Electronics Production and Design

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Fall 2021
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. Already know basic electrical engineering
The next few weeks have a simple task!

1. Already know basic electrical engineering
2. Use it to design a custom circuit board in a new software program
The next few weeks have a simple task!

1. Already know 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 right
The next few weeks have a simple task!

1. Already know 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 right
4. Already know basic programming
The next few weeks have a simple task!

1. Already know 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 right
4. Already know basic programming
5. Write a custom program to test your board
The next few weeks have a simple task!

1. Already know 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 right
4. Already know basic programming
5. Write a custom program to test your board

So if you are now feeling like.....
I HAVE NO IDEA

WHAT I'M DOING
RELAX
WE GOT THIS
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
A short outline for today

1. Almost all you need to know about Electrical Engineering
2. Almost all the tips you need to design custom boards
3. Almost all the steps it will take to produce a custom board
Why do I even need to know anything about electrical engineering?
Why do I even need to know anything about electrical engineering?
Why do I even need to know anything about electrical engineering?
Why do I even need to know anything about electrical engineering?
Why do I even need to know anything about electrical engineering?

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)
- **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**
Ohm’s Law:

\[ V = I \times R \]

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

How much current goes through this resistor?
Ohm’s Law: $V = I \times R$

Voltage (measure in volts)

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

Resistance (measured in ohms)

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)

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

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

How about these resistors?

+3V here!
Ohm’s Law:

\[ V = I \times R \]

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

What about this LED?
Ohm’s Law:

V = I \times R

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

What about this LED?

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

\[ V = I \times R \]

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

What about this LED?

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

\[ V = I \times R \]

**Voltage** (measure in volts)

**Current** (measure in amps)

**Resistance** (measured in ohms)

Ok so what about this (correct direction) LED?
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?

Trick Question Again – \( \infty \)A
Diodes have 0 resistance!
Ohm’s Law:

\[ V = I \times R \]

\( V \): Voltage (measured in volts)
\( I \): Current (measured in amps)
\( R \): Resistance (measured in ohms)

Ok so what about this (correct direction) LED?

Infinite current will go BOOM!

Trick Question Again – \( \infty \)A
Diodes have 0 resistance!
Ohm’s Law: 

\[ V = I \times R \]

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

Ok so what about this (correct direction) LED?

Infinite current will go BOOM! melt

Trick Question Again – \( \infty \)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)

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

![Diagram of a circuit with a 5V source, a 5Ω resistor, and an LED connected in series. A note indicates a current of 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 and final equation - 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)

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)

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

[Diagram of a capacitor]

https://learn.sparkfun.com/tutorials/capacitors/application-examples
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.

https://learn.sparkfun.com/tutorials/capacitors/application-examples
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.

https://learn.sparkfun.com/tutorials/capacitors/application-examples
But how will I know if my component needs a capacitor? And how big of a capacitor will I need?
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?)
Time to read the data sheet!
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</tr>
<tr>
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<td>D0P49</td>
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<tr>
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<td>D0P50</td>
<td></td>
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<td>D0P50</td>
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<tr>
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<tr>
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<td>D0P52</td>
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<tr>
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<td>D0P57</td>
<td></td>
<td></td>
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<td></td>
<td>D0P57</td>
<td></td>
<td></td>
<td></td>
<td>3E</td>
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</table>

**Notes:**
- D0Pn refers to the D0 bit in the n-th position.
- This table is a simplified representation of the register summary.
It's not actually that scary I promise --- also we don't need to memorize all of it! In fact most of the TAs don't know all of it!
Hey look here’s some port stuff seems like it has something to do with the inputs!
Ok so on the Attiny44 we have two ports one with 8 pins and one with 4 pins that logically are connected to different internal things so they can have different roles.

That wasn’t so scary!
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)!
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)!

Neil’s hello world is all of it’s named to the ports on those names!

WOW... NOT BAD

NOT BAD AT ALL...
We got smarter! We know the basics now!
A short outline for today

1. Almost all you need to know about Electrical Engineering
2. Almost all the tips you need to design custom boards
3. Almost all the steps it will take to produce a custom board
Board design quick tips and tricks

1. How to wire up a button (and other inputs)
How do I wire up a button? What do you think?

+5V

Each side is tied together!

Green Check for Pin 1

Red X for Pin 2

Pin 1
Pin 2

Microcontroller
How do I wire up a button?

Pin 1
Pin 2
Microcontroller
Connecting to GND is more power efficient

Red X for Pin 2

Each side is tied together!
How do I wire up a button?

You need a **pullup resistor** — but this is so common there are **built-in pullups** in most microcontrollers you can turn on in software!
A pull what?

Long story short here is that about 0 current goes through a gate (transistor) so we need the resistor to “force” the value to 5v or 0v

https://www.electronics-tutorials.ws/logic/pull-up-resistor.html
How do I wire up a button?

Be careful though if you are connecting to a device that gives a HIGH (+5v) signal you will want the pullup turned off!
Board design quick tips and tricks

1. Connect buttons to ground (and turn on the pullup but no pullup for many other inputs)
2. Always place a filter capacitor AS CLOSE AS POSSIBLE to the chip it is protecting
Board design quick tips and tricks

1. Connect buttons to ground (and turn on the pullup but no pullup for many other inputs)

2. Always place a filter capacitor AS CLOSE AS POSSIBLE to the chip it is protecting

3. Place an LED between power and ground near each microcontroller for testing
Board design quick tips and tricks

1. Connect buttons to ground (and turn on the pullup but no pullup for many other inputs)
2. Always place a filter capacitor AS CLOSE AS POSSIBLE to the chip it is protecting
3. Place an LED between power and ground near each microcontroller for testing
4. READ THE DATA SHEETS FOR EVERYTHING YOU USE!
Quick aside: other common components

MOSFET = code controlled switch (useful for output)

Voltage Regulator = allows for different voltages

Header = make it easy to attach other stuff
OK FINE BUT HOW DO WE ACTUALLY MAKE A BOARD?!?!?
A short outline for today

1. Almost all you need to know about Electrical Engineering
2. Almost all the tips you need to design custom boards
3. Almost all the steps it will take to produce a custom board
Eagle to the rescue
Sorry wrong rescue eagle... but also I’ve heard good things about KiCad
Sorry wrong rescue eagle... but also I’ve heard good things about KiCad

Details about the software will be given in a later recitation but I figure I can give you my “quick tips and tricks”
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)
Tips for board schematics and routing:

1. **Do the schematic first** (and finish it before moving on to routing)

   All of the parts can be found at [https://gitlab.fabcloud.org/pub/libraries/index](https://gitlab.fabcloud.org/pub/libraries/index)
Tips for board schematics and routing:

1. **Do the schematic first** (and finish it before moving on to routing)

2. **Use lots of names** to keep the schematic clean
Tips for board schematics and routing:

1. **Do the schematic first** (and finish it before moving on to routing)
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)
Tips for board schematics and routing:

1. **Do the schematic first** (and finish it before moving on to routing)
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**
Not so different after all...
Tips for board schematics and routing:

1. **Do the schematic first** (and finish it before moving on to routing)
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.
Tips for board schematics and routing:

1. Do the **schematic first** (and finish it before moving on to routing).
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.

I promise it gets way way easier after you do this a couple times.
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

You can save yourself time if you make a board that has an LED and a button so you can program it to turn the LED on and off with the button... (at least that used to be the minimal assignment...)
BUT WAIT!
BUT WAIT!

How do we mill a physical board once we have a board file?!!?
Export the traces and outline

Make sure to export in monochrome and keep track of the DPI
Import it into Neil’s Fab Mods

Make sure to pick the right machine and program for your lab – talk to your lab TAs!
Import it into Neil’s Fab Mods
Import it into Neil’s Fab Mods

Select your image and make sure the DPI matches!
Import it into Neil’s Fab Mods
Import it into Neil’s Fab Mods

Select traces or outline – make sure you have the right bit in the machine – talk to your lab TAs about if you need to adjust this at all
Import it into Neil’s Fab Mods
Import it into Neil’s Fab Mods

Again check with your TAs about these settings but/and after you press calculate it will compute the toolpath.
Import it into Neil’s Fab Mods

You’ll get a pop-up with the design when it’s done
Import it into Neil’s Fab Mods

Really zoom in and check the design!
Import it into Neil’s Fab Mods
Import it into Neil’s Fab Mods

Set the position of your board on the machine and "send file to device"
Import it into Neil’s Fab Mods

Set the position of your board on the machine and “send file to device”

MAKE SURE YOU HAVE SET THE Z=0 Correctly!!!!
And by your final project you too will be making crazy boards like this one!
And by your final project you too will be making crazy boards like this one!

Oh also heat the parts not the solder!!!!
Remember this kid?  This is him now!

We now may be too powerful for our own good!
A short outline for today

1. Almost all you need to know about Electrical Engineering
2. Almost all the tips you need to design custom boards
3. Almost all the steps it will take to produce a custom board
4. Can you do my homework for me?
No.... But/and....
No.... But/and....
Good Luck!

More demos and details can be found from last year at these links (and more software details to come at a later recitation)

Electronics 101 Video
Eagle and KiCaD Overviews Video

And I did a version of this two years ago with a little Eagle demo at this Video