A printed circuit board (PCB):

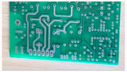
1. Supports the components physically
2. Connects the components electrically

Electronics have become **smaller** and **more complex** leading to the need for **precise planning** and **thorough testing**

- A PCB has two main tasks, one physical, one electrical.
- They get intertwined sometimes making PCB layout something of an art
- we have to start thinking not just how to design something electrically, but physically, how are we going to construct it.
- let's start with connecting the components together

Electrical Connections

- A “trace” is the equivalent of a wire for conduction electricity
- Power/ground traces tend to be larger
- Signal traces are usually narrower

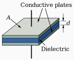


- A trace consists of a flat, narrow piece of the copper.
- We can put traces in categories depending on the nature of the electrical signal they conduct
- Power/ground traces tend to be larger to mitigate temperature rise.
- Signal traces are usually narrower than power/ground traces as they carry less current
- This gives us a basic idea of how a PCB is used to create a circuit. Some piece of material (paper/plastic) has some other material (copper) on it.
- This mostly works out okay but sometimes the physical design and the electrical design get in the way of each other. That’s where the “engineering” starts.
- How do we make trade offs that are acceptable?
- To answer this question we need a lot more knowledge about PCBs
- let’s start with what they are made of

Electrical Properties

Electrical properties include, but are not limited to:

1. Dielectric Constant
2. Dielectric Breakdown Strength
3. Dielectric Strength
4. Arc Resistance



- Each board material has some properties we have to consider.
- let's start with the electrical properties
- Think back to the basics of capacitors
- we're going to take a nicely designed circuit, put it on a PCB, and inadvertently add a bunch of capacitors to the circuit.
- If we do this (an we're going to) we need to understand the properties of those capacitors
- The board material becomes the dielectric material
- Dielectric constant: the ability of a substance to store electrical energy in an electric field
- Dielectric Breakdown Strength: When the voltage applied across an insulator exceeds the breakdown voltage, current will flow through it.

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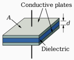

- The closely related, Dielectric Strength: the minimum electric field in an insulator that when exceeded causes current will flow through it.
- Arc resistance: a measure of the time required to make an insulating surface conductive under a high voltage / low current arc. Values are therefore reported in seconds (s).
- All of these properties are typically ignored when pro typing circuit on a breadboard
- if you want to make your circuit small and efficient, you have to start paying attention to the details.
- remember: a PCB does two things. 1) Electrical connection and 2) physical support
- let's look at physical properties of PCBs

Physical Properties

Physical properties include, but are not limited to:

1. Tensile Strength
2. Compression
3. Shear
4. Flexural Strength
5. Impact Strength
6. Laminating difficulty
7. Copper adhesion
8. Machinability
9. Dimensional Stability

- Tensile Strength - will it stretch under tension?
- Compression - will it shrink under compression?
- Shear - when will it break?
- these may seem silly but how many times have you dropped your phone?
- A “nameless” company I've worked with designs electronics that control missiles. The physical deformation of the electronics during launch is a huge problem for them.
- Flexural Strength - can I flex it?
- Impact Strength - can I hit it?
- And we think about manufacturability
- Laminating difficulty - how hard is it to glue together?

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- Copper adhesion - will the traces stay put? remember support the traces is one of its jobs
- Machinability - How hard is it to create the final shap of the board
- Dimensional Stability - once we've machined it, will it stay the same size over its lifetime?
- the lifetime of the product... could be a day, could be 40+ years (submarines,helicopters, etc...)
- what happens to it in that lifetime? Or better stated, what environment is it exposed to?
- the environmental properties of the board material need to be considered

Environmental Properties

Environmental properties include, but are not limited to:

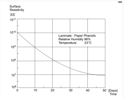
1. Absorption of water
2. Environmental resistance
3. Fungus resistance
4. Flammability
5. Self-extinguishing
6. Heat resistance

- Absorption of water - is it in a humid location and will the change in physical dimension affect performance?
- Environmental resistance
- Fungus resistance - will itself, become a hazard
- Flammability - How hot can it get? VERY IMPORTANT
- Self-extinguishing - What happens wil you exceed its temp limit?
- Heat resistance - how well can it get rid of heat? Electronics get hot. Ask a bitcoin miner.

Paper Laminate

Resin made of phenol and formaldehyde, reinforced with paper filler

- Easy Fabrication
- Low cost
- Poor arc resistance
- High water absorption



- One of the first materials for PCBs
- aka Bakelite
- Easy to work with, cheap to make but...
- poor arc resistance ie limited voltage on the board
- and it will suck up water changing the electrical properties
- is this a problem? depends on the application

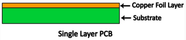
FR4

Reinforced with glass fiber or cloth fiber as filler and epoxy resin

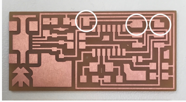
- Good dimensional stability
- Good mechanical strength
- Superior electrical properties
- Low water absorption
- Higher cost

- One of the most common materials for PCBs
- Better than paper laminate in just abut every way but...
- cost
- most consumer electronics are FR4
- some cheaper electronics, especially kits are still paper laminate

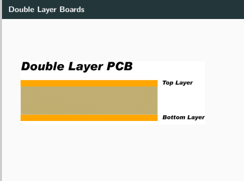
Single Layer Boards



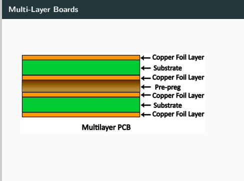
- Now that we have some understanding of base materials how do we build up a circuit?
- layers just like a cake
- here's a side view
- the simplest boards have a single conductive layer
- this conductive layer takes the place of wire in the circuit
- cheapest to produce



- Parts of the copper layer are removed to isolate “traces”
- “subtractive” methods are most common.
- Start with a full layer of copper and remove the unwanted sections.
- Removal can be done by mechanical or chemical means
- Additive methods are still in development (3D printing)
- Start with bare base material and add conductive layers through printing process.
- What can’t you do on a single layer board?
- if you need to jump a trace, use a jumper wire.
- too many jumper wires? consider using a double sided board

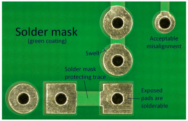


- More complex circuits have more connections.
- Connections may need to cross.
- enter the double layer board
- higher complexity means greater design time, greater cost,
- Layer alignment must be addressed



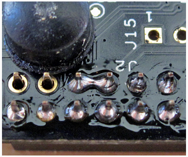
- More layers can be created by taking multiple 2 sided boards and gluing them together using “pre-preg”
- Pre-preg is a layer of uncured FR4, that’s used by PCB manufacturers to glue together layers.
- alignment an even bigger issue
- Thickness may vary. This may be okay, this may not be okay (RF applications)
- cost is higher of course
- but, ultimately, sometimes necessary

Solder Mask



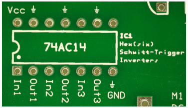
- there are many other layers, here are the most common
- Solder mask, solder stop mask, solder resist, sometimes just resist
- a thin lacquer-like layer of polymer that is usually applied to the copper traces
- for protection against oxidation
- also for to prevent solder bridges from forming (Next slide)
- Its the stuff that makes a lot of PCBs green.
- Other colors used sometimes

Solder Mask

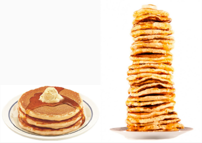


- an unintended electrical connection between two conductors by means of a small blob of solder.

Silk Screen



- a layer of ink to mark component location and orientation, part number, branding



- Board can become quite complex as layers are added.
- Short Stack or Tall Stack, each is made of the same stuff, How many pancakes do you need?

Multi-layer Example

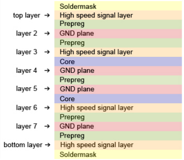


Figure 1 Layer Stack-up Example of An 8-layer PCB

- 22 layer/35 layer boards are not unheard of.

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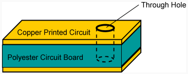
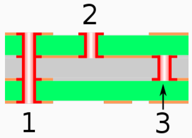


- Board serves to physically mount components.
- There are two predominate methods
- Through-hole mounting is the process by which component leads are placed into drilled holes on a bare PCB.
- Standard method until the 1980s
- Easier to (re)work with
- Higher reliability

Through-hole Plating

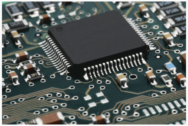
- plating /rivets connect layers on either side of a through hole
- plating formed with chemical process after drill holes are created

- rivets are an alternative to the chemical process
- mechanically intensive process



- connections between layers don't always have a component through them.
- Vias present in though-hole boards and SMT boards (next slides)
- Via - an electrical connection between layers in a physical electronic circuit that goes through the plane of one or more adjacent layers without a component through it.
- Through-hole
- Blind-via
- Buried-via

Surface Mount Technology



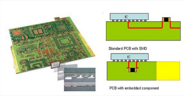
- The other mounting method
- Components are mounted directly onto the surface of the PCB.
- Developed in the 1960s. In the 1980s became more popular
- Removes drilling from PCB fabrication
- Smaller packages allow more dense circuit layout, Smaller devices
- additional layer of solder paste to glue components in place
- lower reliability/yield

SM-Alphabet Soup

1. SMA (surface-mount assembly) a build or module assembled using SMT.
2. SMC (surface-mount components) components for SMT.
3. SMD (surface-mount devices) active, passive, and electromechanical components.
4. SME (surface-mount equipment) machines used for SMT.
5. SMP (surface mount packages) SMD case forms.
6. SMT (surface-technology) the act and method of assembling and mounting electronic technology.

- Too many similar acronyms are used.
- Here's a good list

Embedded Components



- Modern boards may have components embedded between layers
- Tradeoff between manufacturing complexity (and cost) and circuit performance/size