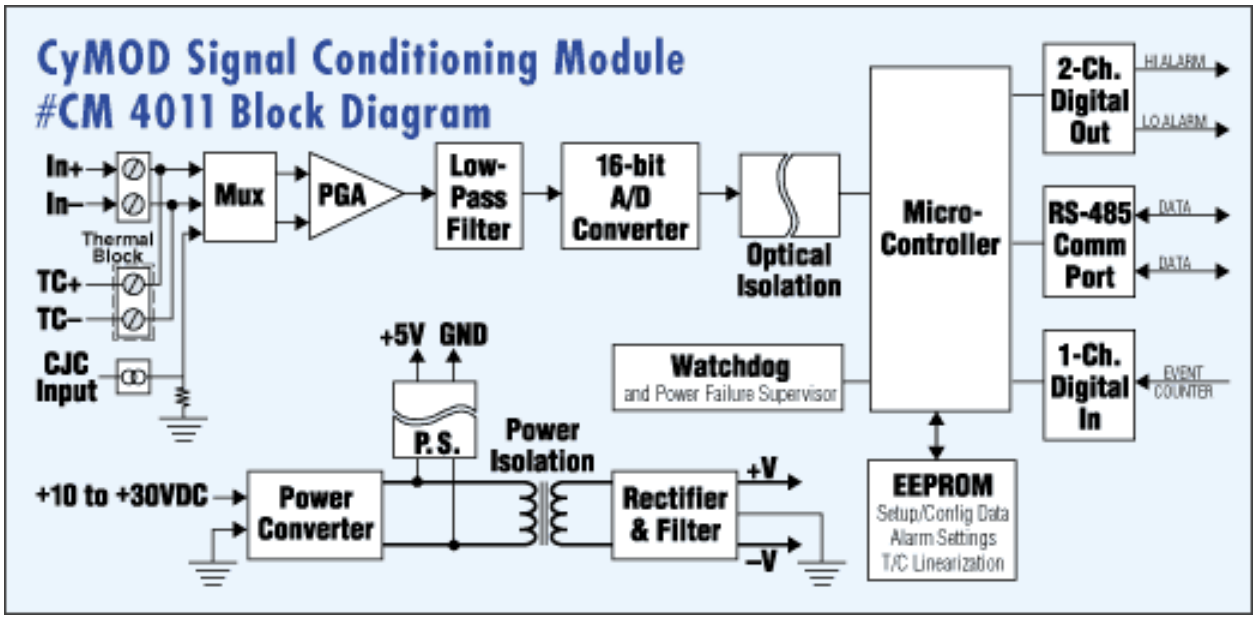
Lecture 22: Instrumentation / Sensors

Computer Interface



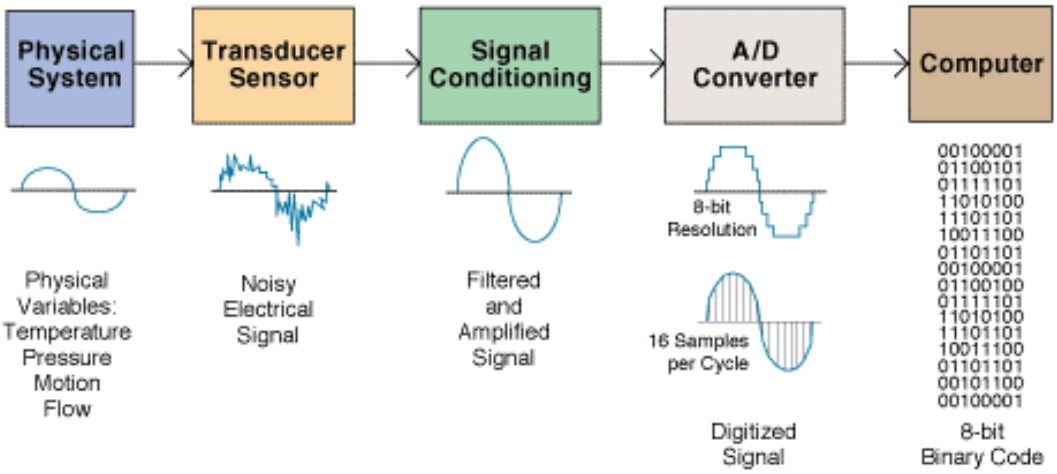
http://www.cyberresearch.com/content/tutorials/tutorial13.htm

In order to sense and measure physical variables such as pressure, flow, & motion, you need to use *transducers* (sensors), which convert physical variables into electrical signals and transmit these signals either to a signal conditioning device or directly to your data acquisition board.
The *signal conditioning device* amplifies and filters the sensor signal, then outputs a voltage which is easy to capture with an analog input board (additional information can be found in the Signal Conditioning tutorial.

Common computer systems in Commercial World for Data Acquisition and Control:

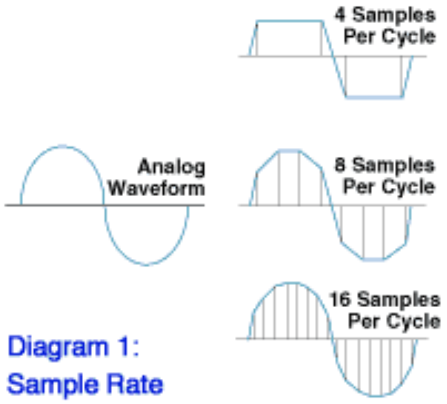
- Desktop / laptop with DAC cards / systems
- PC104 standard http://www.pc104.org/ http://www.pc104.com/whatis.html
- Single Board Computers
- Microprocessors with A/D, D/A, DIO

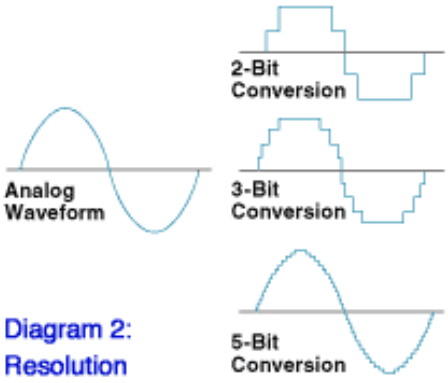
Data Acquisition A/D conversion:



Schematic 1: Data Acquisition System

http://www.cyberresearch.com/content/tutorials/tutorial5.htm





http://www.cyberresearch.com/content/tutorials/tutorial5.htm

Single Ended vs. Differential Input Analog to Digital Conversion

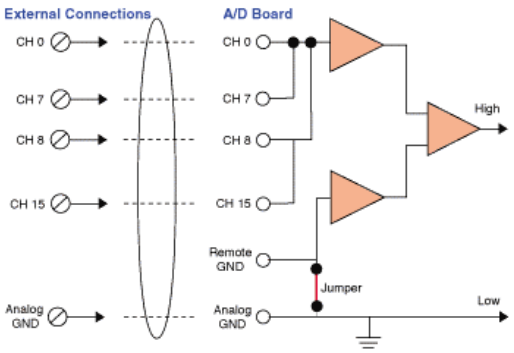


Diagram 3: Single-Ended Inputs

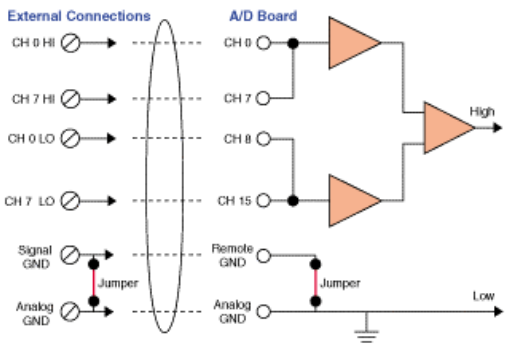


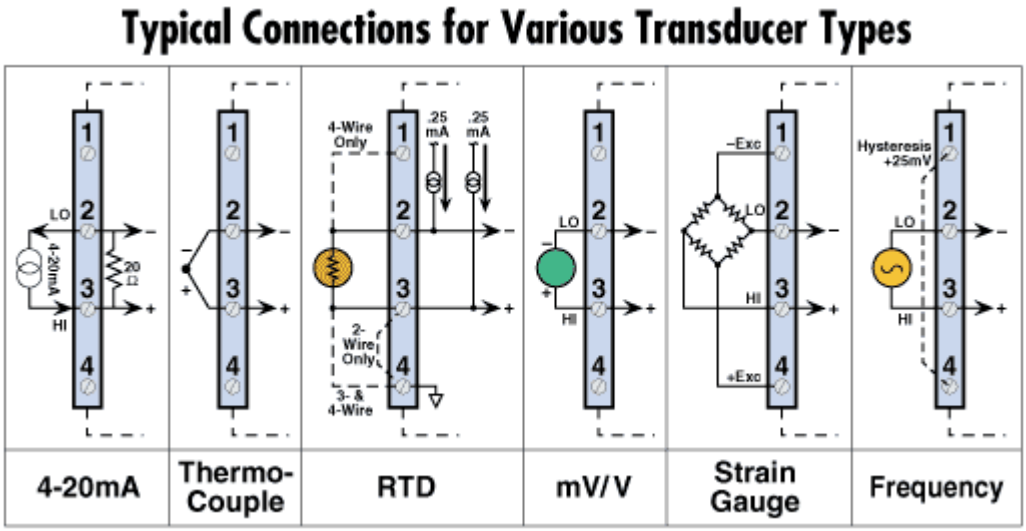
Diagram 4: Differential Inputs

http://www.cyberresearch.com/content/tutorials/tutorial5.htm

Electric sensors – output signal proportional to physical unit of interest
Typical output from sensor:

- Voltage (most common, prone to noise pickup, limit cable length
- Current (less prone to noise pickup, not sensitive to floating ground)
- Digital (communication network)

For Technical Notes, see:
http://www.cyberresearch.com/content/articles/tutorials/tutorials.aspx



Sensor Connectivity:

1-wire: really 2 (or 3)-wire: signal line (can serve as power and digital data line), ground

2-wire: high/low signal lines; self-powered sensors, current flows from interface to sensor and back; one of the lines is typically ground; examples: thermocouples, thermistors

3-wire: power, signal, ground. Signal is referenced to common ground.

4-wire: power/ground and output hi/lo. Note: in most cases, the sensor output LOW line must not be connected to Ground (i.e., often this requires a differential input measurement on the A/D interface). Example: bridge circuitry (strain gauge, pressure sensor,…)

Some Common Sensors

Temperature
Resistive, thermocouple, IC – thermal properties of semiconductor material)
Pressure:
Strain gauge
Light:
Photodiode, photocell, photoresistor (filters to control wavelength)
Spectro-radiometer, pyranometer
Carbon Dioxide Partial Pressure (not v/v – ppm):
Infrared absorption

Oxygen Partial Pressure (not v/v – ppm)::
Electrolytic / oxidation, photoluminescence, paramagnetic properties

Humidity:
Capacitive (change of dielectric constant), dewpoint (optical / cooled), temperature (wet/dry bulb)

Voltage
Direct, or via attenuation / voltage divider, or optically coupled / isolated if required.

Current
Convert to voltage through a precision resistor. Accuracy and dependency of resistor affect accuracy of sensor / acquired signal.

Data Acquisition and Control Check List

Analog Inputs:

- Range of sensor (highest / lowest voltage), sensitivity (mV/physical unit), type of sensor (3-wire, 4 wire, common ground vs. Hi/Lo signal). What frequency is the signal.
    - Unipolar vs. bipolar input range
    - Single ended vs. differential input
    - Gain or range setting, signal conditioning, required bit resolution,.
    - Sampling rate: can I collect the data fast enough to resolve the frequency information in the signal ?
    - For DC signals: much easier to filter digitally (sample multiple times, build average) than making clean DC signal (radiated noise).

Analog Outputs:
An analog output is typically required for any application involving a variable con-trol device such as a servo motor or servo valve. Most D/A boards output voltages; some can output 4–20mA current loops.

- What is connected to it ? Input impedance, range, accuracy
    - Range setting, bit resolution
    - Can the DAC drive this much current into the receiver ??
    - Single ended vs. differential input
    - Gain or range setting, signal conditioning, required bit resolution,.

Digital Inputs / Outputs:
To sense and control high-power AC/DC voltages through solid-state relays.
For low-current TTL signals like limit-switch inputs and other digital lines.

- Digital Inputs are tied high. When nothing is connected, they are held at 5V (high) through a resistor. To get an input to go to low, connect directly to ground (w/o resistor). To provide a high signal to a digital input, connect it to 5V through a resistor (current limit for safety).
- Digital Outputs are sometimes undefined at system start-up. Ensure that your system is not in an uncontrolled state at boot-up.
- Digital outputs can only sink/source a limited amount of current (often only 4 mA). Ensure that the connected device doesn't draw/sink too much current.
- Isolated / optically coupled DIO protect system (LEDs / photodetectors as couplers)
