Electronics Production and Design

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The road ahead

This week

Electronics Production

• Mill and stuff a circuit board
The road ahead

This week
- Electronics Production
  - Mill and stuff a circuit board

2 weeks from now
- Electronics Design
  - Design your own circuit board
  - Mill and stuff it
The road ahead

This week
- Mill and stuff a circuit board

2 weeks from now
- Design your own circuit board
- Mill and stuff it

4 weeks from now
- Design your own circuit board
- Mill and stuff it
- Program it
The next few weeks have a simple task!

1. Learn (or recall) basic electrical engineering
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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
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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
3. Mill it and solder on all the parts properly
The next few weeks have a simple task!

1. Learn (or recall) basic electrical engineering
2. Use it to design a custom circuit board in a new software program
3. Mill it and solder on all the parts properly
4. Learn (or recall) some programming: “Arduino” i.e. C++
The next few weeks have a simple task!

1. Learn (or recall) basic electrical engineering
2. Use it to design a custom circuit board in a new software program
3. Mill it and solder on all the parts properly
4. Learn (or recall) some programming
5. Write a new program to test your custom board
The next few weeks have a simple task!

1. Learn (or recall) basic electrical engineering
2. Use it to design a custom circuit board in a new software
3. Mill it and solder on all the parts
4. Learn (or recall) some programming
5. Write a custom program to test your board

Seems like a lot!
The road ahead

This week
- Electronics Production
  - Mill and stuff a circuit board

2 weeks from now
- Electronics Design
  - Design your own circuit board
  - Mill and stuff it

4 weeks from now
- Embedded Programming
  - Design your own circuit board
  - Mill and stuff it
  - Program it

Today’s Focus
Why do I even need to know anything about electrical engineering?
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We are going to learn how to make our own custom circuit boards that connect inputs and outputs to our own microcontrollers!
Ohm’s Law:

\[ V = I \times R \]

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

Voltage

Measures the \textbf{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
Triplets

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

\[ V = I \times R \]

**Voltage** (measure in volts)

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

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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)

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

How about these resistors?
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

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How about these resistors?

+3V here!

1A
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What about this LED?
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What about this LED?

Trick Question – 0A
All diodes are one way!
Ohm’s Law:

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What about this LED?

Green line on surface mount parts!

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Ok so what about this (correct direction) LED?

Trick Question Again – \( \infty \)A

Diodes have 0 resistance!
Ohm’s Law:

\[ V = I \times R \]

Voltage (in volts)

Current (in amps)

Resistance (in ohms)

Infinite current… the part will melt

Ok so what about this (correct direction) LED?

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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!
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\[ V = I \times R \]

**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!

1A
Ohm’s Law:

- 500 to 1K ohm resistors work well (for me)
- The order of the resistor and LED does **NOT** matter

Ok so what about this (correct direction) LED with a current limiting resistor!
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)

\( \frac{dv}{dt} \): 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)

**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

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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?)
Sometimes: read the datasheet

Often: follow design patterns
Oh hey look at Neil’s hello world board – it looks like the programming 6 pin header has all of it’s named things connected to the ports on the Attiny with those names!

Oh and the clock too (XTAL)!
“EDA” Electronic Design Automation
“ECAD” Electronics Computer Aided Design
Schematic

List the parts and their connections

Board File

Actually route the final traces
Tips for board schematics and routing:

1. Do the schematic first (and finish it before moving on to routing) (Neil’s examples lack schematics)

2. Use lots of names to keep the schematic clean

3. Triple check the schematic before moving onto routing (and have someone else check it)

4. Copy the routing patterns Neil or others use

5. Add 0 ohm resistors if you get stuck routing
Here's a nice example of a 0 ohm resistor that was added later during routing.
Design Patterns in Practice

- Bypass Capacitors
- Current-Limiting Resistors
- Buttons, Pull-Up Resistors
- Voltage Regulators
- RC Filters
- Low-Side Switches
EDA Basics

- Adding / Finding Components
- Modifying “Net Lists”
- Moving, Routing, etc