# Data and Signals

## Introduction

Computer networks transmit signals

Signals are the electric or electromagnetic ***encoding*** of data

Data and signals can be analog or digital

# Data vs Signals

Data is what we want to transmit

- Data is usually stored

Signals are what we use to transmit the data

- Signals are transient

# Data and Signals

Examples of data include:

• computer files

• movie on a DVD

• music on a compact disc

• collection of samples from a blood gas analysis device

# Data and Signals

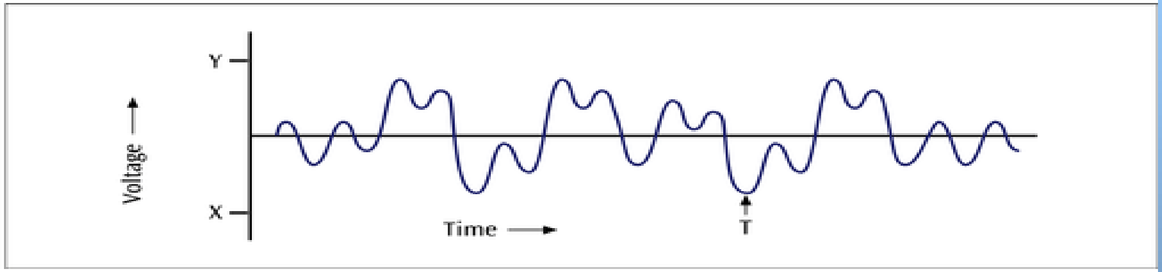
Examples of signals include:

- telephone conversation over a telephone line
- live television news interview from Europe
- web page download over your telephone line via the Internet
- others?

# Analog versus Digital

Analog is a continuous waveform, with examples such as music and video.

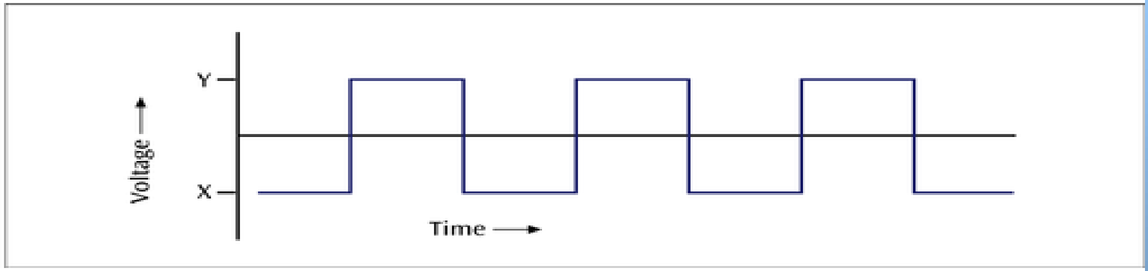
**Figure 2-1**
*A simple example of an analog waveform*



# Analog versus Digital

Digital is a discrete or non-continuous waveform with examples such as computer 1s and 0s.

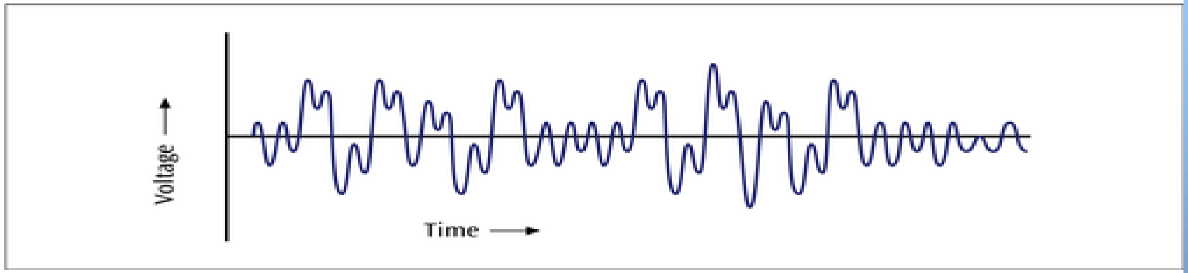
**Figure 2-3**
*A simple example of a digital waveform*



# Analog versus Digital

It is harder to separate noise from an analog signal than it is to separate noise from a digital signal.

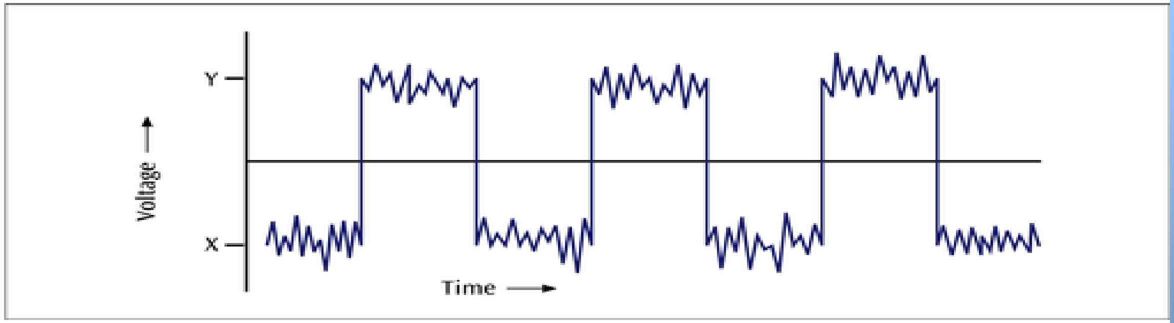
**Figure 2-2**
*The waveform of a symphonic overture with noise*



# Analog versus Digital

Noise in a digital signal. You can still discern a high voltage from a low voltage.

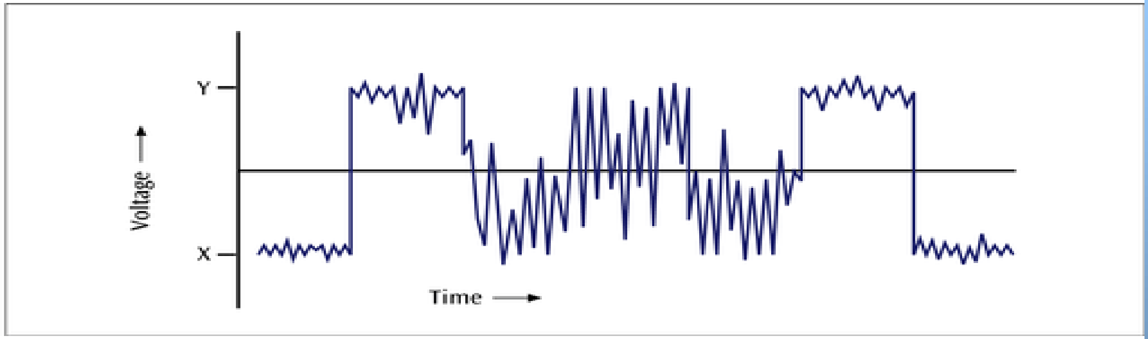
**Figure 2-4**
*A digital signal with some noise introduced*



# Analog versus Digital

Noise in a digital signal. Too much noise - you cannot discern a high voltage from a low voltage.

**Figure 2-5**
*A digital waveform with noise so great that you can no longer recognize the original waveform*



# All Signals Three Components

Amount - Amplitude

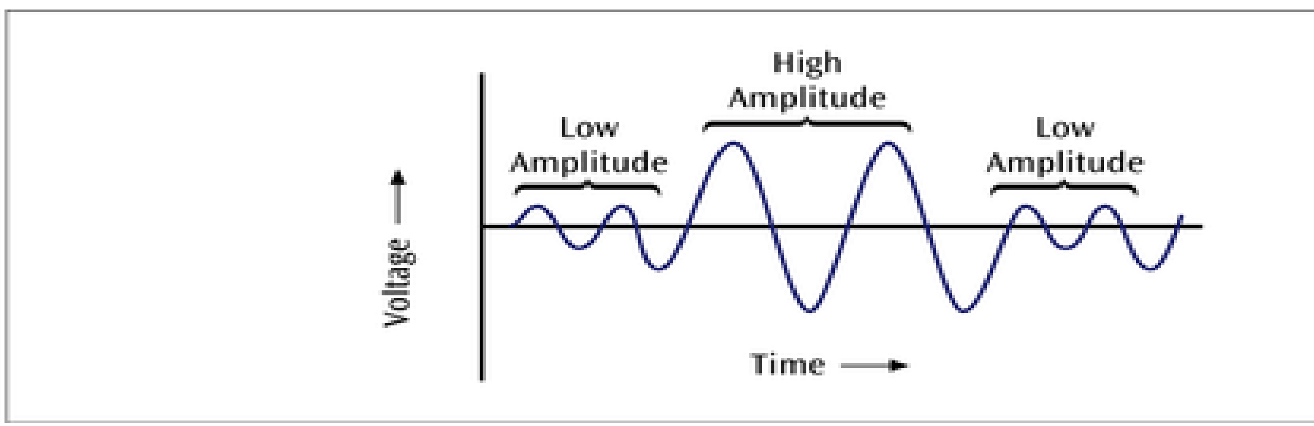
Time - Frequency

Phase

# Amplitude

The amplitude of a signal is the height of the wave above or below a given reference point.

**Figure 2-6**
*A signal with two different amplitudes*



# Frequency

The frequency is the number of times a signal makes a complete cycle within a given time frame.

- Measured in Hz (hertz = cycles/second)
- Period is the length of one cycle = 1/frequency

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

- Human speech: 300 Hz to 3100 Hz

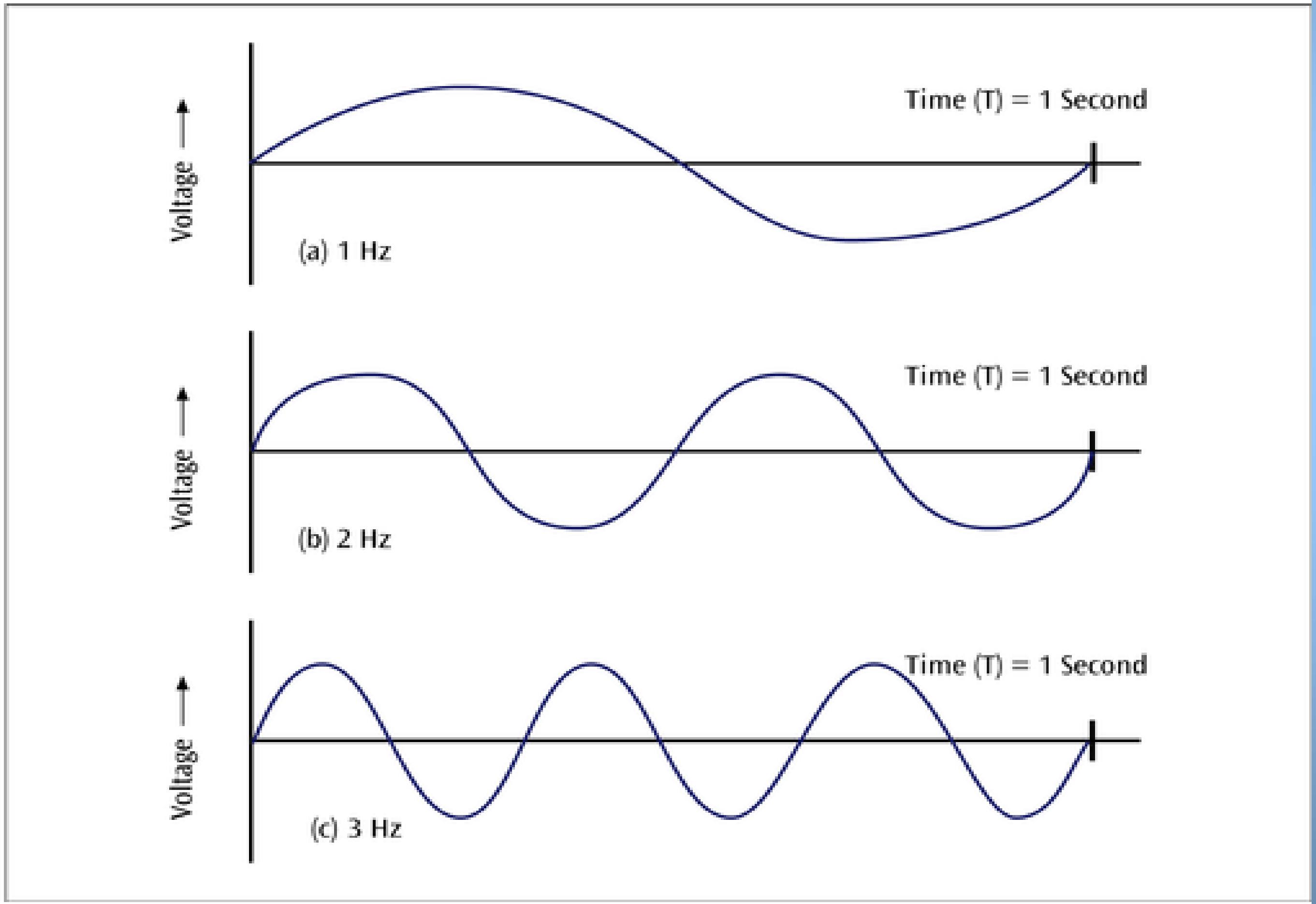
Bandwidth - The absolute value of the difference between the lowest and highest frequencies of a signal.

- Human speech: 2800 Hz

# Data Communications and Computer Networks

## Chapter 2

**Figure 2-7**
*Three signals of 1 Hz, 2 Hz, and 3 Hz*



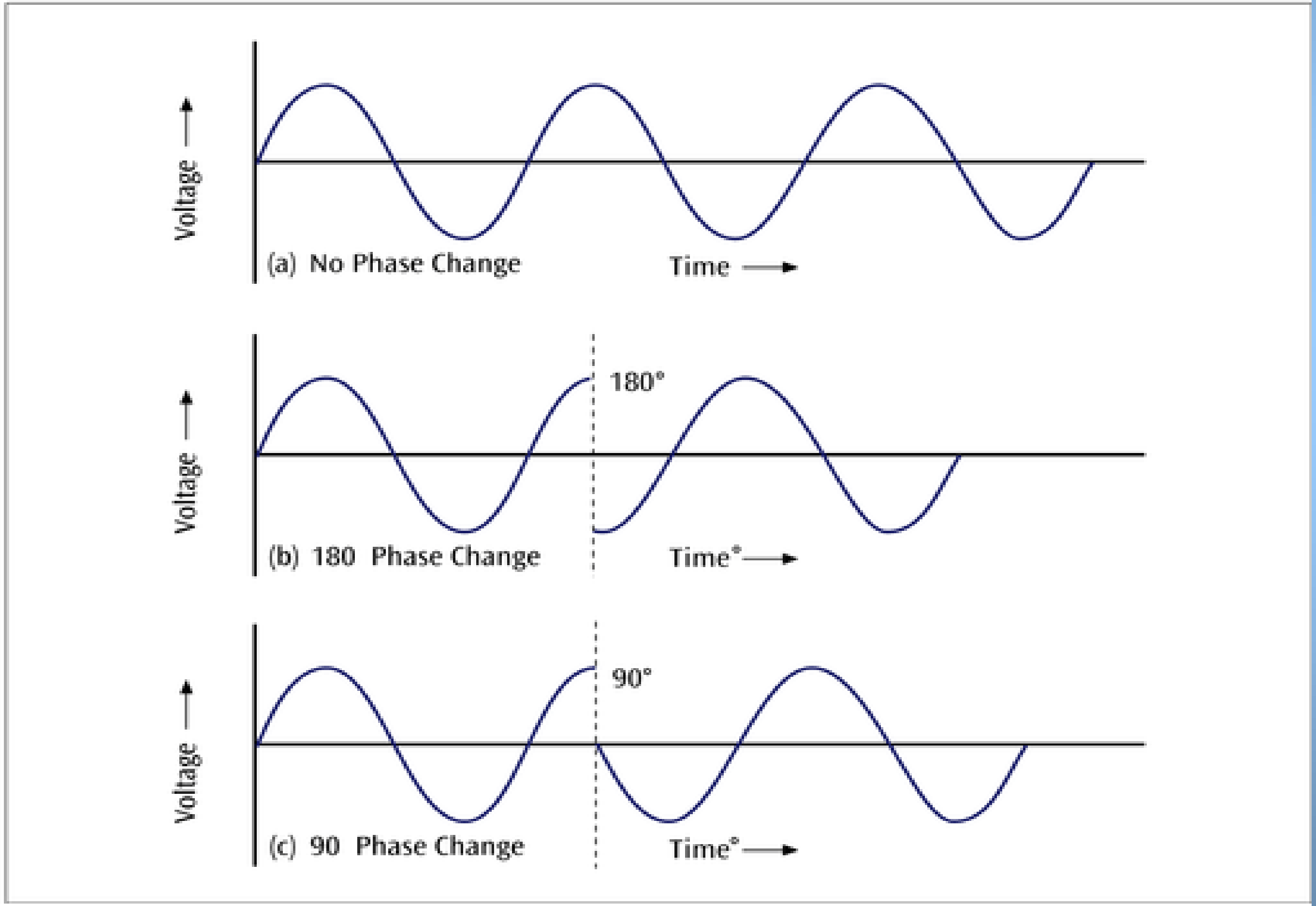
# Phase

The phase of a signal is the position of the waveform ***relative*** to a given moment of time or relative to time zero.

A change in phase can be any number of angles between 0 and 360 degrees.

Phase changes often occur on common angles, such as 45, 90, 135, etc.

**Figure 2-8**
*A sine wave showing no phase change (a), a 180 degree phase change (b), and a 90 degree phase change (c)*



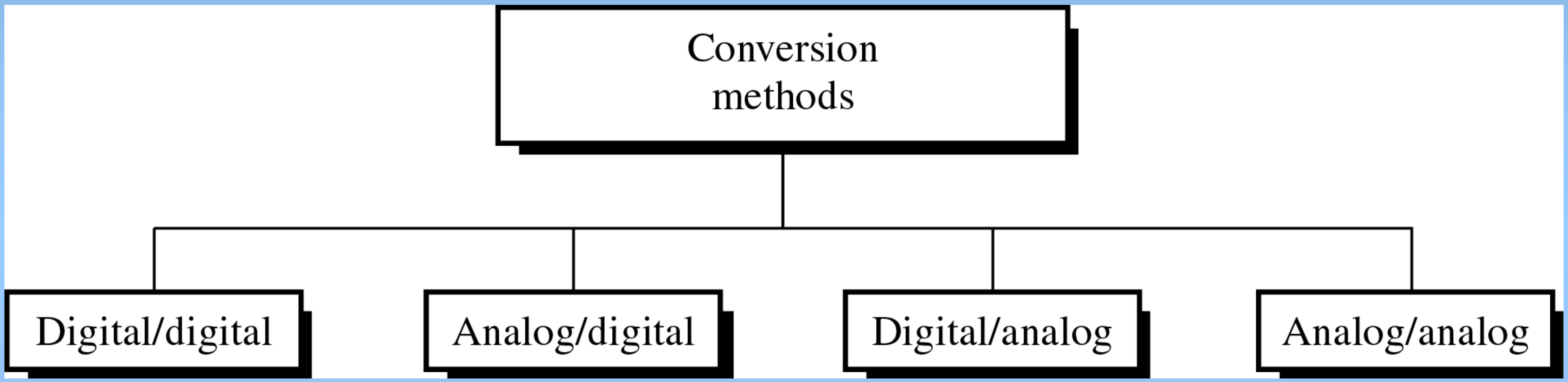
# *Encoding*

# Converting data into signals - types

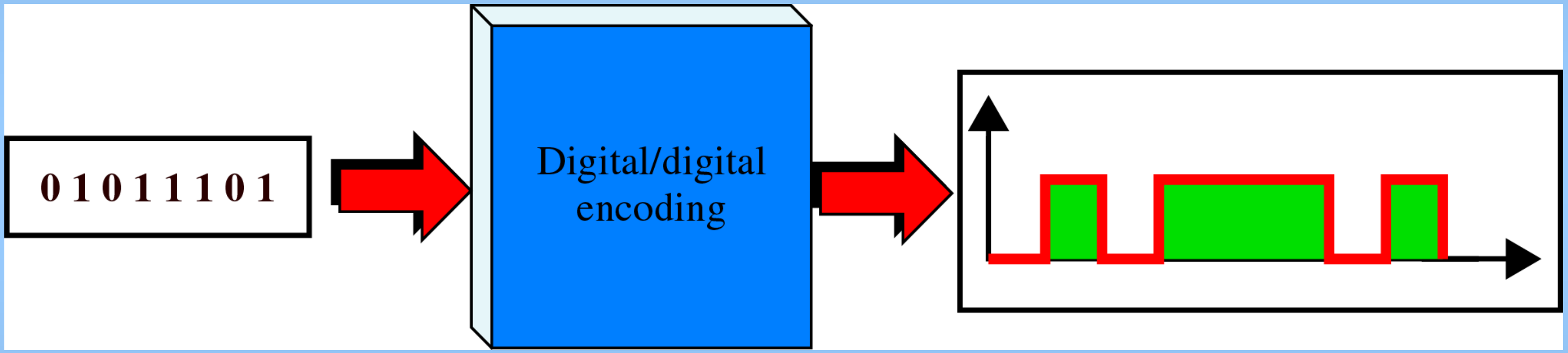
Transmitting

- Digital data to digital signals
- Digital data with analog signals
- Analog data with digital signals
- Analog data with analog signals

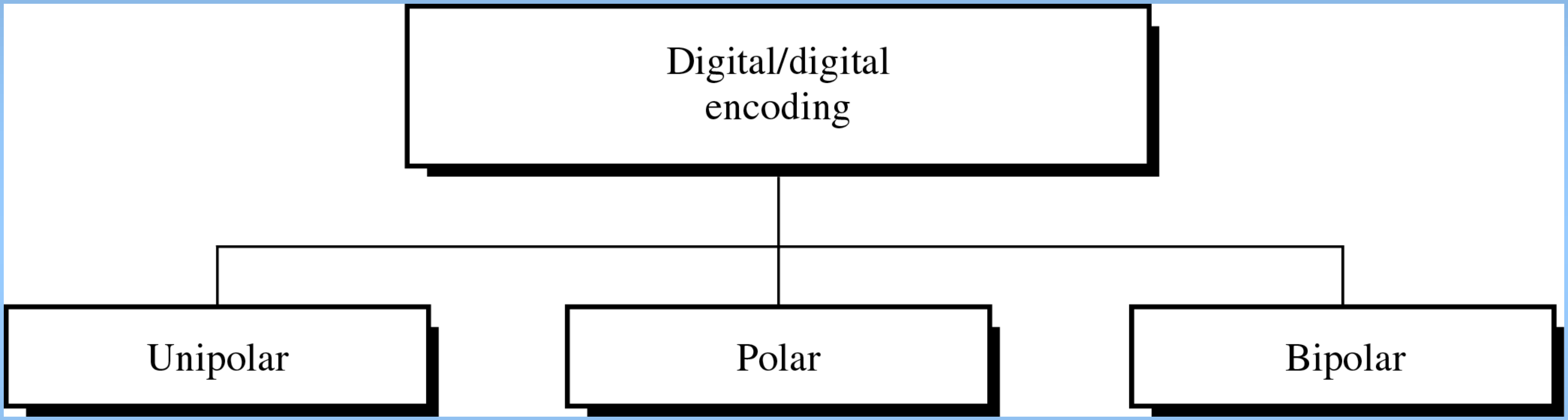
# Different Conversion Schemes



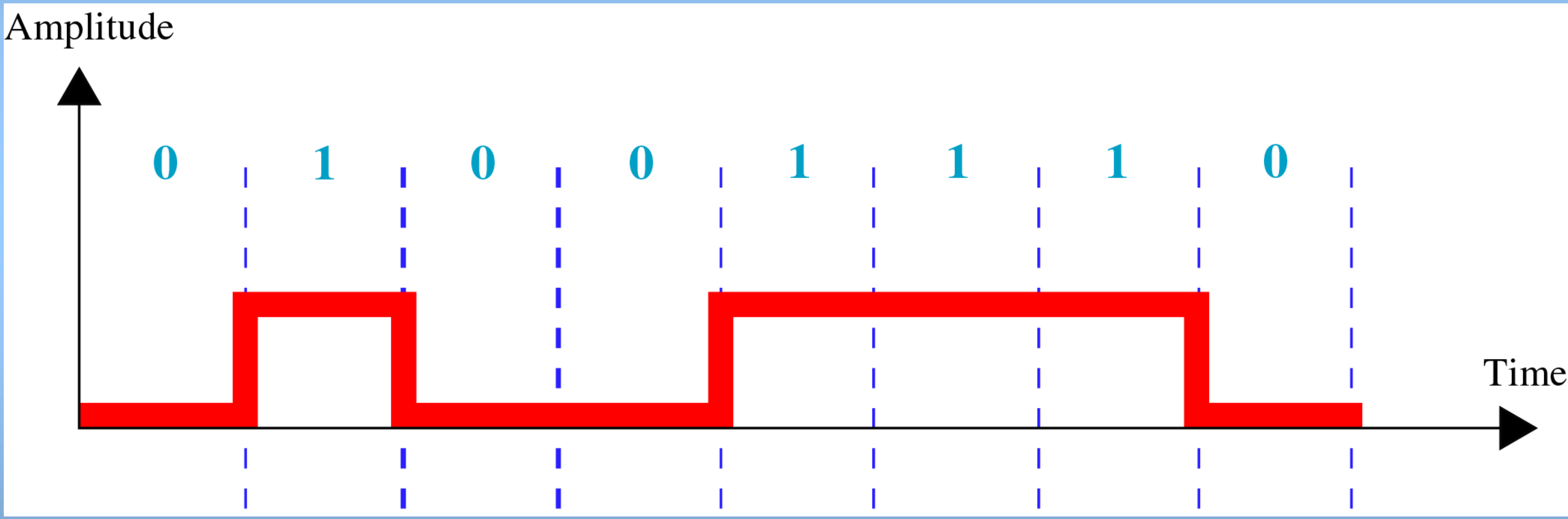
# Digital to Digital Encoding



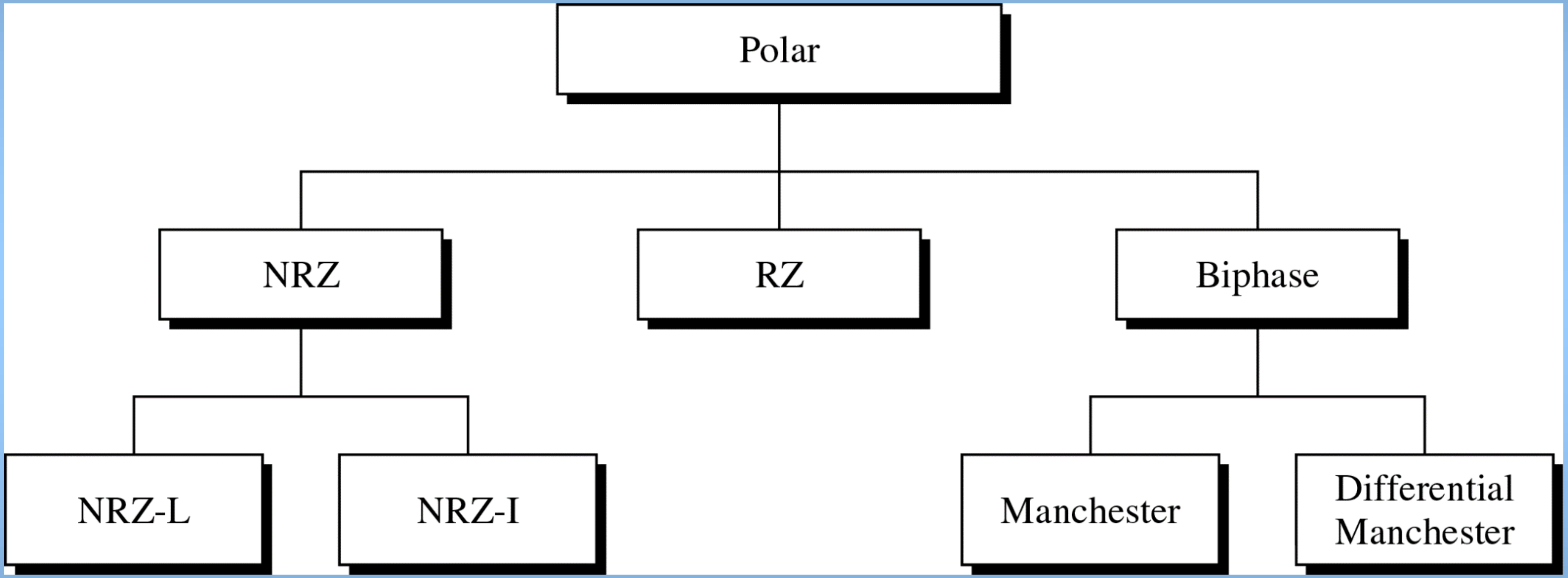
# Types of Digital to Digital Encoding



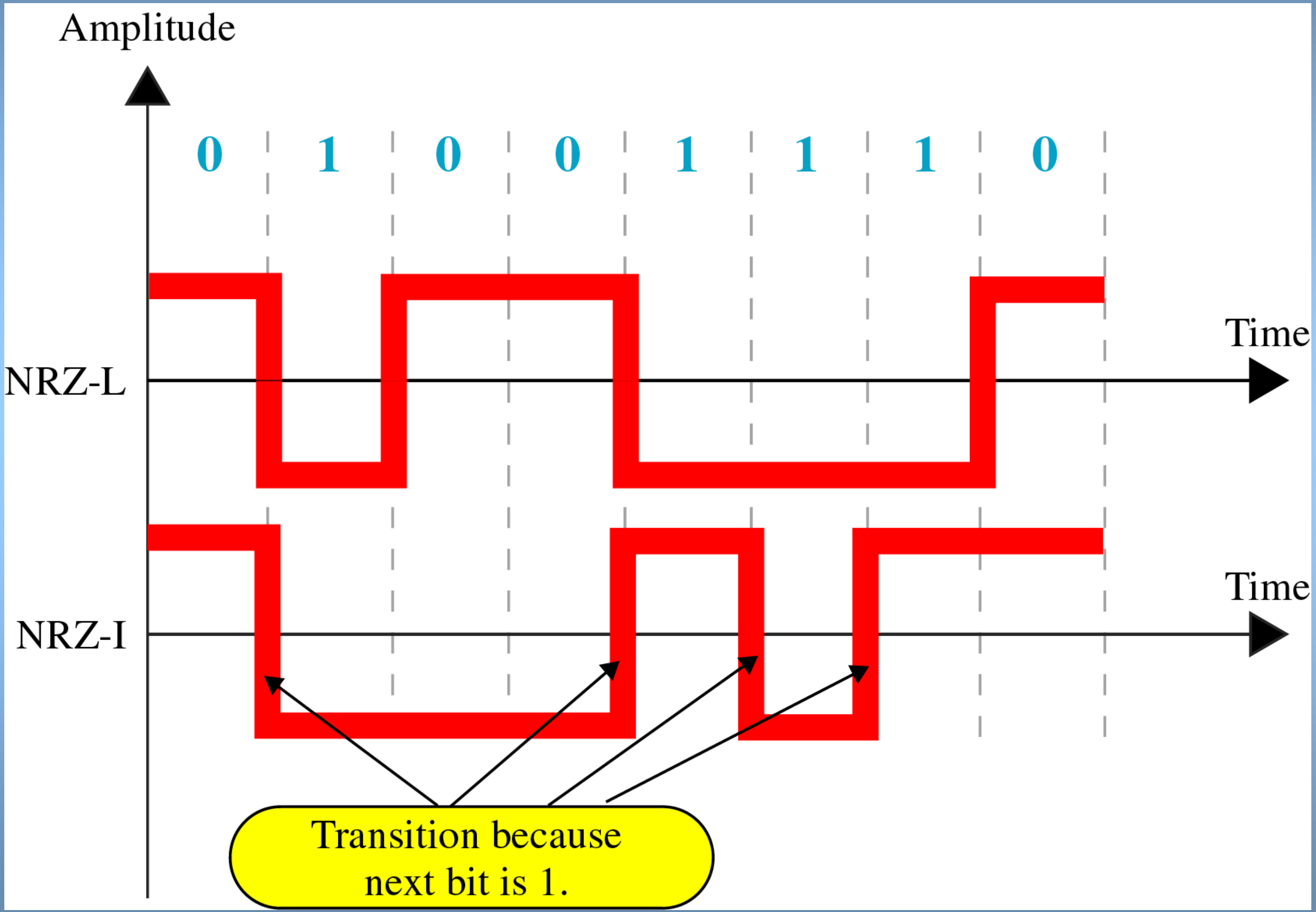
# Unipolar Encoding



# Types of Polar Encoding



# NRZ-L and NRZ-I Encoding



# Manchester and Diff. Manchester Encoding

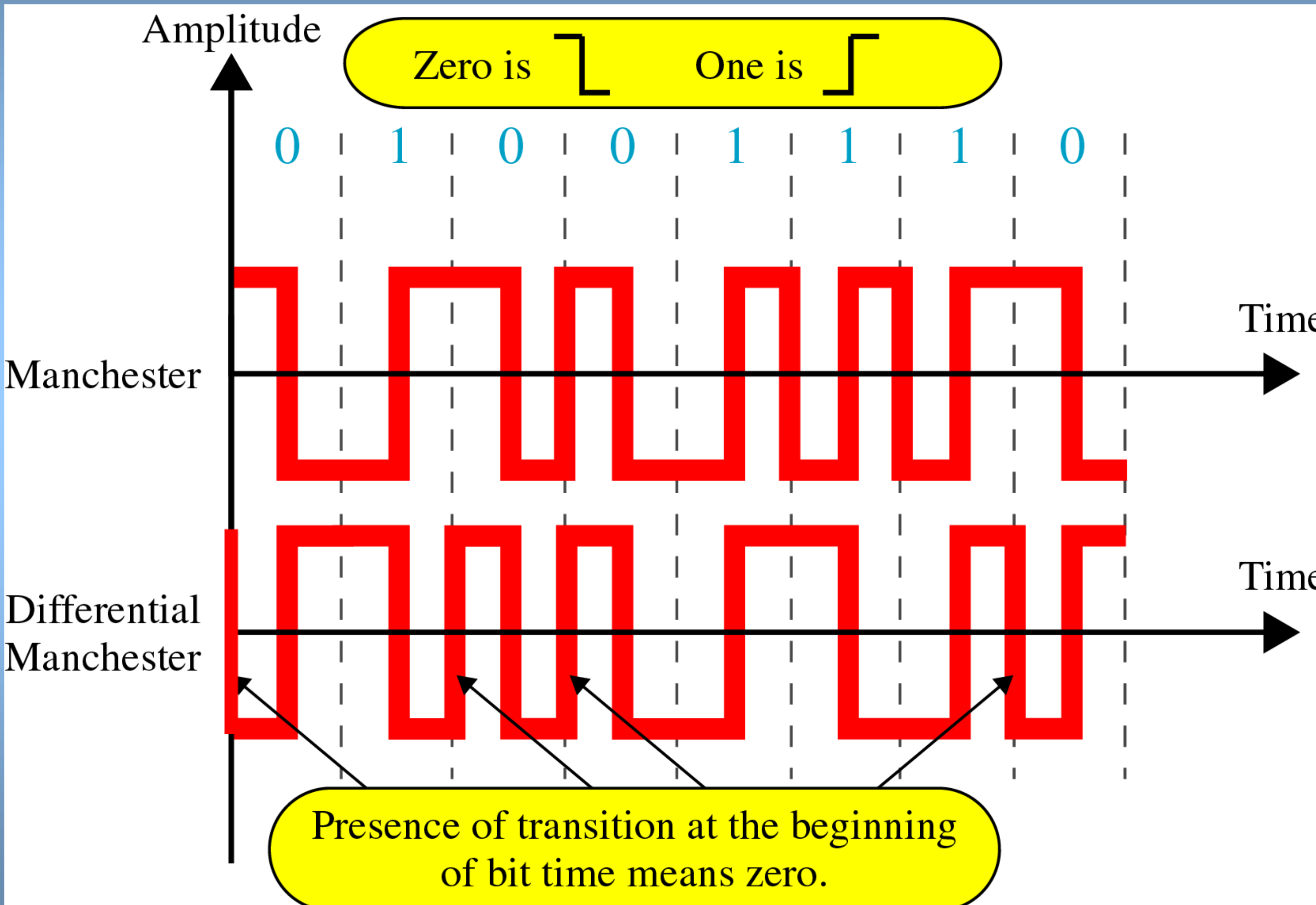
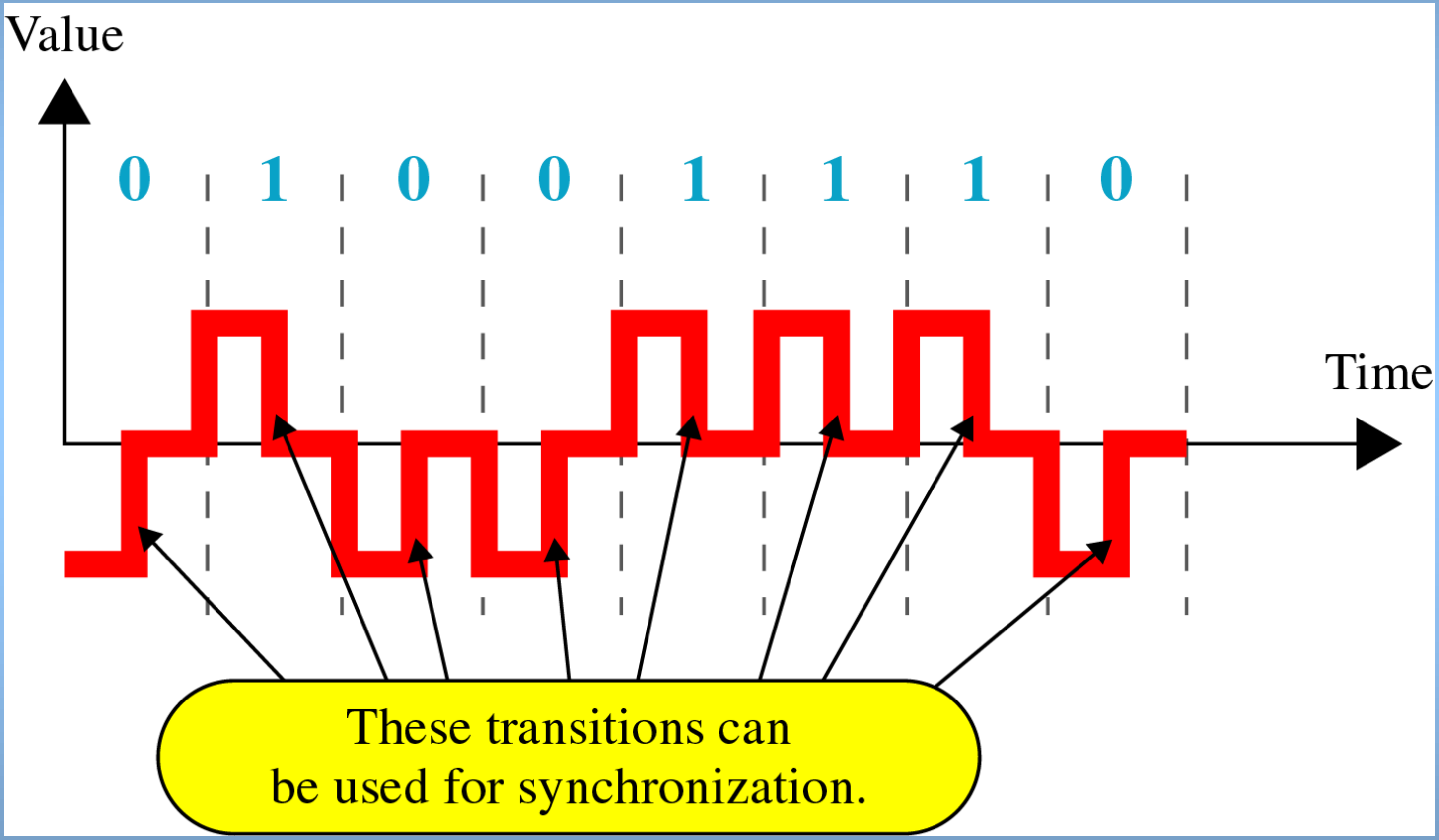


Figure 5-7

# RZ Encoding



# Converting Digital Data into Analog Signals

Modulation: change from one version to another

Three basic techniques:

- Amplitude modulation
- Frequency modulation
- Phase modulation

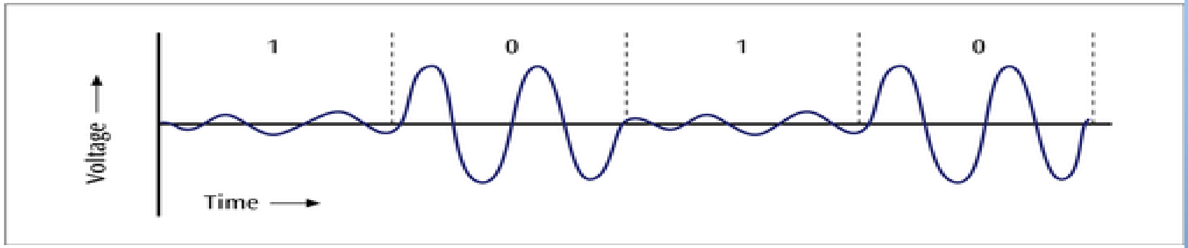
# Modem

- Device that converts digital data to analog signal and back again.
- MOdulator/DEModulator

# Amplitude Modulation

One amplitude encodes a 0 while another amplitude encodes a 1.

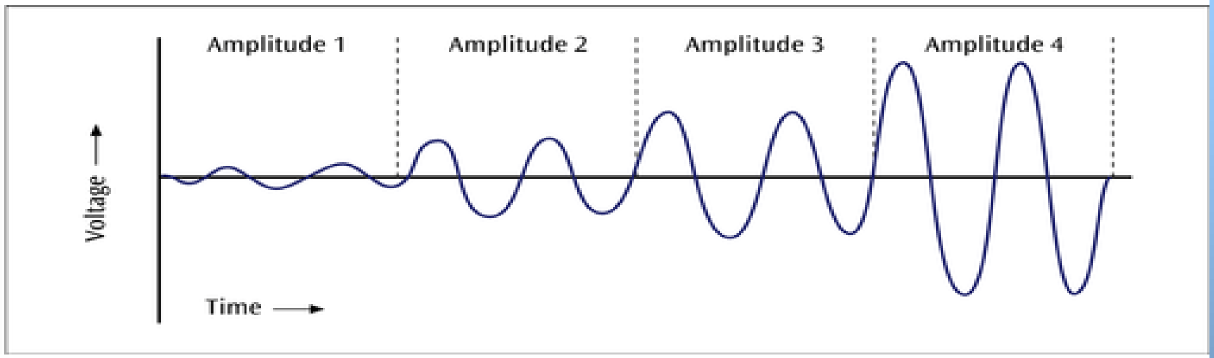
**Figure 2-14**
*Example of amplitude modulation*



# Amplitude Modulation

Some systems use multiple amplitudes.

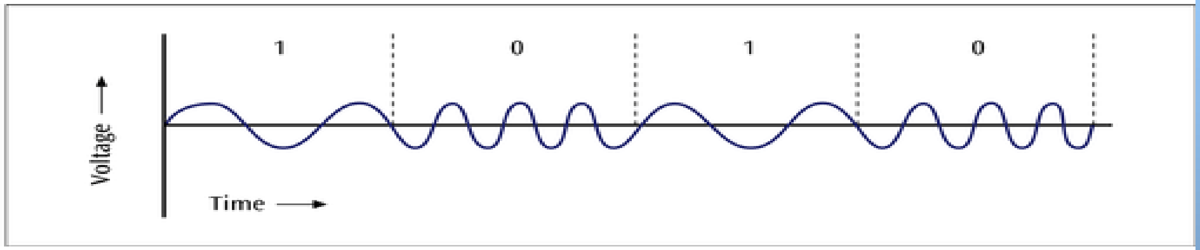
**Figure 2-15**
*Amplitude modulation using four different amplitude levels*



# Frequency Modulation

One frequency encodes a 0 while another frequency encodes a 1.

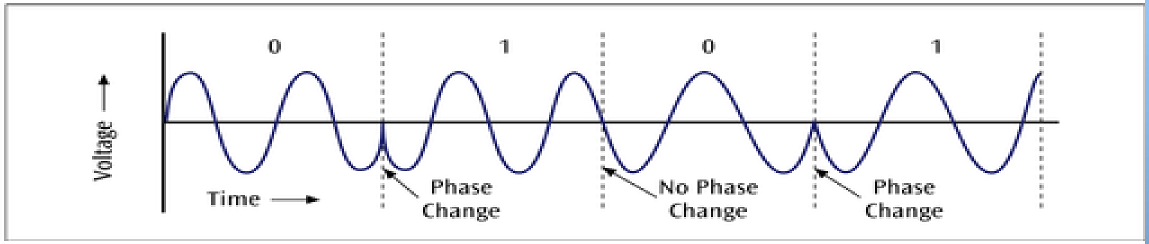
Figure 2-16
*Simple example of frequency modulation*



# Phase Modulation

One phase change encodes a 0 while another phase change encodes a 1. Here, only phase change for a 1.

**Figure 2-17**
*An example of simple phase modulation of a sine wave*



# Converting Analog Data into Digital Signals

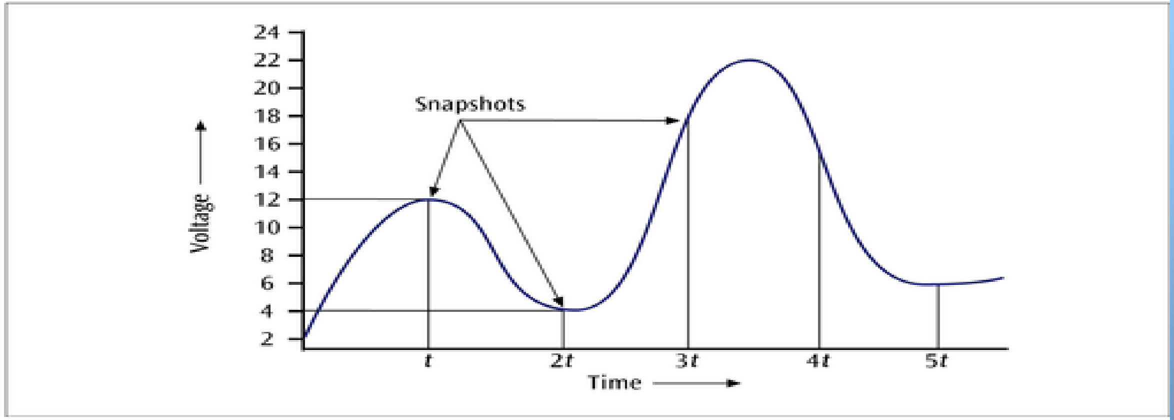
To convert analog data into a digital signal, there are two basic techniques:

- Pulse code modulation (used by telephone systems)
- Delta modulation

# Pulse Code Modulation

The analog waveform is sampled at specific intervals and the “snapshots” are converted to binary values.

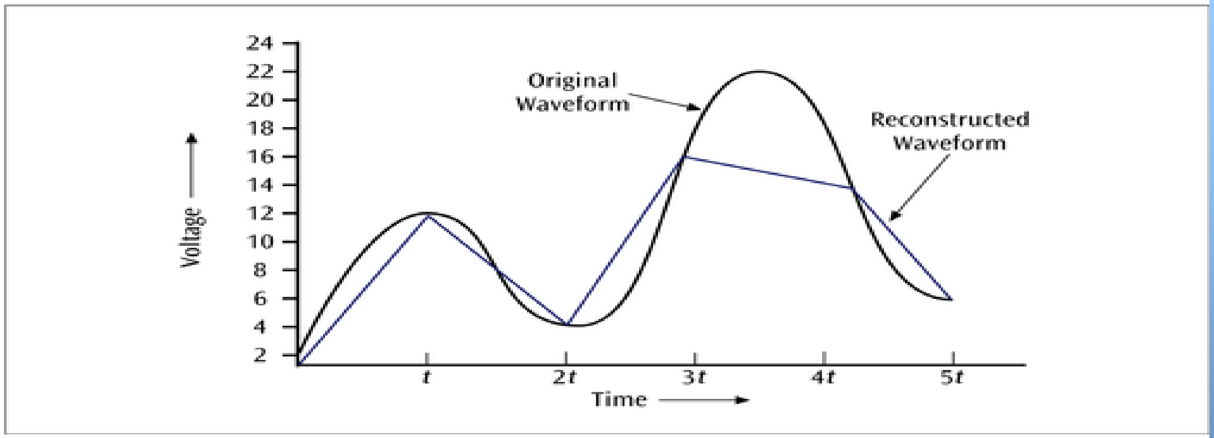
**Figure 2-20**
*Example of taking “snapshots” of an analog waveform for conversion to a digital signal*



# Pulse Code Modulation

When the binary values are later converted to an analog signal, a waveform similar to the original results.

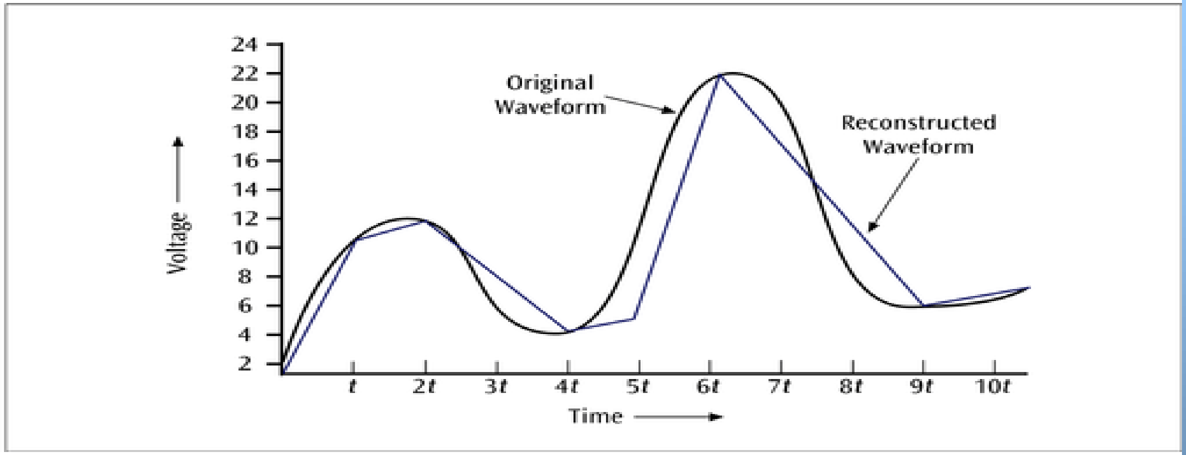
**Figure 2-21**
*Reconstruction of the analog waveform from the digital "snapshots"*



# Pulse Code Modulation

The more snapshots taken in the same amount of time, the better the resolution.

**Figure 2-22**
*A more accurate reconstruction of the original waveform using a higher sampling rate*



# Pulse Code Modulation

Since telephone systems digitize human voice, and since the human voice has a fairly narrow bandwidth, telephone systems can digitize voice into either 128 levels or 256 levels.

These levels are called *quantization levels*.

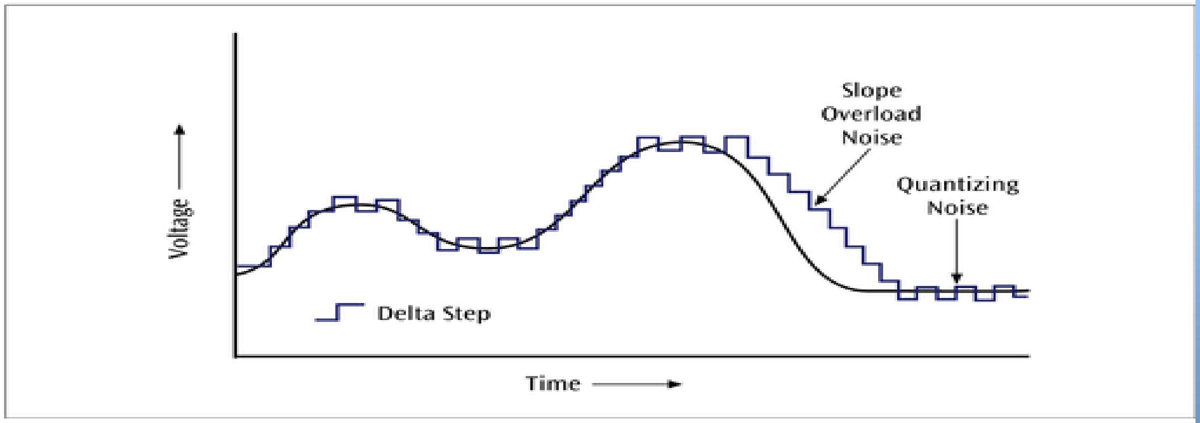
If 128 levels, then each sample is 7 bits (2 ^ 7 = 128).

If 256 levels, then each sample is 8 bits (2 ^ 8 = 256).

# Delta Modulation

An analog waveform is tracked, using a binary 1 to represent a rise in voltage, and a 0 to represent a drop.

**Figure 2-25**
*Example of delta modulation that is experiencing slope overload noise and quantizing noise*



# Converting Analog Data into Analog Signals

Many times it is necessary to modulate analog data onto a different set of analog frequencies.

Broadcast radio and television are two very common examples of this.

Low-frequency analog signals (like human voice, 300 Hz–3.4 kHz) can't travel far on their own.

Modulating them onto high-frequency carrier waves (like 100 MHz for FM radio) helps send them farther.

**Figure 2-26**
*An audio waveform modulated onto a carrier frequency using amplitude modulation*