ECEN 449 – Microprocessor System Design

Pulse Modulation

Objectives of this Lecture Unit

- Get familiar with pulse based communication
  - Different pulse modulation schemes
  - Applicability of these to different design scenarios

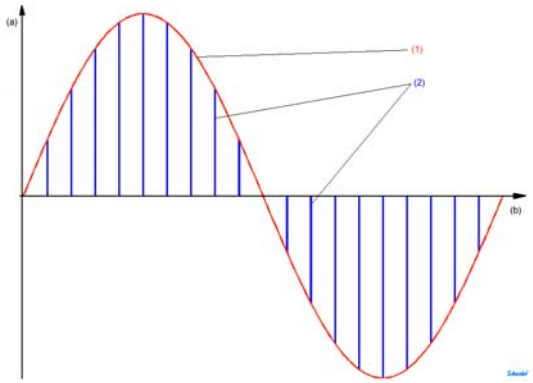
Modulation and Communication

- When we have to communicate information over a medium, we typically
  - Modulate the signal before transmission by the sender
  - Then demodulate the signal at the receiving end to retrieve the information
- Why do this?
  - The modulated signal can be transmitted with low loss
  - Interference with other communications is avoided
  - Receiving antennas can be made quite small
  - Multiple signals can be multiplexed
- Typical modulation schemes – amplitude, frequency, phase, code

What is Pulse Modulation

- Pulse modulation involves communication using a train of recurring pulses.
- Common means of modulating data in digital communication
  - Key advantage is that I can send multiple signals using Time Division Multiplexing
- There are several pulse modulation techniques
  - Pulse Amplitude Modulation
  - Pulse Width Modulation
  - Pulse Code Modulation
  - Pulse Position Modulation

Pulse Amplitude Modulation (PAM)

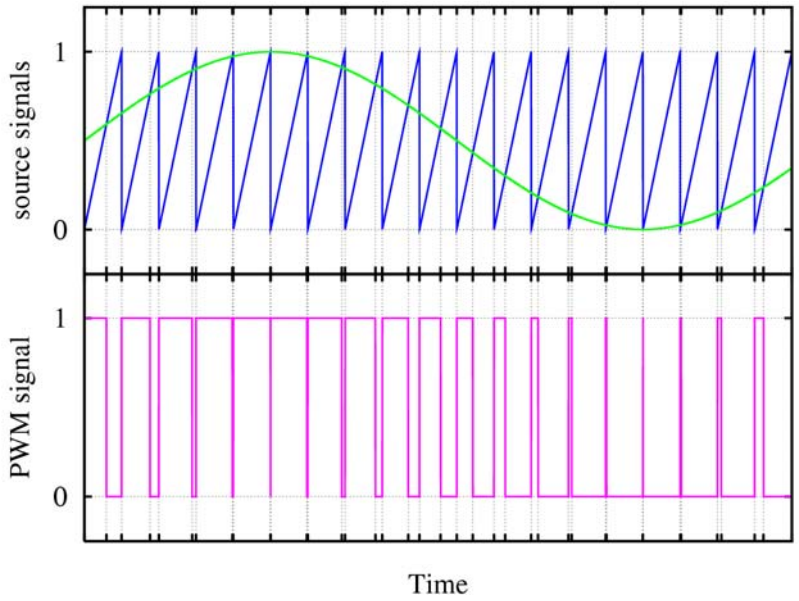


- Message information encoded in the form of the amplitude of pulses.
- Pulse transmitted every T seconds, amplitude of the pulse is quantized to Q values, for PAM-Q.
- Example shown above is the PAM encoded (blue) signal corresponding to a sinusoidal (red) input.

Pulse Amplitude Modulation

- Examples:
  - Telephone modems faster than 300 bits/sec use PAM
  - Ethernet uses PAM.
    - 100BASE-T2 as well as 1000BASE-T use PAM-5
- To achieve full-duplex operation, we can do one of two things
  - Use some kind of carrier sensing (as in Ethernet, which uses Carrier Sense Multiple Access)
  - Or use some flavor of Time Division Multiple Access.

Pulse Width Modulation (PWM)



- Here we modulate the width of pulses (or their duty cycle) to convey information.
- Example above shows the PWM signal (bottom picture) corresponding to a sinusoidal signal (top picture). The PWM signal is typically generated using a sawtooth waveform and a comparator

Pulse Width Modulation

- Popular in digital circuits
  - Generation of PWM signal easy, demodulation typically uses counters and digital-to-analog converters (DACs)
- Three flavors of PWM
  - Pulse center is in the center of the time window
  - Pulse leading edge coincides with leading edge of time window, and the trailing edge is modulated
  - Pulse trailing edge coincides with trailing edge of the time window, and the leading edge is modulated
- Applications
  - Voltage regulators
  - Class D audio amplifiers (feed PWM signal to speaker after filtering to block carrier), which are highly efficient.

Pulse Code Modulation (PCM)

- Means to represent an analog signal in a digital manner
- Sample the analog signal every T seconds, into P values.
  - P is usually a power of two.
- Transmit $\log_2 P$ bits every T seconds (can do compression also)
- Typically sampling is done via an ADC (Analog to Digital Converter).
- Many such PCM datastreams can be multiplexed on to a high bandwidth medium in a Time Division Multiplexing (TDM) fashion.
  - Example voice signals sent over a phone network, or data sent over an optic fiber

Pulse Code Modulation

- Demodulation is done by collecting $\log_2 P$ entries, and feeding them to a Digital to Analog Converter (DAC).
  - Possibly need to do decompression before this.
- Applications
  - Digital audio in computers and CDs
  - Straight PCM not used in video standards (DVD, DVR) since it needs a high bitrate.
- Some PCM techniques transmit the difference between two adjacent samples, rather than the raw sample values. This effectively compresses the transmitted data.

Pulse Position Modulation (PPM)

- Suppose I want to send one of M message bits every T seconds.
- PPM modulates the message by transmitting a single pulse in one of 2^M time slots
  - Each time slot is $T/2^M$ seconds long
- Problematic for communication media where multi-path interference dominates
  - Urban environments
  - Media which exhibit frequency-dependent fading

Pulse Position Modulation

- Commonly used in communication over optic fibers
  - Multi-path fading is minimal
  - No need for Phase-Locked Loop at the receiver (i.e. can use non-coherent receiver). Coherent receivers are prohibitively expensive for optical communication systems.
- Also used in communication for RC aircraft/cars etc.
  - The demodulation is very simple and easy, allowing for a low-cost receiver.
  - Fancier RC systems use PCM (more expensive)

Pulse Frequency Modulation (PFM)

- Conceptually, we could do PFM as well.
- Pulses of constant amplitude are generated, at a rate which is modulated by the signal frequency.
- Problem: arrival rate of pulses is random, and hence demodulation is hard.
- Therefore PFM is mostly a curiosity.