Electronic Circuits in Technology-Enabled Devices
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Electronics inside an electric fan motor.

Electronics inside a Tesla Model 3 Motor.
Upcoming Projects

Our first few projects introduce the use of a microprocessor to control simple electronic devices.

Week 1 (today): Control LED with pushbutton.

Week 2: Control LED with a microcontroller.

Week 3: Implement “Simon” game.
6.A01 Kits

Everything needed for 6.A01 projects is in your kit.

See the “Parts” tab of http://mit.edu for a complete listing, and notify 6a01-instructors@mit.edu if any part is missing or damaged.
Kits: The Electromagnetic Coils are Fragile

Each of your six coils has two leads (white and black) that are made from the same fine wire that forms the coil. The leads are about 12 inches in length and were wound around the coils and secured with a small piece of tape for shipping.

In the lab today, you will use a multimeter to test that the coils are functional by measuring the resistance between the white and black connectors. The resistance should be between $22 \, \Omega$ and $28 \, \Omega$.
Kits: Safety Issues with Magnets

Neodymium magnets are surprisingly strong and can be dangerous.

Please read the safety precautions shipped with the kit.

- Keep magnets away from children and pets.
  - swallowing hazard, may be serious
- Strong magnetic fields can affect medical devices
  - keep away from pacemakers and other implanted devices
- These magnets can demagnetize magnetic media
  - keep away from credit cards, wallets, laptops, ...
- Neodymium is brittle: the magnets shatter when broken.

Always wear eye protection when manipulating the magnets.
**Kits: Safety Issues**

General safety precautions.

- Keep all parts on a single **workspace** (desktop) or **storage box**.
- Keep **children and pets** away from workspace and storage box.
- **Secure all parts** in storage box when not in use.
- Turn on **power** only when work is in progress.
- Disconnect **power** when rewiring circuits.
- Turn off **power** and unplug power supply when unattended.

Wear **safety glasses** when working with small tools or magnets.
Today’s Project: Controlling an LED with a Pushbutton

Simple circuit to illustrate principles.
Today's Project: Controlling an LED with a Pushbutton

Simple circuit to illustrate principles.

We can think of this circuit as having four parts.
Controlling an LED with a Pushbutton

Simple circuit.

When the pushbutton is pressed, current flows around the loop and the LED generates light.
Representations of Circuits

The loop comprises 4 “parts” and 4 pieces of wire.

Each wire forces the electrical potential (voltage) at its ends to be equal. This circuit has 4 “nodes” (points with different potentials).
Representations of Circuits

The LED circuit is represented by the “schematic diagram” below.
Representations of Circuits

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Circuit #2

Here is a different circuit.
What will happen when the button is pushed?

Draw a circuit diagram for this circuit.
Circuit #2

Here is a different circuit.
What will happen when the button is pushed?

Draw a circuit diagram for this circuit.
Circuit #2

Here is a different circuit. What will happen when the button is pushed?
Here is a different circuit. What will happen when the button is pushed?

The LED is on except when the button is pushed.
Prototyping

A protoboard provides a **convenient** way to connect dozens of components **reliably**.

Each hole accepts one lead of a component or jumper wire.
Prototyping

Clips inside the protoboard grab each of the inserted wires and make electrical connections to that wire.

The internal clips are connected together so that wires inserted into 1a, 1b, 1c, 1d, and 1e collectively form a single “node.”

All clips in each of the green boxes are similarly connected together.
Today’s Project

Today’s project is to build a circuit with two pushbutton switches to control a two-color LED.

- When button 1 is pressed, the LED should emit red light.
- When button 2 is pressed, the LED should emit green light.
- When both buttons are pressed, the LED should emit both red and green light.

The following slides illustrate the important parts.
Pushbutton Switch

Each switch is a two-terminal device. The physical device (left) is represented by the schematic drawing on the right.

Normally, the two terminals are electrically isolated from each other.

Pushing the button closes a connection between the terminals – as though the terminals are connected with a wire.
Resistor

A resistor is a two-terminal device. The physical device (left) is represented by the schematic shown on the right.

The current voltage relation for a resistor is given by Ohm’s Law:

\[ \frac{V}{I} = R \]

where \( R \) is the resistance, \( V \) is voltage, and \( I \) is current.
**Light Emitting Diode (LED)**

An LED is a two-terminal device. The physical device (left) is represented schematically (right) as a **diode**, which is a device that conducts current in one direction (downward) but not the other.

The emitted light is proportional to the current through the device.
**Current-Limiting Resistor**

We can adjust the light emitted from an LED by placing a resistor **in series** with the LED.

Ohm’s law: if $R$ is large, then $I$ is small.

Decrease $R$ to make LED brighter, increase $R$ to make LED dimmer.
Two-Color LEDs

We will use two-color LEDs with two separate LEDs in one package. There are only 3 leads since the LEDs share a common “cathode.”

Current into lead A and out of lead C → red light.
Current into lead B and out of lead C → green light.
Two kinds of resistors are provided: $10 \, k\Omega$ and $2.2 \, k\Omega$, which can be distinguished by their color bands.

$10 \, k\Omega$: brown - black - orange

$2.2 \, k\Omega$: red - red - red
LEDs and Resistors

When driven with the same voltage, the two LEDs in the two-LED package are not equally bright: the green LED is brighter than the red LED.

To compensate, put a $2.2 \, k\Omega$ resistor “in series” with the red LED and a $10 \, k\Omega$ resistor “in series” with the green LED.
We can get electrical power directly from the microcontroller card.

There are two USB connectors on the microcontroller card.

The left connector is for programming the microcontroller and connects to your laptop. This connector will NOT be used today.

The right connector is for power and connects to a USB power supply (right, above).
A 3.3 volt power supply is available at the screw connectors.

Loosen the screws by turning counterclockwise.
Insert jumper wire.
Tighten the screws by turning clockwise.
Test that mechanical connection is tight by tugging on jumper wire.
Breakout Groups and Homework

We will divide up now to work in small groups to
• get familiar with the 6.A01 kit, and
• get started (and possibly finish) today’s project.

Homework: Upload a video to demonstrate your pushbutton controlled LED. The upload page is in the project handout for today.

Next week, we will start programming the microcontroller.

Install the Teensy software on your laptop.

https://www.pjrc.com/teensy/td_download.html