This Lecture

- Signal Characteristics
  - Analog vs. Digital.
- Binary number system
**Typical Instrumentation System**


**Data Acquisition and Control**

- Computers are nearly always in the middle of any instrumentation system. They provide a complete interface between sensors and output devices.

*Digital control system with analog I/O*
Data Acquisition Systems

Analog Versus Digital

**Analog**
Continuous signal that can be quantized using an infinite number of amplitudes.

**Digital**
Discrete numbers that represent instantaneous amplitudes of an analog signal, generally measured at equally spaced points in time.
Analog Representation of Sound

Magnified vinyl phonograph record grooves viewed from above:

When viewed from the side, channel 1 goes up and down, and channel 2 goes side to side.

Analog to Digital Recording Chain

- **Microphone** converts acoustic to electrical energy. It’s a *transducer*.
- Continuously varying electrical energy is an analog representation of the sound pressure wave.
- An ADC (Analog to Digital Converter) converts an analog signal to an equivalent digital representation.
- A DAC (Digital to Analog Converter) converts a digital representation into an analog signal – like for your headphones.
Review - Properties of a Sinusoidal Waveform

The general form of sinusoidal wave is:

\[ v(t) = V_m \sin(\omega t + \theta) \]

where:
- \( V_m \) is the amplitude (volts peak);
- \( \omega \) is the angular frequency (radian/sec), also \( 2\pi f \);
- \( \theta \) is the phase shift in degrees or radians.

Frequency Review

\[ T = \frac{1}{f} \]

Period \( \approx 6.28 \) seconds, Frequency \( = 0.1592 \) Hz
Amplitude Review

Peak: Blue 1 volt, Red 0.8 volts
Peak-to-Peak: Blue 2 volts, Red 1.6 volts
Average: 0 volts

Phase Shift Review

\[ y_{\text{blue}} = \sin(t) \]
\[ y_{\text{red}} = 0.8 \sin(t + 1) \]

Red leads Blue by 57.3 degrees (1 radian)

\[ \phi = \frac{1}{6.28} \times 360^\circ = 57.3^\circ \]
Understanding “Digital” for Instrumentation

- I will keep the details to a minimum, but there is a need to understand some of the issues imposed on a measurement system by a computer in the control loop:
  - Binary number system.
  - Conversions between binary and decimal, decimal and binary.
  - Accuracy of conversions, what is gained and what is lost.

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Numbers in Different Systems

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<th>Octal</th>
<th>Hexadecimal</th>
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Positional Number Representation

- **Decimal**
  - $D = d_n...d_2d_1d_0$
  - $V(D) = d_{n-1} \times 10^{n-1} + d_{n-2} \times 10^{n-2} + ... + d_1 \times 10^1 + d_0 \times 10^0$
  - Example: $432_{10} = (4x10^2 + 3x10^1 + 2x10^0)_{10}$

- **Binary**
  - $B = b_n...b_2b_1b_0$
  - $V(B) = b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + ... + b_1 \times 2^1 + b_0 \times 2^0$
  - Example: $1101_2 = (1x2^3 + 1x2^2 + 0x2^1 + 1x2^0)_10$

- **Hexadecimal**
  - $H = h_n...h_2h_1h_0$
  - $V(H) = h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + ... + h_1 \times 16^1 + h_0 \times 16^0$
  - Example: $6e2f_{16} = (6x16^3 + ex16^2 + 2x16^1 + fx16^0)_{10}$

Conversion: Binary to/from Decimal

- **Conversion of binary to decimal:**
  - $V = b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + ... + b_1 \times 2^1 + b_0$
  - $(1101)_2 =$

- **Conversion of decimal to binary:**
  - Use power's of two table or repeated division method.
  - $(857)_{10} =$
Decimal to Binary Conversion Example

Convert \((857)_{10}\)

\[
\begin{array}{ccc}
\text{Remainder} & & \\
857 : 2 &=& 428 & 1 & \text{LSB} \\
428 : 2 &=& 214 & 0 \\
214 : 2 &=& 107 & 0 \\
107 : 2 &=& 53 & 1 \\
53 : 2 &=& 26 & 1 \\
26 : 2 &=& 13 & 0 \\
13 : 2 &=& 6 & 1 \\
6 : 2 &=& 3 & 0 \\
3 : 2 &=& 1 & 1 \\
1 : 2 &=& 0 & 1 & \text{MSB}
\end{array}
\]

Result is \((1101011001)_{2}\)