Fundamentals of Data and Signals

Chapter 2

Learning Objectives

After reading this chapter, you should be able to:

- Distinguish between data and signals and cite the advantages of digital data and signals over analog data and signals
- Identify the three basic components of a signal as amplitude, frequency, and phase
- Discuss the bandwidth of a signal and how it relates to data transfer speed
- Identify signal strength and attenuation and how they are related
- Outline the basic characteristics of transmitting digital data with digital signals, analog data with digital signals, digital data with analog signals, and analog data with analog signals
- List and be able to draw diagrams of the basic digital encoding techniques, including the advantages and disadvantages of each
- Identify the different shift keying techniques and describe their advantages, disadvantages, and uses
- Identify the two most common digitization techniques, pulse code modulation and delta modulation, and describe their advantages and disadvantages
- Identify the different data codes and how they are used in communication systems

Chapter Outline

1. Introduction

2. Data and Signals
    a. Analog versus digital
    b. Fundamentals of signals

3. Converting Data into Signals
    a. Transmitting analog data with analog signals
    b. Transmitting digital data with digital signals: digital encoding schemes
        - Non-return to zero digital encoding schemes
        - Manchester digital encoding schemes
        - Bipolar-AMI encoding scheme
        - 4B/5B digital encoding scheme
    c. Transmitting digital data with discrete analog signals

- Amplitude shift keying
- Frequency shift keying
- Phase shift keying
- Combinations of shift keying methods

d. Transmitting analog data with digital signals

- Pulse code modulation
- Delta modulation

4. Data Codes

a. EBCDIC
b. ASCII
c. Unicode

5. Data and Signal Conversions in Action: Two Examples

6. Summary

Lecture Notes

Introduction

Data and signals are two of the basic building blocks of any computer network, but they are not two terms that mean the same thing. Stated simply, a signal is the transmission of data. Both data and signals can be in either analog or digital form, which gives us four possible combinations: transmitting digital data using digital signals, transmitting digital data using discrete analog signals, transmitting analog data using digital signals, and transmitting analog data using analog signals.

Data and Signals

Information that is stored within computer systems and transferred over a computer network can be divided into two categories: data and signals. Data are entities that convey meaning within a computer or computer system. If you want to transfer this data from one point to another, either by using a physical wire or by using radio waves, the data has to be converted into a signal. Signals are the electric or electromagnetic encoding of data and are used to transmit data.

Converting Data into Signals

Like data, signals can be analog or digital. Typically, digital signals convey digital data, and analog signals convey analog data. However, you can use analog signals to convey digital data and digital signals to convey analog data. The choice of using either analog or digital signals often depends on the transmission equipment that is used and the environment in which the signals must travel. There are four combinations of data and signals: digital data transmitted using digital signals, digital data transmitted using discrete analog signals, analog data transmitted using analog signals, and analog data transmitted using digital signals.

Converting digital data into discrete analog signals is probably the most complex topic in the chapter. So much data today is binary, but when it is transmitted, the data needs to be converted into an analog signal. But the great thing about digital signals is that it is easier to detect errors in the transmission. So to send analog signals in a digital fashion, a discrete number of analog signals are used to convey the 1s and 0s of the original data.

Data Codes

One of the most common forms of data transmitted between a sender and a receiver is textual data. This textual information is transmitted as a sequence of characters. To distinguish one character from another, each character is represented by a unique binary pattern of 1s and 0s. The set of all textual characters or symbols and their corresponding binary patterns is called a data code. Three important data codes are EBCDIC, ASCII, and Unicode.

Data and Signal Conversions In Action

Figures 2-29, 2-30, and 2-31 demonstrate two fairly complete examples of data and signal conversions within a typical business environment. The first examples shows the ASCII codes generated from a text string and then how those ASCII codes are converted into Differential Manchester. The second example involves the telephone system and shows how the analog voice is converted back and forth between analog and digital forms.

Quick Quiz

1. What is the difference between data and signals?

Data are the entities that convey meaning and signals are the electric or electromagnetic encoding of data.

2. In order for the data rate of a signal to increase, what is the key ingredient that must change?

The frequency of the signal has to increase.

3. What is the basic function of a modem?

To convert digital data to an analog signal and back again.

4. What is the basic function of a codec?

To convert analog data to a digital signal and back again.

5. Why are digital encoding techniques necessary?

Because digital data must be converted to digital signals for proper transmission over a medium.

Discussion Topics

1. Create a list of technologies that have gone from analog to digital. What was the reasoning for each conversion?

2. Is there truth to the statement that some people can actually hear the quantization error in compact disc recordings?

Teaching Tips

1. Stress the advantages of digital over analog. Use examples of television (HDTV), compact discs, mini-discs, and digital cameras and VCRs. Some people, however, claim they cannot withstand digital music and much rather prefer analog sources.

2. Digital data and digital signals are not the same thing. The difference can be as simple as the voltage levels being different. More than likely a 1 or a 0 is represented by multiple voltage and phase change levels, such as in the QAM encoding techniques.

3. Whenever you convert from analog to digital or vice versa, some precision is lost. This is an important point and will be seen again later during the discussion of modems.

Solutions to Review Questions

1. What is the difference between data and signals?

Data are entities that convey meaning, while signals are the electric or electromagnetic encoding of data.

2. What are the main advantages of digital signals over analog signals?

Easier to remove noise.

3. What is the difference between a continuous signal and a discrete signal?

Continuous takes on an infinite number of values, discrete does not.

4. What are the three basic components of all signals?

Amplitude, frequency, and phase.

5. What is the spectrum of a signal?

The range of frequencies that a signal spans from minimum to maximum.

6. What is the bandwidth of a signal?

The absolute value of the difference between the lowest and highest frequencies.

7. Why would analog data have to be modulated onto an analog signal?

To move it to a different frequency. To prepare an analog signal for transmission with other analog signals.

8. How does a differential code such as differential Manchester code differ from a non-differential code such as the NRZs?

Differential code is based on the signal difference between two bits.

9. What does it mean when a signal is self-clocking?

The signal changes at a regular interval, thus providing a type of clock signal.

10. What is the definition of baud rate?

Number of signal changes per second.

11. How does baud rate differ from bits per second?

One baud change can represent multiple bits of information, or one bit of information could involve multiple baud (signal changes).

12. What are the three main types of shift keying?

Amplitude, frequency, and phase.

13. What is the difference between pulse code modulation and delta modulation?

Pulse code modulation takes a snapshot at intervals and converts each snapshot into an *n*-bit sample. Delta modulation simply tracks a signal and uses a 1 or a 0 to denote the signal rising or falling.

14. What is meant by the sampling rate of analog data?

How many times per second an analog signal is sampled.

15. What are the differences between EBCDIC, ASCII and Unicode?

ASCII is a 7-bit code, EBCDIC is an 8-bit code, and Unicode is 16-bit. ASCII can incorporate parity checking. Unicode can support multiple languages.

Suggested Solutions to Exercises

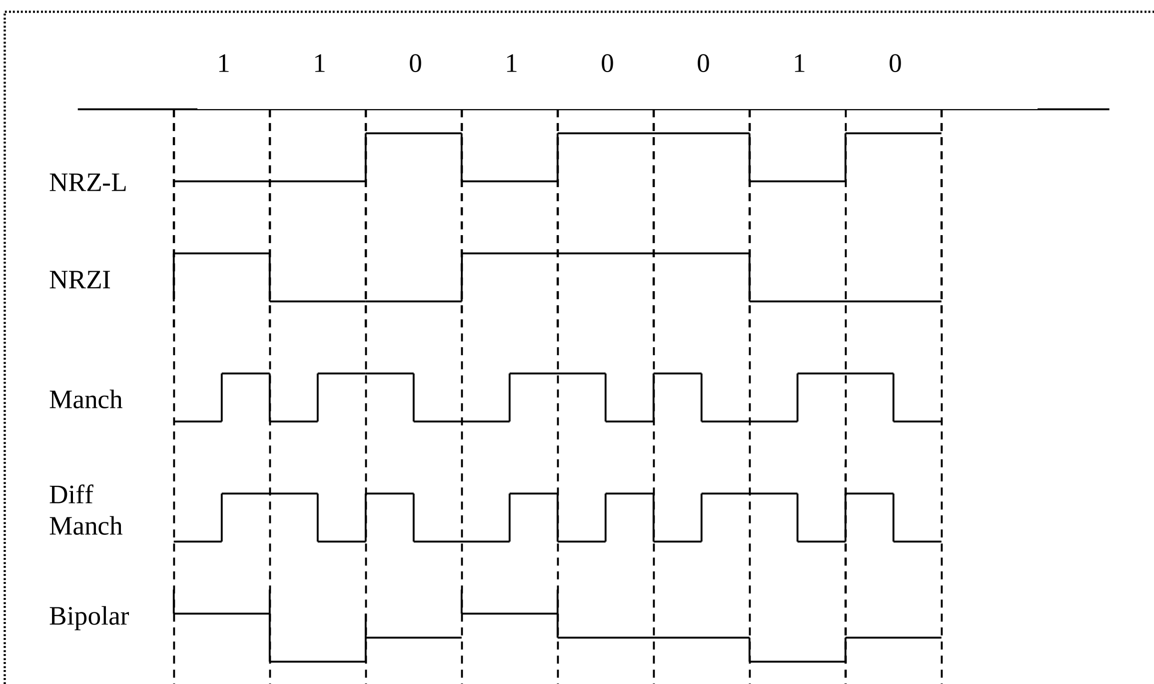
1. What is the frequency in Hertz of a signal that repeats 80,000 times within one minute? What is its period?

1333.3 Hz. Period = 0.00075 seconds

2. What is the bandwidth of a signal composed of frequencies from 50 Hz to 500 Hz?

450 Hz.

3. Draw in chart form (as shown in Figure 2-12) the voltage representation of the bit pattern 11010010 for the digital encoding schemes NRZ-L, NRZ-I, Manchester, differential Manchester, and bipolar-AMI.



4. What is the baud rate of a digital signal that employs differential Manchester and has a data transfer rate of 2000 bps?

4000 baud (worst case)

5. Show the equivalent 4B/5B code of the bit string 1101 1010 0011 0001 1000 1001.

11011 10110 10101 01001 10010 10011

6. What is the data transfer rate in bps of a signal that is encoded using phase modulation with 8 different phase angles and a baud rate of 2000?

6000 bps

7. If quadrature amplitude modulation is used to transmit a signal with a baud rate of 8000, what is the corresponding bit rate?

32,000 bps (4 bits per baud)

8. Draw or give an example of a signal for each of the following conditions: the baud rate is equal to the bit rate, the baud rate is greater than the bit rate, and the baud rate is less than the bit rate.

The NRZ schemes have baud rate equal to bit rate; the Manchester schemes have baud rate greater than bit rate; an encoding scheme that uses four or more amplitude, frequency, or phase changes.

9. A signal starts at point X. As it travels to point Y, it loses 8 dB. At point Y, the signal is boosted by 10 bB. As the signal travels to point Z, it loses 7 dB. What is the dB strength of the signal at point Z?

-5 dB

10. In the preceding problem, if the signal started at point X with a strength of 100 watts, what would be the power level of the signal at point Z?

31.6 watts

11. Draw an example signal (similar to those shown in Figure 2-12), using NRZI, in which the signal never changes for 7 bits. What does the equivalent differential Manchester encoding look like?

If you transmit 7 0s in a row, using NRZI the voltage will be a straight line. If you transmit those 7 0s using differential Manchester, the voltage will change at the beginning of each bit, and once again in the middle of each bit.

12. Show the equivalent analog sine-wave pattern of the bit string 00110101 using amplitude shift keying, frequency shift keying, and phase-shift keying.

Too messy to draw the analog signals here.

13. Twenty-four voice signals are to be transmitted over a single high-speed telephone line. What is the bandwidth required (in bps) if the standard analog to digital sampling rate is used and each sample is converted into an 8 bit value?

Assume each voice channel is 4000 Hz. To convert from analog to digital, you must sample at 2 times the bandwidth, thus 2 times 4000 equals 8000 samples per second. If each sample is converted into an 8-bit value, that yields 8 bits times 8000 samples/second, or 64,000 bps. Twenty-four voice channels would yield 24 times 64,000 bps, or 1,536,000 bps.

14. Given the analog signal shown in Figure 2-32, what are the 8-bit pulse code modulated values that will be generated at each time *T*?

Approximate decimal values are 4.4, 5.9, 2.8, 1.5, 3.0, 1.6, 5.8, 7.2, 5.1, 1.7, 1.6. To convert these values to binary, you could multiple each value first by 10, then convert.

15. Using the analog signal from problem 14 and a delta step that is one-eighth inch long and one-eighth inch tall, what is the delta modulation output? Point out any slope overload noise.

Using the figure in the book and one-eighth inch steps, delta modulation will not track the signal very closely. A possible sequence might be: 1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,1,1,1,0,0,0,0,0,0,1.

16. Using EBCDIC, ASCII, and Unicode character code sets, what are the binary encodings of the message "Hello, World"?

Hello in EBCDIC: 11001000, 10000101, 10010011, 10010011 10010110
Hello in ASCII: 1001000, 1100101, 1101100, 1101100, 1101111
Hello in Unicode: 0000 0000 0100 1000, 0000 0000 0110 0101, 0000 0000 0110 1100, 0000 0000 0110 1100, 0000 0000 0110 1111

17. You just created a pulse code modulated signal, but it is not a good representation of the original data. What can you do to improve the accuracy of the modulated signal?

Increase the number of samples per second of increase the number of quantization levels.

18. What is the decibel loss of a signal that starts at point A with a strength of 2000 watts and ends at point B with a strength of 400 watts?

-6.9dB

19. What is the decibel loss of signal that starts at 50 watts and experiences a 10-watt loss over a given section of cable?

Approximately 1db.

20. What is the decibel loss of a signal that loses half its power during the course of transmission?

-3db

Exercises from the Details sections:

21. Using Nyquist's Theorem, what is the channel capacity C of a signal that has 16 different levels and a frequency of 20,000 Hz?

160,000 bps

22. Using Shannon's formula, calculate the data transfer rate given the following information:
signal frequency = 10,000 Hz
signal power = 5000 watts
noise power =230 watts.

45,076 bps

23. Using Nyquist's theorem and given a frequency of 5000 Hz and a data rate of 20,000 bps, how many signal levels (L) will be needed to convey this data?

4 levels

Thinking Outside the Box

1. Workstation: digital data; LAN: digital signals; modem: converts to analog signals; telephone lines: combination of analog and digital signals; receiving modem: converts to digital data; mainframe computer: digital data

2. Sampling rate: 2 x 4000 Hz or 8000 samples per second; quantization levels: either 7 or 8 bits per sample; assume 8 bits per sample: 8 x 8000 = 64,000 bits per second; not the same as CD – CD has sampling rate of 44.1 MHz and typically 16 bits per sample

3. According to Nyquist, data rate = 2 times frequency times $\log_2$ of signal levels. Solving for signal levels, signal levels = 6.9. This is the basic concept behind modem modulation, but reader should note that a telephone line cannot carry a signal of 6000 Hz (is about one half).

4. No they cannot. Modems input digital data and produce analog signals, while codecs input analog data and produce digital signals.

5. All other schemes are essentially unipolar.