EAGLE Schematic Capture & PCB Layout

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EECS 373 10/30/2014

Goals

- Learn basic PCB creation theory
- Learn commands for navigating EAGLE
- Create a new part, place it in a schematic, and route it into a design
- Utilize tools to check your work

Background

It will be helpful to know how much you already know

- EECS 215?
- PCB Software?
- Circuit Design Experience?
- Working on an existing project?
  - (read: does you 373 project have custom aspects)?
- Theory:
  - ESR?
  - LDO Design?
  - Decoupling?

Background

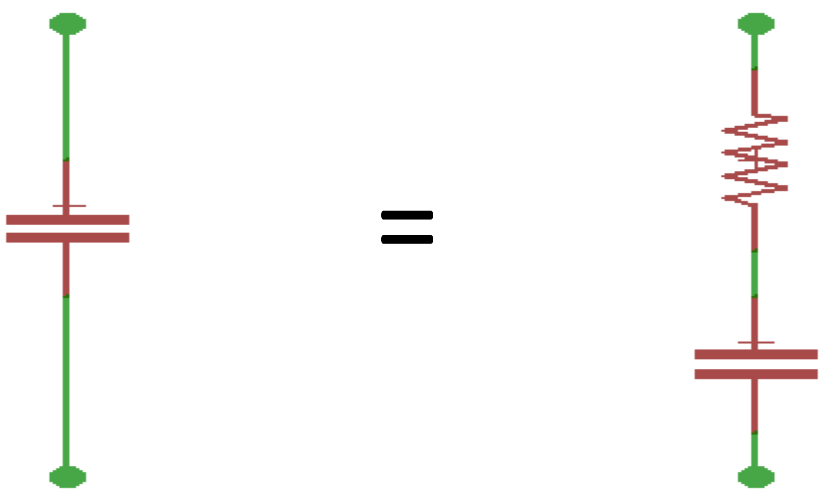
It will be helpful to know how much you already know

- More Theory:
  - Capacitive loading on a crystal?
  - Decoupling capacitors?
  - Symbolic nets?
  - PCB as a stack of layers?

- Does anybody have EAGLE installed on their machine in front of them right now?

Theory – Lets make a power supply

Equivalent Series Resistance (ESR) - A capacitor has non-zero resistance between its terminal and the plate itself



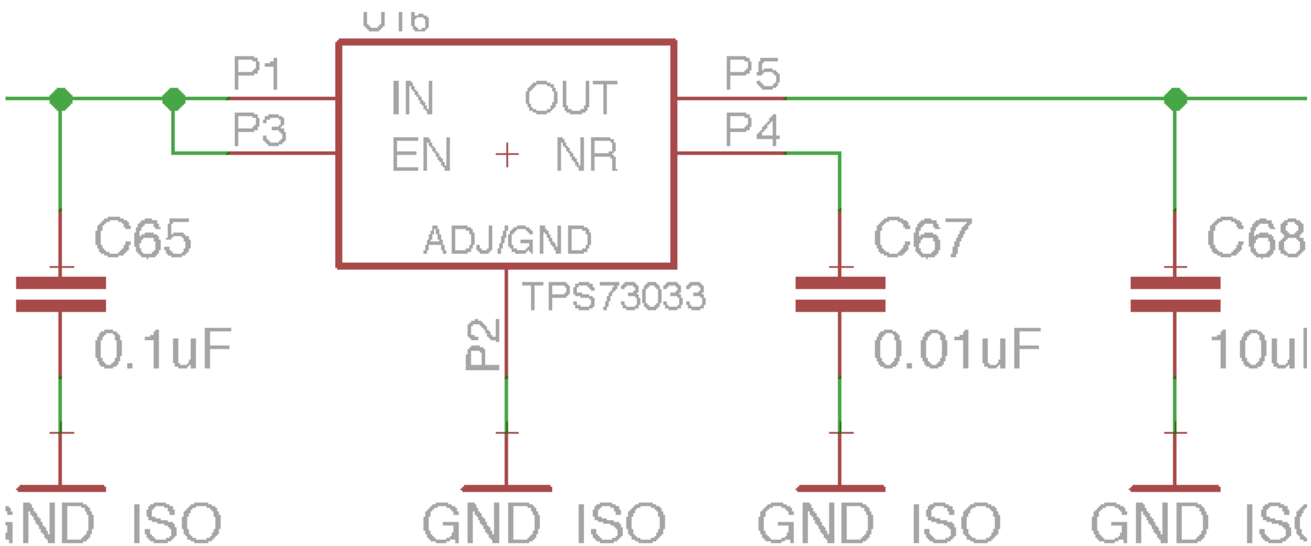
Theory – Lets make a power supply

Equivalent Series Resistance (ESR) - A capacitor has non-zero resistance between its terminal and the plate itself

Low ESR	Ceramic ($)	Low Value
High ESR	Aluminum ($$)	High Value
Low ESR	Tantalum ($$$)	High Value

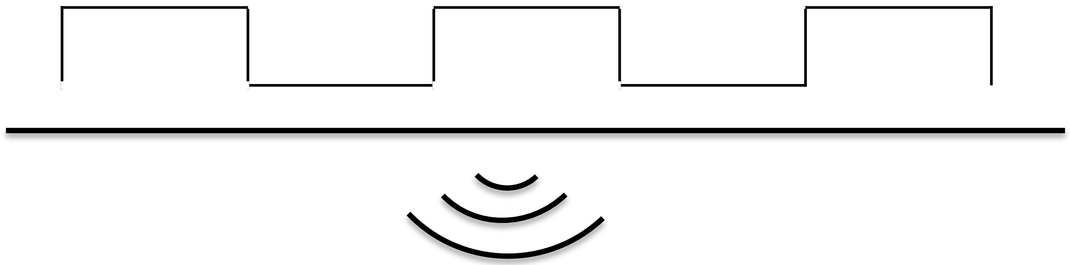
Theory – Lets make a power supply

LDO Design – simple supply and easy to get right, but consider ESR



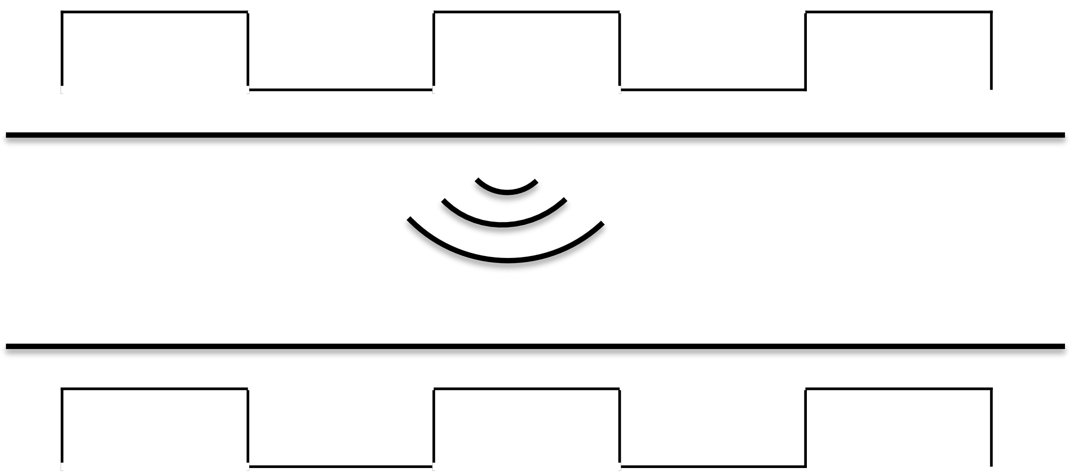
Low ESR requirement means use at least one ceramic cap, close to the IC

Theory – Signals can Interfere



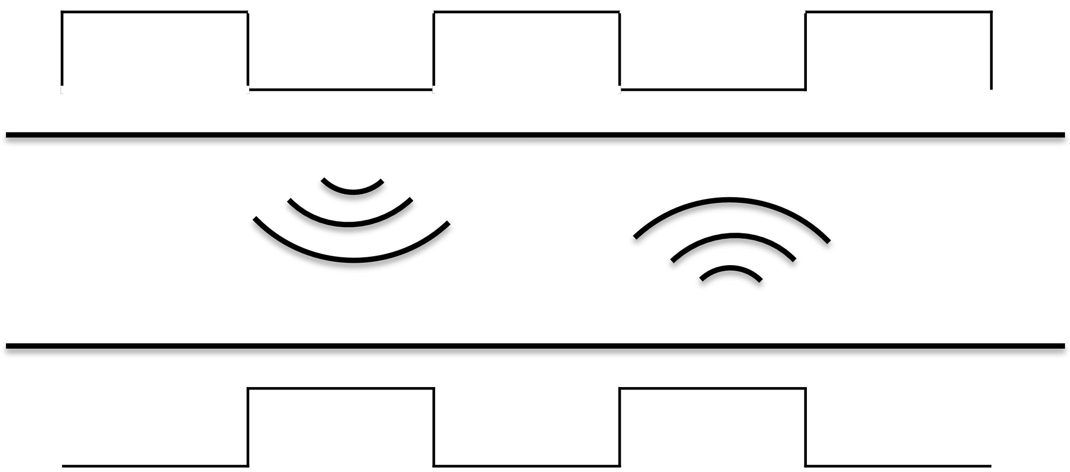
A high speed digital signal in a wire will act as an antenna

Theory – Signals can Interfere



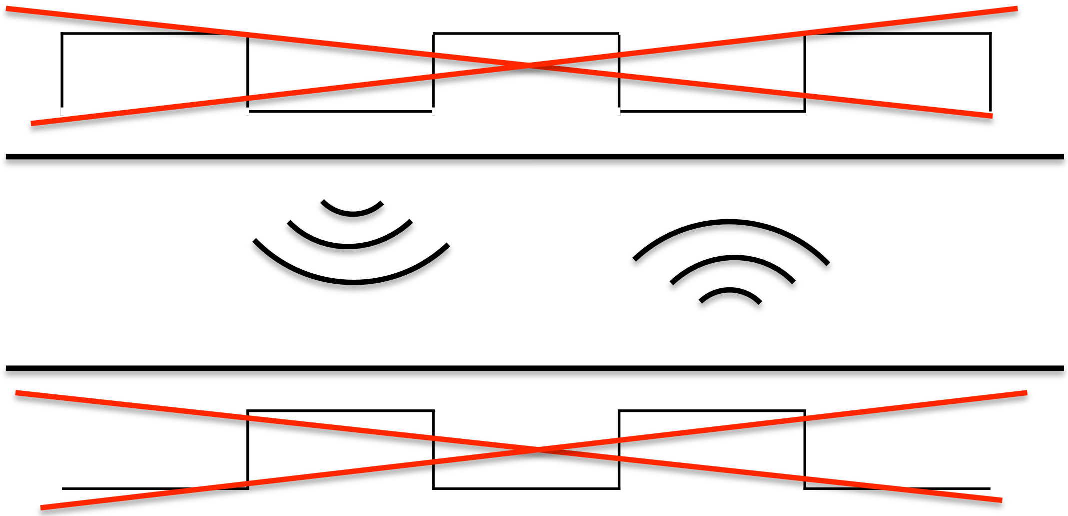
And will induce a similar signal in adjacent wires

Theory – Signals can Interfere



Worse, it goes both ways!

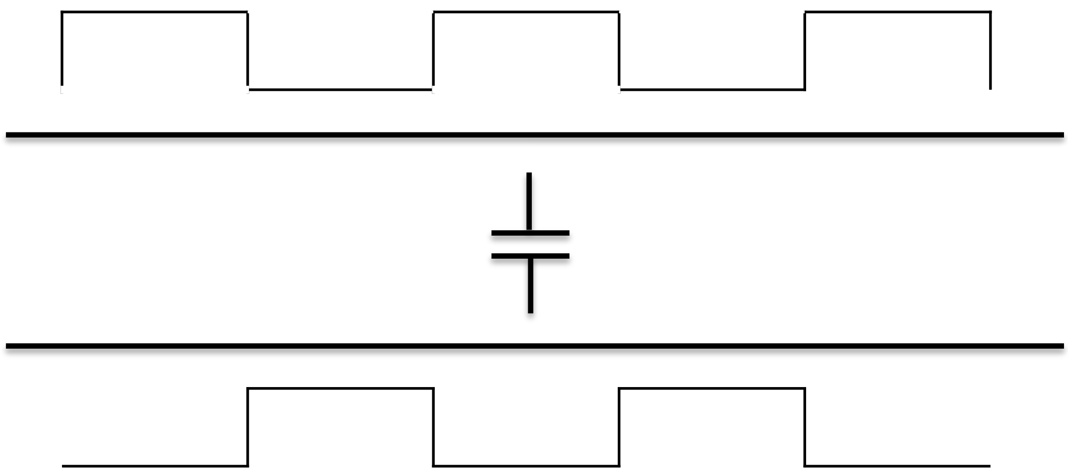
Theory – Signals can Interfere



Neither signal is usable

Worse, it goes both ways!

Theory – Signals can Interfere

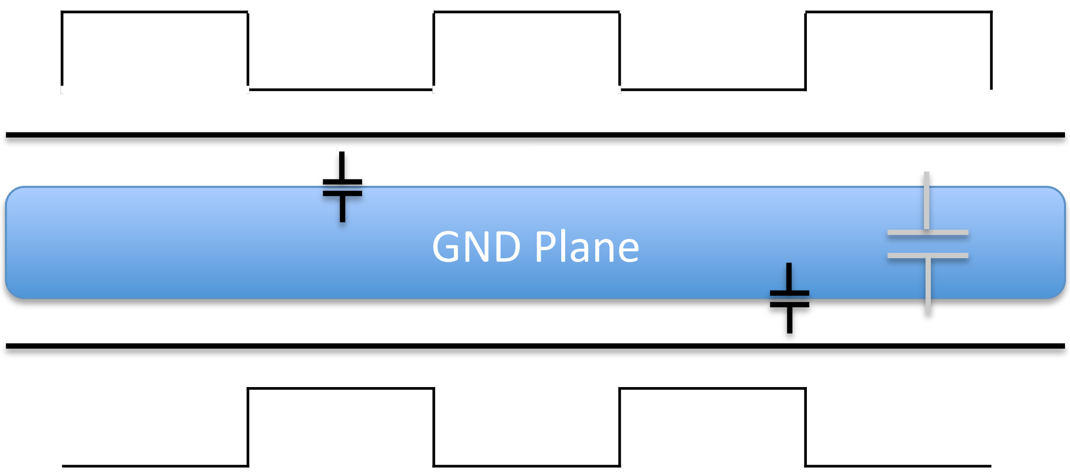


If the antenna analogy doesn't work for you, its also called

Capacitive Coupling

An implied capacitor between the lines, and a capacitor resists changes in voltage

Theory – Signals can Interfere



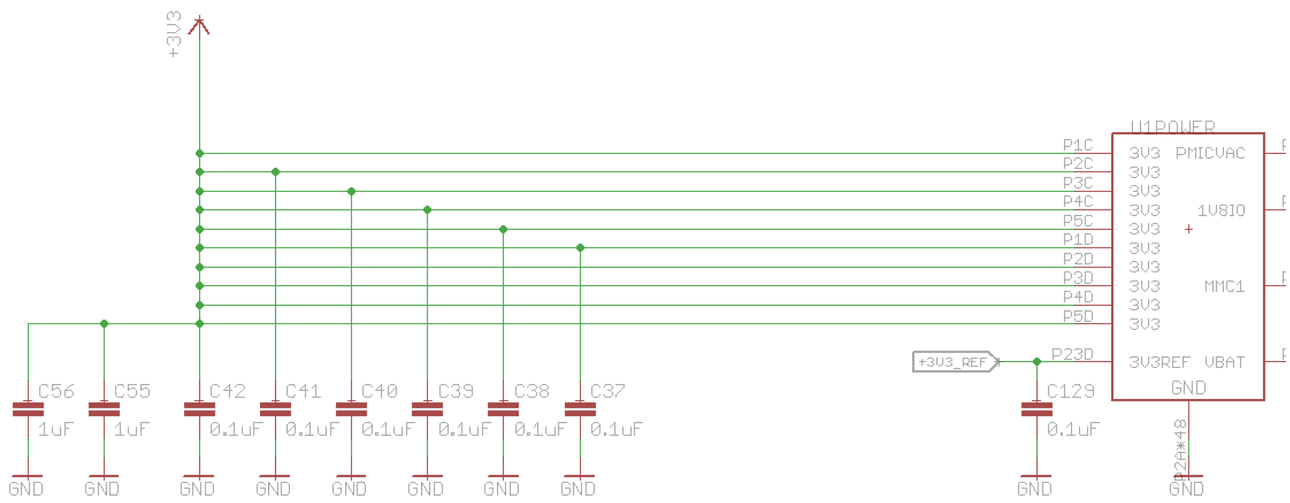
Either way, solve it with a ground plane (copper poured in-between and connected to GND):

For you antenna folks, the plane is a faraday cage

For you capacitor folks, the plane is dominated by two separate capacitors

Theory – Decoupling

Power supplies are inherently noisy, microprocessors and other ICs cant handle that



Microprocessor App Note will describe decoupling requirements, location is key!

Typically at least one 0.1uF ceramic for every power pin

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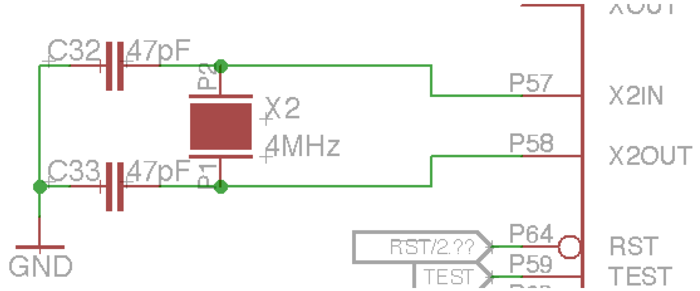
Theory – Capacitive Loading

Capacitive loads are used to temper crystal oscillations speeds – more capacitance means slower oscillation

Both the crystal and the microcontroller are expecting a certain load

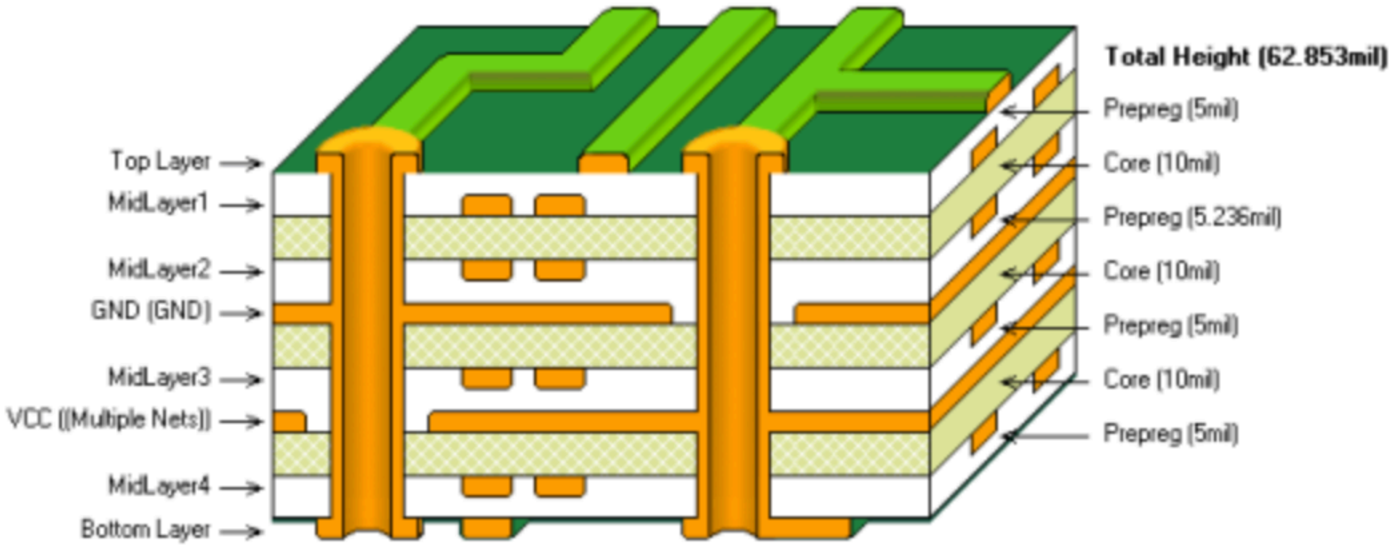


$$C_L = \frac{C_{X1} * C_{X2}}{C_{X1} + C_{X2}} + C_{stray}$$

This is voodoo magic, best practice is to get the crystal part number from the microcontroller datasheet, and use the capacitor values it recommends

Theory – PCB is a stack of layers

Alternating metal and non-metal. At least two metal layers, or many more



Vias (plated holes) allow signals to move between the layers

Questions about the theory?

Circuit Design – 30,000 feet

1. What is the circuit supposed to do? Where will power come from? What are the form factor requirements? (concept)

2. Which parts are need to be included to realize goals? (part selection)
   1. Do you have libraries? (part creation)

3. How does it all connect? (schematic capture - readable)

4. Where does it all go? (PCB layout – no shorts)

EAGLE - Navigation

- Zoom in/out with the scroll wheel
- Pan by pressing & holding the middle mouse button
- Mac multitouch works well (two finger zoom, three finger pan, etc)
- Otherwise I don't recommend using a trackpad

EAGLE - Commands

- Commands can be launched from the command line or from buttons

  Move a part by typing ‘move’ or pressing 

- You can ‘click’ from the command line too

  When running ‘wire’, put a wire at point x=0.1”, y=0.1” either by clicking there or typing (0.1 0.1)

- Only interact with a part at its origin

- Exit out of a command with ‘;’ or 

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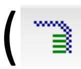
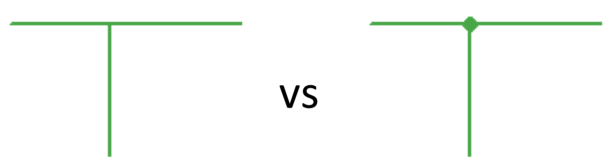
EAGLE – Schematic Capture

- Add parts using ‘add’ or 
- Copy parts using ‘copy’ or 
- Move using ‘move’ or 
- Lots of other commands for part manipulation including ‘rotate’, ‘delete’, ‘mirror’ to be explored

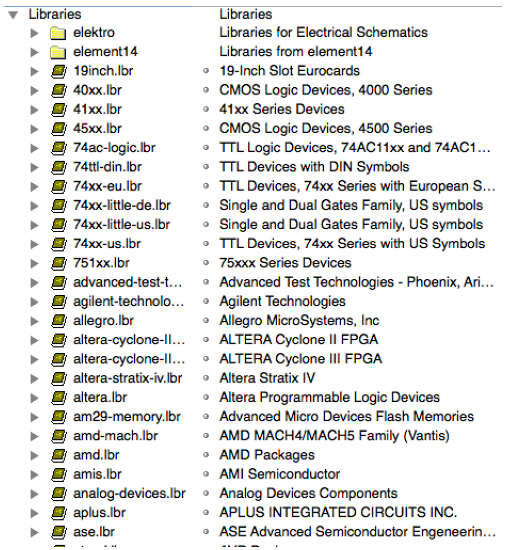
EAGLE – Schematic Capture

- Once you have added parts, connect them with the ‘net’ command ()
- Net allows you to draw wires between pins, but don’t use ‘wire’!!!
- Difference lies in junctions (‘junc’):



EAGLE – Schematic Capture

- Until this point, we haven't talked about libraries.
- EAGLE has lots of preloaded parts, but what if you want a different part?
- Make a new library!



EAGLE – Part Creation Interlude

- Making parts is hard, and you need to be very careful
- Like the pairing of the schematic capture and the PCB board layout, a Part has multiple components
    - The Symbol is what goes in the schematic
    - The Package is what goes in the board
    - The Part is what links the two.
        - The part is where you map Symbol pins to Package pads. Can store pn# too.

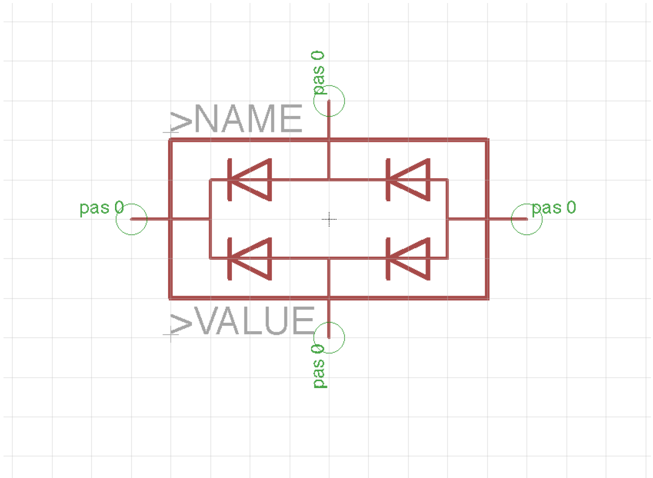
EAGLE – Symbol Creation

- Making the symbol involves placing **pins** and connecting them with some sort of an outline

- Can include identifying symbols and names too

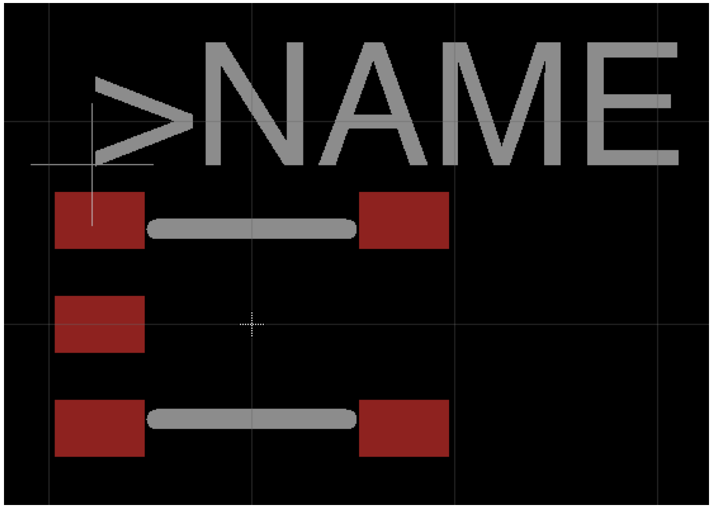
- This is the readable version

- Lots of flexibility with how this looks, depends on how you want to see it



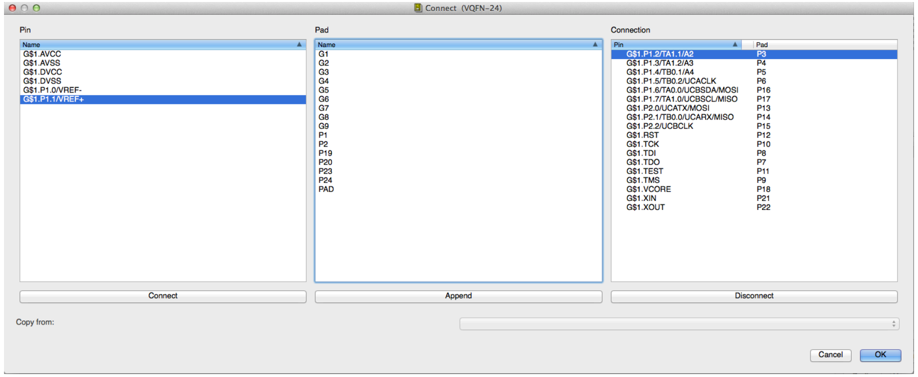
EAGLE – Package Creation

- Making the package involves placing **pads and smds**
- Can still include a name (called a Reference Designator)
- This is the physical version
- Needs to be exactly the size and dimensions of the actual part



EAGLE – Part Creation

- Part is what you actually add to circuit
- Contains both symbol and package
- Primary function is to connect pins from the symbol to pads and smds in the package
- Can also store other info (attributes)



EAGLE – Part Creation Interlude

- The 'use' command allows you to add parts from your new library into the schematic
- The command 'use -*' un-uses all the default libraries if you want to de-clutter and start over
- EAGLE scripting is great for this (outside this scope, but follow up if youre interested).

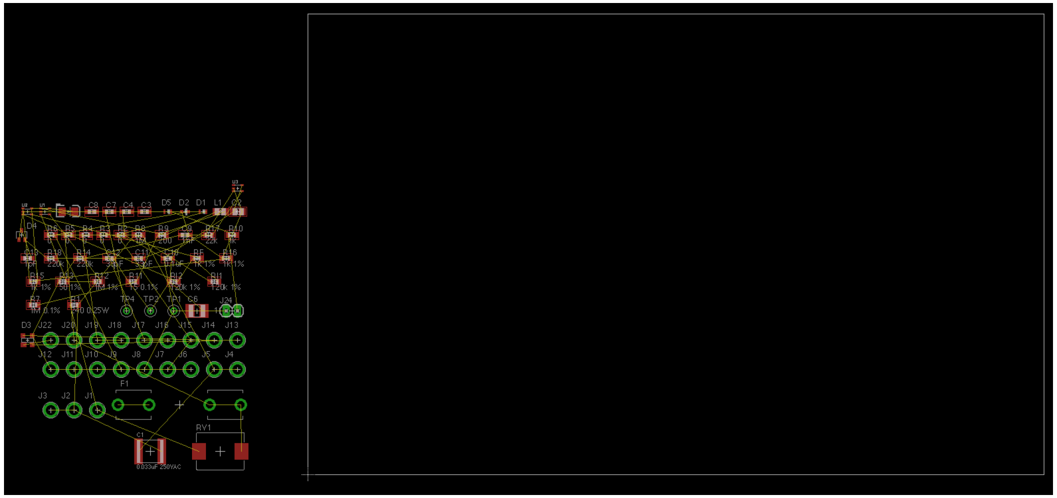
EAGLE – Schematic Capture

- Other useful commands in the schematic
  - 'name' - allows you to assign a net's name. **Nets with the same name will be connected.**
  - 'label' – put a visual label showing a net's name
  - 'text' – put text down in the schematic
  - 'smash' – move a part's name label freely
  - Don't forget about supply net symbols!

Plus lots more!

EAGLE – Sch -> Brd

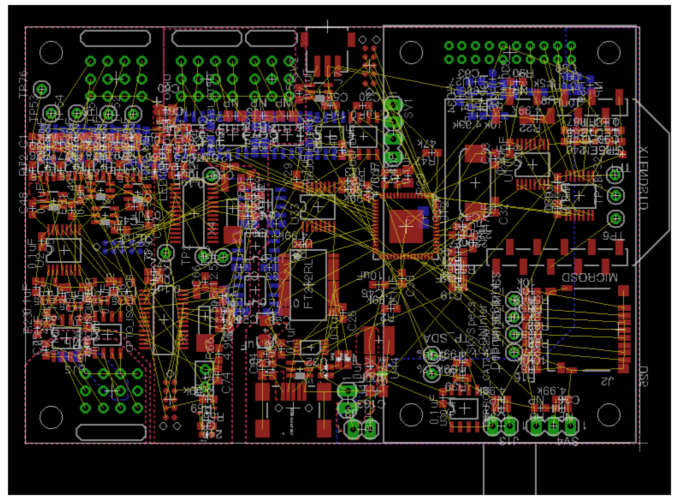
- Once youre (mostly) done type ‘board’ or 



And the board is made, although it looks pretty funky

EAGLE – Board Layout

- Layout is two interweaving but separate actions:
  - Placement
  - Routing



- Don’t be fooled into thinking routing is the important step. A well placed board routes itself (not literally)

- Place based on 1) use and 2) circuit

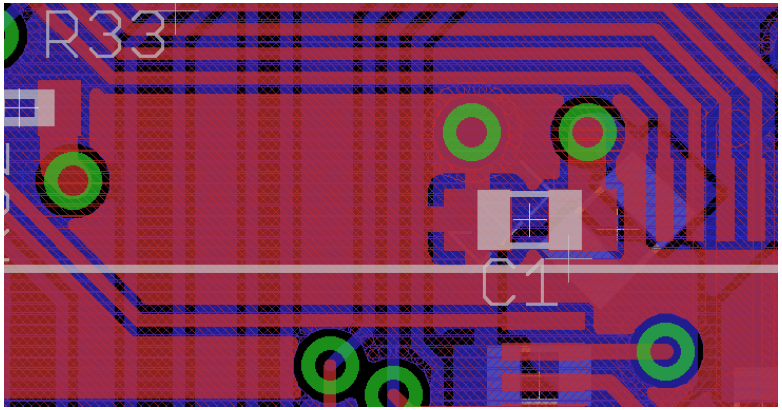
EAGLE – Routing

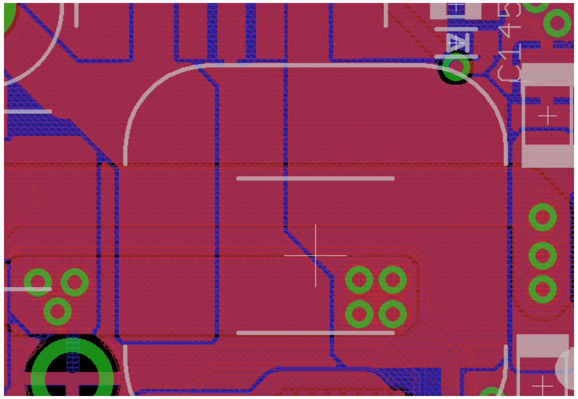
- Once youre done placing, ‘route’
- Those yellow lines are **airwires** that represent routes-to-be
- Quick tips
  - ‘route <width>’ will route with a certain width trace
  - Typing ‘layer <l>’ while routing will place a via and switch to that layer
  - Middle click while routing also switches layer
  - Left click changes angle style
  - Run ‘drc’ often

EAGLE – Routing

- Polygons are large spaces of copper "poured" (remember a GND pour shields traces)

- Polygons on the board are ranked, and will avoid traces





- Generally recommended to pour top and bottom with GND

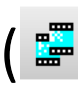
EAGLE – Checking Your Work

- Run ‘erc’:
    - Checks for inconsistencies between sch and brd
    - Checks for minor errors in sch (single pin nets)

- Run ‘drc’: (early and often!)
    - Checks for violations of the design rules

- Run ‘rats’: (also early and often!)
    - Re-process all polygons
    - Re-draw all airwires to shortest paths
    - Count remaining airwires (displayed in bottom left)
    - ‘rip @;’ hides polygons afterward

EAGLE – Finishing Up

- Board house (Advanced Circuits, Sunstone) needs Gerber files
- Generate these using the CAM processor ()
- One Gerber file for each layer
- Check your work with online Gerber viewer tools
- Use EAGLE scripts to generate dxf’s for stencils, BOMs, etc

Seek out EAGLE dru and CAM job files from the board house

PCB Best Practices/Final Checks

- Is the silkscreen correct? (Important for assembly)
- Is the silkscreen readable?
- Are connectors obvious in the silkscreen?
- Do parts have part numbers?
- Do you have enough test points (1.03mm)?
- Can everything be accessed and assembled?
- Are LEDs labeled?
- Is there a power LED (alive indicator)?
- I2c addresses non conflicting, CAN stubs short
- Name & date & version number in the silkscreen

Questions?

MESH has tutorials complete with sample .sch, .brd, and .lbr files