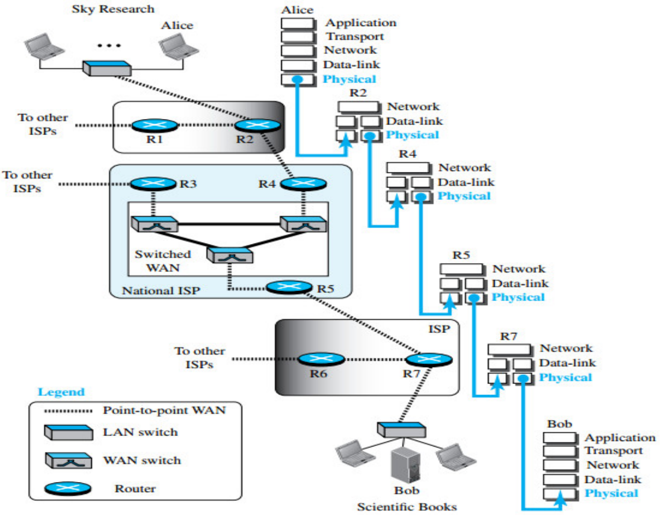
Principles of Data Communications

Reference Book: Data Communications and Networking by Behrouz A. Forouzan

Communication at the physical layer



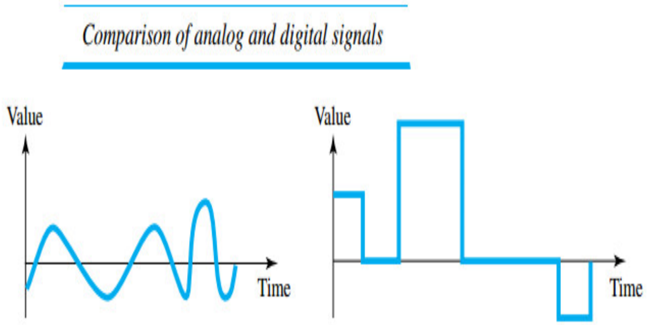
- Although Alice and Bob need to exchange data, communication at the physical layer means exchanging signals.
- Data need to be transmitted and received, but the media have to change data to signals.
- Both data and the signals that represent them can be either analog or digital in form.

Analog and Digital Data

- Data can be analog or digital.
- The term analog data refers to information that is continuous; digital data refers to information that has discrete states. For example, an analog clock that has hour, minute, and second hands gives information in a continuous form; the movements of the hands are continuous. On the other hand, a digital clock that reports the hours and the minutes will change suddenly from 8:05 to 8:06.
- Analog data, such as the sounds made by a human voice, take on continuous values. When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal.
- Digital data take on discrete values. For example, data are stored in computer memory in the form of 0s and 1s. They can be converted to a digital signal or modulated into an analog signal for transmission across a medium.

Analog and Digital Signals

- Signals can be either analog or digital.
- An analog signal has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.
- A digital signal, on the other hand, can have only a limited number of defined values. Although each value can be any number, it is often as simple as 1 and 0.



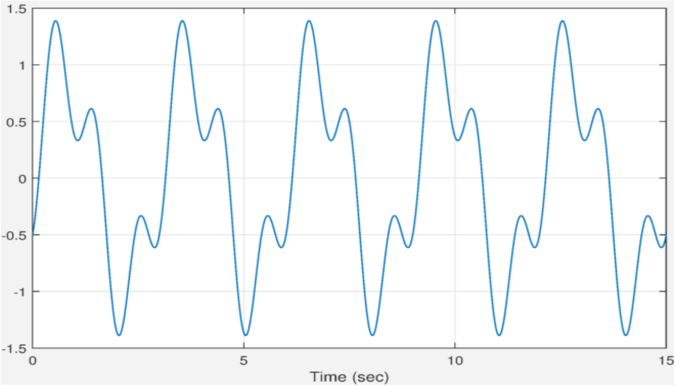
a. Analog signal

b. Digital signal

Periodic and Nonperiodic

- Both analog and digital signals can take one of two forms: periodic or nonperiodic
- A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods.
- The completion of one full pattern is called a cycle.
- A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time.
- Both analog and digital signals can be periodic or nonperiodic.
- **In data communications, we commonly use periodic analog signals and nonperiodic digital signals.**

Periodic Signal



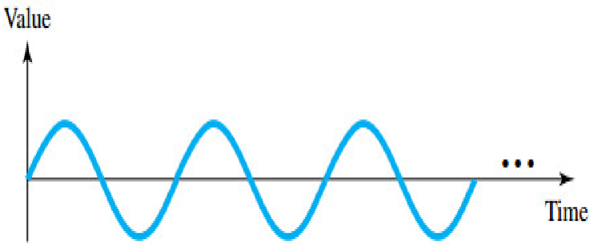
PERIODIC ANALOG SIGNALS

- Periodic analog signals can be classified as simple or composite.
- A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals.
- A composite periodic analog signal is composed of multiple sine waves.

Sine Wave

- The sine wave is the most fundamental form of a periodic analog signal.
- When we visualize it as a simple oscillating curve, its change over the course of a cycle is smooth and consistent, a continuous, rolling flow.

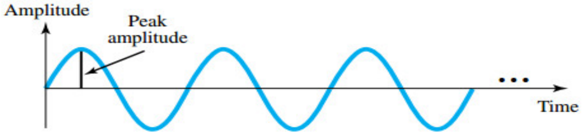
A sine wave



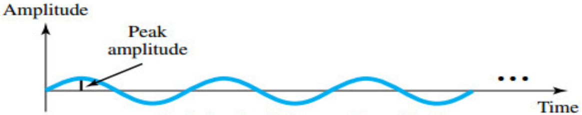
- A sine wave can be represented by three parameters.
  - Peak Amplitude
  - Frequency
  - Phase
- These three parameters fully describe a sine wave.

- The peak amplitude of a signal is the absolute value of its highest intensity, proportional to the energy it carries.
- For electric signals, peak amplitude is normally measured in volts.

Two signals with the same phase and frequency, but different amplitudes



a. A signal with high peak amplitude



b. A signal with low peak amplitude

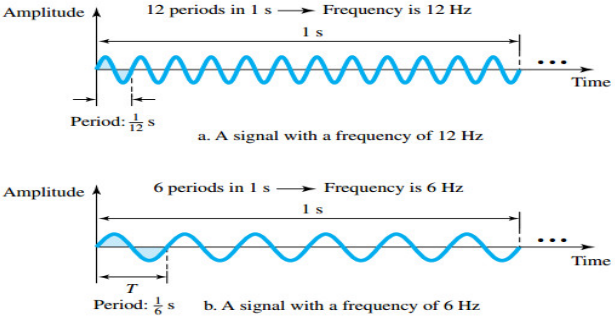
What is the Amplitude of Sound?

- The amplitude of a sound wave is the measure of the height of the wave. The amplitude of a sound wave can be defined as the loudness or the amount of maximum displacement of vibrating particles of the medium from their mean position when the sound is produced.
- Loudness is directly proportional to the amplitude of the sound. If the amplitude of a sound wave is large then the loudness of sound will be more. If the amplitude is small then the sound will be feeble.

Period and Frequency

- Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.
- Frequency refers to the number of periods in 1 s. Note that period and frequency are just one characteristic defined in two ways.
- Period is the inverse of frequency, and frequency is the inverse of period.
- $f = 1/T$
- $T = 1/f$
- Period is formally expressed in seconds.
- Frequency is formally expressed in Hertz (Hz), which is cycle per second.

Two signals with the same amplitude and phase, but different frequencies



Units of period and frequency

Period		*Frequency*	
Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

- Express a period of 100 ms in microseconds.
- The period of a signal is 100 ms. What is its frequency in kilohertz?
- Express a period of 100 ns in microseconds.
- The period of a signal is 100 ns. What is its frequency in kilohertz?

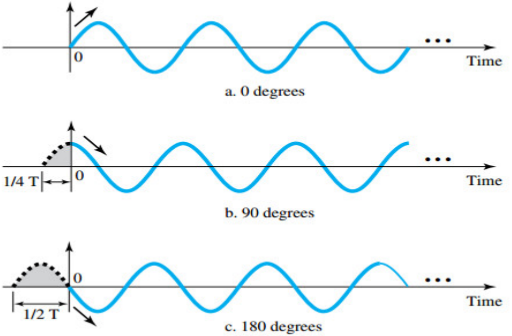
- Frequency is the rate of change with respect to time.
- Change in a short span of time means high frequency.
- Change over a long span of time means low frequency.
- If a signal does not change at all, its frequency is zero.
- If a signal changes instantaneously, its frequency is infinite.

Phase

- The term phase, or phase shift, describes the position of the waveform relative to time 0.
- If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of the first cycle
- Phase describes the position of the waveform relative to time 0.

- Phase is measured in degrees or radians. A phase shift of 360 degree corresponds to a shift of a complete period; a phase shift of 180 degree corresponds to a shift of one-half of a period; and a phase shift of 90 degree corresponds to a shift of one-quarter of a period

Three sine waves with the same amplitude and frequency, but different phases

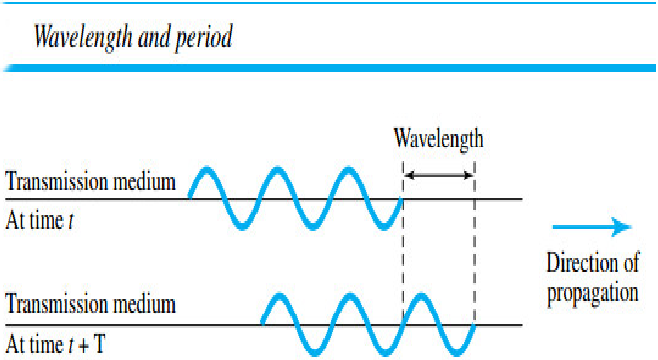


- A sine wave with a phase of 0 starts at time 0 with a zero amplitude. The amplitude is increasing.
- A sine wave with a phase of 90 starts at time 0 with a peak amplitude. The amplitude is decreasing.
- A sine wave with a phase of 180 starts at time 0 with a zero amplitude. The amplitude is decreasing.

- A sine wave with a phase of 0 degree is not shifted.
- A sine wave with a phase of 90 degree is shifted to the left by cycle. However, note that the signal does not really exist before time 0.
- A sine wave with a phase of 180 degree is shifted to the left by cycle. However, note that the signal does not really exist before time 0.

Wavelength

- Wavelength is another characteristic of a signal traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium



- While the frequency of a signal is independent of the medium, the wavelength depends on both the frequency and the medium.
- Wavelength is a property of any type of signal.
- In data communications, we often use wavelength to describe the transmission of light in an optical fiber.
- The wavelength is the distance a simple signal can travel in one period.

- Wavelength can be calculated if one is given the propagation speed (the speed of light) and the period of the signal. However, since period and frequency are related to each other, if we represent wavelength by λ, propagation speed by c (speed of light), and frequency by f, we get
- $Wavelength = (propagationspeed) \times period = propagationspeed/frequency$
- $\lambda = c/f$

Summary

- Analog and Digital Data
- Analog and Digital Signal
- Periodic and Non Periodic Signals
- Sine Wave: Peak Amplitude, Frequency, Phase
- Wavelegth

THANK YOU