The second stage has P_G = 40 dB and NF = 6.5 dB. The output is driving a load of 300 Ω. In testing this system, the noise of a 100-kΩ resistor is applied to its input. Calculate the input and output noise voltage and power and the system noise figure. (19.8 μV, 0.206 mV, 9.75×10^{-16} W, 1.4×10^{-10} W, 3.6 dB)
28. A microwave antenna (T_{eq} = 25 K) is coupled through a network (T_{eq} = 30 K) to a microwave receiver with T_{eq} = 60 K referred to its output. Calculate the noise power at its input for a 2-MHz bandwidth. Determine the receiver's NF. (3.17×10^{-15} W, 0.817 dB)
29. A high-quality FM receiver is to be tested for SINAD. When its output contains just the noise and distortion components, 0.015 mW is measured. When the desired signal and noise and distortion components are measured together, the output is 15.7 mW. Calculate SINAD. (30.2 dB)
30. Explain SINAD.

Section 1-5

31. Calculate the noise power at the input of a microwave receiver with an equivalent noise temperature of 45 K. It is fed from an antenna with a 35 K equivalent noise temperature and operates over a 5-MHz bandwidth. (5.52×10^{-15} W)
32. Calculate the minimum signal power needed for good reception for the receiver described in Problem 31 if the signal-to-noise ratio must be not less than 100 : 1. (5.52×10^{-13} W)
33. Calculate the NF and T_{eq} for an amplifier that has Z_{in} = 300 Ω. It is found that when driven from a matched-impedance diode noise generator, its output noise is doubled (as compared to no input noise) when the diode is forward biased with 0.3 mA. (2.55 dB, 232 K)
34. Describe the procedure used for noise measurement using the noise diode generator.
35. Describe what is known as a DUT.
36. Describe the procedure for noise measurement using the tangential technique.

Section 1-6

37. Define *information theory.*
38. What is Hartley's law? Explain its significance.
39. What is a *harmonic*?
40. What is the seventh harmonic of 360 kHz? (2520 kHz)
41. Why does transmission of a 2-kHz square wave require greater bandwidth than a 2-kHz sine wave?
42. Draw time- *and* frequency-domain sketches for a 2-kHz square wave. The time-domain sketch is a standard oscilloscope display while the frequency domain is provided by a spectrum analyzer.
43. Explain the function of Fourier analysis.
44. A 2-kHz square wave is passed through a filter with a 0- to 10-kHz frequency response. Sketch the resulting signal, and explain why the distortion occurs.
45. A triangle wave of the type shown in Table 1-4(e) has a peak-to-peak amplitude of 2 V and f = 1 kHz. Write the expression $v(t)$, including the first five harmonics. Graphically add the harmonics to show the effects of passing the wave through a low-pass filter with cutoff frequency equal to 6 kHz.
46. The FFT shown in Figure 1-38 was obtained from a DSO.
    (a) What is the sample frequency?
    (b) What frequency is shown by the FFT?
47. Figure 1-39 was obtained from a DSO.
    (a) What are the frequencies of the third and fifth harmonics?
    (b) This FFT was created by inputting a 12.5-kHz square wave into a DSO. Explain where 12.5 kHz is located within the FFT spectrum.

Section 1-7

48. Explain the makeup of a practical inductor and capacitor. Include the quality and dissipation in your discussion.
49. Define *resonance* and describe its use.
50. Calculate an inductor's Q at 100 MHz. It has an inductance of 6 mH and a series resistance of 1.2 k. Determine its dissipation. (3.14×10, 0.318×10^{-3})

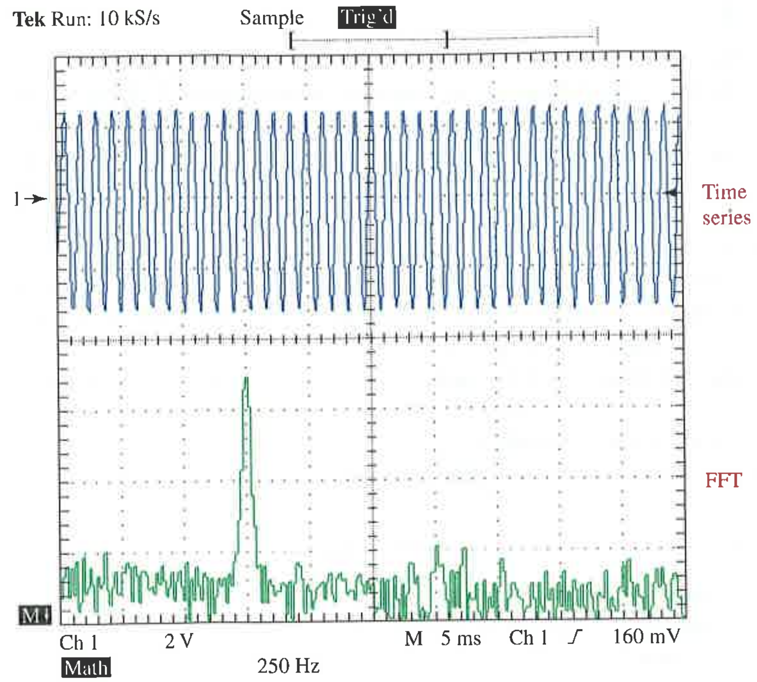

FIGURE 1-38 FFT for Problem 46.

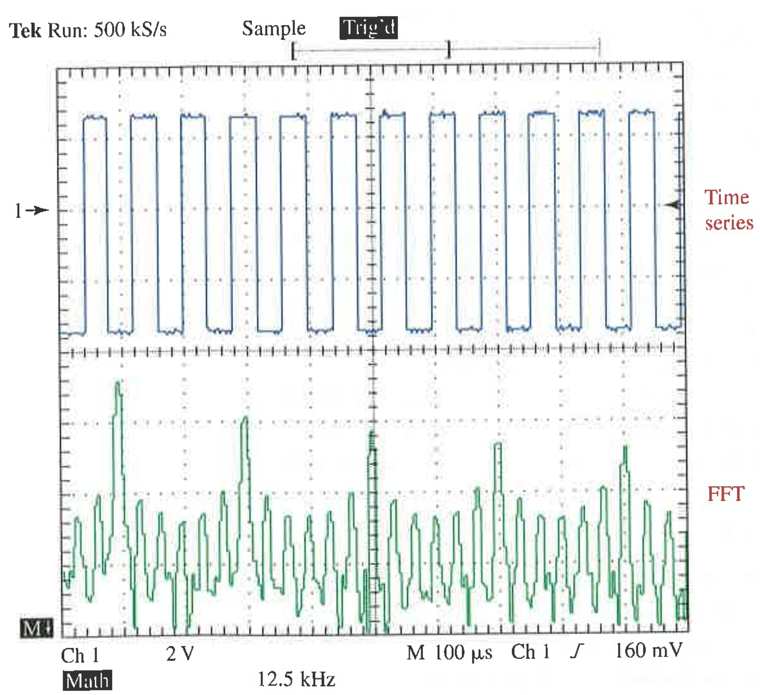

FIGURE 1-39 FFT for Problem 47.

51. Calculate a capacitor's Q at 100 MHz given 0.001 μF and a leakage resistance of 0.7 MΩ. Calculate D for the same capacitor. (4.39×10^5, 2.27×10^{-6})
52. The inductor and capacitor for Problems 50 and 51 are put in series. Calculate the impedance at 100 MHz. Calculate the frequency of resonance (f_r) and the impedance at that frequency. (3.77 MΩ, 65 kHz, 1200 Ω)
53. Calculate the output voltage for the circuit shown in Figure 1-15 at 6 kHz and 4 kHz. Graph these results together with those of Example 1-12 versus frequency. Use the circuit values given in Example 1-12.
54. Sketch the e_{out}/e_{in} versus frequency characteristic for an LC bandpass filter. Show f_{lc} and f_{hc} on the sketch and explain how they are defined. On this sketch, show the bandwidth (BW) of the filter and explain how it is defined.
55. Define the quality factor (Q) of an LC bandpass filter. Explain how it relates to the "selectivity" of the filter. Describe the major limiting value on the Q of a filter.
56. An FM radio receiver uses an LC bandpass filter with $f_r = 10.7$ MHz and requires a BW of 200 kHz. Calculate the Q for this filter. (53.5)
57. The circuit described in Problem 56 is shown in Figure 1-18. If $C = 0.1$ nF (0.1×10^{-9} F), calculate the required inductor value and the value of R. (2.21 μH, 2.78 Ω)
58. A parallel LC tank circuit has a Q of 60 and coil winding resistance of 5 Ω. Determine the circuit's impedance at resonance. (18 kΩ)
59. A parallel LC tank circuit has $L = 27$ mH, $C = 0.68$ μF, and a coil winding resistance of 4 Ω. Calculate f_r, Q, Z_{max}, the BW, f_{lc}, and f_{hc}. (1175 Hz, 49.8, 9.93 kΩ, 23.6 Hz, 1163 Hz, 1187 Hz)
60. Explain the significance of the k and m in constant-k and m-derived filters.
61. Describe the criteria used in choosing either an RC or LC filter.
62. Explain why keeping lead lengths to a minimum is important in RF circuits.
63. Describe a pole.
64. Explain why Butterworth and Chebyshev filters are called constant-k filters.

Section 1-8

65. Draw schematics for Hartley and Colpitts oscillators. Briefly explain their operation and differences.
66. Describe the reason that a Clapp oscillator has better frequency stability than the Hartley or Colpitts oscillators.
67. List the major advantages of crystal oscillators over the LC varieties. Draw a schematic for a Pierce oscillator.
68. The crystal oscillator time base for a digital wristwatch yields an accuracy of ± 15 s/month. Express this accuracy in parts per million (ppm). (± 5.787 ppm)

Section 1-9

69. List and briefly describe the four basic troubleshooting techniques.
70. Describe the disadvantages of using substitution at the early stages of the troubleshooting plan.
71. Explain why resistance measurements are done with power off.
72. Describe the major types of circuit failures.

73. Describe when it is more appropriate to use the signal injection method.
74. What would the output of the Clapp oscillator in Figure 1-33 look like if C2 was open?
75. In the crystal test setup shown in Figure 1-32, explain the difference in output at the series and parallel resonant frequencies.

Questions for Critical Thinking

76. You cannot guarantee perfect performance in a communications system. What two basic limitations explain this?
77. You are working on a single-stage amplifier that has a 200-kHz bandwidth and a voltage gain of 100 at room temperature. The external noise is negligible. A 1-mV signal is applied to the amplifier's input. If the amplifier has a 5-dB NF and the input noise is generated by a 2-kΩ resistor, what output noise voltage would you predict? (458 μV)
78. How does equivalent noise resistance relate to equivalent noise temperature? Explain similarities and/or differences.
79. Describe a situation in which you would use the Barkhausen criteria for oscillation. How would positive feedback be involved in your use of these criteria?