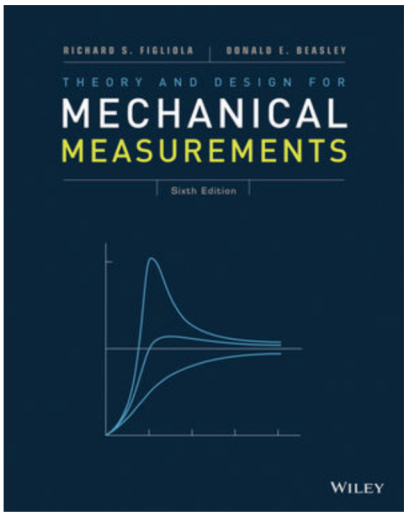


Data Acquisition and Number Systems

Engr325

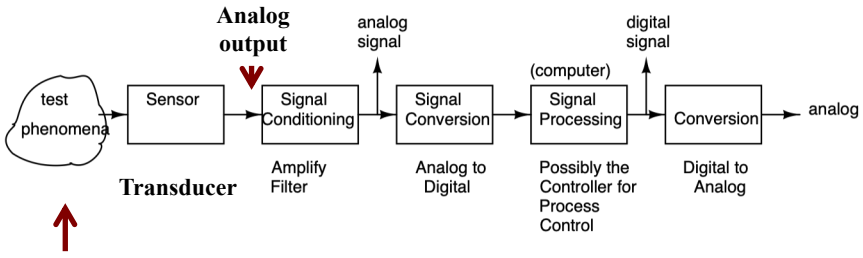
Instrumentation

Dr Curtis Nelson

This Lecture

- Signal Characteristics
  - Analog vs. Digital.
- Binary number system

Typical Instrumentation System

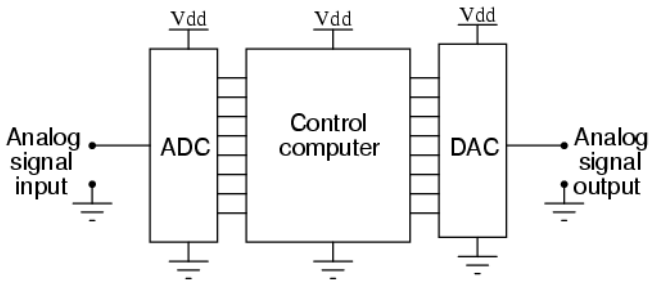


Temperature, Light, Displacement, Position, Vibration, Strain, Angle, Velocity, Acceleration, Flow rate, Pressure, Viscosity, Heart Rate, Etc.

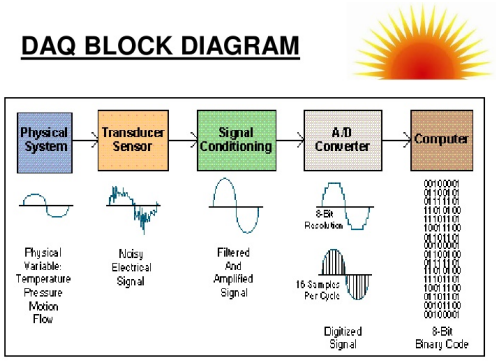
Data Acquisition and Control

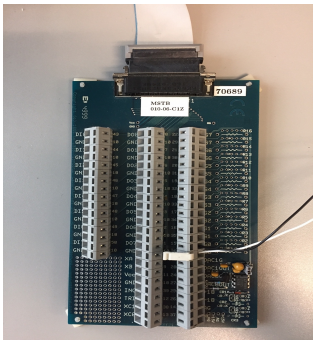
- Computers are nearly always in the middle of any instrumentation system. They provide a complete interface between sensors and output devices.

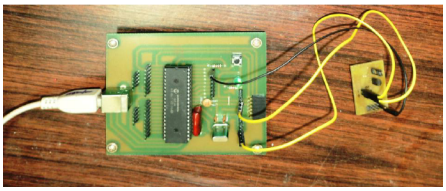
Digital control system with analog I/O



Data Acquisition Systems







Analog Versus Digital

Analog

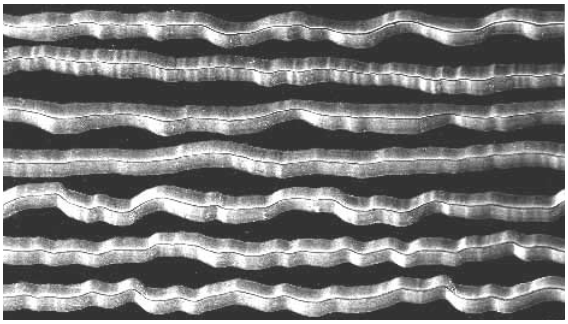
Continuous signal that can be quantized using an infinite number of amplitudes.

Digital

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

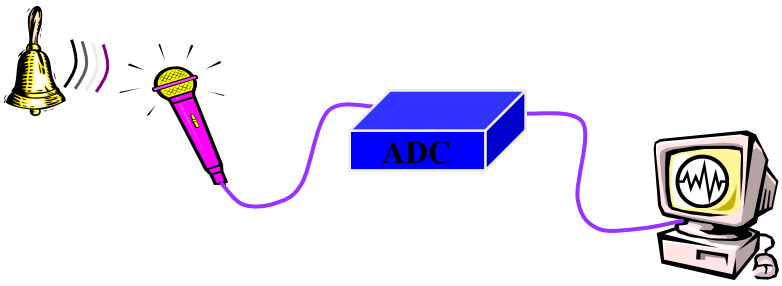
Analog Representation of Sound

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

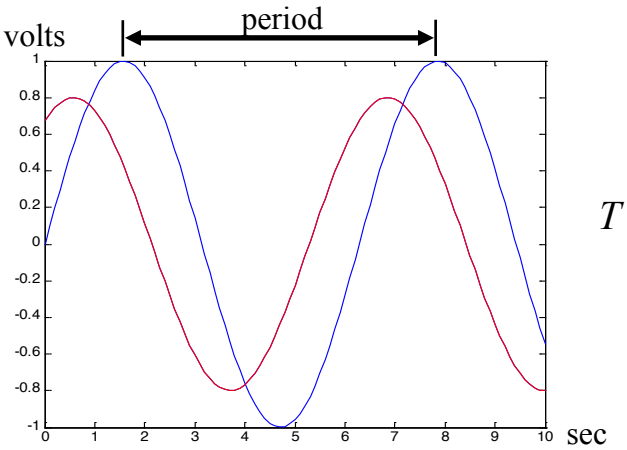
The general form of sinusoidal wave is:

$$v(t) = V_m \sin(\omega t + \theta)$$

where:

- V_m is the amplitude ($volts_{peak}$);
- ω is the angular frequency (radian/sec), also $2\pi f$;
- θ is the phase shift in degrees or radians.

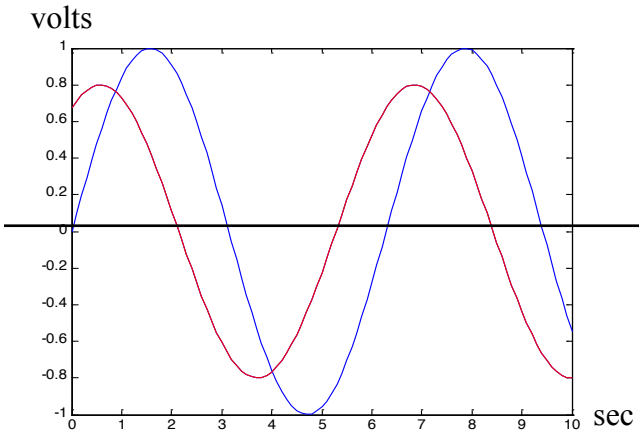
Frequency Review



$$T = \frac{1}{f}$$

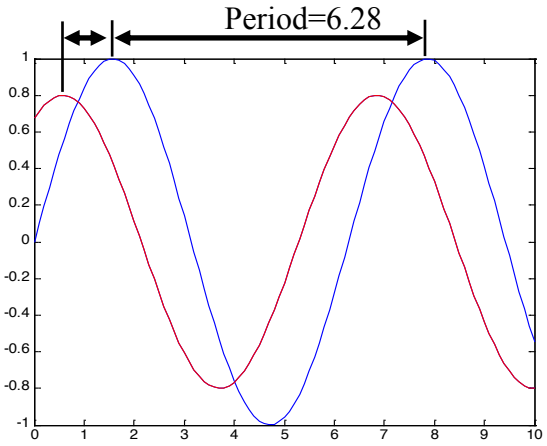
Period ≈ 6.28 seconds, Frequency = 0.1592 Hz

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



$$y_{blue} = \sin(t)$$
$$y_{red} = 0.8\sin(t+1)$$

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 for you to understand 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.

Numbers in Different Systems

Decimal	Binary	Octal	Hexadecimal
00	00000	00	00
01	00001	01	01
02	00010	02	02
03	00011	03	03
04	00100	04	04
05	00101	05	05
06	00110	06	06
07	00111	07	07
08	01000	10	08
09	01001	11	09
10	01010	12	0A
11	01011	13	0B
12	01100	14	0C
13	01101	15	0D
14	01110	16	0E
15	01111	17	0F
16	10000	20	10
17	10001	21	11
18	10010	22	12

Positional Number Representation

- Decimal
  - $D = d_{n-1}d_{n-2}...d_1d_0$
  - $V(D) = d_{n-1} \times 10^{n-1} + d_{n-2} \times 10^{n-2} + ... + d_1 \times 10^1 + d_0 \times 10^0$
  - Example: $432_{10} = (4x10^2 + 3x10^1 + 2x10^0)_{10}$
- Binary
  - $B = b_{n-1}b_{n-2}...b_1b_0$
  - $V(B) = b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + ... + b_1 \times 2^1 + b_0 \times 2^0$
  - Example: $1101_2 = (1x2^3 + 1x2^2 + 0x2^1 + 1x2^0)_{10}$
- Hexadecimal
  - $H = h_{n-1}h_{n-2}\ldots h_1h_0$
  - $V(H) = h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + ... + h_1 \times 16^1 + h_0 \times 16^0$
  - 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 $(857)_{10}$

				Remainder	
857	: 2	=	428	1	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	MSB

Result is $(1101011001)_2$