the maximum input frequency never exceeds $f_s/2$. If the Nyquist criteria is not met, aliasing frequencies will be generated, leading to a decrease in system performance.

One of the Electronics Workbench™ exercises that follows further investigates the sample-and-hold circuit and provides you with the opportunity to examine the spectral content of a signal generated by a sample-and-hold circuit. Additionally, two of the exercises have faults incorporated in the circuit and provide you with the opportunity to troubleshoot the circuit.

Electronics Workbench™ Exercises

1. Open the file **FigE8-2** on your EWB CD. Use the spectrum analyzer to determine the frequencies generated in the sampled signal. The input frequency is 5 kHz. Where did the 3-kHz signal come from?
2. Open the file **FigE8-3** on your EWB CD. This circuit contains a fault. Start the simulation and use the oscilloscope to isolate the fault. When you discover the fault, double-click on the component, click on the **fault** tab, and set the faults to none. Restart the simulation and see if you have repaired the circuit. Specifiy what component(s) you repaired.
3. Open the file **FigE8-4** on your EWB CD. This circuit contains a fault. Start the simulation and use the oscilloscope to isolate the fault. When you discover the fault, double-click on the component, click on the **fault** tab, and set the faults to none. Restart the simulation and see if you have repaired the circuit. Specifiy what component(s) you repaired.

Summary

In Chapter 8 we studied the coding techniques commonly used in digital communications. The techniques behind pulse-code modulation were explored, as were digital signal encoding formats, coding principles, and error correction and detection. The major topics you should now understand include:

- the definition of the Nyquist sampling frequency
- aliasing and foldover distortion
- the definition of the dynamic range of a sampled signal
- identification of the major digital encoding formats including the NRZ, RZ, phase-encoded, and multilevel binary formats
- the concept of Hamming distance
- the explanation of the various codes' error detection and correction methods, including parity, cyclic redundancy check (CRC) codes, Hamming code, and Reed–Solomon codes

Questions and Problems

Section 8-1

(b) Both digital and data.
(c) Data but not digital.

2. Define *digital signal processing*. Provide an example that is not described in this book.

Section 8-2

3. What do the abbreviations ASCII and EBCDIC stand for?
4. Provide the ASCII code for 5, a, A, and STX.
5. Provide the EBCDIC code for 5, a, A, and STX.
6. Describe the Gray code.
7. Provide an application of the Gray code.

Section 8-3

8. Define *acquisition time* for a sample-and-hold circuit.
9. Define *aperture time* for a sample-and-hold circuit.
10. What is the typical capacitance value for a sample-and-hold circuit?
11. Draw the PAM signal for a sinusoid using
    (a) Natural sampling.
    (b) Flat-top sampling.
12. An audio signal is band-limited to 15 kHz. What is the minimum sample frequency if this signal is to be digitized?
13. A sample circuit behaves like what other circuit used in radio-frequency communications?
14. What is the dynamic range (in dB) for a 12-bit PCM system?
15. Define the resolution of a PCM system. Provide two ways that resolution can be improved.
16. Calculate the number of bits required to satisfy a dynamic range of 48 dB.
17. What is meant by quantization?
18. Explain the difference in linear PCM and nonlinear PCM.
19. Explain the process of companding and the benefit it provides.
20. A μ-law companding system with $\mu = 100$ is used to compand a 0- to 10-V signal. Calculate the system output for inputs of 0, 0.1, 1, 2.5, 5, 7.5, and 10 V. (0, 1.5, 5.2, 7.06, 8.52, 9.38, 10)

Section 8-4

21. Describe the characteristics of the four basic encoding groups: NRZ, RZ, phase-encode binary, and multilevel binary.
22. Sketch the data waveforms for 1 1 0 1 0 using NRZ-L, biphase M, differential Manchester, and dicode RZ.
23. What are the differences between bipolar codes and unipolar codes?
24. Which coding format is considered to be self-clocking? Explain the process.

Section 8-5

27. Determine the number of errors that can be detected and corrected for data values with a Hamming distance of
    (a) 2.
    (b) 5.
28. Determine the distance between the following two digital values:

    1 1 0 0 0 1 0 1 0
    0 1 0 0 0 0 0 1 0

29. What is the minimum distance between data words if
    (a) Five errors are to be detected?
    (b) Eight errors are to be detected?

Section 8-6

30. CRC codes are commonly used in what computer networking protocol?
31. Provide a definition of systematic codes.
32. With regard to (n, k) cyclic codes, define n and k.
33. What is a block check code?
34. How are the feedback paths determined in a CRC code-generating circuit?
35. Draw the CRC generating circuit if $G(x) = x^4 + x^2 + x + 1$.
36. Given that the message value is 1 0 1 0 0 1 and $G(x) = 1\ 1\ 0\ 1$, perform modulo-2 division to determine the block check code (BCC). (111)
37. What is a syndrome?
38. What does it mean if the syndrome value is
    (a) All zeros?
    (b) Not equal to zero?
39. What does it mean for a code to be forward error-correcting?
40. What popular commercial application uses Reed–Solomon coding and why?

Section 8-7

41. What is the type of difference equation that makes use of past output values?
42. What is the type of difference equation that makes use of only the present and past input values?
43. What is the order of a difference equation that requires four past input and output values?
44. What is the order of the following difference equation? Is this a recursive or a nonrecursive algorithm?

    $$y_0 = x_0 - x_{(1)}$$

45. Given the following difference equations, state the order of the filter and identify the values of the coefficients.
    (a) $y = 0.9408\ x_0 - 0.5827\ x_1 + 0.9408\ x_2 + 0.5827\ y_1 - 0.8817\ y_2$
    (b) $y_0 = 0.02008\ x_0 - 0.04016\ x_2 + 0.02008\ x_4 + 2.5495\ y_1 - 3.2021\ y_2 + 2.0359\ y_3 - 0.64137\ y_4$

Questions for Critical Thinking

46. Explain why a technique such as CRC coding is used. [illegible]

47. A PCM system requires 72 dB of dynamic range. The input frequency is 10 kHz. Determine the number of sample bits required to meet the dynamic range requirement and specify the minimum sample frequency to satisfy the Nyquist sampling frequency. (12 bits, 20 kHz)
48. The voltage range being input to a PCM system is 0 to 1 V. A 3-bit A/D converter is used to convert the analog signal to digital values. How many quantization levels are provided? What is the resolution of each level? What is the value of the quantization error for this system? (8, 0.125, 0.0625)