How To Make (Almost) Anything 2023
Recitation - Electronics

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Slides adapted from prior HTMAA years

Slides available here:
https://docs.google.com/presentation/d/1RAJqF2f2H65iTIq9B1hG3qcKtz2Ty1I/edit?usp=sharing&ouid=111928349056878132437&rtpof=true&sd=true
The next few weeks have a simple task!

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3. Mill it and solder on all the parts properly
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1. Learn (or recall) basic electrical engineering
2. Use it to design a custom circuit board in a new software program (EDA)
3. Mill it and solder on all the parts properly
4. Program your board to do something
Ohm’s Law:

\[ V = I \ast R \]

- Voltage (measure in volts)
- I: Current (measure in amps)
- Resistance (measured in ohms)

Voltage

Measures the difference in electrical potential between two points – often an input voltage (vcc) and ground (gnd)
Current

Measures the **rate of flow of electrons** in a circuit.
Resistance

Measures **how hard it is for electrons to move through a circuit**
Triplet

- **Voltage**: potential to do work (electron pressure)
- **Current**: work (electron flow)
- **Resistance**: ... friction (electron resistance)
Ohm’s Law:

\[ V = I \times R \]

\textbf{Voltage} (measure in volts)

\textbf{I: Current} (measure in amps)

\textbf{Resistance} (measured in ohms)

How much current goes through this resistor?
Ohm’s Law:

\[ V = I \times R \]

**Voltage** (measure in volts)

**I**: Current (measure in amps)

**Resistance** (measured in ohms)

\[ V = I \times R \]

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

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

How much current goes through this resistor?

1A
Ohm’s Law:

\[ V = I \times R \]

**Voltage** (measure in volts)

**I**: Current (measure in amps)

**Resistance** (measured in ohms)

\[ V = I \times R \]
\[ I = \frac{V}{R} \]
\[ R = \frac{V}{I} \]
Ohm’s Law:

• Resistance in series adds

• To learn more about series and parallel check out this link: https://en.wikipedia.org/wiki/Series_and_parallel_circuits

How about these resistors?
Ohm’s Law:

Voltage divider

Very useful for monitoring battery voltage
Diodes:

Current flow in one direction only

Sort of... :p
Diodes:

Who is this
Diodes:

Light emitting diode (LED)
Ohm’s Law:

\[ V = I \times R \]

Voltage (measure in volts)

I: Current (measure in amps)

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What about this LED?

0A … installed wrong way
Ohm’s Law:

\[ V = I \times R \]

**Voltage** (measure in volts)

**I**: Current (measure in amps)

**Resistance** (measured in ohms)

\[ V = I \times R \]
\[ I = \frac{V}{R} \]
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Ohm’s Law:

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**Voltage** (measure in volts)

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\[ V = I \times R \]

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

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

Ok so what about this (correct direction) LED?

Diodes have 0 resistance!
Ohm's Law:

Ok so what about this (correct direction) LED?

\[ \text{INFINITE CURRENT} \rightarrow \text{THE PART WILL MELT : (} \]

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

\[ \infty \text{A} \]

Diodes have 0 resistance!
Ohm’s Law:

\[ V = I \times R \]

**Voltage** (measure in volts)

**I**: Current (measure in amps)

**Resistance** (measured in ohms)

Ok so what about this (correct direction) LED with a current limiting resistor!
Ohm’s Law:

\[ V = I \times R \]

- **Voltage** (measure in volts)
- **I**: Current (measure in amps)
- **Resistance** (measured in ohms)

\( V = I \times R \)

\( I = \frac{V}{R} \)

\( R = \frac{V}{I} \)

Ok so what about this (correct direction) LED with a current limiting resistor!
In practice, you will probably use in the range of 250-1000Ω resistors. (I basically always do either 499Ω or 1kΩ since they’re always in stock :p)

Ohm’s Law:

\[ V = I \times R \]

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

\[ R = \frac{V}{I} \]
Switch
Switch - slide switch

SPDT: Single Pole, Double Throw

A: OFF
B: ON
Switch- tactile switch

SW1
Our second equation - Capacitance

\[ C = I \times \frac{dV}{dt} \]

- **Capacitance** (measured in farads) (also a charge measurement, charge = CV)
- **I**: Current (measure in amps)
- **dV/dt**: Change in Voltage over time (measure in volts/second)

https://learn.sparkfun.com/tutorials/capacitors/
Capacitance

\[ C = I \times \frac{dV}{dt} \]

- Capacitance (measured in farads)
- I: Current (measured in amps)
- \( \frac{dV}{dt} \): Change in Voltage over time (measured in volts/second)

Energy is stored in an *electric* field
Capacitance

The science here can get a little complicated but/and I like to think of a capacitor as a **filter** for changes in voltage.

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Capacitance - switch debouncing

https://www.allaboutcircuits.com/technical-articles/switch-bounce-how-to-deal-with-it/
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Inductance

\[ v(t) = L \frac{di}{dt} \]

Inductance (measured in “henry”s)

\( v(t) \): voltage induced by inductor at this instant

\( \frac{di}{dt} \): Change in Current over time (measure in volts/second)
Inductance

Energy is stored in a magnetic field (!)
Triplets

- Resistance / Resistors: resists voltage, “does work”
- Capacitance / Capacitors: resists change in voltage
- Inductance / Inductors: resists change in current
Triplets

• *everything* has *some* resistance, inductance, and capacitance; resistors are inductors, capacitors are resistors, inductors are capacitors, etc…

• we can largely ignore this inconvenience until we hit high powers, high frequencies, and high precision
But how will I know if my component needs a capacitor? And how big of a capacitor will I need? (and what are all of those labels?)

Neil’s SAMD11 Hello World board:
Sometimes: read the datasheet

Often: follow design patterns
USB HEADER
(prefix J in Neil’s boards often mean some type of connector)
This gets 5V

So this (voltage regulator) Drops it to 3.3V for this microcontroller

Most of the microcontrollers you will encounter in this class will run at either 3.3V or 5V – Be careful about not cooking a 3.3V micro with 5V!
Bypass capacitor as we discussed!

Value: 1uF
Programming header—how you (initially) load code onto this microcontroller!

We see the J prefix again—this is a header — and SWD denotes the interface.
Microcontroller

SAMD11D

This is a SAMD11 in the D package

We also stock SAMD11C, which has less pins but the same package.
Neil uploads photos of these boards to the components link—check this if you’re not sure what you’re looking for.
Seeed XIAO ("小": means "small")

RP2040

ESP32C3
Seeed XIAO ("小": means "small")

Power: Can be used to power other components.
+5V: from USB
+3.3V: from LDO

Digital  Analog  Micropython  IIC  Power  GND  SPI  UART