**Computer Interface Terminology**

- **D/A converter (or DAC):** Digital to Analog converters are used to “map” a finite number of ______values onto a physical output range (usually a ____________).
- **A/D converter (or ADC):** Analog to Digital converters are used to convert continuous physical signals (usually ________) into equivalent ________ or binary numbers.

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**Theoretical 1 Bit A/D Converter**

**Digital (Binary) Output**

- Analog Voltage Input

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**Theoretical 3 Bit A/D Converter**

**Digital (Binary) Output**

- Analog Voltage Input

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**Offset Binary 3 Bit A/D Converter**

**Digital (Binary) Output**

- Analog Voltage Input

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**Computer Interface Terminology**

- **Bits:** The number of digits in a binary number. A 1 bit binary number is either 0 or 1, a 2 bit binary number is either 00, 01, 10, or 11, etc. An N bit binary number can have _______ different values.
- **Binary:** Binary numbers are in base 2, only allowable digits are 0 and 1.
- **Hex (or hexadecimal):** Digital values expressed in base 16. Note that 1 hex digit is exactly 4 binary digits.
Computer Interface Terminology

- **Range**: The difference between the min and max analog voltages that can be accurately converted to binary. Common ranges are ____ volts (____ range), 0 to +10 V (10 V range), and ____ volts (____ V range).
- **Resolution**: Amount of analog voltage equivalent to a single binary bit = range / \(2^N\) – resolution of 12 bit A/D with a ± 5 V range.

ADC Formulas - Bipolar Input

- Bipolar input: \(-V_{REF} \leq V_{IN} \leq +V_{REF}\)
- midpoint or nominal voltage, \(V_{nom} = \frac{\text{digital value}}{2^n}\)
- the resolution is centered about the nominal value, so \(V_{in} = V_{nom} \pm \frac{1}{2} \left( \frac{V_{REF} - (-V_{REF})}{2^n} \right)\)

ADC Formulas - Unipolar Input

- Unipolar input: \(0 \leq V_{IN} \leq + V_{REF}\)
- midpoint or nominal voltage, \(V_{nom} = \frac{\text{digital value}}{2^n}\)
- the resolution is centered about the nominal value, so \(V_{in} = V_{nom} \pm \frac{1}{2} \left( \frac{V_{REF} - 0}{2^n} \right)\)

Example #1

- Given a 12 bit, ±5V ADC, what is the nominal voltage for a digital value of 1000?
- What range of input voltages would all be converted to the digital value of 1000?

Example #2

- Given a 10 bit, 0 to 10 V ADC, what is the nominal voltage for a digital value of 763?
- What range of input voltages would all be converted to the digital value of 763?

Example #3

- Given a 12 bit, ±10V ADC, what digital value would \(V_{in} = +5.423V\) convert to?
- Given an 8 bit, 0 to 5V ADC, what digital value would \(V_{in} = 1.234V\) convert to?
Computer Interface Terminology

- **Multiplexer**: A switching device to connect different analog signals to the same ADC.
  - 8 or 16 different analog inputs common,
  - single-ended or differential inputs used,
  - inputs often amplified near multiplexer.

**Single-Ended Multiplexer**

All 16 inputs must have the same ground (common).

From http://www.cyberresearch.com/cyb/cybtechtut.htm

**Differential Input Multiplexer**

Must be careful with these.

All 8 inputs can have different grounds (commons).

From http://www.cyberresearch.com/cyb/cybtechtut.htm

**National Instruments**

**PCI-6221 M-Series Board**

- 16 bit resolution (~0.3 mV/bit)
  - accuracy specs on manufacturer’s datasheet
- ±10 volts full scale input (bipolar)
- offset binary coding
- 8 channel differential input multiplexer
- maximum single or multi-channel sampling rate of 250 kS/s (250,000 samples/sec)

**Sources of Additional Info**

- Omega – Transactions on Data Acq.
  - www.omega.com/literature/transactions/volume2/analogio.html
  - Locally stored at 360 website (Weblinks)
- CyberResearch
  - www.cyberresearch.com/Members/DADesign.html
- EE Lab at University of Pennsylvania
  - www.ee.upenn.edu/rca/software/Labview/daqlvOverview.html
Chapter 5
Discrete Sampling and Analysis

Sampling rate affects Accuracy

Input @ 10 rad/s, Sample @ 20 Hz
Sample @ 20 Hz

Input @ 10 rad/s, Sample @ 15 Hz
Sample @ 15 Hz

Input @ 10 rad/s, Sample @ 10 Hz
Sample @ 10 Hz

From http://www.cyberresearch.com/cyb/cythechtut.htm
Data Acquisition

How fast should you sample?

- Nyquist Theorem: \[ \text{as fast as the highest frequency component of your input signal!} \]
  - or you will get “_______________” - samples of a high frequency signal “look” like a low frequency
  - In many (but not all!) applications, sample \[ \text{times the highest frequency component of input signal!} \]

How do you prevent aliasing?

- \[ \text{(at least 2x highest frequency in input)} \]
  - can lead to “too much” data!

- to “attenuate” (or reduce) amplitude of high frequency signals
  - a simple RC low-pass filter is often included on data acquisition boards!

“Anti-aliasing” Filters
Signal Express - Configuration

Brief Intro to Spectrum Analysis

- Analysis relates time and frequency domains
- Any \( \text{(time domain)} \) can be represented by sine and cosine waves \( \text{(frequency domain)} \)

Where is spectral analysis used?

- Monitoring
  - Roller bearing faults will generate vibration signals at characteristic multiples of the shaft speed
- "Spikes" in the frequency domain often indicate system's natural frequencies
  - Generally want to avoid "exciting" the system at these frequencies

Sample Data Set #1

- 1024 data points collected at 1000 Hz sampling rate (using A/D converter)

After Fast Fourier Transform (FFT)

- "Aliasing" of the ~30 Hz signal appears at ~970 Hz
- "Aliasing" of the ~100 Hz signal appears at ~900 Hz
Sample Data Set #2
1024 data points collected at 1000 Hz sampling rate (using A/D converter)

After Fast Fourier Transform (FFT)
First Data Set, 1024 Data Points @ 1000 Hz
"Folding" Frequency or Nyquist Limit of 500 Hz

Lower Half of FFT Data
First Data Set, 1024 Data Points @ 1000 Hz
"most" of the original signal is
"some" of the original signal is
"noise" and artifacts from FFT process