Introduction to Arduino HW Labs

• In the next six lab sessions, you’ll attach sensors and actuators to your Arduino processor
• This session provides an overview for the devices
  – LED indicators
  – Text/Sound Output
  – Passive Sensors
  – Active Sensors
  – Buzzers/Motors
  – Servomotors
LED Indicators

• Any diode has high resistance in one direction and low resistance in the opposite direction

• An LED is a Light Emitting Diode
  – If it is carrying current, it emits light
  – If it carries too much current, it emits smoke 😞
Text Display

- Fixed text display devices can be sent characters to display in a bit matrix format
- ASCII characters can be transmitted serially to the device in the sequence desired for display
- It is possible to configure the bit matrix patterns for special characters that don’t correspond to any character in the ASCII code set
- Application: Cheap hand-held device displays
Sound Output

• Piezoelectric materials (certain ceramics) can be used to sense strain or generate vibrations
  – As a sensor, a PZ material generates an electric signal when exposed to levels of mechanical stress/strain
  – As a sound/ultrasound source, a PZ material expands and contracts when a varying voltage is applied to it
• Application: Cards that sing “Happy Birthday”
• Our text display device generates tones of various frequencies – hence it can produce sound output
Passive Sensors

• Passive sensors detect some physical signal from the external environment being monitored

• A passive sensor may detect
  – Electromagnetic energy (light, night vision, radio)
  – Acoustic energy (sound, ultrasound, vibration)
  – Seismic Energy (earthquakes, atomic bomb tests)

• They are not always as accurate as active sensors but their presence usually cannot be detected (useful for monitoring enemies on a battlefield)

• Usually low power requirements, e.g. batteries
Active Sensors

• Active sensors generate a physical signal and then detect the reaction to it from the environment

• An active sensor may generate and detect:
  – Radio signals and echo returns (radar)
  – Acoustic signals and echo returns (ultrasound, sonar)
  – Light signals and echo returns (laser ranging, scanners)

• Disadvantages of an active sensor:
  – It can be detected by whomever it is monitoring
  – It may require a lot of power to generate the signal
Buzzers / Motors

• Controlling a high current device may need to be done using an external electronic switch

• Example high current devices
  – Motors
  – Solenoids / Electromagnets

• Electronic switches
  – Electromechanical Relays
  – Transistors
Buzzers / Motors

- Relays have a metal frame, an electromagnetic coil, and a spring to control an electrical switch.
- Contacts can be normal open or normal closed.

![Diagram of relay circuit with labeled parts: Power Source, Control Signal, Ground, Spring, Normal Open, Normal Closed, To Controlled Devices.]
Buzzers / Motors

• Solid state transistors allow a small current to be amplified and control a larger current to a “load”

• NPN Transistor

\[
\text{Load Current} = \beta \times \text{Control Current}
\]
Suppressing “Back EMF”

- When the circuit providing current to a coil of wire is shut off, the collapsing magnetic field produces a large voltage - briefly making the coil try to supply power back to the rest of the circuit.
- This called a Back Electromotive Force (EMF).
- Application: Ignition coils in automobile engines to fire the spark plugs (Ouch - Don’t touch!!)
- It can damage other parts of the electronics such as the transistors controlling the coil current.
Suppressing “Back EMF”

• We put a diode in parallel with the coil oriented in the opposite direction to normal current flow
  – The diode does not carry any current while the coil current is present – It is reverse polarized

  [Diagram of a simple circuit showing a diode in parallel with a coil, illustrating current flow with and without the switch being opened.]

  – The diode short circuits the current generated by the transient back EMF when coil current is turned off
Suppressing Voltage Spikes

• Some power sources or loads can cause voltage spikes on the power lines to the other electronic parts causing errors in their operation
  – Example: The commutator in a motor
• A capacitor across the power lines absorbs these spikes – smoothing out the voltage on the lines
• A capacitor works like a “bucket” for electric charge
Suppressing Voltage Spikes

• Water and Electricity Analogy

[Diagram showing water analogy with a motor, capacitor, and ground.]

Irregular flow due to pumping action

Regular flow due to bucket's capacity

Input voltage with spikes due to sparks

Output voltage without spikes

Motor

Capacitor

Ground
Servomotors

- There are two types of servomotors
  - Standard (Controlled Position)
  - Continuous Rotation (Controlled Speed/Direction)
- A servomotor contains a feedback circuit that compares input from SW to information about the current state of the HW device (position or speed)
Servomotors

- A standard servomotor can be used to control the position of a valve, electronic control knob, steering wheel position, robotic arm position, etc.
- The desired position is compared to the current position and a loop update signal causes motion toward the desired position and stopping there.
Servomotors

• A continuous rotation servomotor can be used to move a robotic device, material in an assembly line, paper in a copier, fax, or printer, etc.

• The desired speed and direction is compared to the current speed and direction and a loop update signal causes the device to speed up, slow down, stop, or reverse direction

• A calibration step to “zero the speed” when the control input is set to zero is usually required
Potentiometers

- In Labs 9 and 10, you will use a potentiometer as a manual input controller for the servomotors.
- A potentiometer is sometimes referred to as a "variable resistor", but it is a variable tap on a resistor spanning a signal or power and ground.
- There are 3 poles:
  - The two end poles are on opposite ends of a resistor.
  - The center pole "wiper" turns along the resistor to vary the resistance between it and each of the ends based on a mechanical input such as a manual dial.
Potentiometers

• The schematic for a potentiometer:

0 to +5V based on wiper position