EECS 373
Introduction to Embedded System Design

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Lecture 11: Memory and PCBs

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Review

- Misc project-related applications and examples
- Prototyping

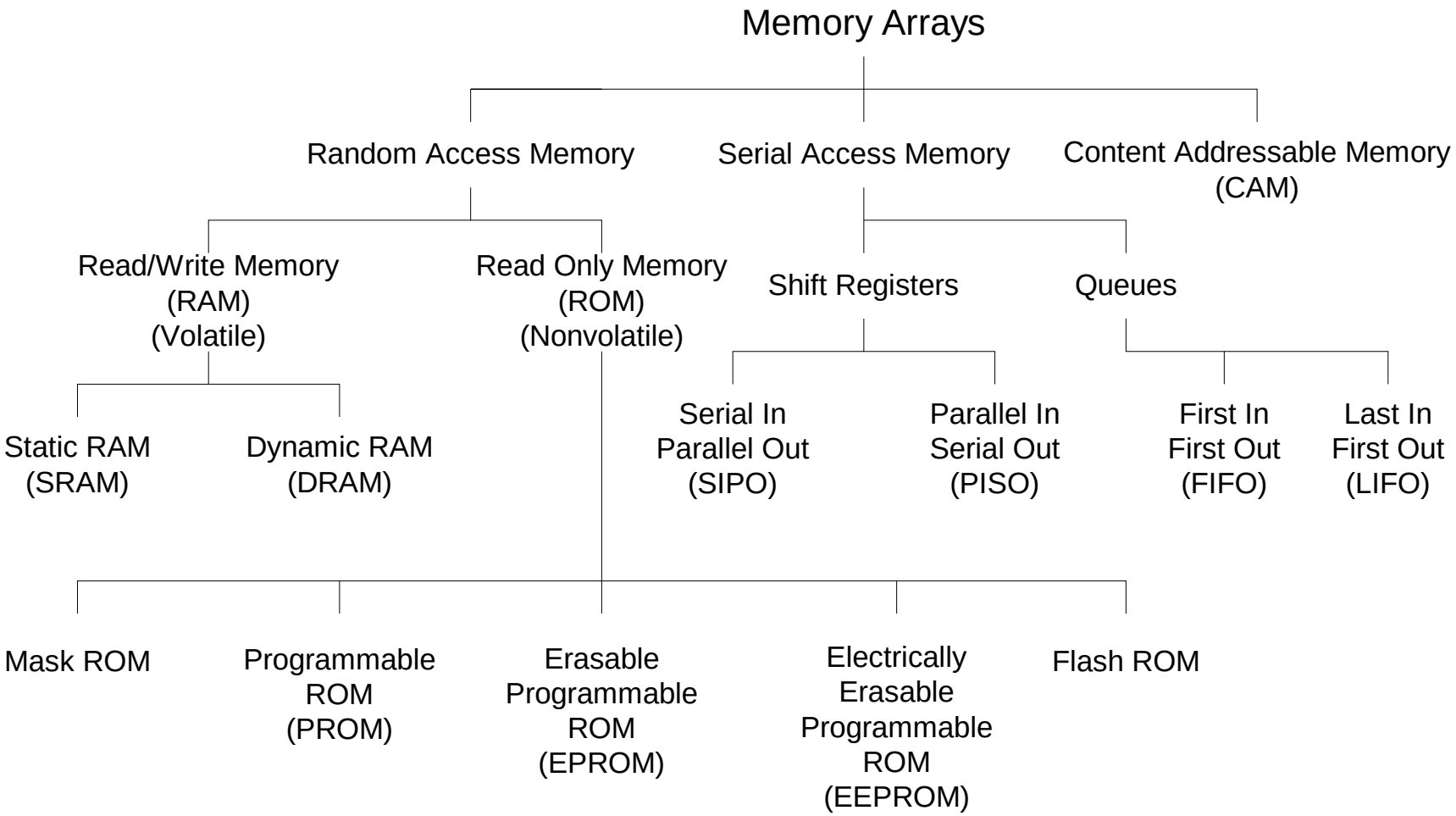
Outline

- **Memory**
- PCB design

Memory: why?

- You'll be dealing with this a lot in your career.
- Technologies will change.

Memory types



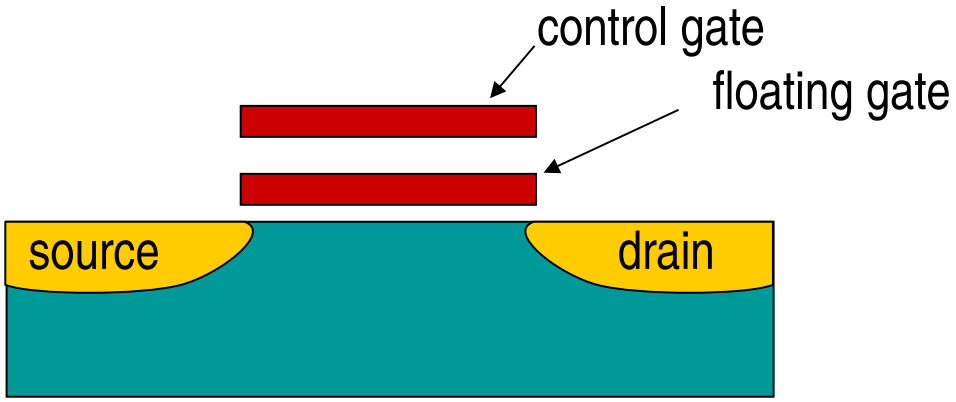
Nonvolatile memory types

- Flash: ~ms. 10E6 V/cm. Around 1E6 write cycles.
- EEPROM: ~ms.
- SRAM/DRAM: ~ns.
- Spin-Transfer Torque Magnetic Memory: Recently entered commercial production. Compared to Flash, high endurance (10E12 write cycles), low or no leakage, fewer masks, write energy of 120 fJ/bit.

- Others still at / just left research stage.
  - Bipolar-Filamentory OxRAM: Make / break conductive filament. Write energy of 230 nJ/bit. High switching currents prevent large arrays.
  - Spin-Orbit Torque.
  - Voltage Controlled Magnetic Anisotropy (6 fJ/bit write energy).
  - Bi-Polar Non-filamentory OxRAM; Conducting Bridge Memory.
  - Macromolecular (Polymer) Memory.
  - Ferroelectric FET.
  - Ferroelectric Tunnel Junction.

Floating gates

- Write: hot-electron injection or Fowler-Nordheim tunneling.
  - High voltage on control gate >> operating voltage
  - Electrons are trapped in the floating gate.
  - Will not discharge for many years.
- Erase? Fowler-Nordheim tunneling.



- Read by seeing whether it acts like a transistor or a wall.
- Tend to self-destruct after 100,000 writes/erasures.

Outline

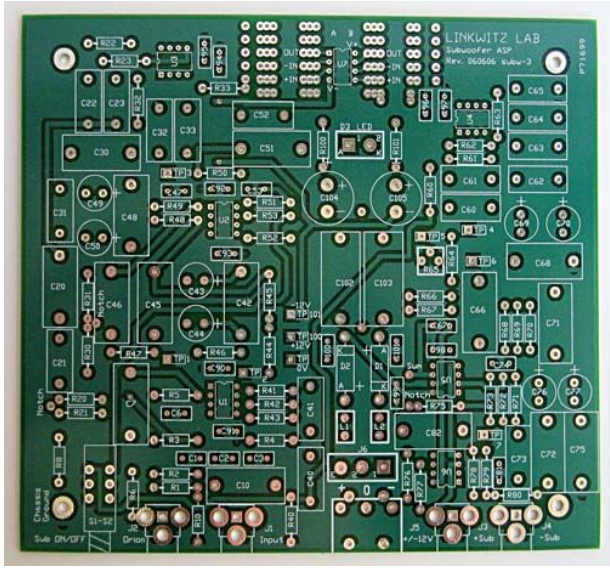
- Memory
- **PCB design**

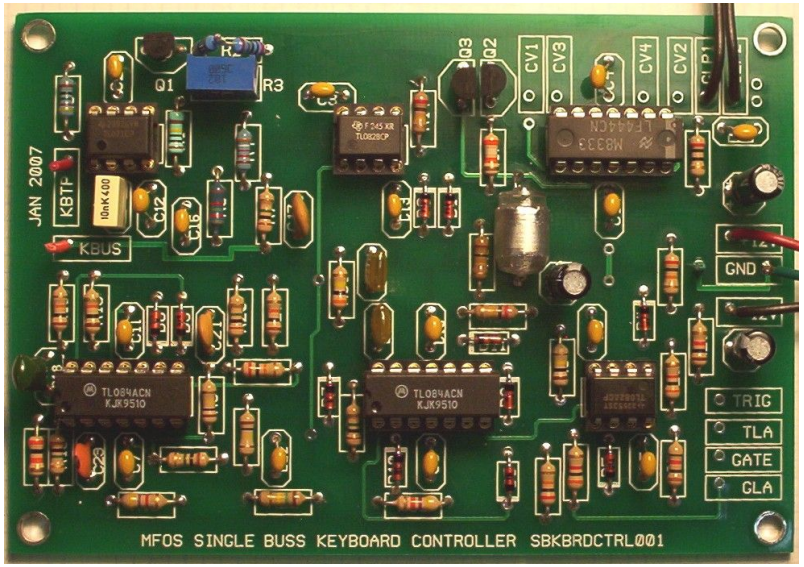
PCBs: why?

- Even if you aren't making one for your project, need to understand how they work for debugging / reverse engineering.

Printed circuit board design

- Physical support.
- Electrical connections.
  - Traces have restricted size.
  - Thin, high resistance.
  - Holes/vias and pads.
  - Rework is hard.

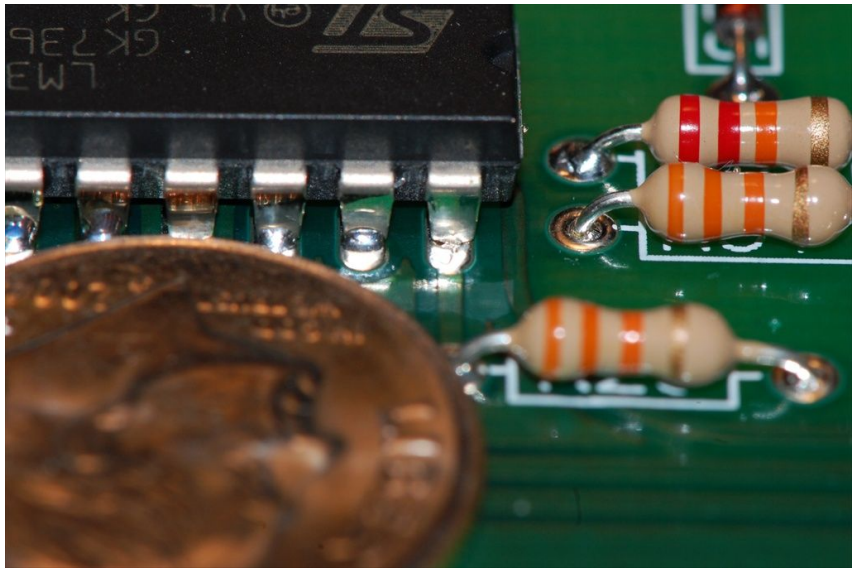


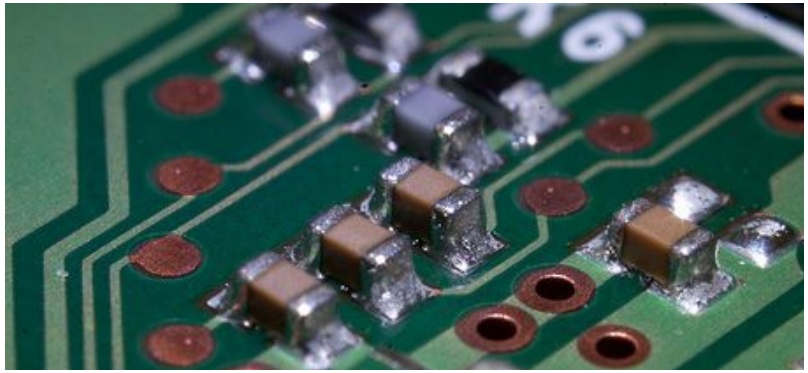


http://www.linkwitzlab.com/Pluto/supplies-subw.htm,
http://www.musicfromouterspace.com/analogsynth/SINGLEBUSSKEYBOARD2007/SINGLEBUSSKEYBOARD2007.php

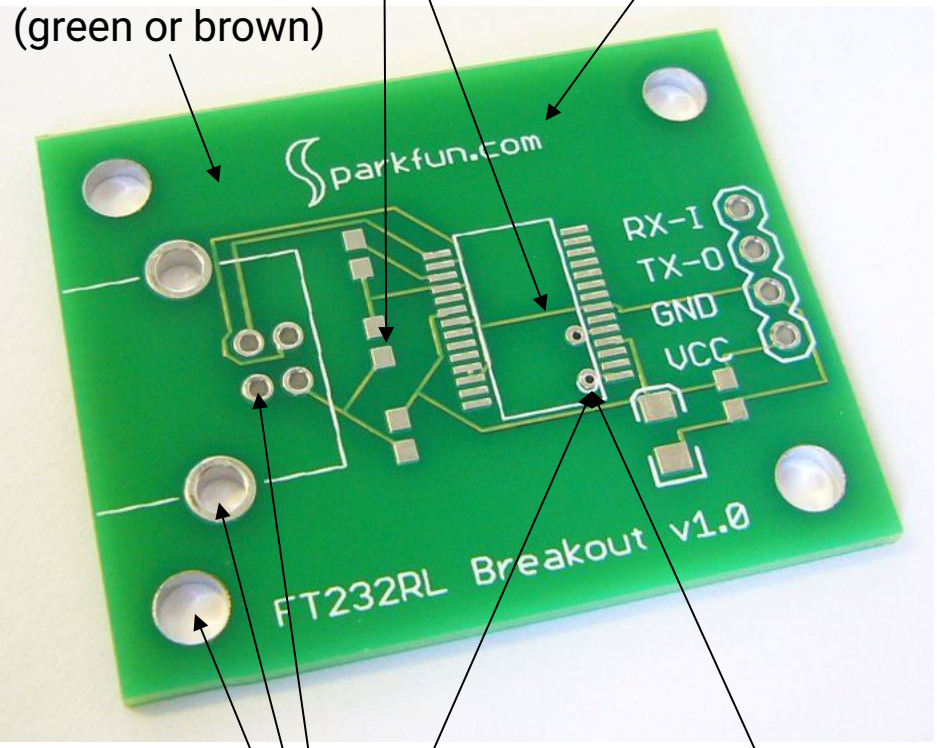
Basic terminology

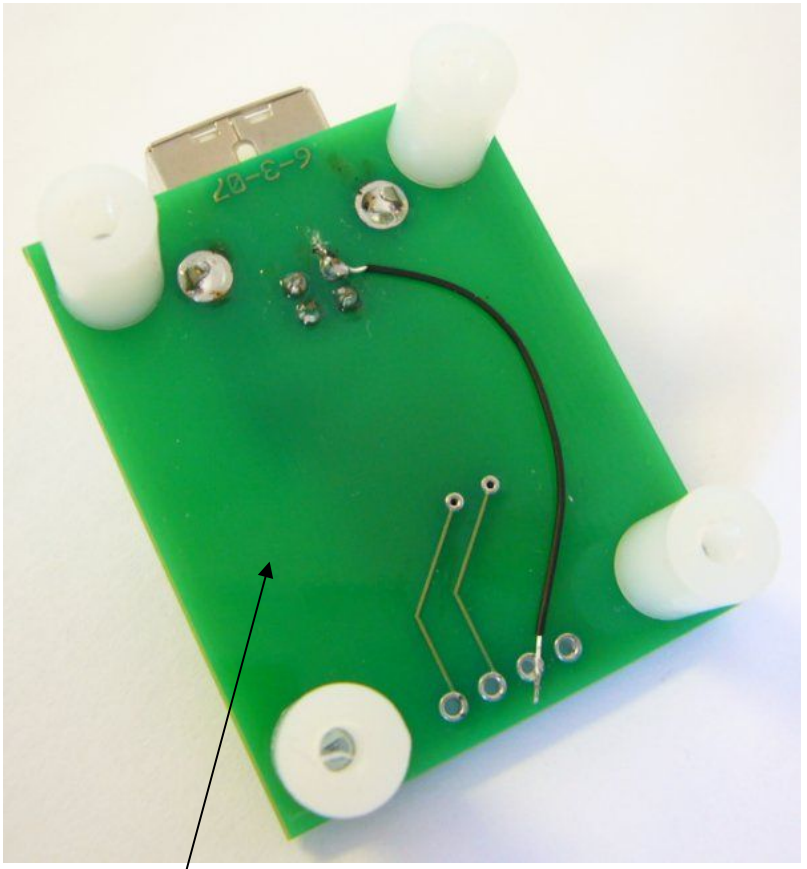
- Interconnects: traces.
- Traces that touch on the same layer are electrically connected.
- Multilayer common: stack.
- Through-hole: for pins.
- Surface mount.





Parts of a PCB





Vias

- Connect traces on layers.
- Use a via: plated-through hole
- Generally smaller than a through hole for a pin.

Clearances

- Space between the traces, other traces, and plated holes.
- Meet manufacturer requirement.

The layered construction of a PCB: a six layer board

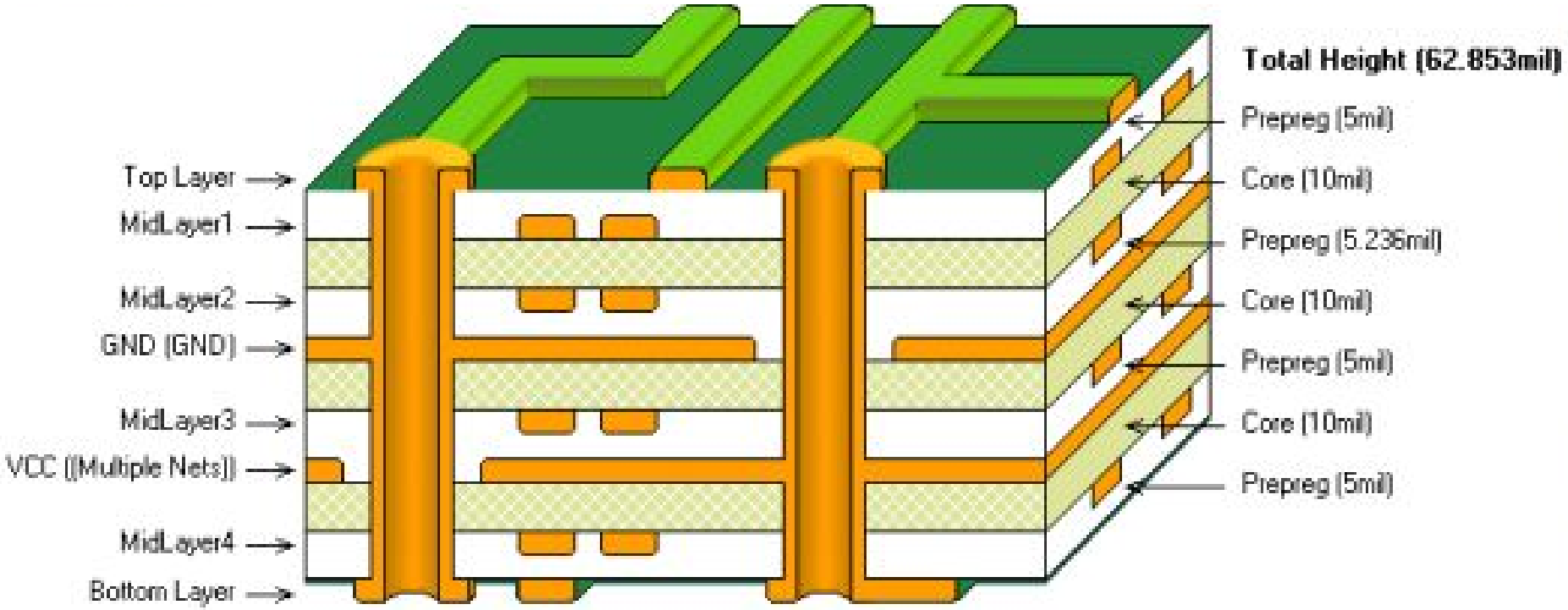


Figure from altium.com

What do do with layers?

- Mostly orthogonal routing layers.
- Ground planes.
  - Increase power supply capacitance
  - Minimize resistance.
  - Some shielding effect.
- Power plane for similar reasons.
- More layers → higher cost.

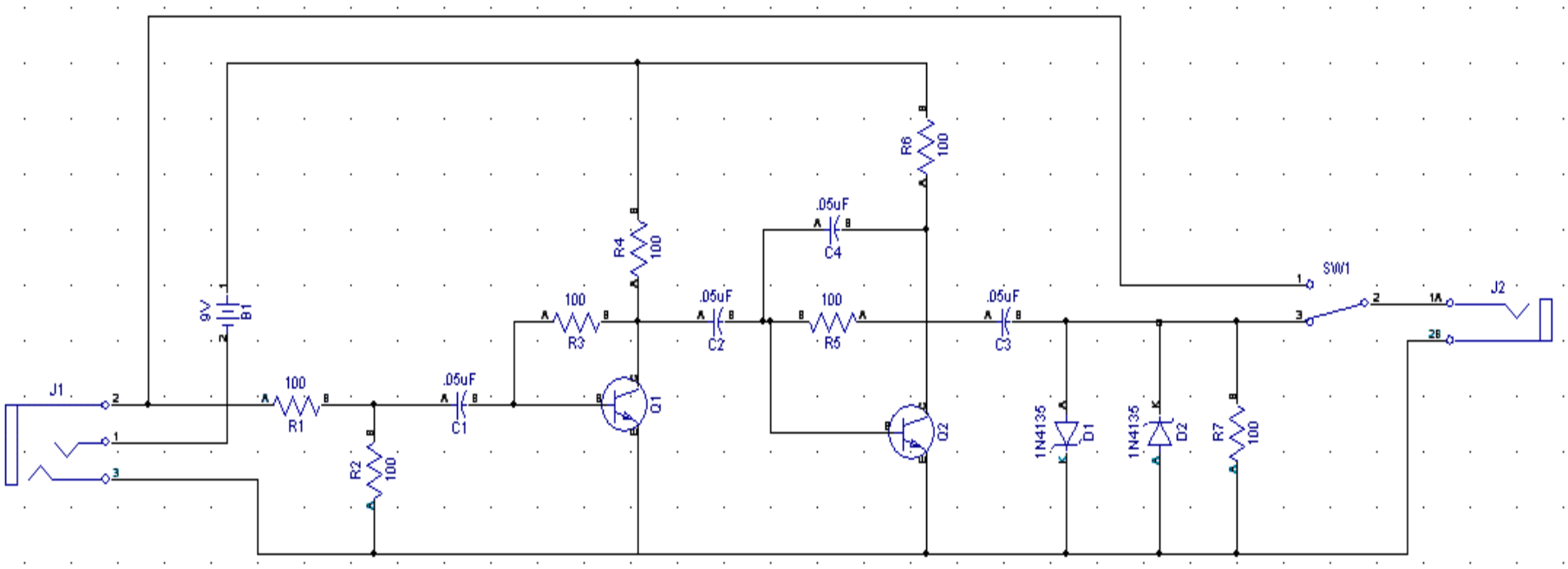
How to design PCB

1. Create schematic
2. Place parts
3. Route interconnect
4. Generate files

Step 1: Create schematic

- Show devices and connections.
  - May consider pinouts.
- Layout follows functionality and connectivity, not physical structure.

Example schematic



Purposes of schematic

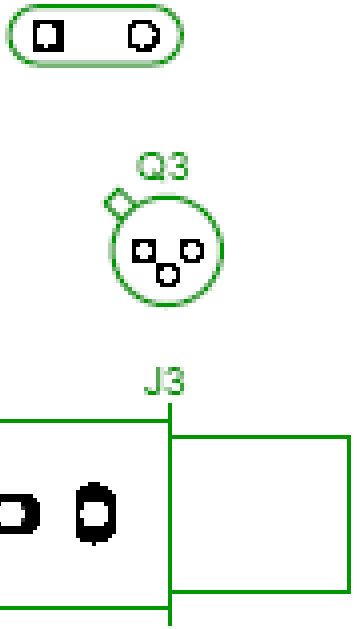
- Communication and formalization.
- Bug hunting.
- Synthesis.

Step 2: Place parts

- Place patterns on board.
  - No component overlaps on same side.
  - Leave room for traces.
- An art.
- Some tools help.
- Sometimes they fail.

Patterns

- Trace/component sizes.
- Hole positions.
- Each device has a pattern.
- Many are standard.
- Some aren't: create own.



Step 3: Route interconnect

- Route: connection among devices.
  - Multiple traces.
- Design rules.
  - Minimum trace width.
  - Minimum traces–hole spacing.
  - Minimum hole–hole.
- Rules vary by manufacturer.
- Units vary by manufacturer.

Issues of measure

- PCB designers use odd terminology.
- A “thou” is a thousandth of an inch.
- A “mm” is a millimeter.
- A “mil” is a thousandth of an inch.
  - Thou is generally preferred over mil to avoid confusion, but most tools/vendors use mil.

Trace width

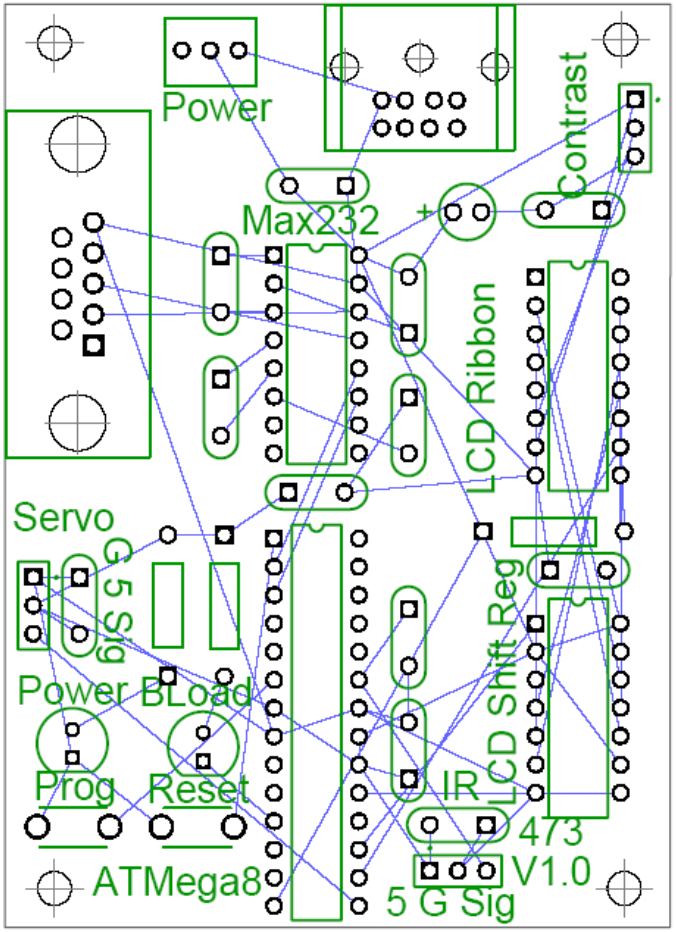
- Trace width minimum of 6-10 thous common.
  - Finer at a price.
- Guidelines to control R and temperature:
  - 50 thou min for power/ground.
  - 25 thou min.
  - 10 cm trace >= 10 thou wide at 1 amp.
  - 5 amps >= 110 thou.

Trace width continued

- Wide traces hard to route.
- Necking down sometimes acceptable.
- Consider series resistances.

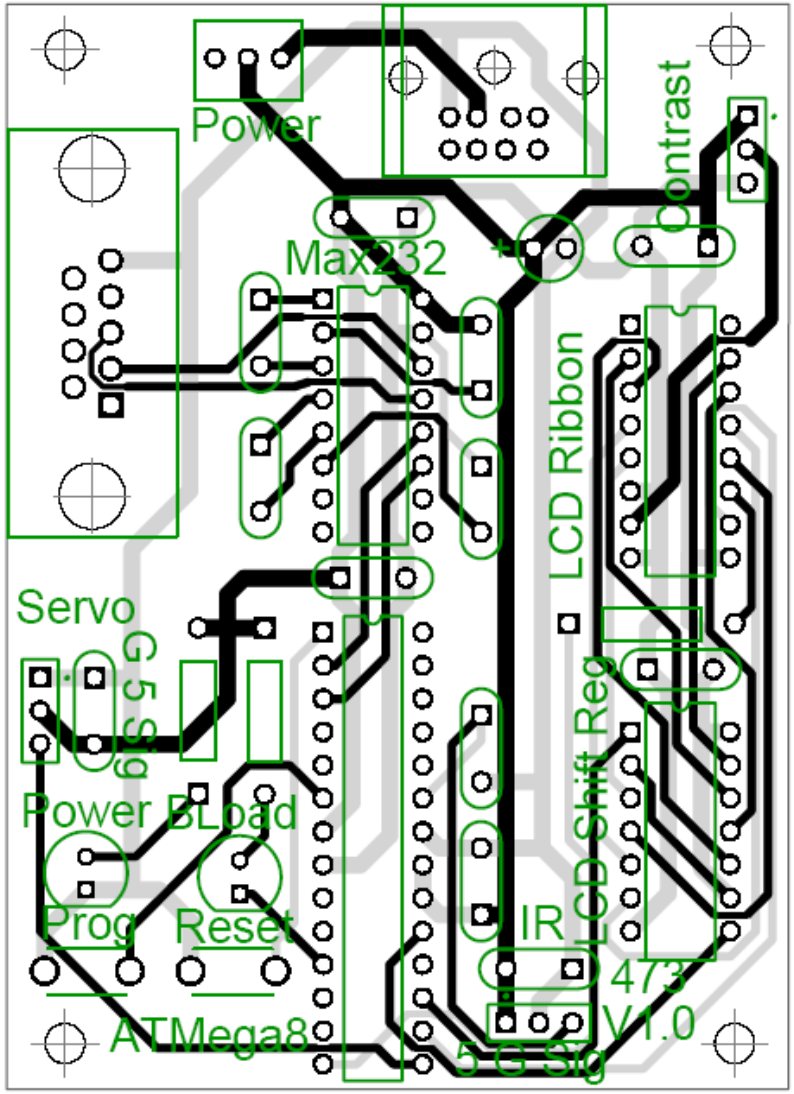
Rat's nest

- Device placements and connections.
- Automatically generated.

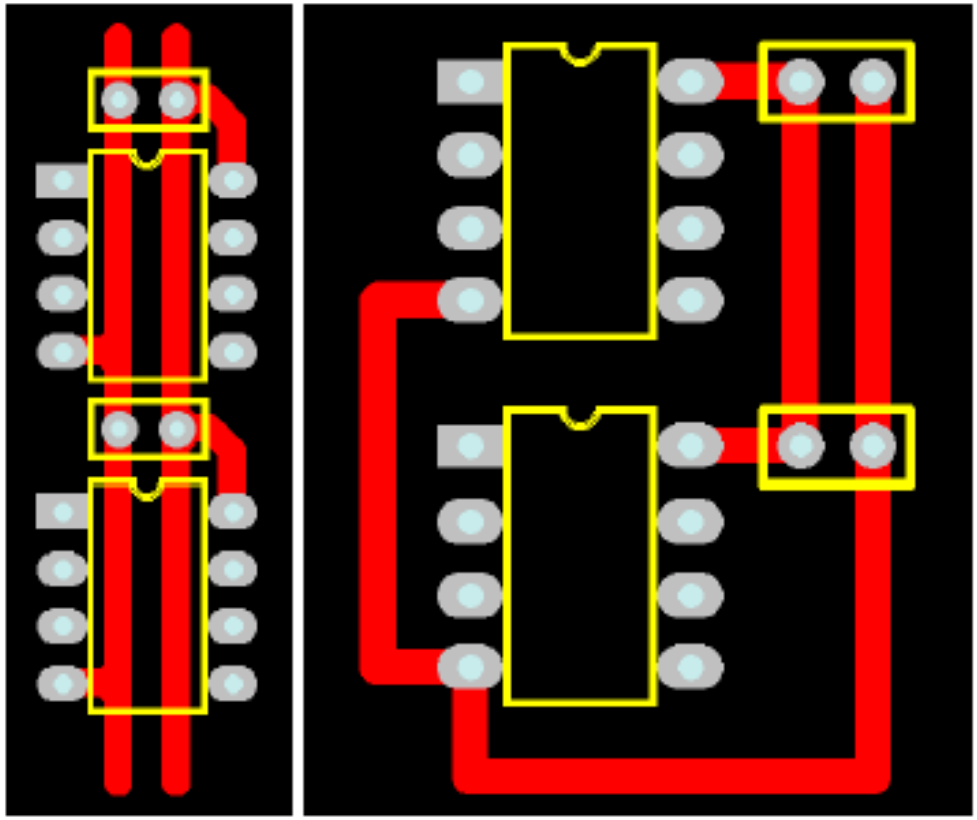


Routing for real

- Autorouter
  - May seem disorganized.
  - Quick.
  - Often worse than manual.
- Some nets fail.
- Do them manually.



Routing quality

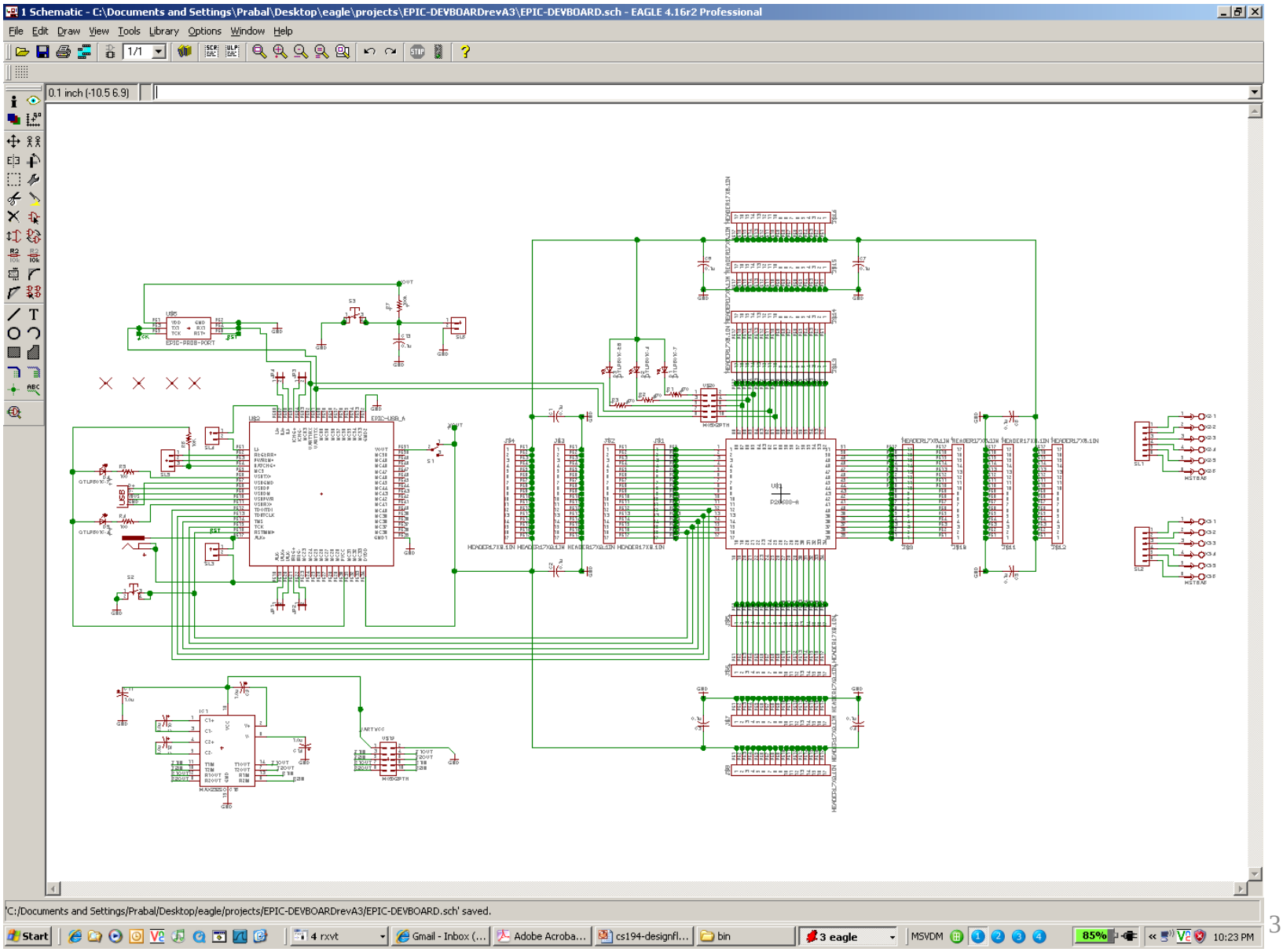


An example of GOOD power routing (Left) and BAD power routing (Right)

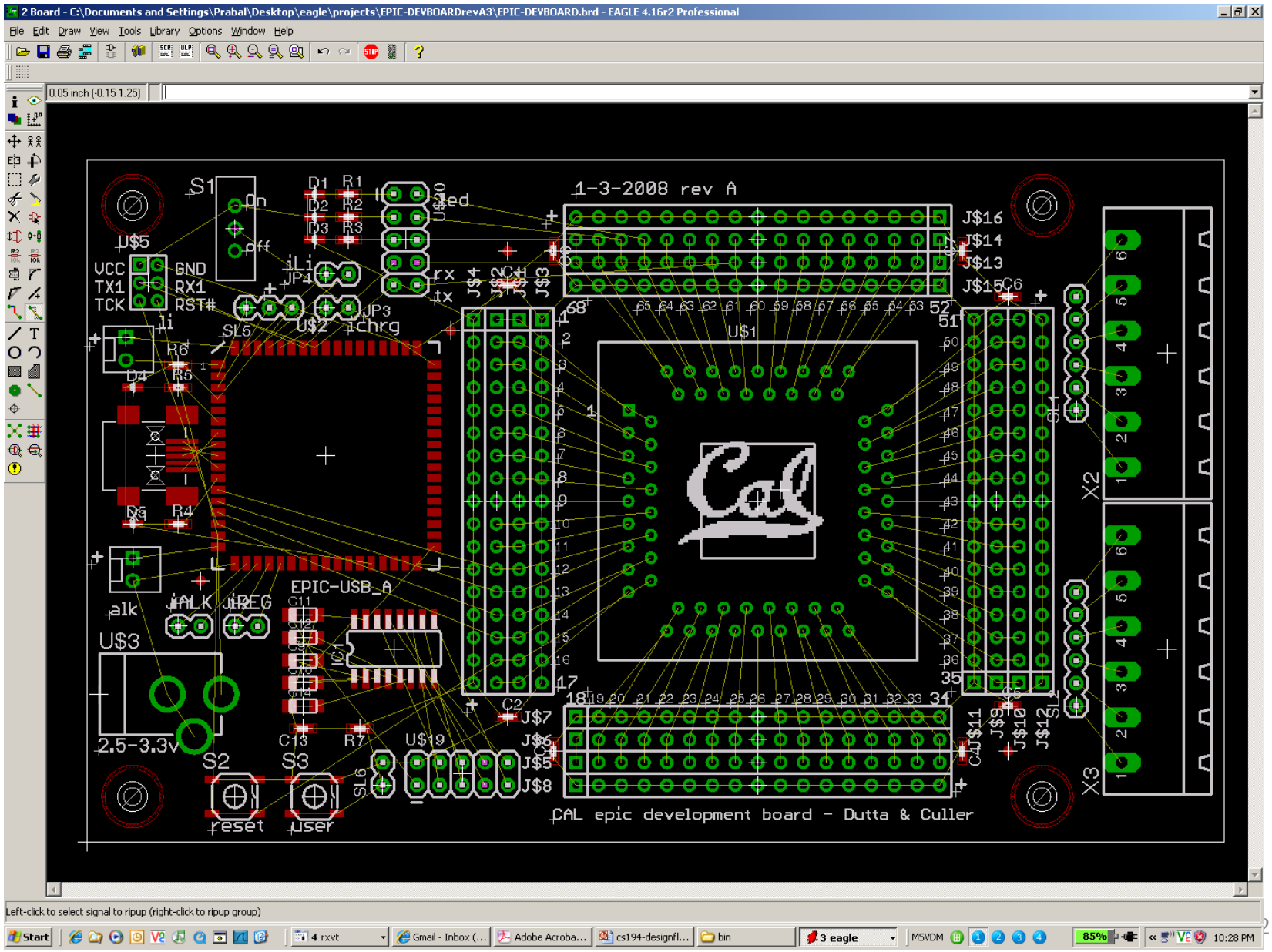
Step 4: Generate files

- Different layers/stages.
  - Copper on a given layer.
  - Silkscreen.
  - Solder mask.
- Gerber format common.
  - Human-readable (barely) ASCII.
  - Commands like draw and fill.
- Drill files in Excellon.
  - Human-readable (barely) ASCII.
  - Hole locations and diameters.
- Archive and send all files to PCB house.

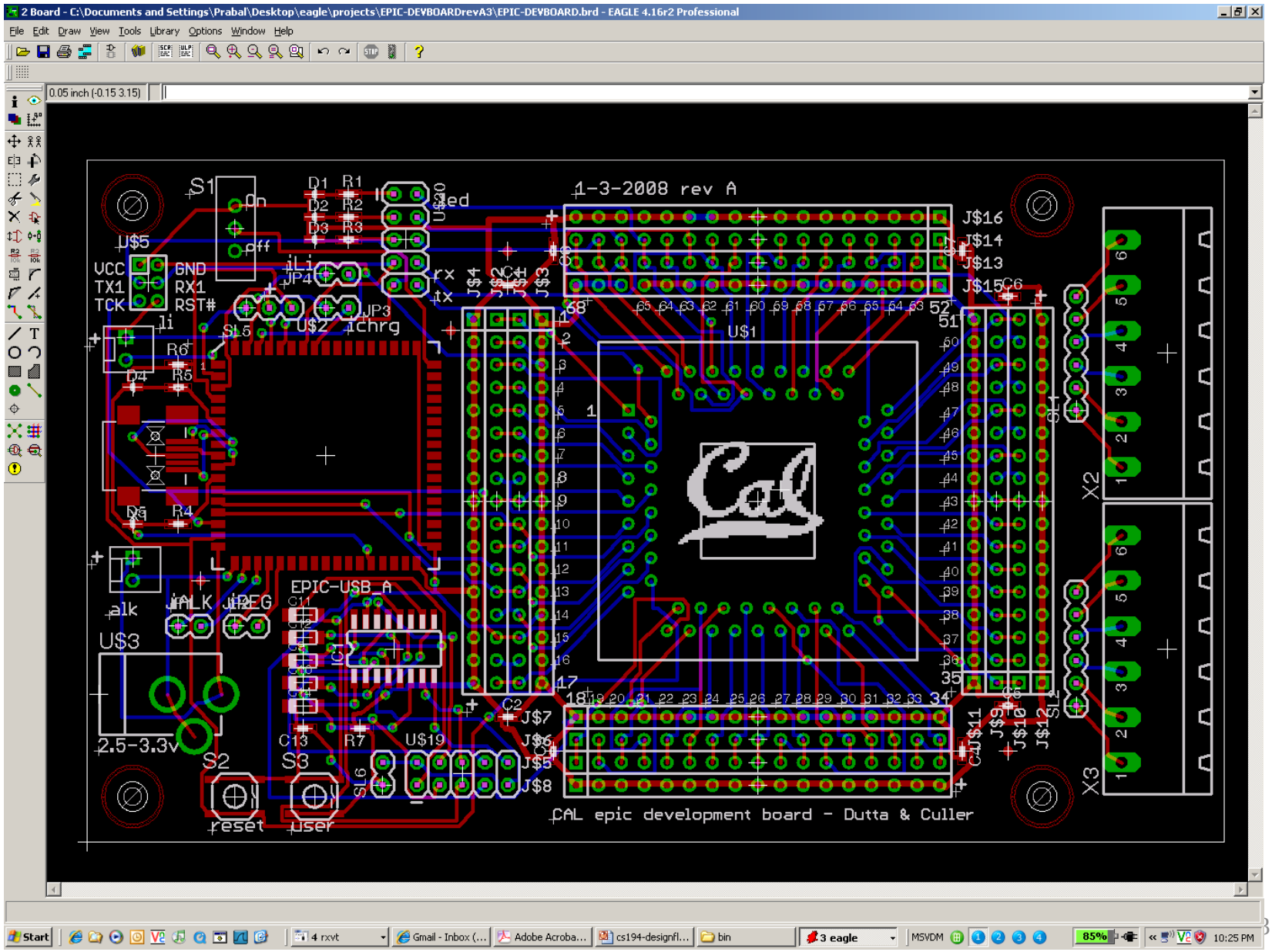
The schematic captures the logical circuit design



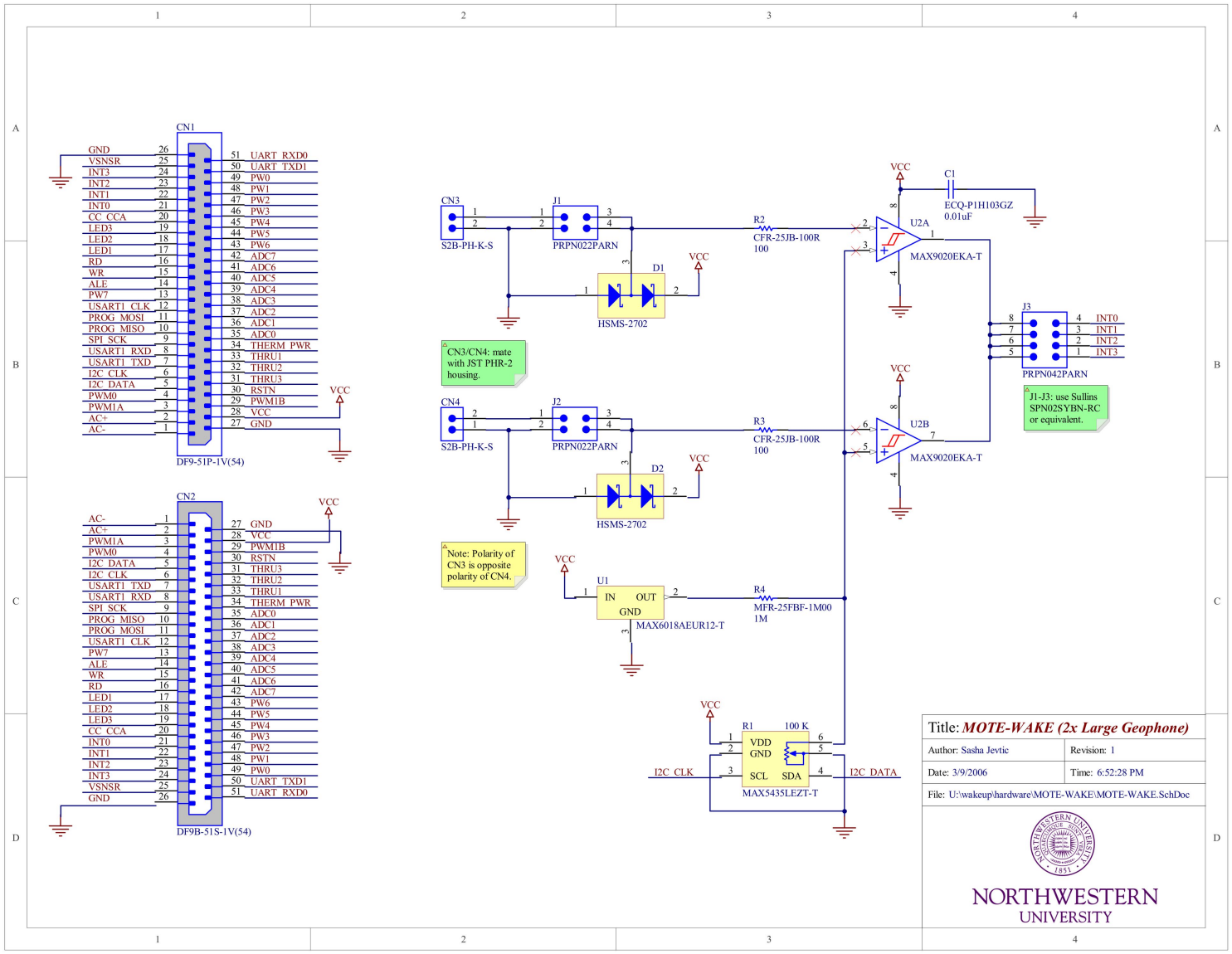
Floorplanning captures part locations



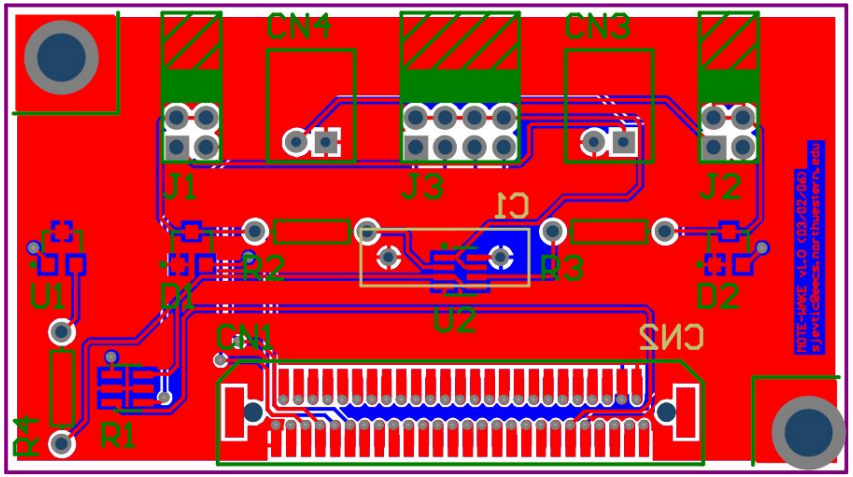
The auto-router places tracks on the board, saving time

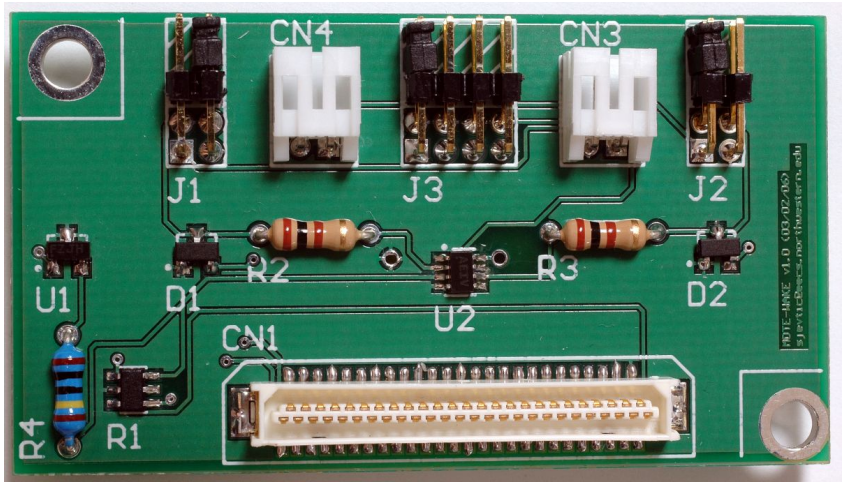


Another design, all the way to production



Another simple design, all the way to production





- Simple design that solved a hard problem.
- Deployed at many sites around U.S.

Not a simple design

- Note component density
- Can mount components on each side.
- Relationship between PCB layout, pinouts, and external components important.
  - LED.
  - Battery.
  - Others, e.g., big inductors.
- Form (and board shape) follows function.
- RF subsystem physical design tricky.

The layered construction of a PCB: A six layer board

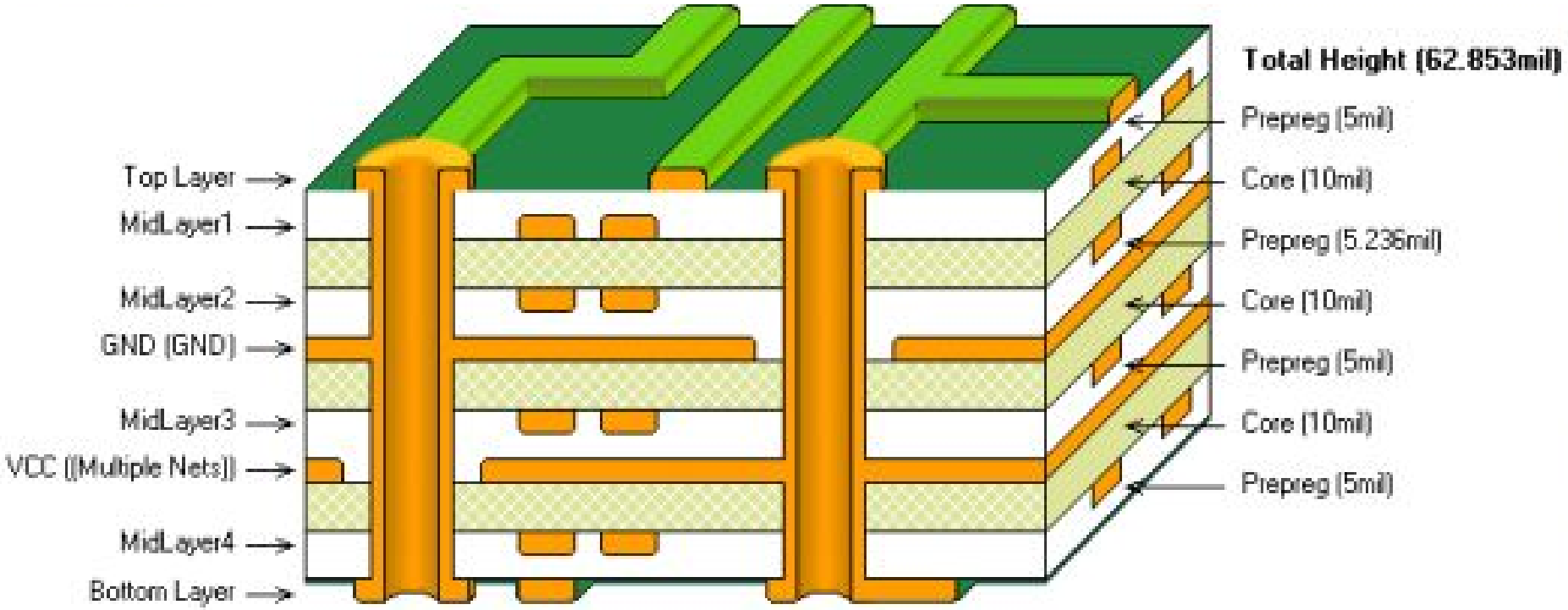


Figure from altium.com

Doesn't need to be expensive / complex

- Can CAD/CAM mill away solid Cu layer.
- Can use lithography.
  - Photoresist.
  - Mask (can print with laser printer).
  - Projector.
  - Etchant (many are dangerous to breathe and touch).
  - Safe way to dispose of Cu-containing solution.

Done.