Sampling, A/D and D/A

Part 8e of
"Electronics and Telecommunications"
A Fairfield University E-Course
Powered by LearnLinc

Module: Digital Electronics
(in two parts)

- Text: "Digital Logic Tutorial ," Ken Bigelow, http://www.play-hookey.com/digital/
- References:
  - "Electronics Tutorial", part 10 (Thanks to Alex Pounds) http://doctord.dyndns.org:8000/courses/Topics/Electronics/Alex_Pounds/Index.htm
- Contents:
  - 7 – Digital Electronics 1
    - 5 on-line sessions plus one lab and a quiz
  - 8 – Digital Electronics 2
    - 5 on-line sessions plus one lab and a quiz
- Mastery Test part 4 follows this Module

Section 7: Digital Electronics 1

- Logic gates and Boolean algebra
- Truth Tables
- Binary numbers
- Memory
- Flip-Flops

Section 8: Digital Electronics 2

- Clocks and Counters
- Shift Registers
- Decoders
- Multiplexers & Demultiplexers
- Sampling

- **MT4**

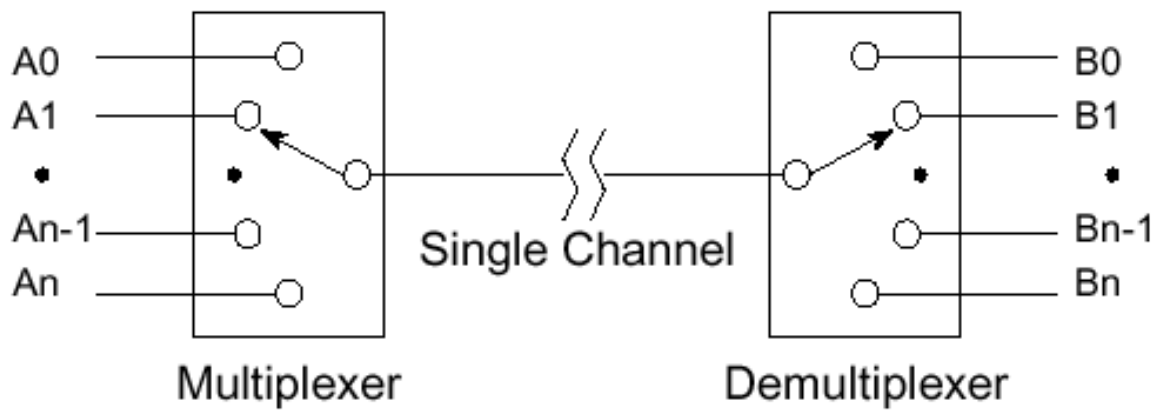
Section 8 Schedule

Session 8a	04/02	Clocks and Counters	"Hookey": "Counter" pages Alex Pounds: Part 27
Session 8b	04/09	Shift Registers	"Hookey": "Register" pages
Session 8c	04/14	Decoders	"Hookey": Decoders and Demultiplexers
Session 8d	04/16	Multiplexers and Demultiplexers	"Hookey": Multiplexers, Decoders and Demultiplexers
Session 8e	**04/21**	**Sampling (A/D & D/A)**	**Notes**
Session 8f (Quiz 8 due 04/27)	04/23	Review for Quiz 7	
Session 8g	04/28	Quiz Results	
Session 8h (Lab - 05/03, Sat.)	04/30	MT4 Q&A	
MT4 (Sat, Cheshire)	05/10		
MT4 Results	05/12		

Mux and Demux Review

4.4 Multiplexer

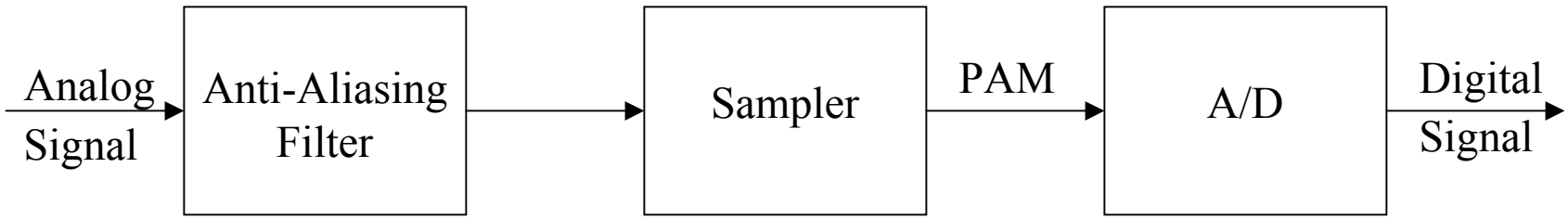
- Multilexer - A ***data selector*** that selects one of may inputs to appear on a single output line
- Demultiplexer - A ***data distributor*** that takes a single input line and routes it to one of several output lines



Why Digital?

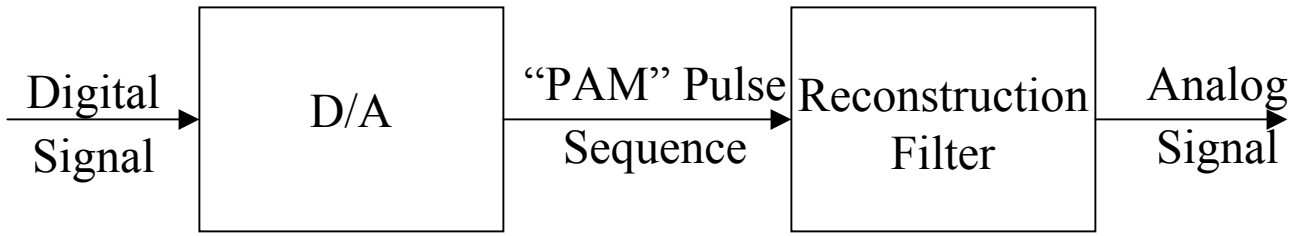
- Transmit signals long distances with almost no loss in fidelity
- Use rapidly evolving digital logic technology
  - Low cost
  - High capacity (speed allow multiplexing)
- Integration of switching and transmission
- Allows use of Digital Signal Processing
- Ease of encryption

Analog to Digital Conversion



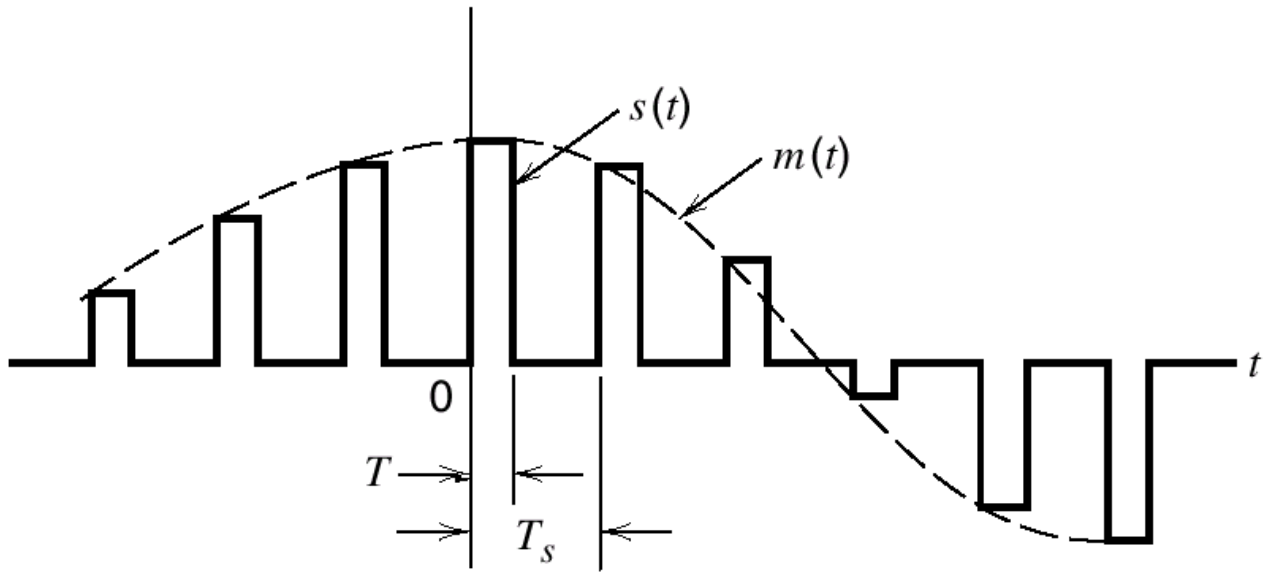
- **Analog Signal:** A continuous electrical signal
- **Aliasing:** Confusion of high and low frequencies if sampling is too slow
- **Sampling:** The process of approximating an analog signal by a sequence of narrow pulses
- **A/D:** Representing the "strength" of a pulse by a binary number

Digital to Analog Conversion



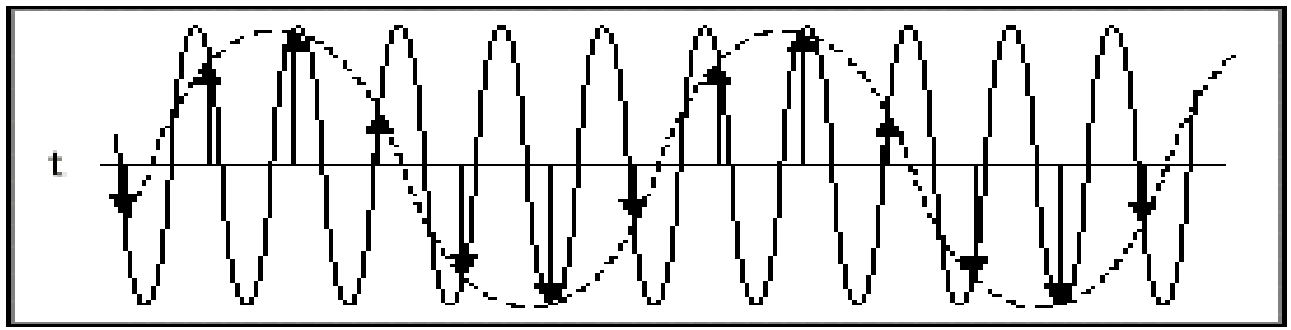
- **Digital Signal:** A sequence of binary numbers representing an analog signal
- **PAM:** Pulse Amplitude Modulation - A sequence of pulses with strengths corresponding to the analog signal
- **Reconstruction:** Averaging out a "Discrete-Time" pulse sequence to reproduce the original analog signal

Sampling: Pulse Amplitude Modulation



- Each pulse takes on the value of the signal at the moment of the pulse
- If the pulse rate ($f_s = 1/T_s$) is fast enough, the original signal can be recovered without distortion.

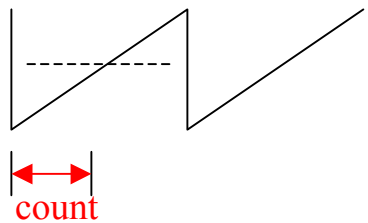
Aliasing and Nyquist



- Sampling slower than the Nyquist rate ($f_s > 2*f_{max}$) causes a high frequency signal to be interpreted as a low frequency signal.
- An “anti-aliasing” filter (low-pass) is used to insure that there is no energy above ½ the sampling rate before passing the signal to the sampler and the signal is recoverable.

Analog to Digital Conversion

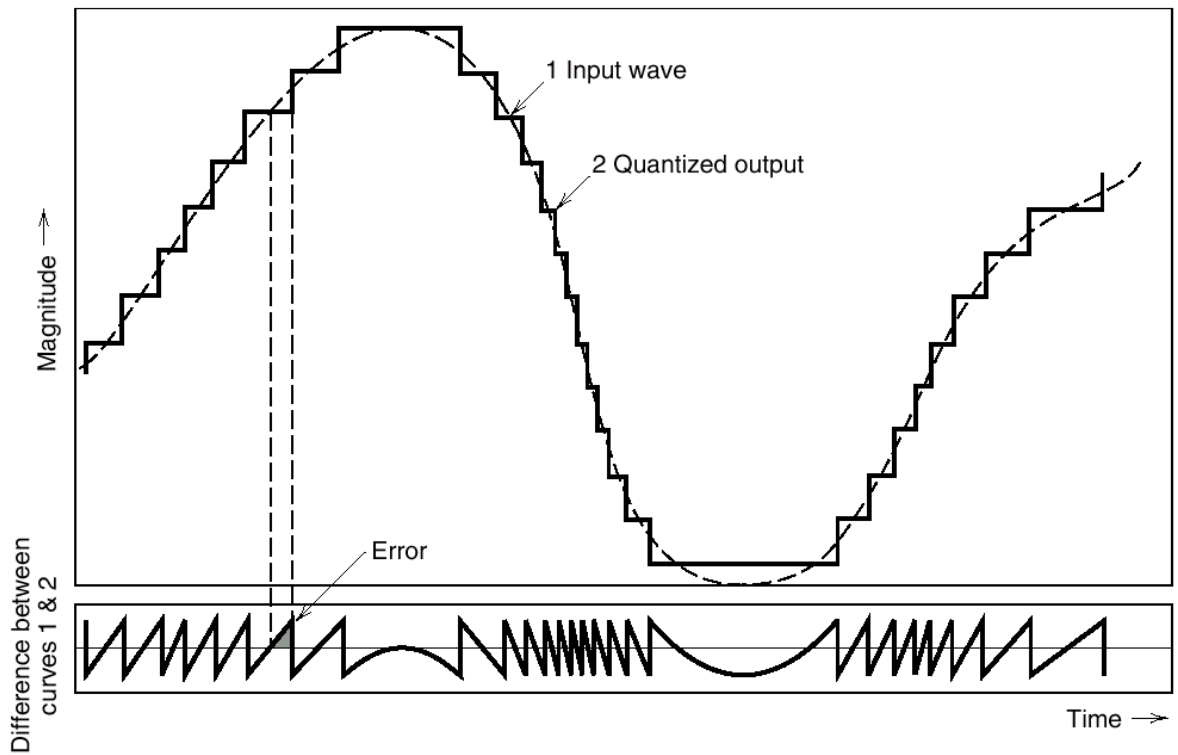
- Flash (or parallel)A/D
  - Very fast
  - Either low resolution (8-bits) or very expensive
- Successive approximation A/D
  - Determines the MSB first
  - Repeatedly refines the representation
  - Accurate (high resolution) but slow
- Counting A/D: Uses a ramp signal and a high speed counter to determine the time that the ramp exceeds the signal value



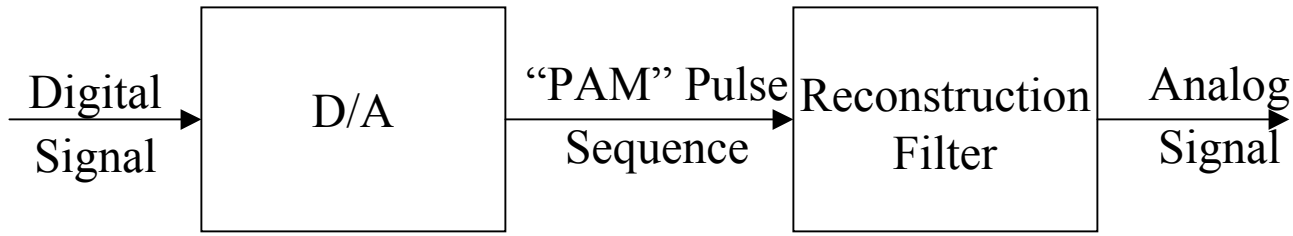
- Over-Sampled (Sigma-Delta) A/D
  - Flash encodes a low-resolution value at high speeds
  - Uses a digital filter (anti-alias) to lower the bandwidth
    - Allows reduction of the sampling rate
    - Improves the resolution (number of bits)

Digital Distortion
(Called noise)

- Each additional bit reduces the voltage error by a factor of 2
- That's a 6 dB improvement
- Your 16 bit CD has about 96 dB dynamic range



Digital to Analog Conversion



- Reverses the A/D sequence
- D/A: generates a PAM pulse sequence where each pulse magnitude corresponds to the value of the corresponding digital number
- Reconstruction filter: Almost identical to the Anti-Aliasing filter used in A/D. Smoothes out the pulse sequence to reproduce the original signal.

Applications

- North American Telephony (64 kbits/sec)
  - Sampling rate = 8 kHz (3 dB: 3.3 kHz , f_{max}: 3.8 kHz)
  - μ255 (logarithmic), 8-bit words (256 levels)
- CD Audio
  - Sampling rate = 44.1 kHz per channel (3 dB: 20 kHz, f_{max}: 21 kHz) (note: DAT = 48 kHz - Prof Audio = 96 kHz, 24 bit)
  - Linear 16-bit words
- PC sound card:
  - Sampling rate = 8, 16, 11.025, 22.05, 44.1 kHz
  - 8 or 16 bit word size

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