

ECE4634

Digital Communications

Fall 2007

Instructor: R. Michael Buehrer
Lecture #4: Introduction to
Digital Communications



Analog and Digital Communications



Lecture Overview

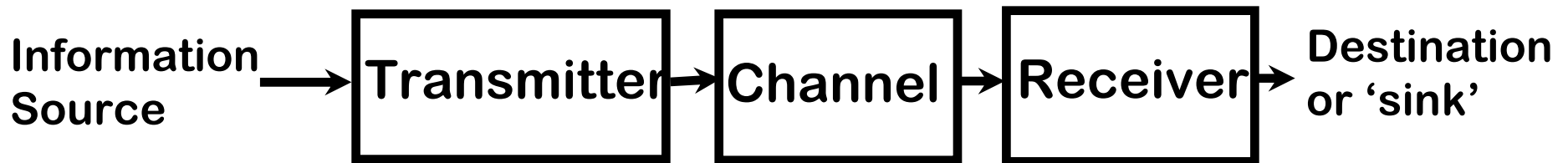
- This course deals with the study of digital communications systems
- To date we have reviewed the tools necessary for the study of communication signals and systems
 - Fourier Transforms – allow us to examine the frequency representation of signals
 - Later we will review *random variables* which will allow the study of the *performance*
- Today we begin our study of digital communications systems by examining the basic features of digital systems, particularly baseband systems
- What to read – Skim chapters 5-6 in the text

Communications



Analog and Digital Communications

- **Definition:** Communications is the transfer of information at one time or location to another time or location



Can be analog or digital. Almost always baseband signal

Converts information into appropriate waveform
Can include analog-to-digital conversion, modulation and waveform coding. Can be baseband or bandpass

Transports and corrupts signal

Makes best guess as to what the transmitted signal was

Examples



Analog and Digital Communications

- Broadcast television
- Broadcast radio
- Cellular telephony
- Wireless LAN
- Landline telephony
- Global position system
- Internet
- Cable TV



Transmitting Information

- The basic function of a communication system is to transfer the source information from source to sink
- The transmitter converts the message signal to a format suitable for transmission
- The message sent can be
 - Analog or digital
 - Baseband or bandpass
- In 3614 we emphasized analog message signals
- In this class we will focus on digital messages even if the underlying source is analog
- We will initially focus baseband waveforms and later bandpass waveforms



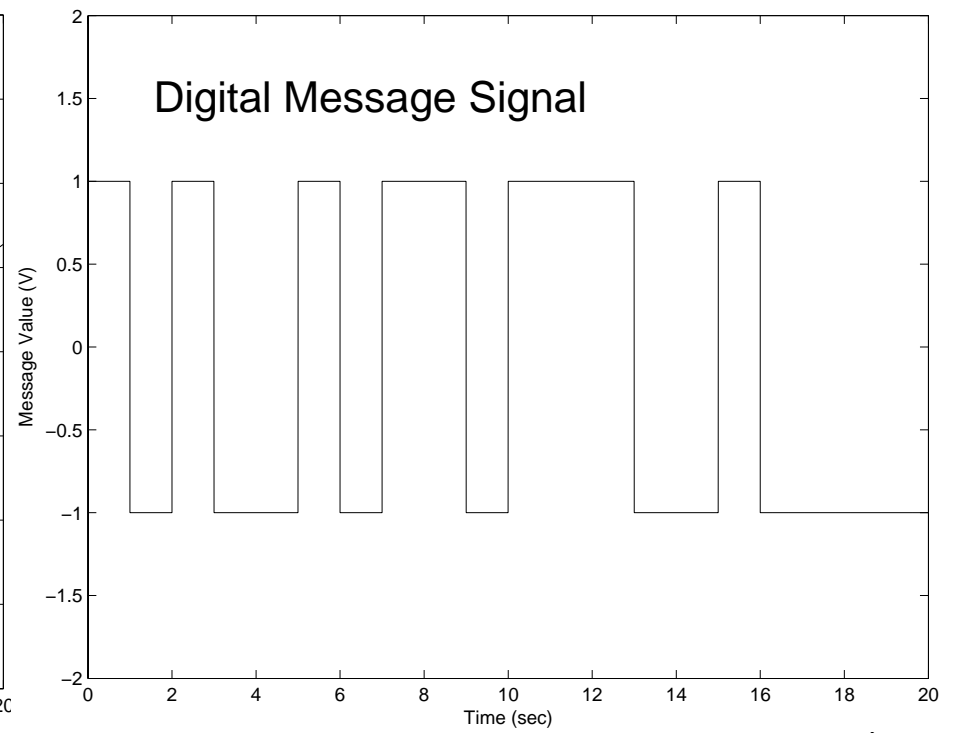
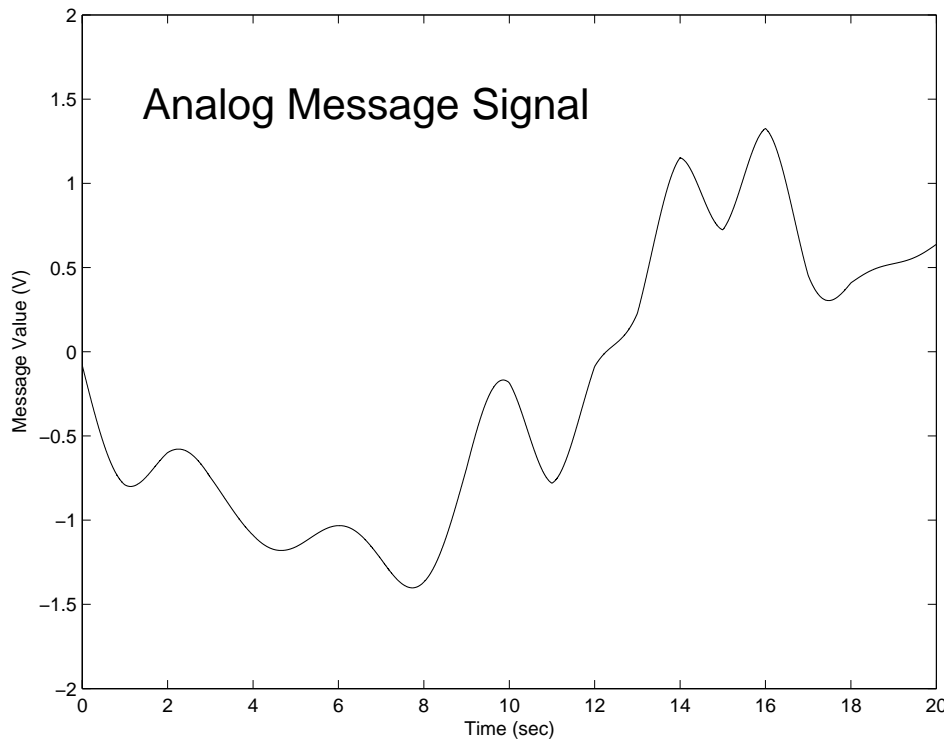
Analog vs. Digital

- Analog Communications
 - The message signal can take on an infinite number of possible values
 - Directly uses an analog information source (or some one-to-one mapping of it) as the message to be sent
- Digital Communications
 - The message signal must be one of a small number of discrete messages
 - Must convert analog signals into a sequence of discrete messages
 - If the number of possible messages is 2, the system is *binary* and the messages are termed binary digits or *bits*.



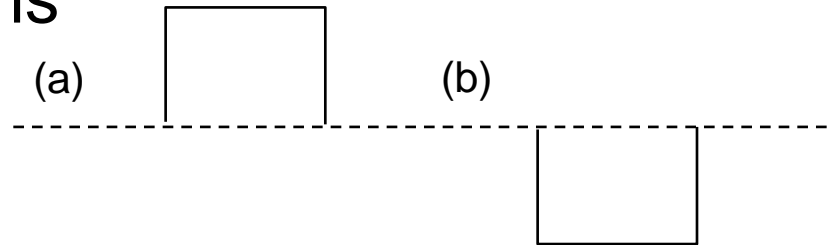
Example

- Analog system that transmits a voltage value between $-2V$ and $+2V$.
- An example digital system transmits either $+1V$ or $-1V$



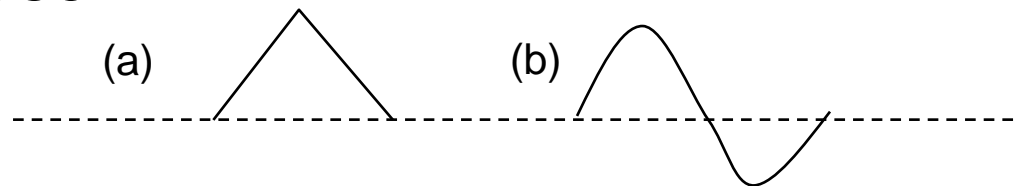
Digital Examples

- The previous example of a digital system used the two waveforms



- We could use any two (or more) waveforms that we wished to use

- Ex:



- The keys to choosing waveforms are (a) are they easy to distinguish from each other and (b) what are their spectra like?



Baseband vs Bandpass

- The transmitter's job is to convert the information source into a waveform suitable for transmission.
- The resulting transmit signal can either be “baseband” or “bandpass”
 - Baseband - frequency content is primarily around DC
 - sent signal is typically a series of modulated pulses
 - Bandpass – frequency content is primarily around some center frequency $f_c \gg 0$
 - sent signal is typically a modulated sinusoid

Why digital communications?



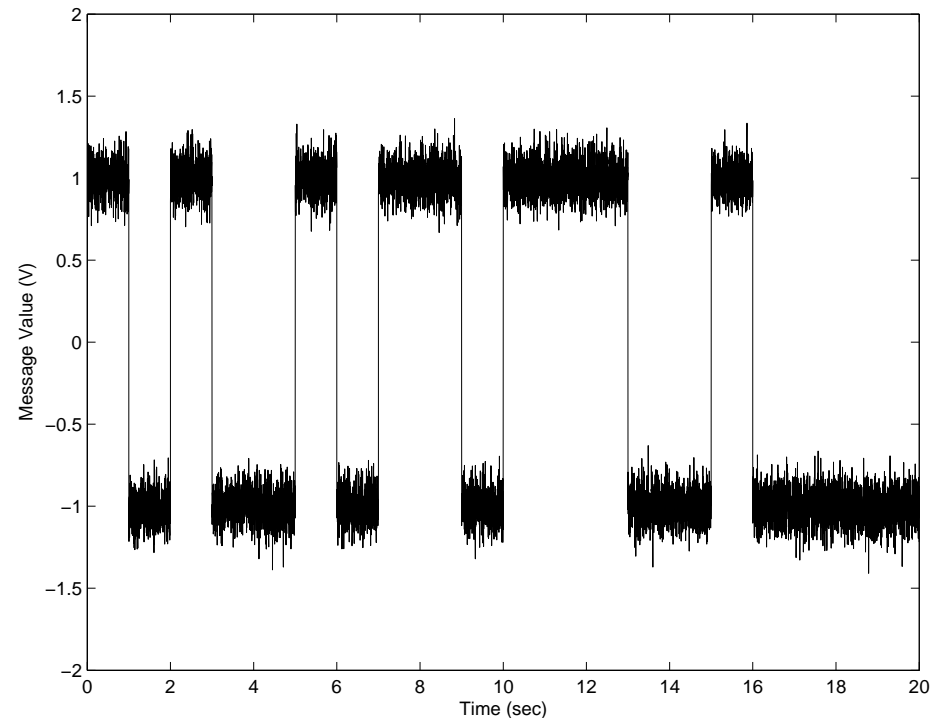
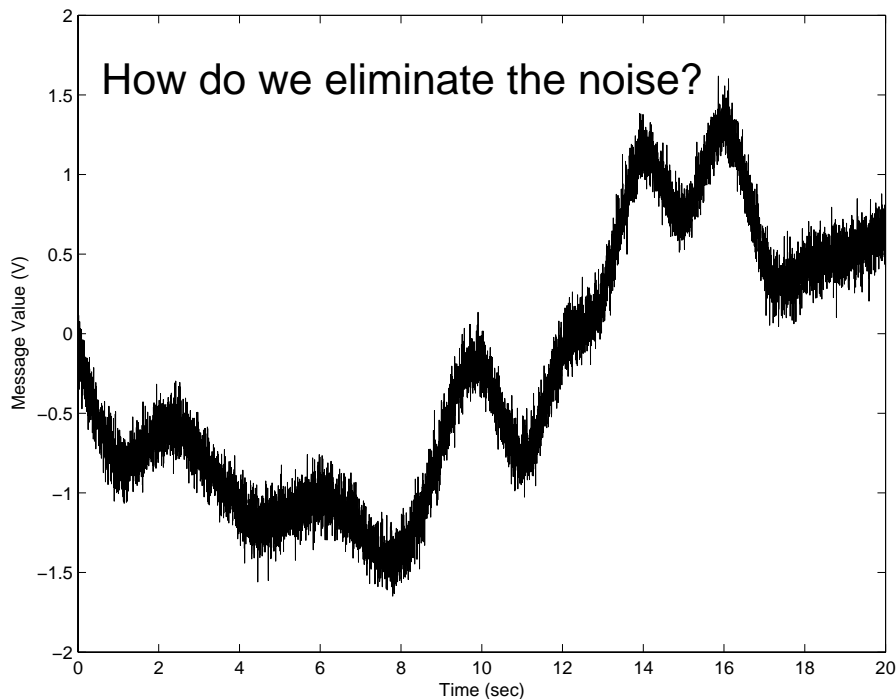
Analog and Digital Communications

- Any noise introduces distortion to an analog signal. Since a digital receiver need only distinguish between a finite number of waveforms it is possible to recover digital information without corruption a large percentage time.
- Many signal processing techniques are available to improve system performance: source coding, channel (error-correction) coding, equalization, encryption
- Digital ICs are inexpensive to manufacture. A single chip can be mass produced at low cost, no matter how complex
- Digital communications allows integration of voice, video, and data on a single system
- Digital communications systems provide a more flexible tradeoff between bandwidth efficiency and energy efficiency than analog communications



Example Revisited

- When noise is added to the signal, all of the values are still valid
- When noise is added to the signal, the resulting values are not valid, thus we can correct them.





Limitation of Digital

- Analog system can naturally represent all of the message signal values
- Digital systems cannot represent all possible input values, thus, if the message is analog then all of the information can not be transmitted
- The process of converting an analog input signal to a digital signal is termed *analog-to-digital conversion* and is a lossy process

In class drill

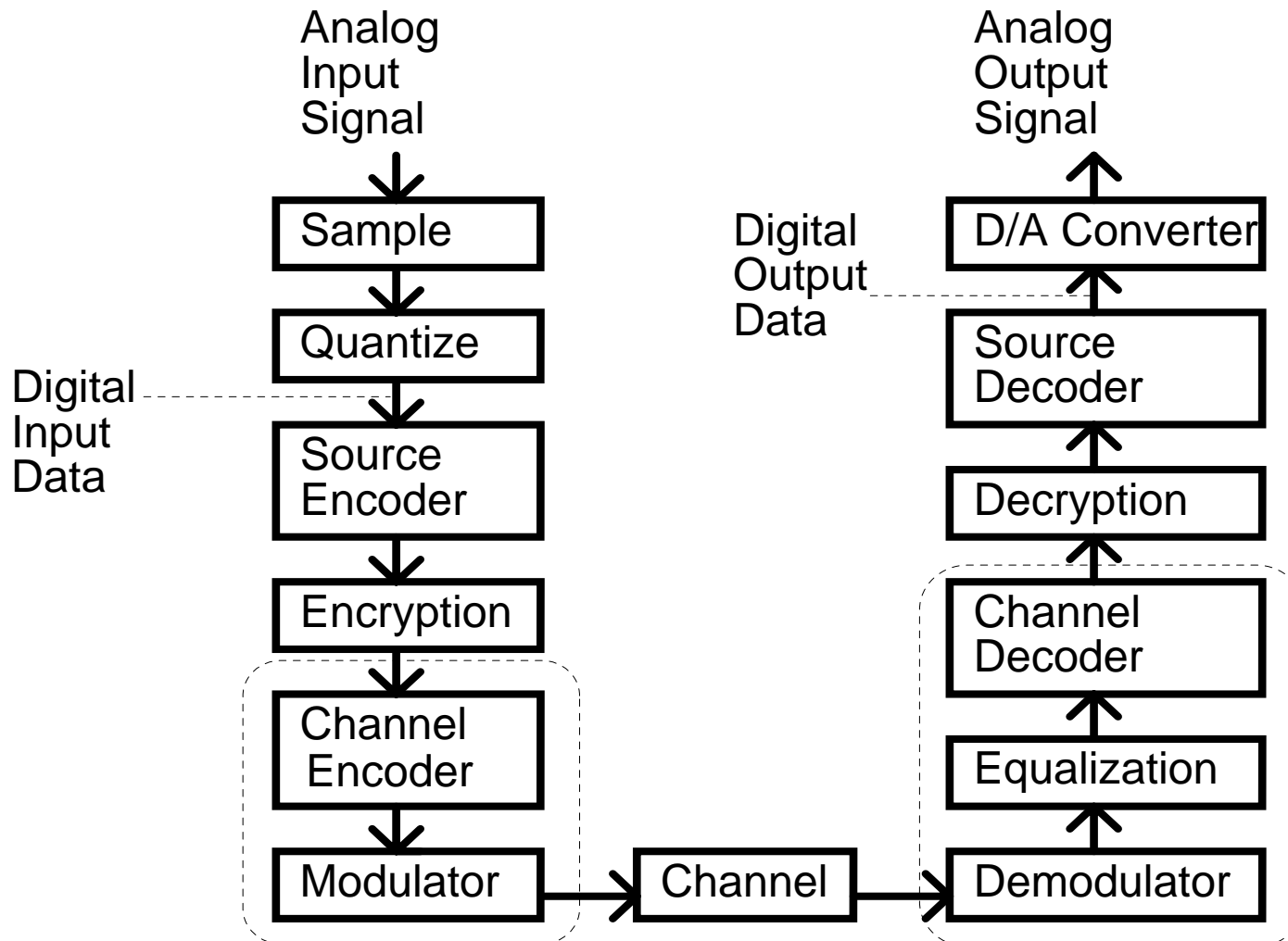


Analog and Digital Communications

Block Diagram of Digital Communications System



Analog and Digital Communications



Overview of Upcoming Lectures/Chapters



Analog and Digital Communications

- Sampling (Lecture 5 – Section 5.1)
 - Needed for analog information source
- Analog Pulse Modulation (Lecture 6 – Sections 5.2-5.3)
- Digital Pulse Modulation (Lectures 7-9 – Sections 5.4-5.9)
 - Includes quantization for analog information source
- Choosing the proper pulse or ‘pulse shaping’ – Lectures 10-12 (Sections 6.1-6.8)
 - Includes intersymbol interference and equalization
- Sinusoidal modulation (Lectures 13-21 – Chapter 7)

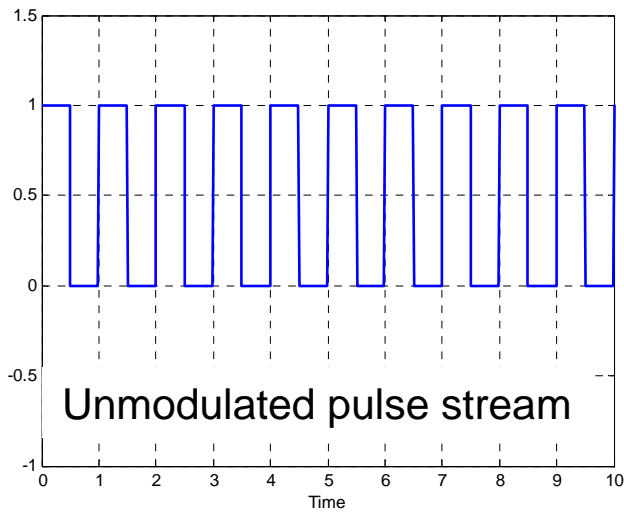


Modulation

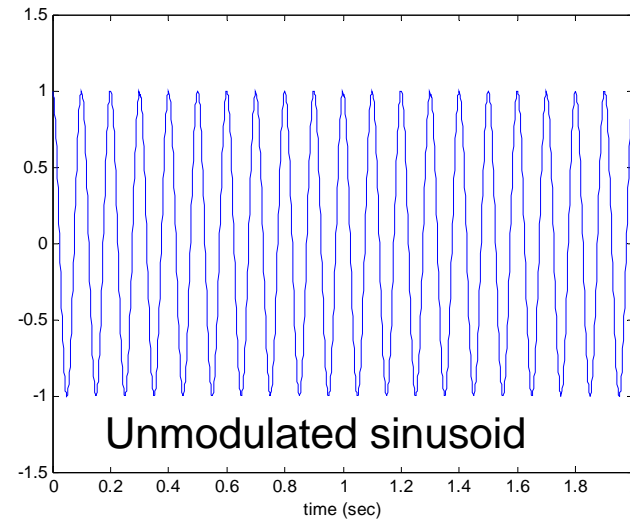
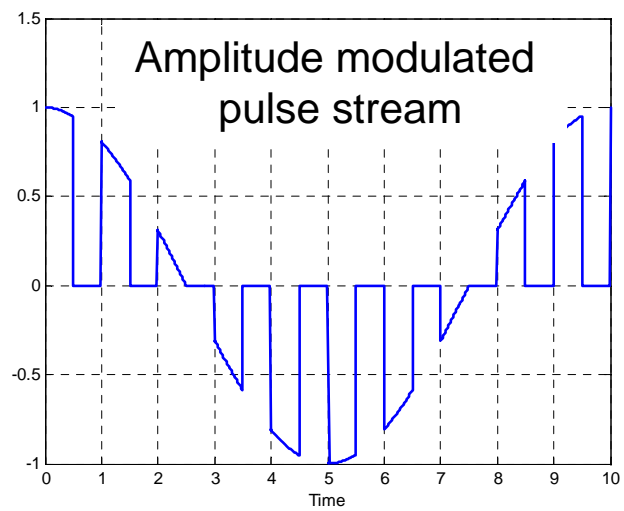
- In communication systems, information is conveyed by *modulating* (i.e., changing some parameter of) a carrier
- The carrier is typically either
 - Pulse train
 - Sinusoid
- Modulation can either be
 - Analog – an infinite number of possible messages
 - Digital – a finite number of possible messages



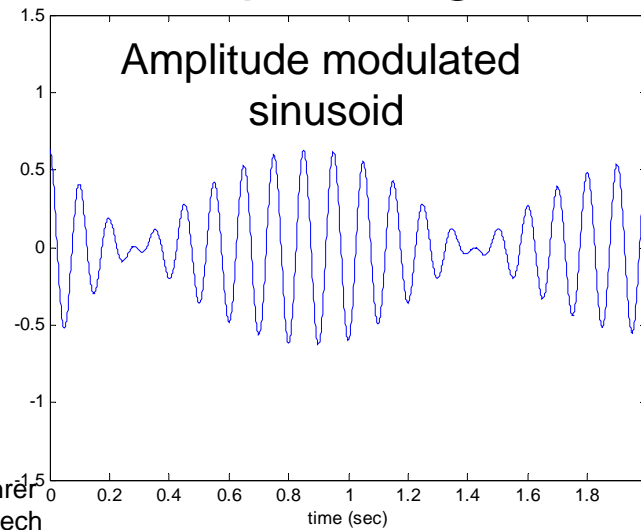
Modulation



Baseband signal



Bandpass signal





Baseband Communications

- Over the next few weeks we will study baseband communications techniques that modulate a pulse train using the message signal

- Pulse Amplitude Modulation (PAM)
- Pulse Width Modulation (PWM)
- Pulse Position Modulation (PPM)
- Pulse Code Modulation (PCM)

Pulse modulated
by analog or
digital signal

Requires conversion to
digital signal
prior to modulation



Analog Information

- Regardless of the type of system (analog or digital; bandpass or baseband) the original information source can be either analog or digital
- Traditional communication systems focused on the transfer of analog information
 - Examples: voice or video
- If the system uses continuous pulse modulation, the analog information signal must be sampled (made discrete in time)
- If the system is digital, the analog information signal must be sampled and quantized (made discrete in time and amplitude)



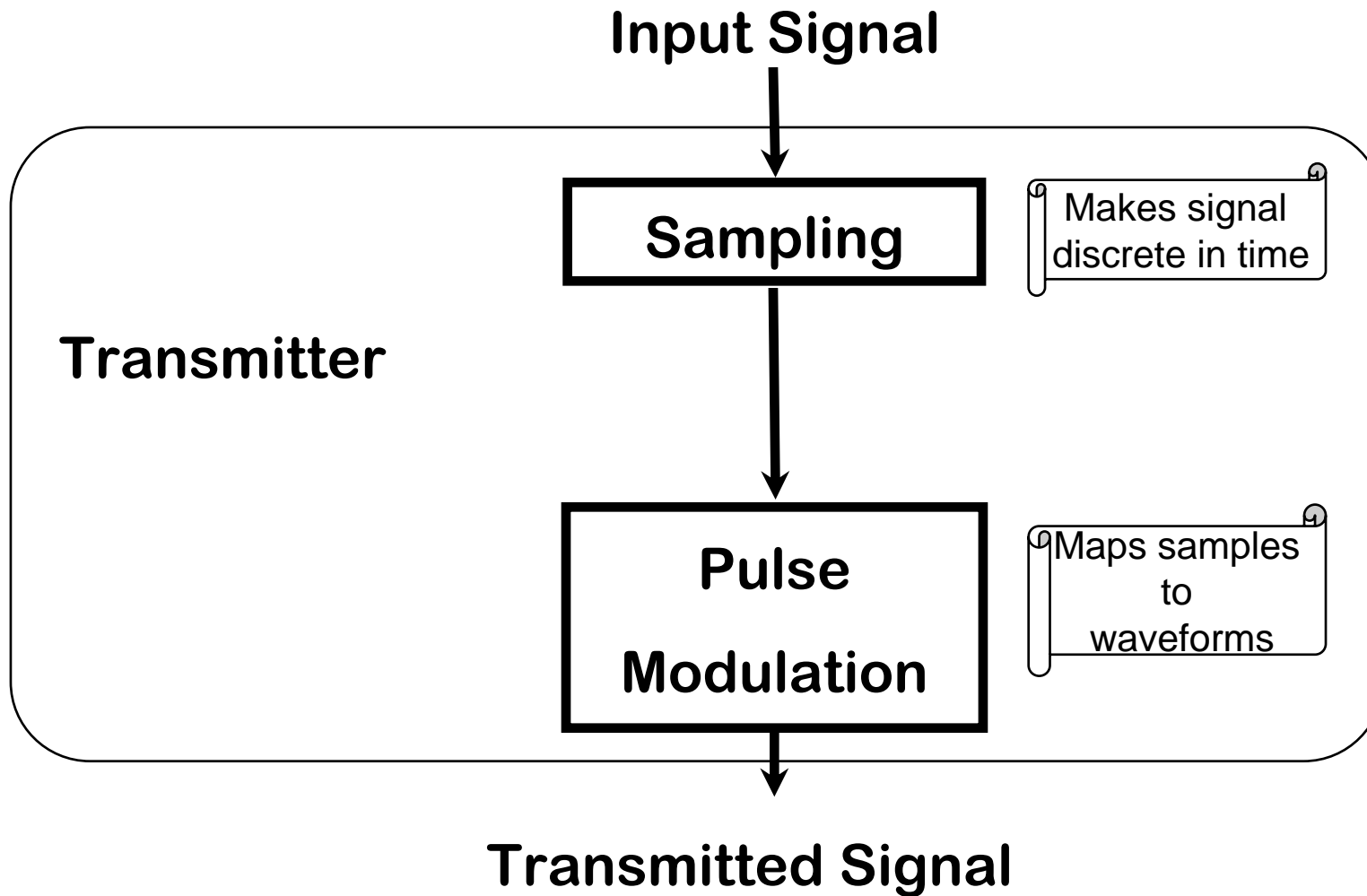
Digital Information

- With the rise of the internet, very often the ‘source’ of information is simply a computer which inherently uses digital information
- Such digital information fits naturally with a digital communication system
- No analog-to-digital conversion is necessary
- There may be conversion from binary to M -ary information within the digital communication system

Basic Structure of PAM / PPM / PWM



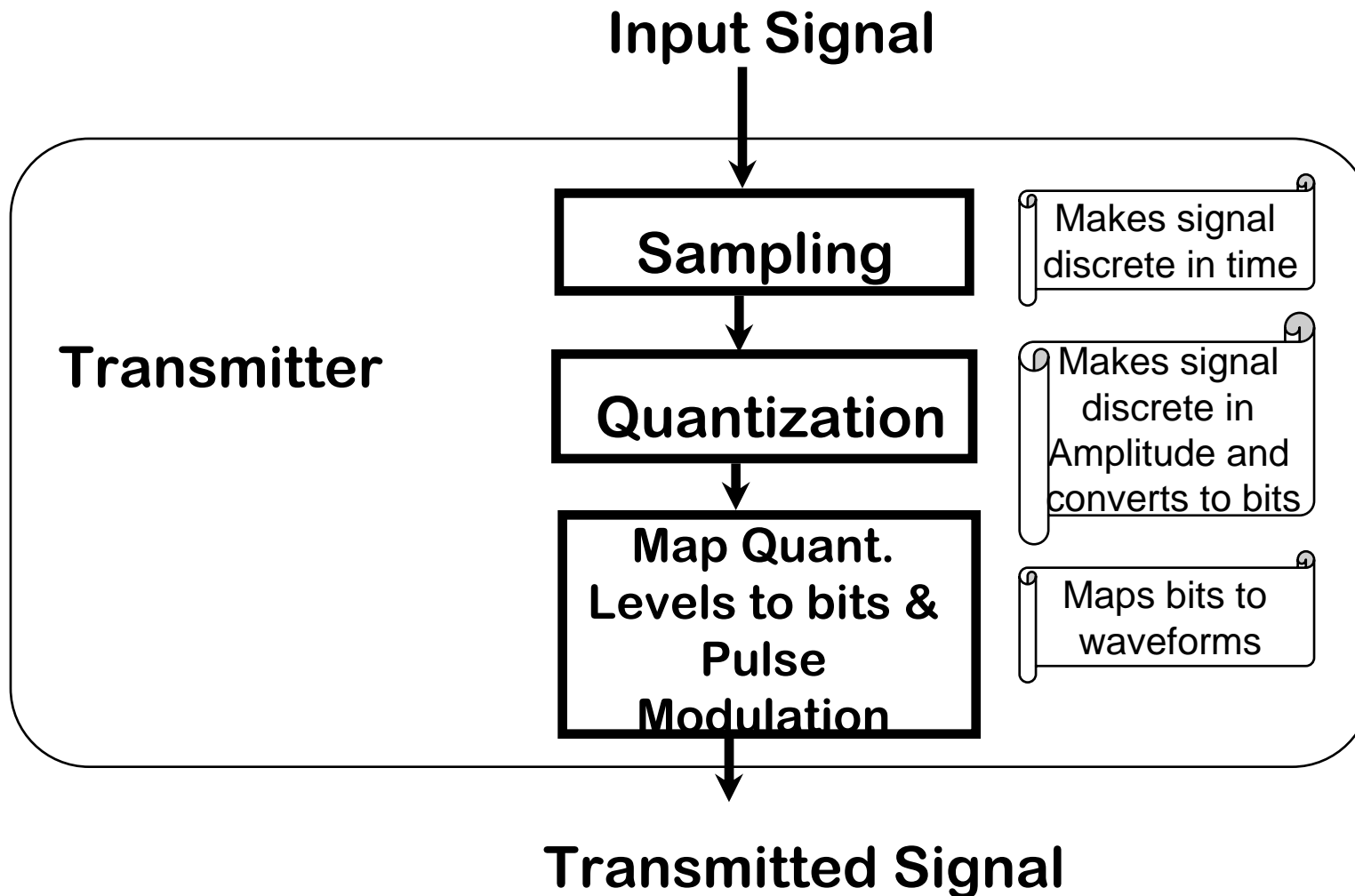
Analog and Digital Communications



Basic Structure of PCM



Analog and Digital Communications





PAM / PWM / PPM vs PCM

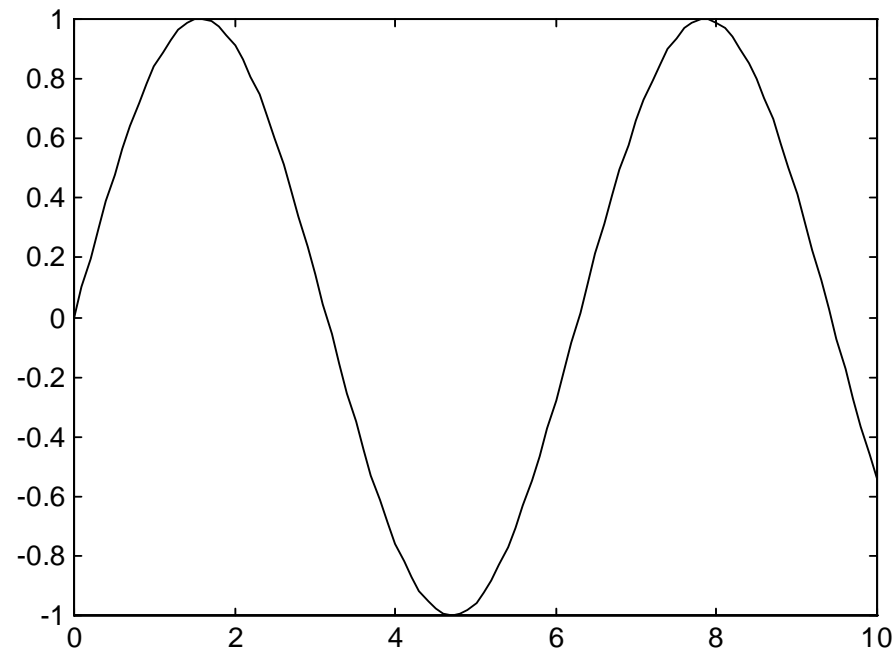
- PAM/PWM/PPM are systems where the information signal is typically discrete in time but not necessarily in amplitude (thus not truly digital)
 - Infinite number of waveforms can be sent
 - Useful for time multiplexing multiple signals
 - Noise readily degrades information
 - Not particularly common
 - PAM is the first step in PCM, thus is useful for study of PCM
- PCM are systems where the information must be discrete in time and amplitude
 - Finite number of waveforms can be sent (i.e., digital)
 - Requires both sampling and quantization
 - Can be made more robust to noise
- Both require sampling, thus we study sampling first

Digital Representation of Analog Signals



Analog and Digital Communications

- Analog signals (e.g. voice, video) are continuous in time and amplitude:

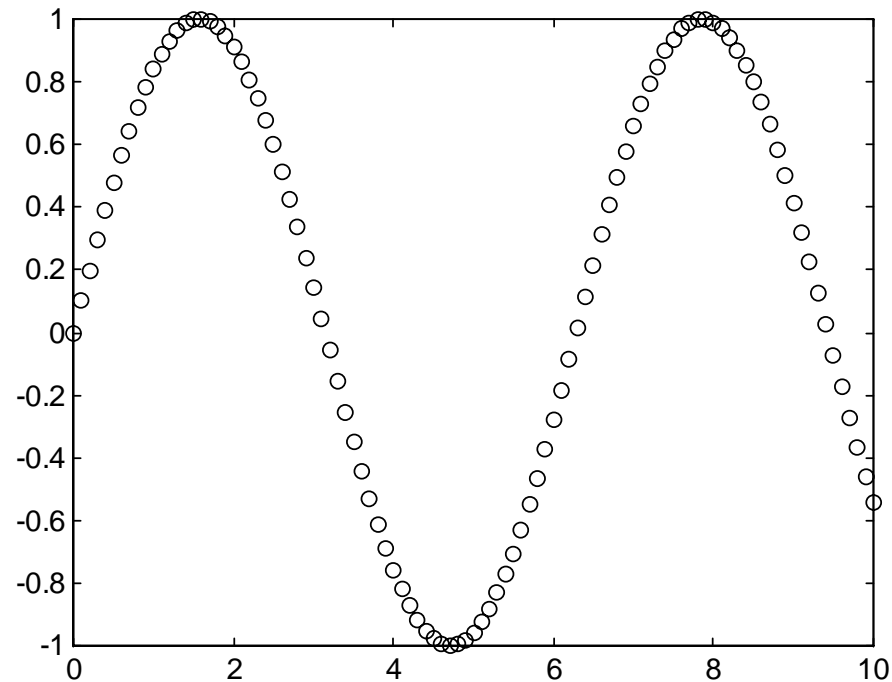


Digital Representation of Analog Signals



Analog and Digital Communications

- Sampling analog signals makes them discrete in *time*:

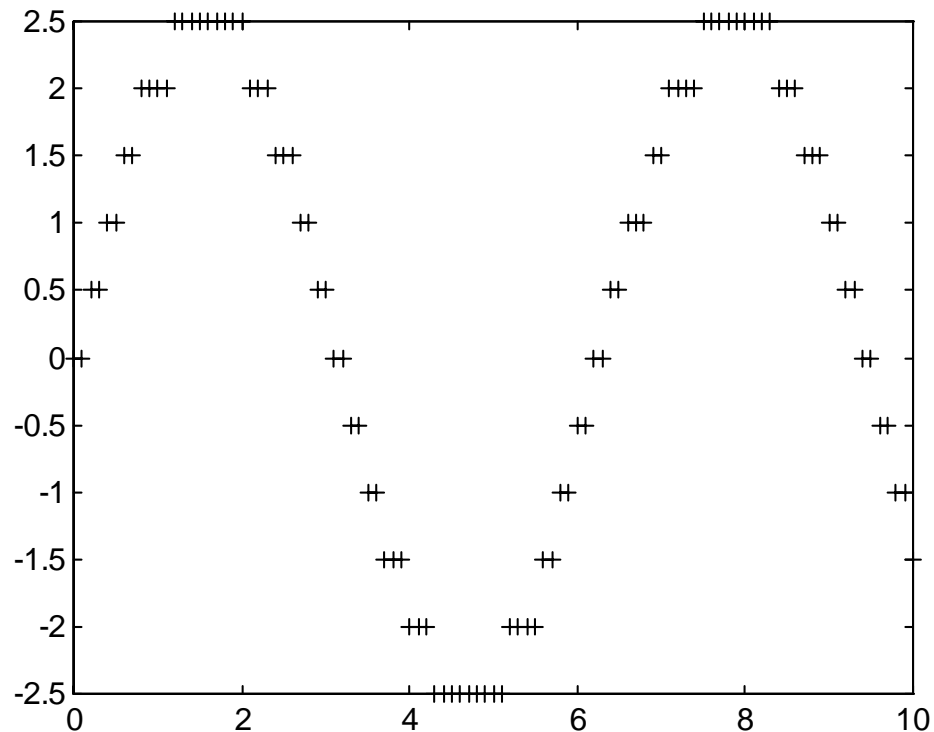


Digital Representation of Analog Signals



Analog and Digital Communications

- Quantization of sampled analog signals makes the samples discrete in amplitude:



- **The number of discrete amplitude levels is directly related to the number of bits we are willing to use to represent each sample. Thus, we trade-off bit rate and fidelity**

Digital Representation of Analog Signals



Analog and Digital Communications

- If done properly, sampling introduces no distortion into the signal
- Quantization does introduce distortion
 - There is a tradeoff between distortion and bandwidth requirements
 - More bits per sample → less distortion
 - Fewer bits per sample → lower bandwidth requirements
- We will consider sampling in the next lecture.
- We will discuss quantization next week.



Summary

- In this lecture we have briefly overviewed some of the basic concepts in digital communications including
 - Analog vs Digital communications
 - Baseband vs. Bandpass signals
 - Pulse Amplitude Modulation, Pulse Position Modulation, Pulse Code Modulation
- Next lecture we begin to study digital communications in detail by studying sampling