Electronics: Why do we care?  
Two main reasons

• Every instrumental measurement involves a *transduction* step that converts a chemical/physical response into an electrical signal.
  – Need to ensure that signal is a good reflection of the response

• Many instruments are now interfaced with computers
  – Need to ensure that analog and digital components communicate effectively

Signal Transduction: Data Domains

• Information can be “stored” or communicated in several ways
Golden Rules of Circuits: Dust off the physics!

- Ohm’s Law:
  - Voltage drop across a resistor is proportional to the flow of electrons (current) through the resistor and the magnitude of the resistance
    \[ E = IR \]

- Kirchoff’s Laws:
  - All of the currents in and out of a node must sum to zero.
  - The voltages around a loop must sum to zero

- Power Dissipation:
  - The power dissipated in a circuit is related to the current and the resistance of the circuit
    \[ P = IE = I^2R \]

Basic Circuits: Passive Components

- Two main types: Resistors and Capacitors

- Resistance in circuits
  - Series:
  - Parallel:
Capacitance: Charge Storage

- Store charge by applying potential (Voltage) across a dielectric.
  \[ C = \frac{Q}{V} \text{ (C has units of Farads)} \]

- Capacitors are affected by changing currents and voltages
  \[ \frac{dQ}{dt} = I = C \frac{dV}{dt} \]

- Capacitors in series and parallel:
  - Series:
  - Parallel:

Important Passive Component Combinations

- Voltage Divider
Important Passive Component Combinations

- Series RC Circuit

\[ V_s \]
\[ C \]
\[ R \]

Semiconductor Devices

- Diodes
  - greater conductivity in one direction
  - Made by coupling n-type and p-type semiconductors

- Transistors
  - Combinations of diode junctions
  - Useful for switching and amplification
Diodes

- Band or other mark on cathode end
- Light-emitting Diode (LED)

Power Supplies
- Convert AC to DC to operate semiconductor devices
- Two functions
  - Remove oscillation in voltage
  - Establish constant voltage
Operational Amplifiers

- **Solid-state device**
  - combination of transistors, diodes, resistors, capacitors on a chip
  - many, many applications!

- **General Characteristics:**
  - All potentials are relative to *circuit common*
  - Response: $v_o = A(v_+ - v_-)$
  - Ideal characteristics:
    - Large open loop gain ($A$)
    - High input impedance: no current through the op-amp!
    - Low output impedance:

Op-Amps

![Op-Amps diagram](image-url)
Op-Amp Circuit Analysis

- Remember A is huge ($10^4$ to $10^6$ or larger)
- AND no current through the op-amp!
Op-Amp Possibilities (only a few)

Practical Considerations

- Common wiring pattern
  - Power supply connections (+/- 15 VDC)
  - “Trim” connections
    - offset voltage compensation

- Response time considerations:
  - Slew Rate
Communications between an Instrument and a Computer: Analog Regime to Digital Regime

- In order for information to be transferred an analog to digital conversion must occur.
  - Analog: continuous in magnitude and time
  - Digital: discontinuous, finite number of values, "quantized"

- Centered on binary logic
  - only two states: "on" and "off"
  - Example: 8-bit binary number: 10010110

  - Least Significant Bit (LSB):

Counting with Flip-Flop Logic

- Flip-flop: Only changes output when the input changes from 1 to 0 (only one direction)
A/D and D/A Conversion

• From instrument to computer:
  A/D Conversion

  Figure 4.4 A successive-approximation ADC. (a) output of the DAC during the conversion process, (b) block diagram of the ADC.

• From computer to instrument:
  D/A Conversion

  Figure 4.7 A 4-bit digital-to-analog (DAC) converter. Here A, B, C, and D are +5 V for logic state 1 and are 0 V for logic state 0.

• Resolution Considerations
  – What if we need to encode (or decode) a ±2V signal with resolution of 1mV? How many bits do we need?
Considerations of Analog↔Digital Conversion

- Sampling Considerations: Need the digital signal to be a good representation of real life.
  - Counting
  - Timing
  - A/D or D/A conversion

- Aliasing

- Rule of thumb: Signals should be sampled at a rate at least twice the highest frequency component of the signal. (Nyquist Theorem)