

Electronic circuit design and component selection

Nan-Wei Gong

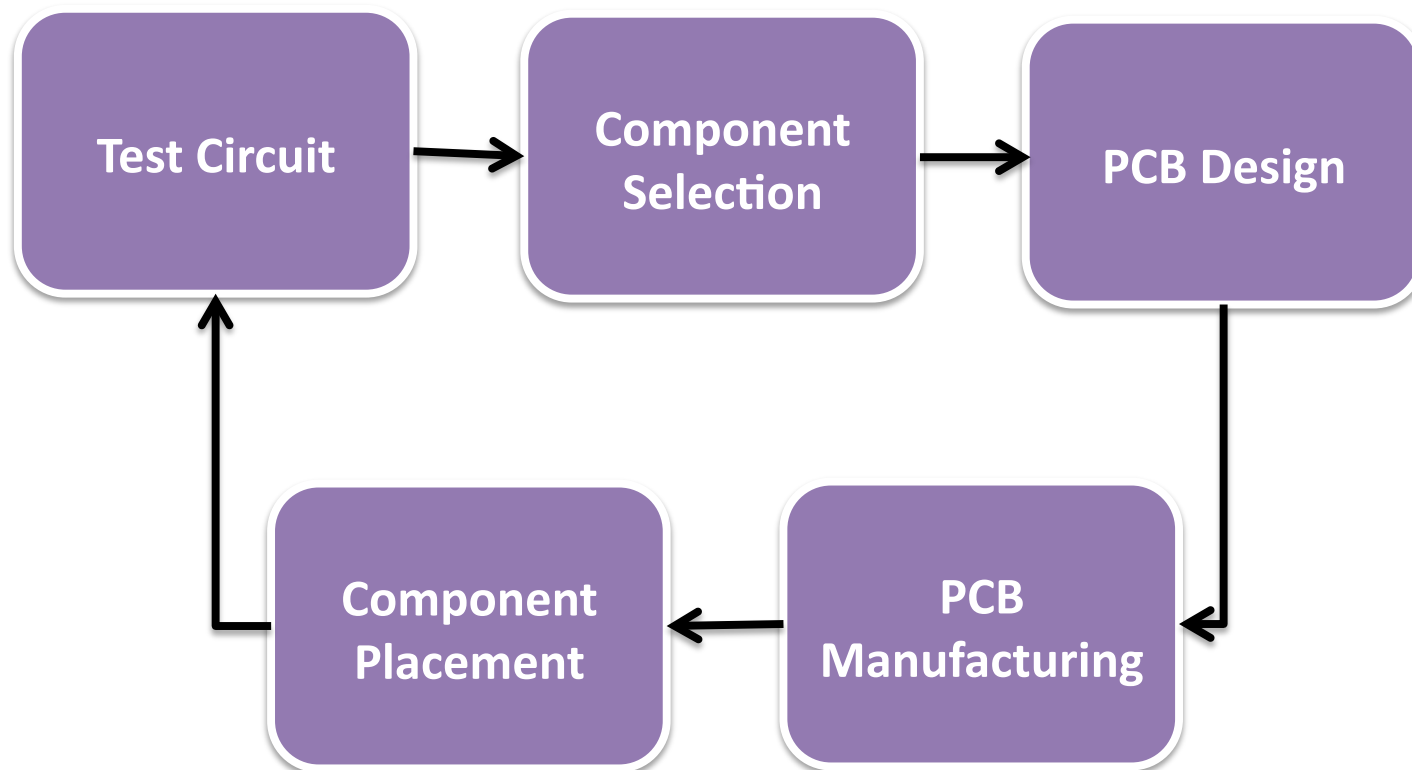
MIT Media Lab

MAS.S63: Design for DIY Manufacturing

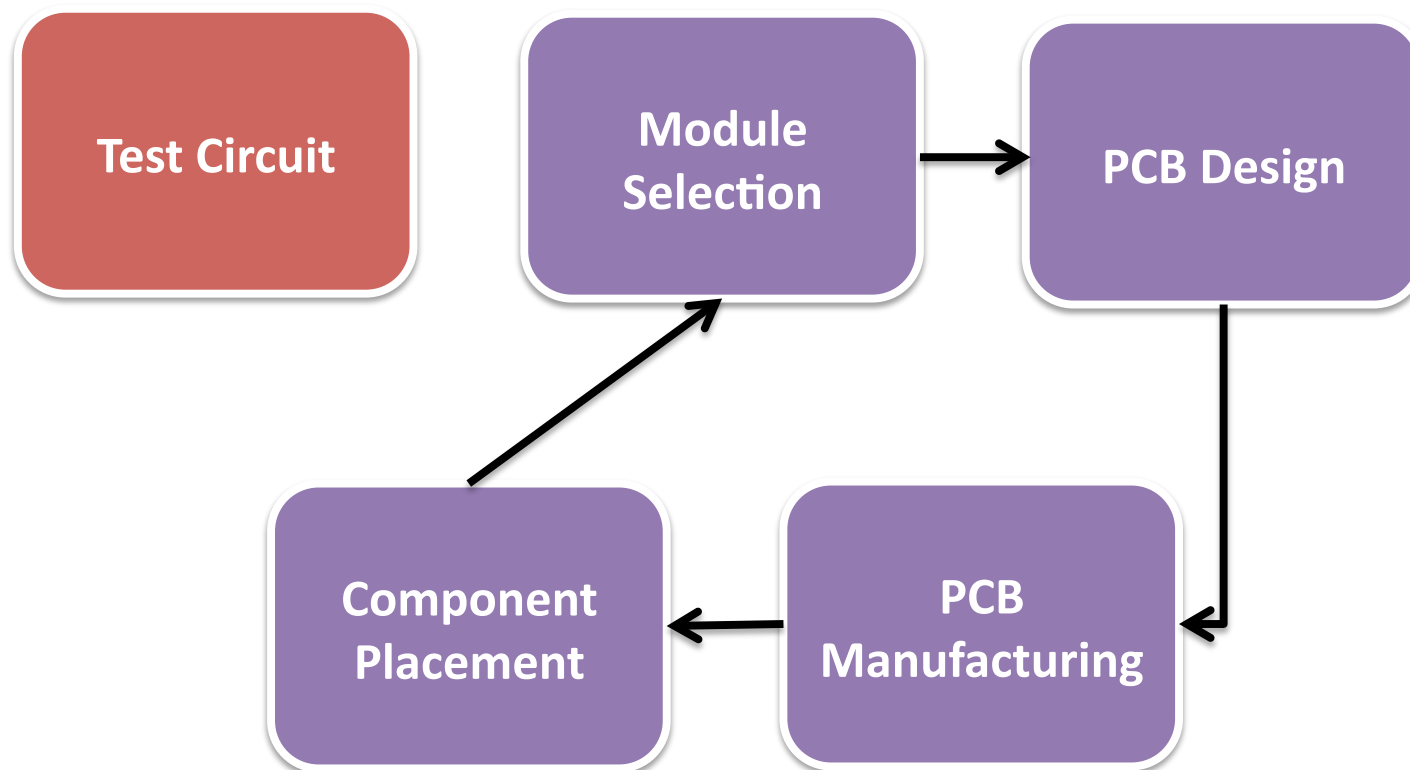
Goal for today's lecture

- How to pick up components for your project
- Rule of thumb for PCB design
- Suggestions for PCB layout and manufacturing
- Soldering and de-soldering basics
- Small - medium quantity electronics project production
- Homework :
Design a **PCB** for your project with a **BOM** (bill of materials) and estimate the **cost** for making 10 | 50 | 100 (PCB manufacturing + assembly + components)

Design Process



Design Process

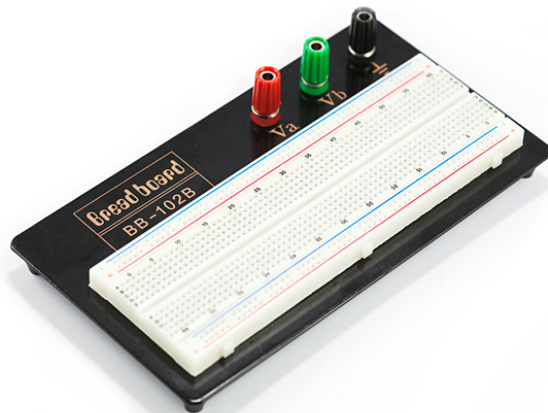


Design Process

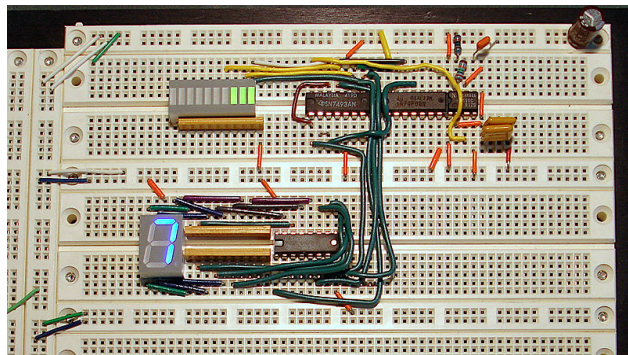
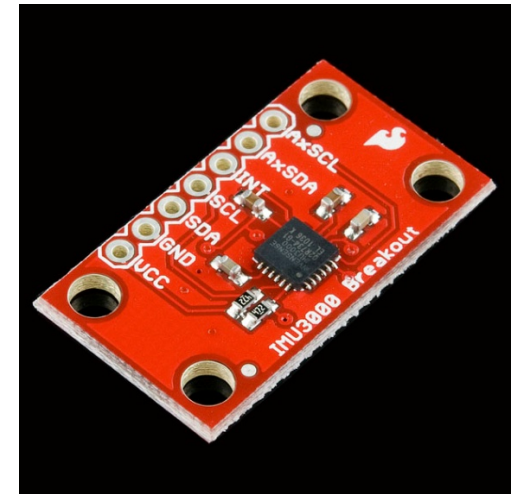
- **Test circuit** – bread boarding/ buy development tools (breakout boards) / simulation
- **Component Selection**– spec / size / availability (inventory! Need 10% more parts for pick and place machine)
- **PCB Design**– power/ground, signal traces, trace width, test points / extra via, pads / mount holes, big before small
- **PCB Manufacturing** – price-time trade-off/
- **Place Components** – first step (check power/ground)
-- work flow

Test Circuit Construction

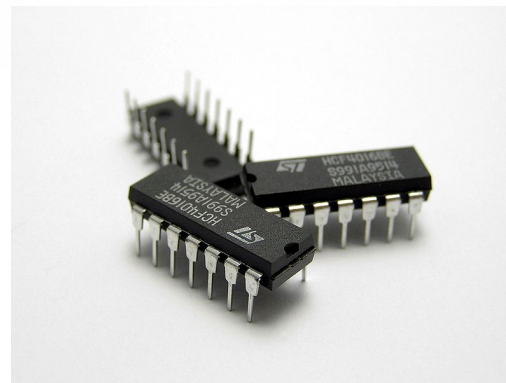
Breadboard + through hole components +
Breakout boards, surfboards + hookup wires



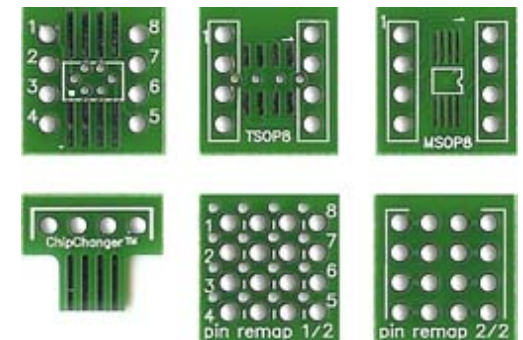
Breakout boards



Surfboard : surface-mount to
through hole



Dual in-line (DIP) packaging

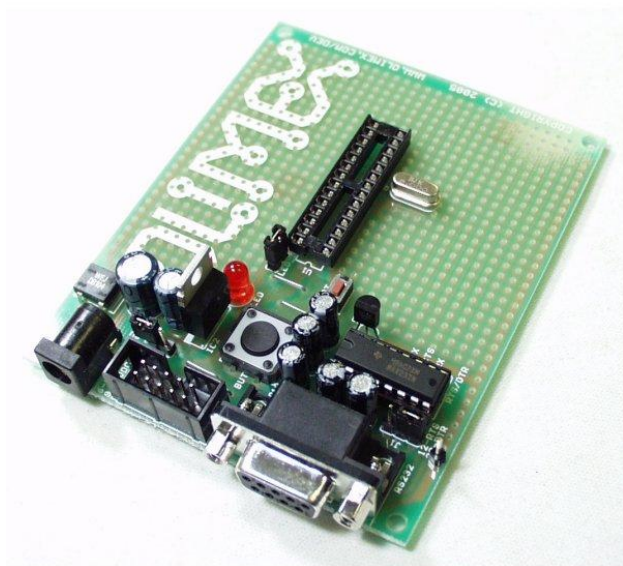


Source : http://en.wikipedia.org/wiki/File:Breadboard_counter.jpg

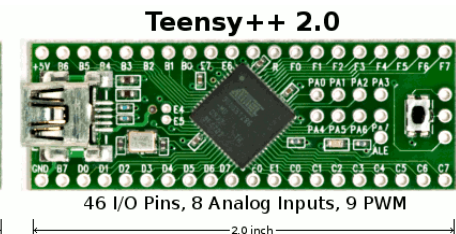
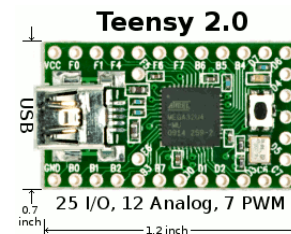
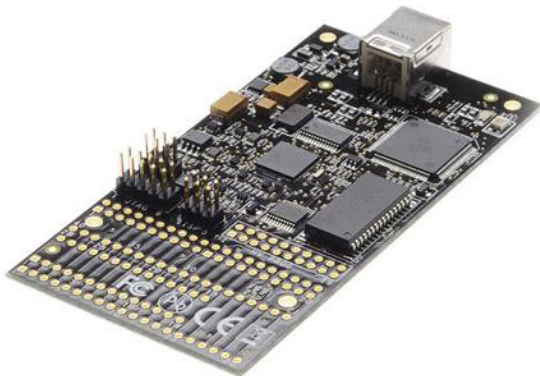
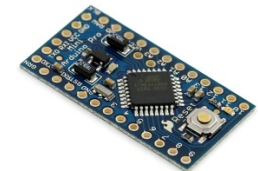
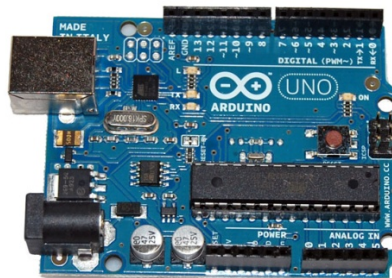
<http://www.beldynsys.com/cc521.htm>

Development Boards

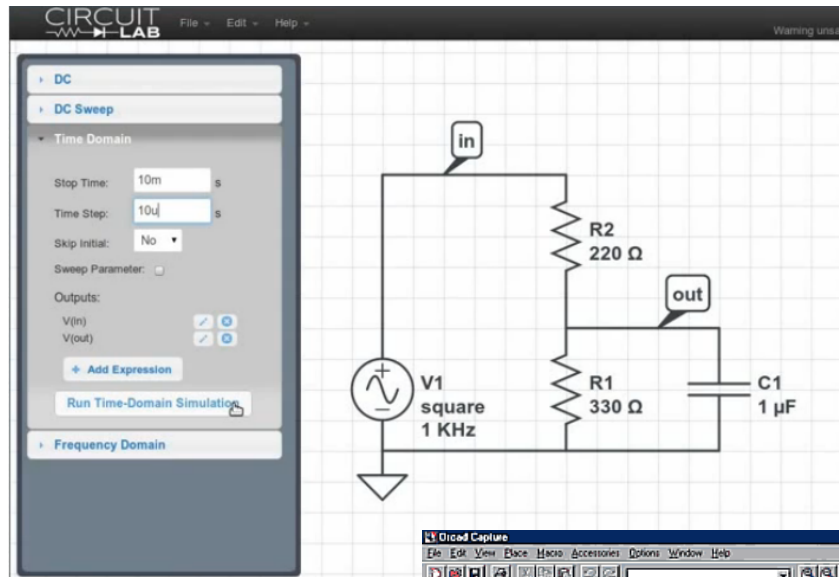
- good reference for circuit design and component selection



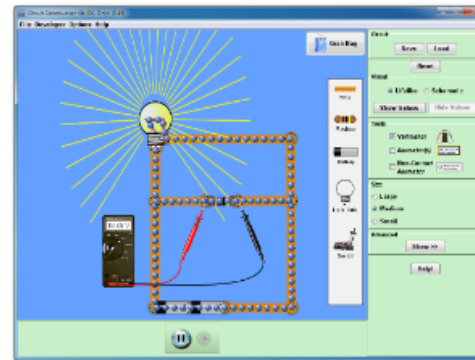
Sometimes, it can be cheaper to pair your design with a development board for your “product” if you are only manufacturing in a small quantity..



Simulate you (analog) circuit if needed!



Circuit Construction Kit (DC Only)



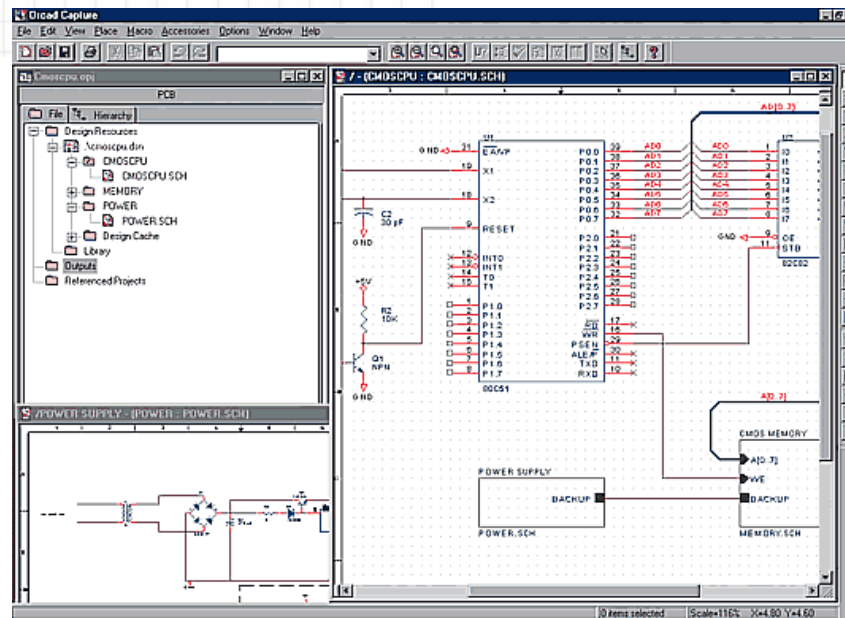
An electronics kit in your computer! Build circuits with resistors, light bulbs, batteries, and switches. Take measurements with the realistic ammeter and voltmeter. View the circuit as a schematic diagram, or switch to a life-like view.

Support PhET >



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and educators like you.
Thanks!



<http://www.ecircuitcenter.com/>
<https://www.circuitlab.com/>
<http://phet.colorado.edu/en/simulation/>

<http://www.openmusiclabs.com/testpage/>
<http://www.daycounter.com/>
 ...and more!

Design Process

- **Test circuit** – bread boarding/ buy development tools (breakout boards) / simulation
- **Component Selection**– spec / size / availability (inventory! Need 10% more parts for pick and place machine)
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-- work flow

Electronic Components Distributor



Components



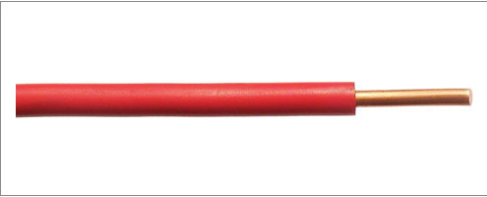
Wire Selection

Wire Gauge	Conductor Strand	Length	Jacket (Insulation) Material	Jacket (Insulation) Diameter	Jacket (Insulation) Thickness	Voltage	Operating Temperature
8 AWG	Solid	1' (304.8mm)	Cross-Linked Polyethylene (XLPE)	0.183" (4.65mm)	-	-	-60°C ~ 200°C
10 AWG	7/30	100' (30.5m)	Ethylene-Propylene Rubber (EPR)	0.184" (4.67mm)	0.004" (0.11mm)	250V	-55°C ~ 105°C
12 AWG	7/32	250' (76.2m)	Poly-Vinyl Chloride (PVC)	0.193" (4.90mm)	0.005" (0.13mm)	300V	-55°C ~ 125°C
14 AWG	7/38	500' (152.44m)	Polytetrafluoroethylene (PTFE)	0.198" (5.03mm)	0.006" (0.15mm)	500V	-55°C ~ 200°C
16 AWG	10/30	1000' (304.8m)	Polyvinylidene Fluoride (PVDF)	0.208" (5.28mm)	0.010" (0.25mm)	600V	-40°C ~ 105°C
17 AWG	16/30		Silicone	0.217" (5.51mm)	0.016" (0.41mm)	750V	-40°C ~ 125°C
18 AWG	19/26			0.248" (6.30mm)	0.024" (0.60mm)	10kV	-40°C ~ 150°C
20 AWG	19/29			0.268" (6.80mm)	0.028" (0.70mm)	15kV	-40°C ~ 90°C
22 AWG	19/38			0.312" (7.92mm)	0.031" (0.80mm)	20kV	-20°C ~ 105°C
24 AWG	26/30			0.380" (9.65mm)	0.032" (0.81mm)	25kV	-10°C ~ 105°C

- **WIRE GAUGE – AWG** (American wire gauge)
 - the diameters of round, solid, nonferrous, electrically conducting wire. The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity.
 - **JACKET** (Insulation)
 - The jacket physically protects the internal components of a cable, improves the cable's appearance and provides flame retardancy – Protects from the environment–Protects from the rigors of installation
- <http://www.belden.com/docs/upload/Insulations-Jackets.pdf>

Cabling

Solid



breadboard jumpers – 23 AWG
on-board jumpers > 30 AWG

Pre-crimped wire



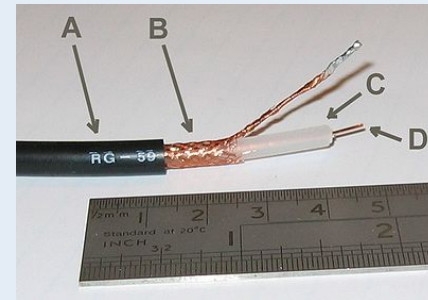
Stranded



http://www.oregonrfid.biz/store/index.php?main_page=page&id=3

Stranded wire is used when higher resistance to metal fatigue is required.

Coax - BNC



RG-59 CABLE

A: outer plastic sheath
B: woven copper shield
C: inner dielectric insulator
D: copper core

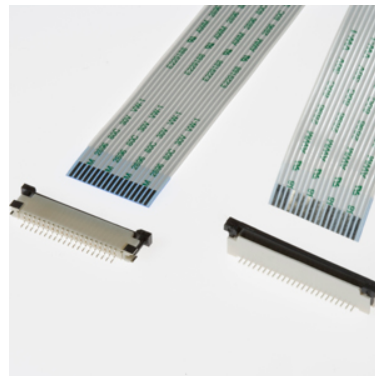
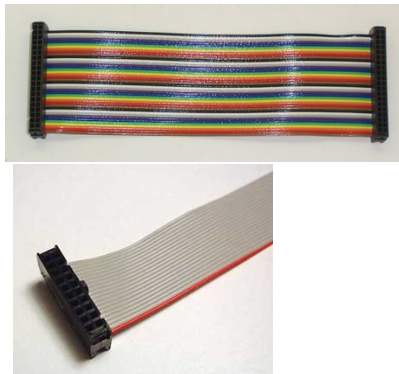
RF signals

Coax - SMA



Flexible flat cable (FFC)

Ribbon

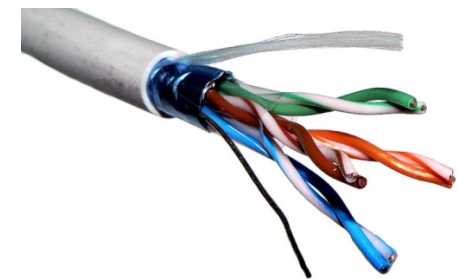


<http://www.asiconnectors.com/member/x964-Flexible-Flat-Cable-Connectors.asp>



www.conductiveinkjet.com/

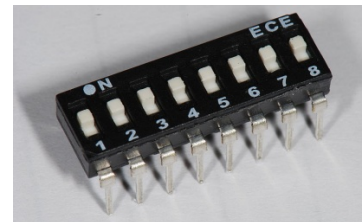
Twisted Pair



two conductors (the forward and return conductors of a single circuit) are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources

Switches - mechanical or actuators

- [Accessories \(4,049 items\)](#)
- [Accessories - Caps \(1,798 items\)](#)
- [Configurable Switch Components - Body \(783 items\)](#)
- [Configurable Switch Components - Contact Block \(199 items\)](#)
- [Configurable Switch Components - Illumination Source \(91 items\)](#)
- [Configurable Switch Components - Lens \(188 items\)](#)
- [DIP \(4,011 items\)](#)
- [Keylock \(609 items\)](#)
- [Keypads \(503 items\)](#)
- [Magnetic, Reed \(776 items\)](#)
- [Navigation, Joystick \(184 items\)](#)
- [Programmable Display \(18 items\)](#)
- [Pushbutton \(12,919 items\)](#)
- [Pushbutton - Hall Effect \(15 items\)](#)
- [Rocker \(4,502 items\)](#)
- [Rotary \(1,226 items\)](#)
- [Selector \(541 items\)](#)
- [Slide \(1,647 items\)](#)
- [Snap Action, Limit, Lever \(8,655 items\)](#)
- [Tactile \(4,462 items\)](#)
- [Thumbwheel \(336 items\)](#)
- [Toggle \(6,699 items\)](#)



DIP switch



Tactile button



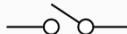
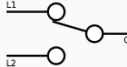
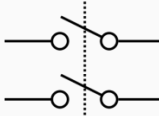
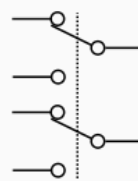
SPST switch



SPDT switch

<http://search.digikey.com/scripts/DkSearch/dksus.dll?x=0&y=0&lang=en&site=us&Keywords=switch>

Switches

Electronics specification	Expansion	Description	Symbol
SPST	Single pole, single throw	A simple on-off switch: The two terminals are either connected together or disconnected from each other. An example is a light switch .	
SPDT	Single pole, double throw	A simple changeover switch: C (COM, Common) is connected to L1 or to L2.	
SPCO SPTT, c.o.	Single pole changeover or Single pole, centre off or Single Pole, Triple Throw	Similar to <i>SPDT</i> . Some suppliers use <i>SPCO/SPTT</i> for switches with a stable off position in the centre and <i>SPDT</i> for those without. [citation needed]	
DPST	Double pole, single throw	Equivalent to two <i>SPST</i> switches controlled by a single mechanism	
DPDT	Double pole, double throw	Equivalent to two <i>SPDT</i> switches controlled by a single mechanism.	
DPCO	Double pole changeover or Double pole, centre off	Equivalent to <i>DPDT</i> . Some suppliers use <i>DPCO</i> for switches with a stable off position in the centre and <i>DPDT</i> for those without.	

<http://en.wikipedia.org/wiki/Switch>

Battery

Three basic things - Cell Voltage, Load Current, Amp-Hour (symbol Ah, AHr, A·h, A h)

NiCad	NiMH	Lead Acid	Li-Ion	Li-Polymer	Rechargeable Alkaline	
Gravimetric Energy Density (Wh/kg)	45 - 80	60 - 120	30 - 50	110 - 160	100 - 150	80 (initial)
Internal Resistance (mΩ) (includes peripheral circuits)	100 - 200 6V pack	200 - 300 6V pack	<100 12V pack	150 - 250 7.2V pack	200 - 300 7.2V pack	200 - 2000 6V pack
Cycle Life (to 80% of initial capacity)	1500	300 - 500	200 - 300	500 - 1000	300 - 500	50 (to 50%)
Self-discharge / Month (room temp)	20%	30%	5%	10%	10%	0.3%
Cell Voltage (nominal)	1.25V	1.25V	2V	3.6V	3.6V	1.5V
Load Current*						
- peak	20C	5C	5C	>20C	>20C	0.5C
- best result	1C	0.5C or less	0.2C	5C or less	5C or less	0.2C or less
Operating Temperature	-40 - 60°C	-20 - 60°C	-20 - 60°C	-20 - 60°C	0 - 60°C	0 - 65°C
Maintenance Requirement	30 - 60 days	60 - 90 days	3 - 6 months	not req.	not req.	not req.

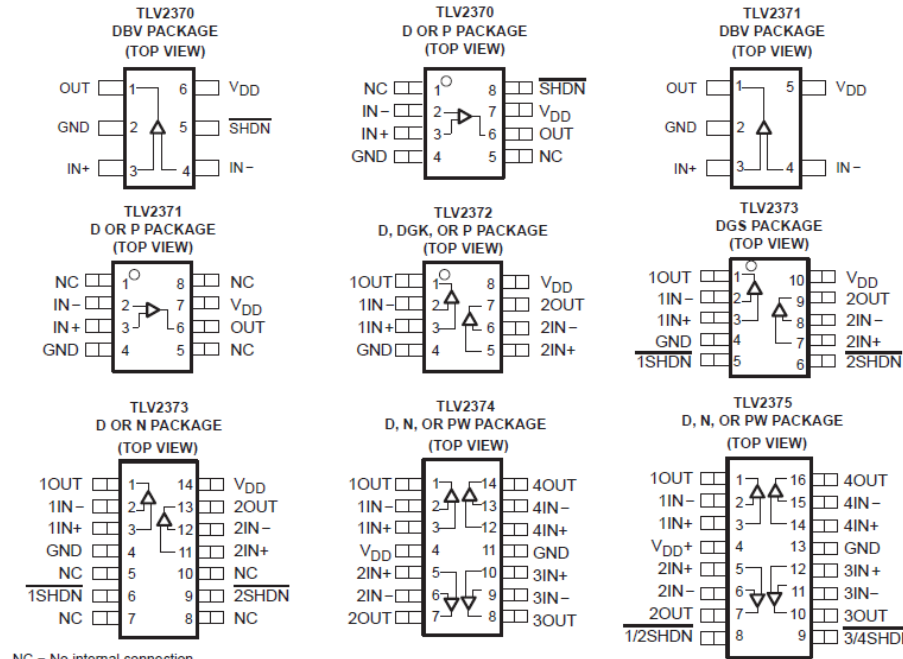
<http://www.rfcafe.com/references/electrical/batteries.htm>

Footprint - same component / IC comes in different footprints

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

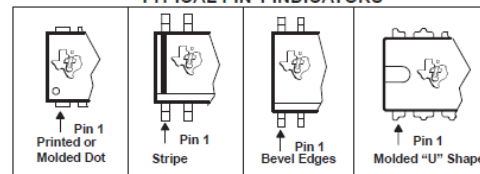
SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TLV237x PACKAGE PINOUTS⁽¹⁾



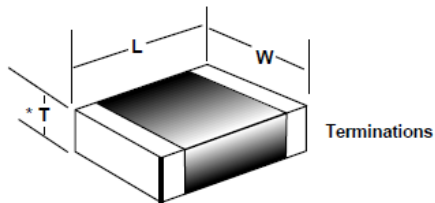
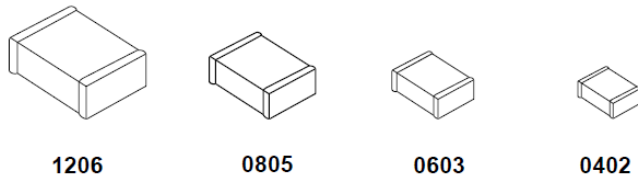
NC – No internal connection

TYPICAL PIN 1 INDICATORS



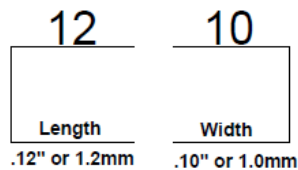
NOTE: (1) If there is not a Pin 1 indicator type device to enable reading the symbol from the left to right, Pin 1 is at the lower left corner of the

Flat Chips - Capacitors and Resistors



*Thickness is not included
in the 4-digit size code.

Example:



Caution: Must verify if size
code is metric or
inches.

How to read the value :

334 = 33×10^4 ohms = 330 kilohms

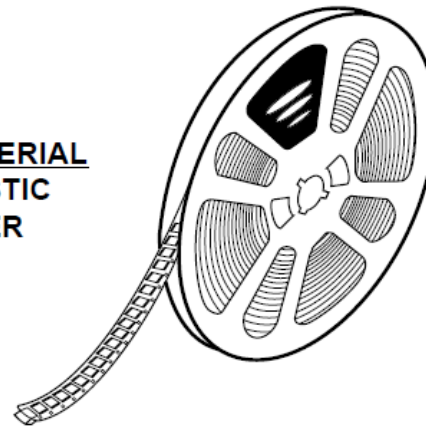
222 = 22×10^2 ohms = 2.2 kilohms

473 = 47×10^3 ohms = 47 kilohms

105 = 10×10^5 ohms = 1.0 meg ohm

REEL MATERIAL

- PLASTIC
- PAPER



**7" DIAMETER
STANDARD**

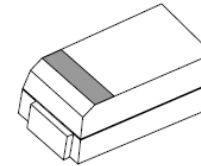
**13" SPECIAL
ORDER**

Capacitors

Voltage rating for capacitors –
Really important for power circuits

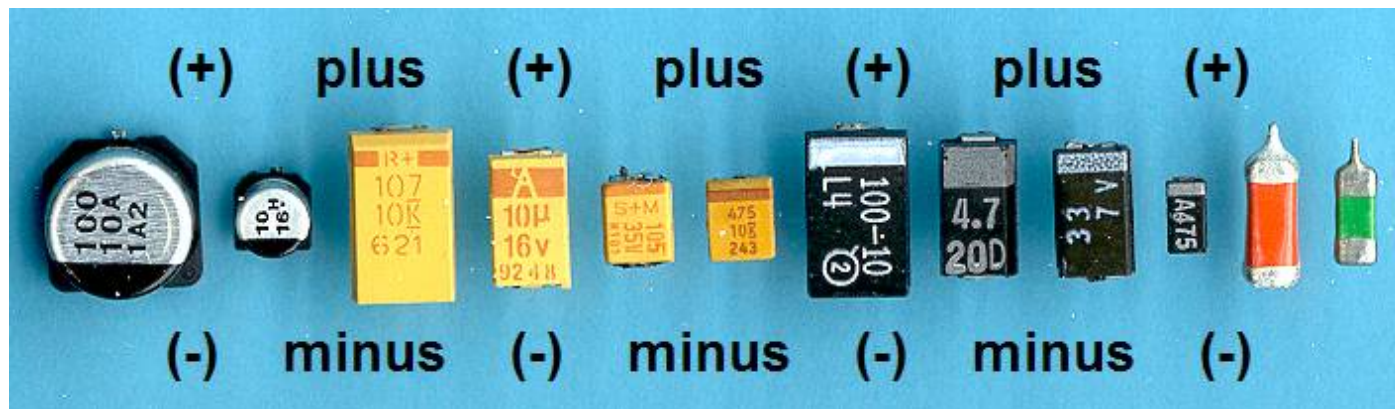


<http://www.bcae1.com/capacitr.htm>



Example:

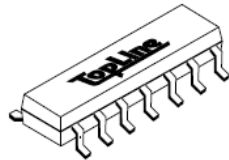
A case =	32	16
	Length	Width
	3.2 mm	1.6 mm



<http://en.wikipedia.org/wiki/File:Cap-elko-smd-polarity.jpg>

Footprint - same IC comes in different footprints

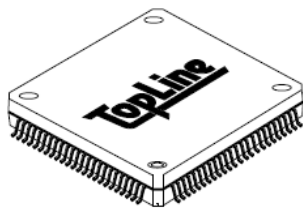
SMD (surface-mount device) ICs



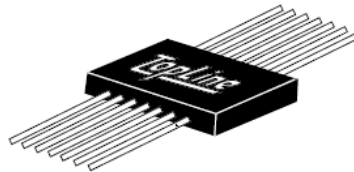
SMALL
OUTLINE



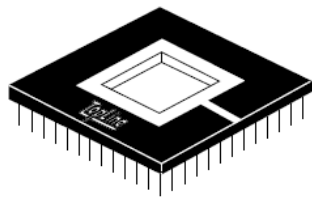
LEADED CHIP
CARRIER



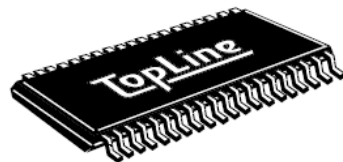
QUAD FLAT PACK



FLAT PACK



PIN GRID ARRAY



TSOP

6-lead WLCSP



5-lead SC70



5-lead SOT-23



6-lead SOT-23



8-lead SOT-23



16-lead LFCSP



8-lead MSOP



10-lead MSOP



8-lead TSSOP



16-lead TSSOP



8-lead SOIC



14-lead SOIC



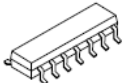
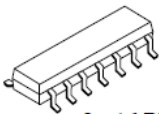
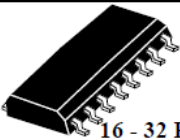
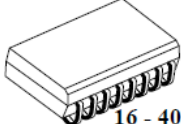



16-lead SOIC



<http://www.topline.tv/SMDnomen.pdf>

Courtesy of Analog Device's poster

SOIC (Small Outline Integrated Circuit)

DRAWING	NOMENCLATURE	BODY WIDTH	LEAD TYPE
 8 - 16 PIN	SO = Small Outline	156 mil	Gull 50 mil Pitch
 8 - 16 PIN	SOM = Medium Outline	220 mil*	
 16 - 32 PIN	SOL = "Large" Outline SOP = "Small" Outline Package	300 mil	
 16 - 40 PIN	SOJ or SOL-J = "J" - Lead Large Outline	300 mil*	J- Lead 50 mil
 32 - 56 PIN	VSOP = Very Small Outline Package	300 mil	Gull Wing 25 mil
 8 - 30 PIN	SSOP = Shrink Small Outline Package	208 mil	Gull Wing 25 mil
 20 - 56 PIN	QSOP = Quarter Small Outline Package	156 mil	Gull Wing 25 mil

*Up to 440 mils

SMD leads styles

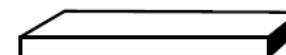
- GULL-WING



- J-LEAD



- FLAT



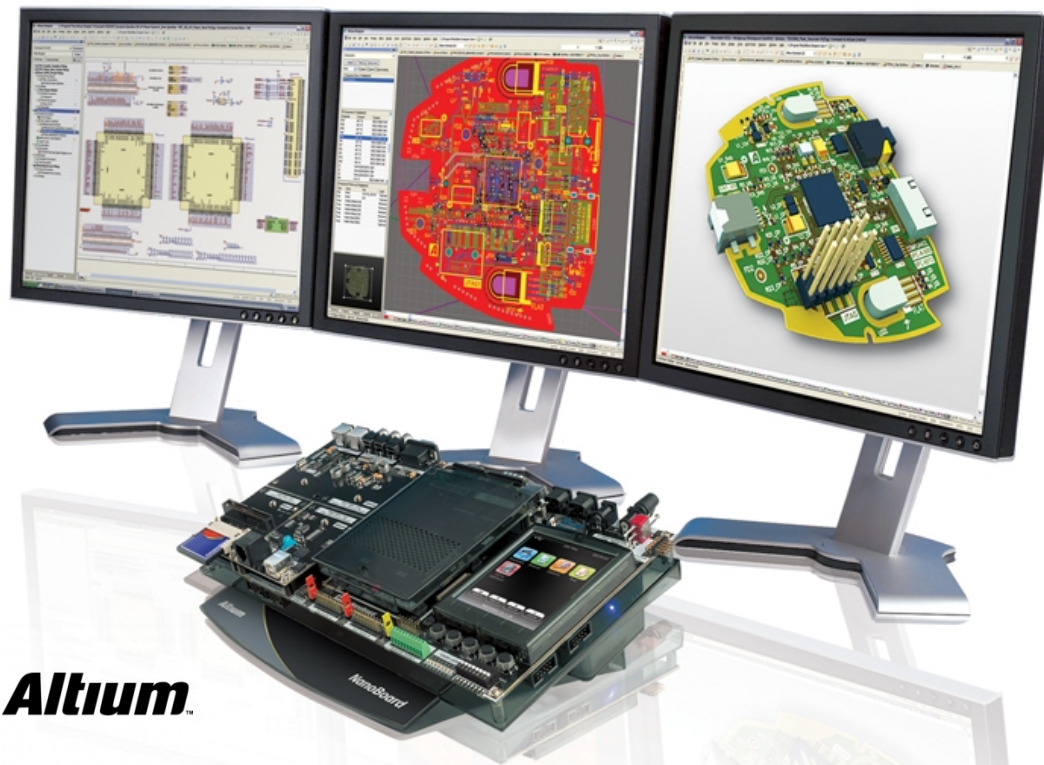
PCB design software



Free software

EAGLE (Easily Applicable Graphical Layout Editor) <http://www.cadsoftusa.com/>

Tutorials from Sparkfun -> <http://www.sparkfun.com/tutorials/109>



Two major components

- **Schematics**
- **PCB Layout**

And sometimes.. 3D simulation

<http://www.freepcb.com/>

<http://www.expresspcb.com/>

<http://www.4pcb.com/free-pcb-layout-software/>

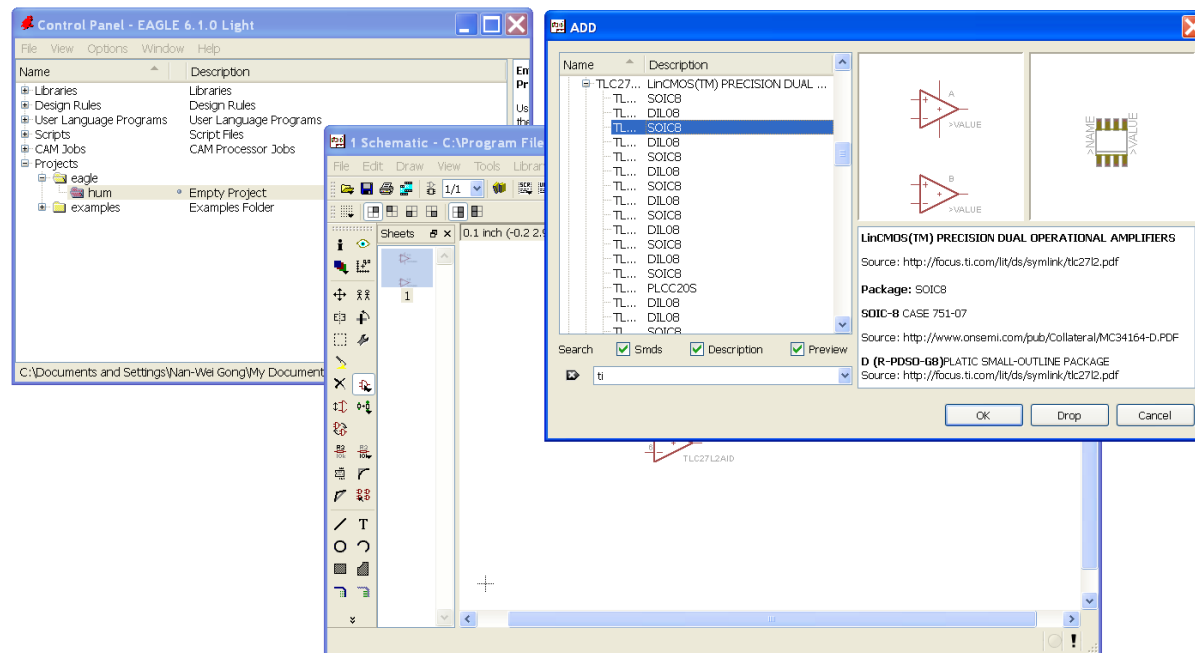
And more...

But it's just another CAD software

PCB design software

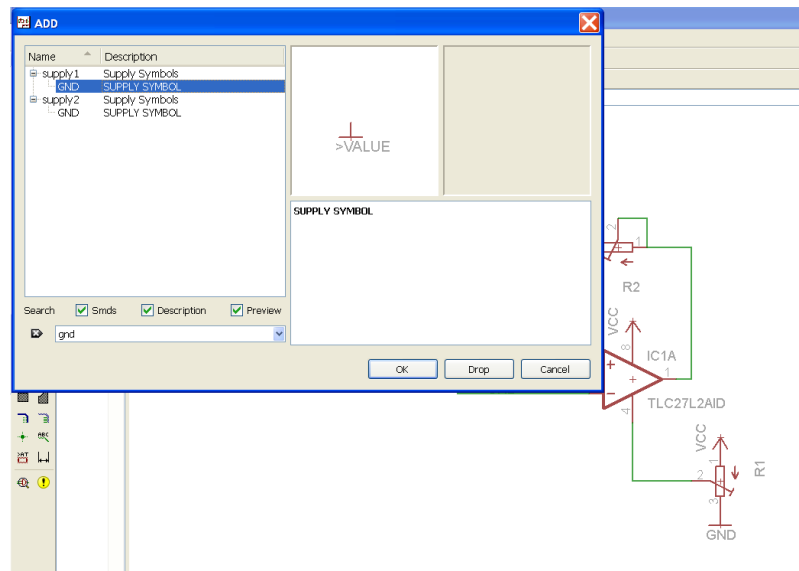
Things you need to know

1. Pick your software (we will have a tutorial on EAGLE)
2. Pick the parts → build “footprint” for the parts, or find them from a library
3. Draw circuit diagram → Schematics
4. Route the physical circuitry → PCB Layout



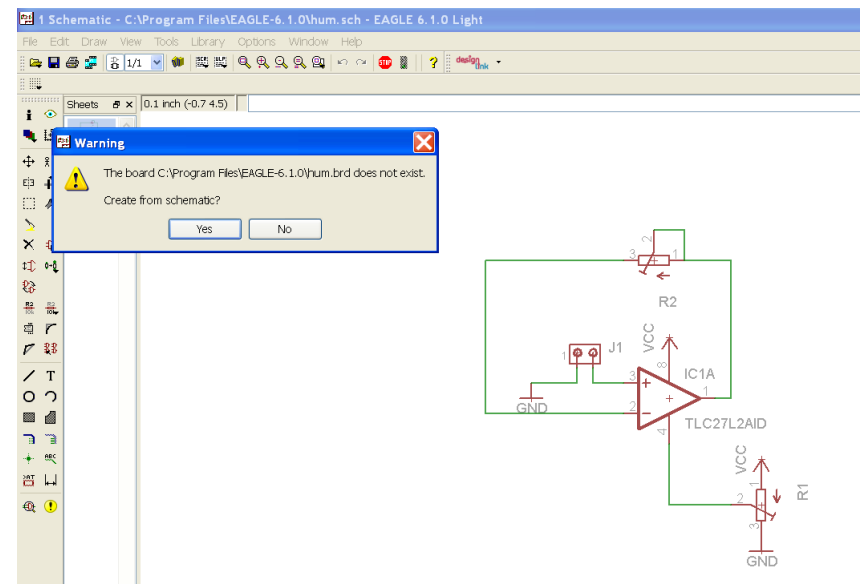
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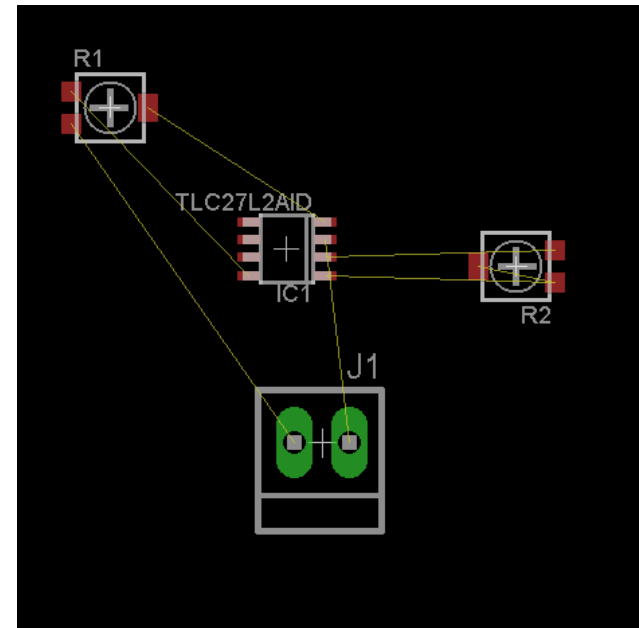
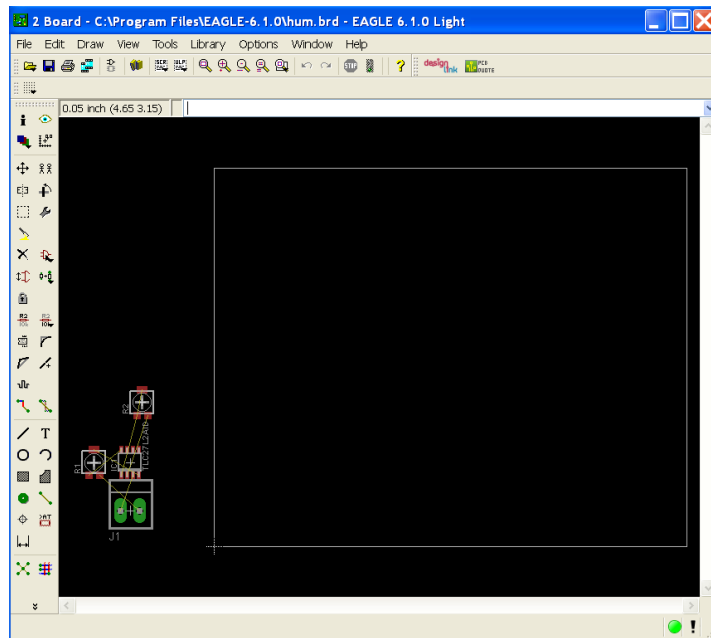
Design schematics with components from a library

Create PCB file from schematics



Things you need to know

1. Pick your software (we will have a tutorial on EAGLE)
2. Pick the parts → build “footprint” for the parts, or find them from a library
3. Draw circuit diagram → Schematics
4. Route the physical circuitry → PCB Layout



Tips - right click to switch through routing menu
middle click to switch between layers

PCB design rule of thumb

- **Trace width for signal and power lines**
 - When placing narrow traces, 0.012" or less, avoid sharp right angle turns, use 45 or 135 degree turns. The problem here is that in the board manufacturing process, the outside corner can be etched a little more narrow and causes transmission reflections.
 - Power trace width depending on the current
- **Noise reduction**
 - Decoupling capacitors
 - Analog/Digital trace placement
- **Via and mount holes**
 - Resistance and power drop of vias
 - Mount holes for better ground connections
 - Connectors for better debugging
 - Repurpose of your PCBs
- **Design iteration**

Trace width calculation – to avoid voltage drop (trace resistance) and over heating

PCB Trace Width Calculator January 31, 2006

This Javascript web calculator calculates the trace width for printed circuit boards based on a curve fit to IPC-2221 (formerly IPC-D-275). Also see the [via calculator](#).

New features:

- Results update as you type
- Several choices of units
- Units and other settings are saved between sessions
- Blog format allows user comments

Inputs:

Current	2	Amps
Thickness	1	oz/ft^2

Optional Inputs:

Temperature Rise	10	Deg C
Ambient Temperature	25	Deg C
Trace Length	1	inch

Results for Internal Layers:

Required Trace Width	80.0	mil
Resistance	0.00631	Ohms
Voltage Drop	0.0126	Volts
Power Loss	0.0252	Watts

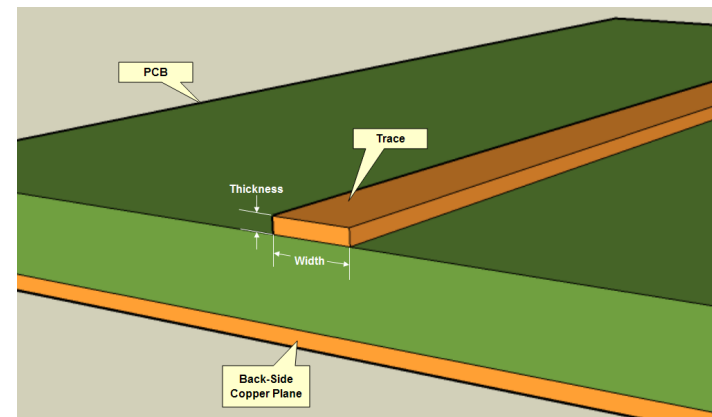
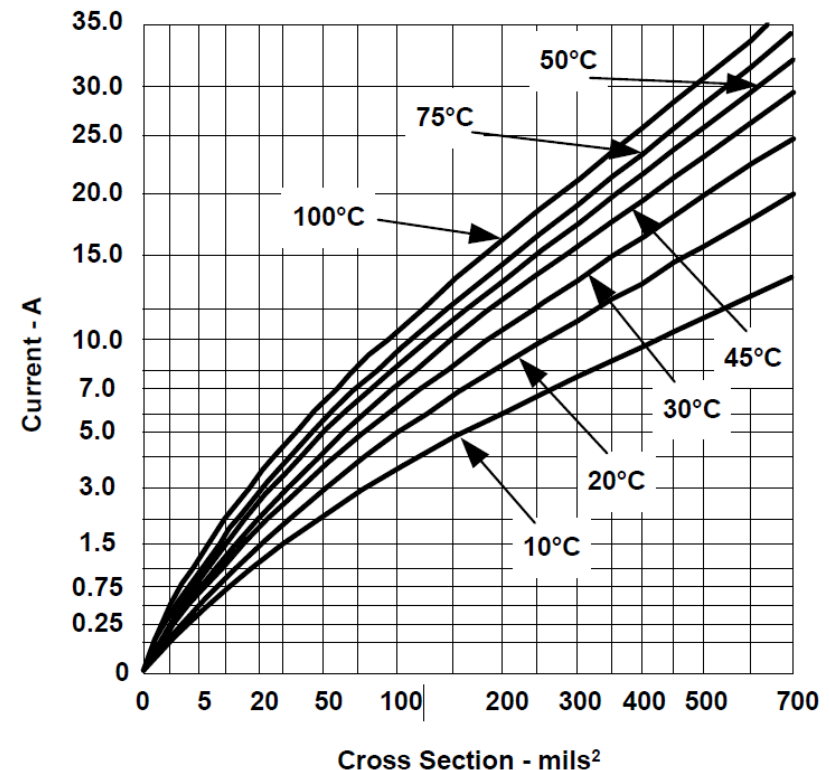
Results for External Layers in Air:

Required Trace Width	30.8	mil
Resistance	0.0164	Ohms
Voltage Drop	0.0328	Volts
Power Loss	0.0656	Watts

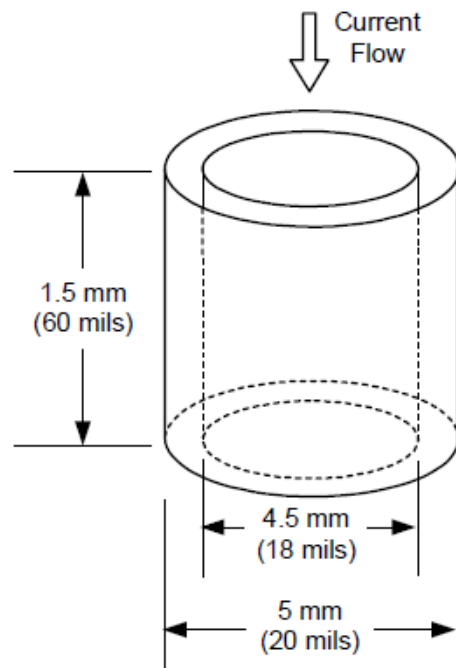
$$\text{Area}[\text{mils}^2] = (I[\text{Amps}] / (k * (\text{Temp_Rise}[\text{deg. C}])^b))^{\frac{1}{c}}$$

Then, the Width is calculated:

$$\text{Width}[\text{mils}] = \text{Area}[\text{mils}^2] / (\text{Thickness}[\text{oz}] * 1.378[\text{mils/oz}])$$



<http://circuitcalculator.com/wordpress/2006/01/31/pcb-trace-width-calculator/>



$$R = \frac{\rho l}{A}$$

$$R = \frac{\rho l}{\pi(r_o^2 - r_i^2)}$$

$$R = \frac{2.36 \times 10^{-6} \times 0.06}{\pi(0.01^2 - 0.009^2)} = 2.4 \text{ m}\Omega$$

Fig. 3. Vias have resistance too!

PCB Via Calculator March 12, 2006

This Javascript web calculator calculates the resistance, voltage drop, and power loss of printed circuit board vias. Note that vias are made out of plated copper which typically has a resistivity of 1.7E-6 to 2.2E-6 Ohm-cm. The calculator has an input box for the resistivity which defaults to 1.9E-6 Ohm-cm.

Updates:

May 22, 2006 – Added thermal resistance calculation.

January 19, 2007 – Minor Clarifications.

March 28, 2007 – Updated resistivity. See comment 12.

June 21, 2007 – Added estimated ampacity. See comment 17.

Inputs:

Finished Hole Dia	18	mil	▼
Plating Thickness	1	mil	▼
Via Length	60	mil	▼

Optional Inputs:

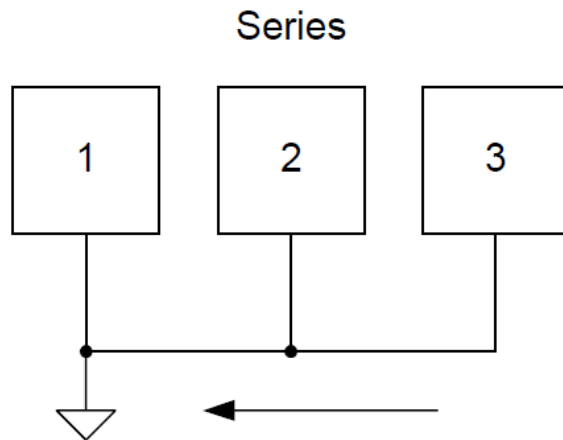
Applied Current	1	Amps
Plating Resistivity	1.9E-6	Ohm-cm

Electrical Results:

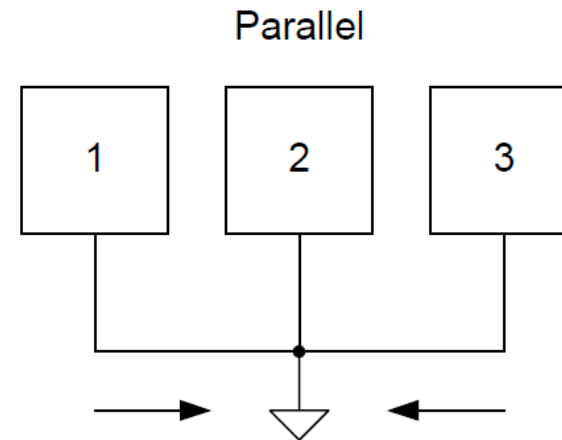
Resistance	0.000752	Ohms
Voltage Drop	0.000752	Volts
Power Loss	0.000752	Watts
Estimated Ampacity	2.56	Amps

Thermal Results:

Thermal Resistance	98.5	Deg. C/Watt
--------------------	------	-------------



- Simple wiring
- Common impedance causes different potentials
- High impedance at high frequency (>10 kHz)



- Complicated wiring
- Low differential potentials at low frequencies
- High impedance at high frequency (>10 kHz)

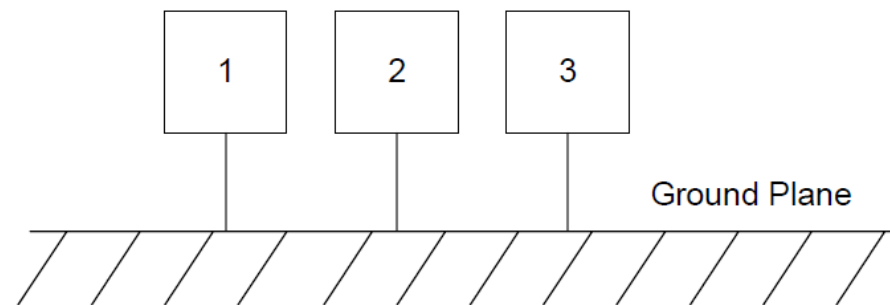
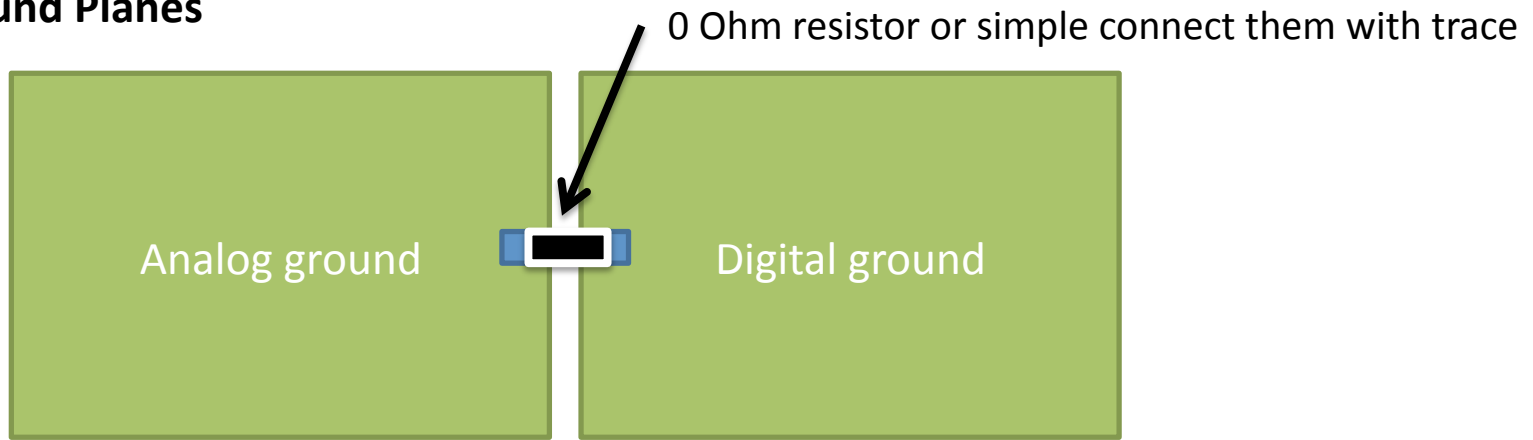
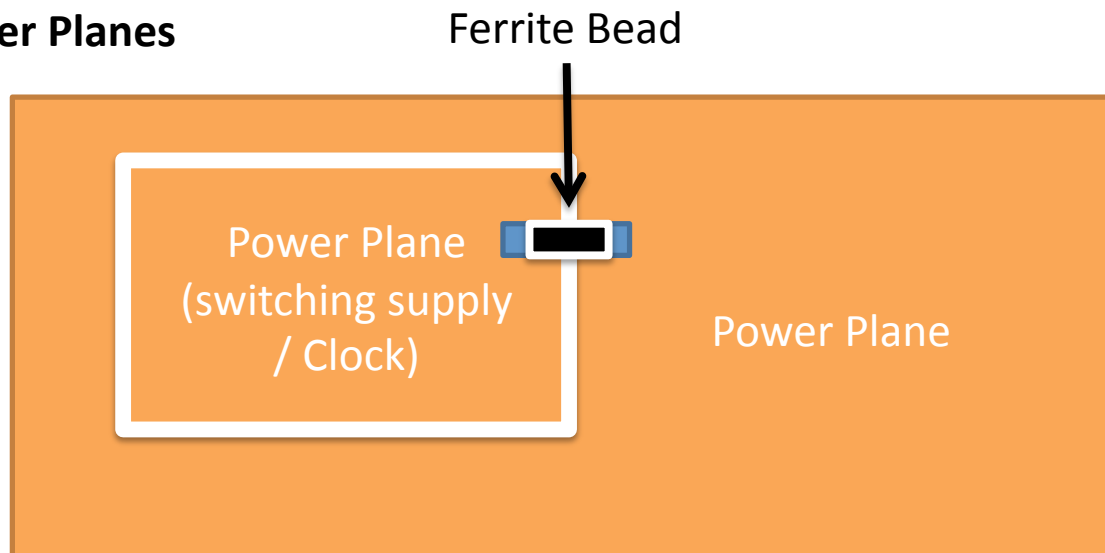


Fig. 15. Ground plane provides near ideal single point ground.

Split Ground Planes



Split Power Planes

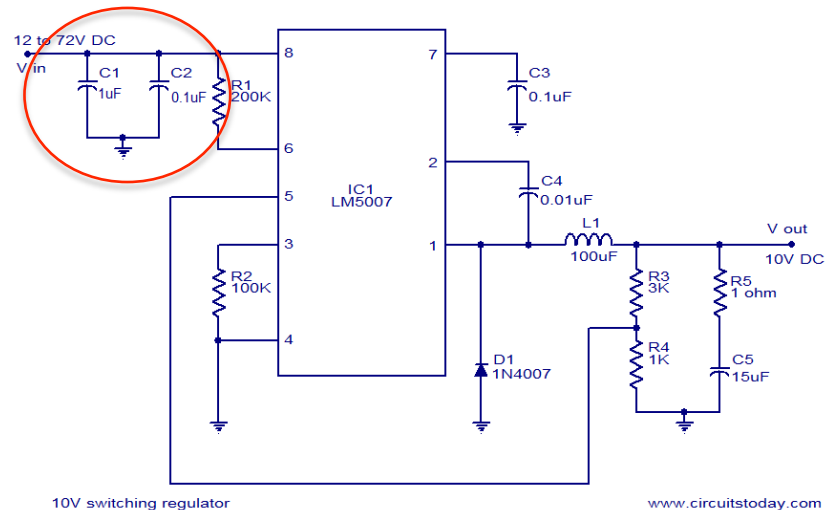
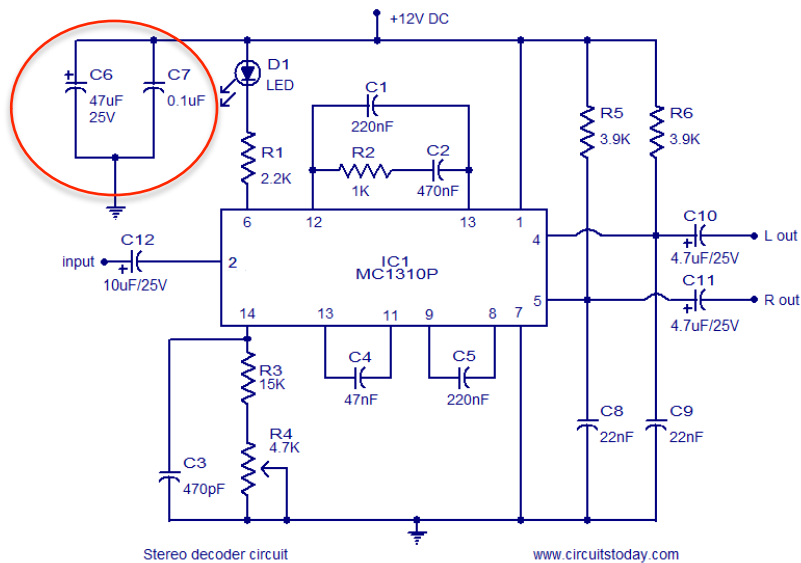


A **ferrite bead** is a passive electric component used to suppress high frequency noise in electronic circuits. It employs high dissipation of high frequency currents in a ferrite to build high frequency noise suppression devices.

http://en.wikipedia.org/wiki/Ferrite_bead

Decoupling

- http://en.wikipedia.org/wiki/Decoupling_capacitor
- Decoupling is the process of adding small LC networks to ICs to provide a low impedance to ground at high frequencies and surge current at switching frequencies.
- A big capacitor in parallel with a small capacitor
- Make sure the capacitors are placed right next to the power input



PCB layers

- The basic layers are: copper, silk screen, solder mask, and NC Drill.

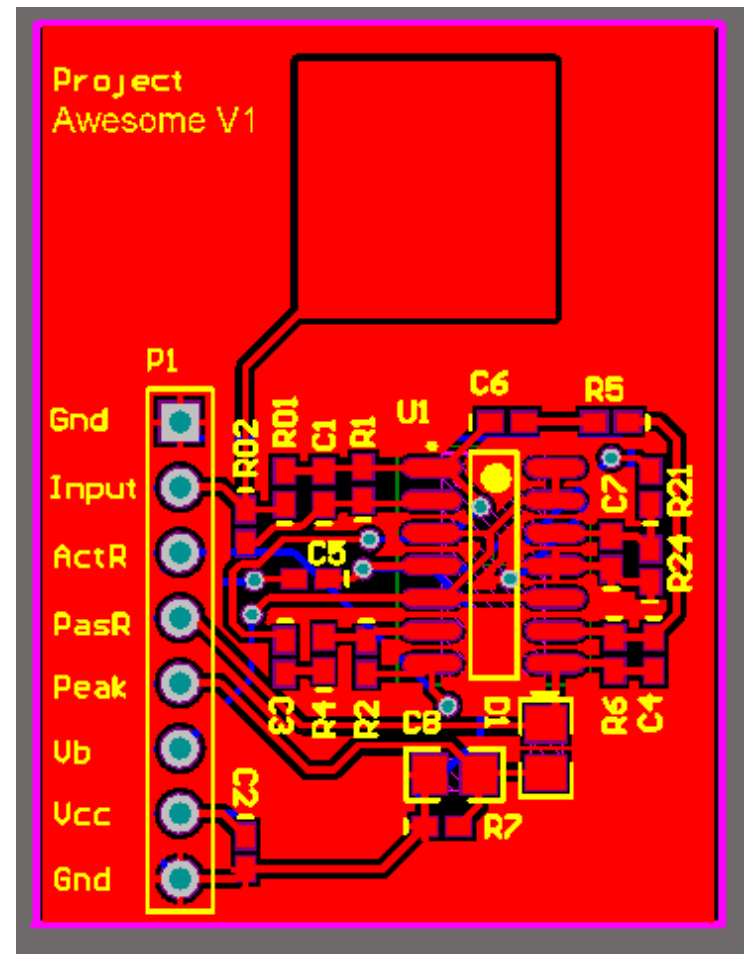
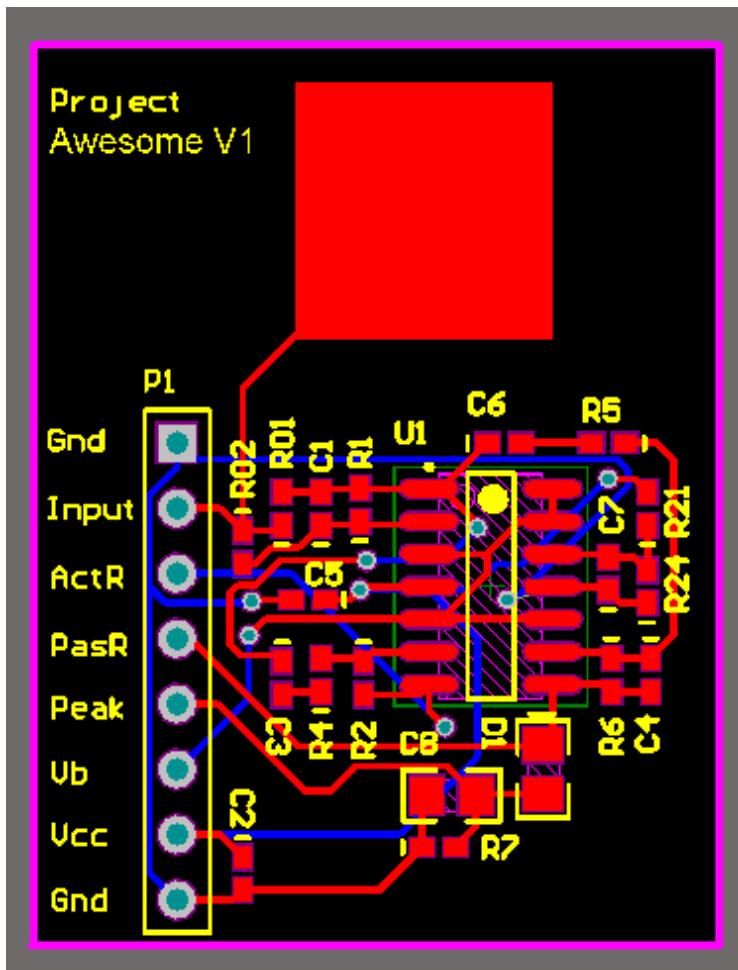
Copper layer stands for the conductive wires, silk screen is the marks and names, solder mask(stop layer)is the top non-conductive layer, and NC drill is the drill hole location.

For example, if you need a two layer PCB with top layer silk screen, you will need to send

- Top Copper (GTL)
- Top Solder mask (GTS)
- Top Silkscreen (GTO)
- Bottom Copper (GBL)
- Bottom Solder mask (GBS)
- Bottom Silkscreen (GBO)
- Drill File

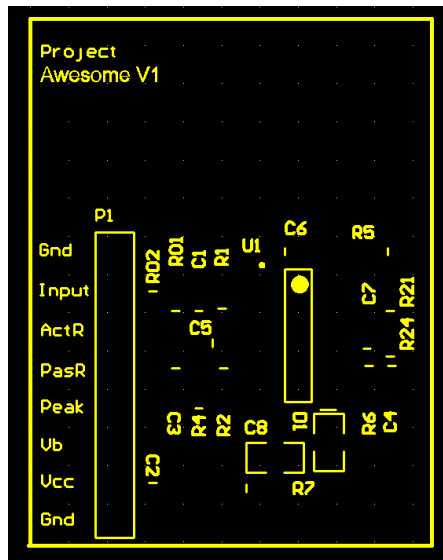


Solder mask comes in different colors

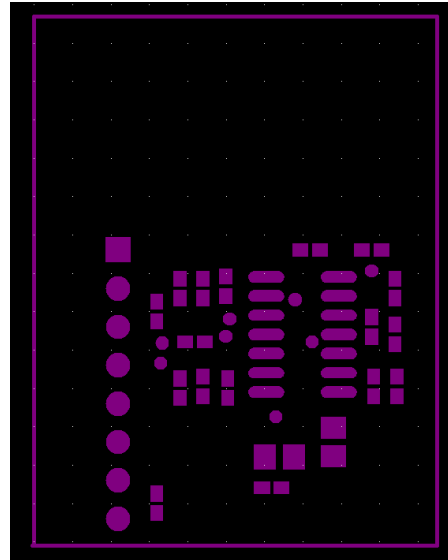


Don't connect grounds with traces, use polygon pour

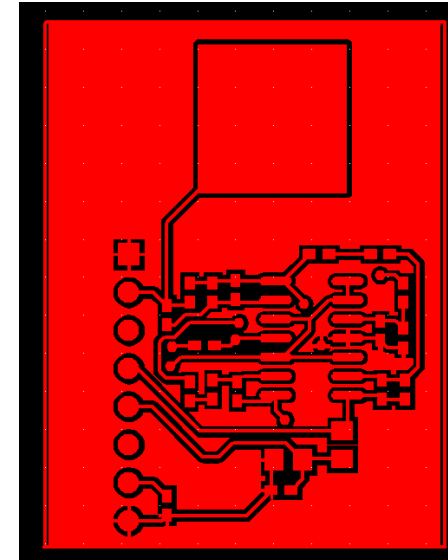
Top Silkscreen



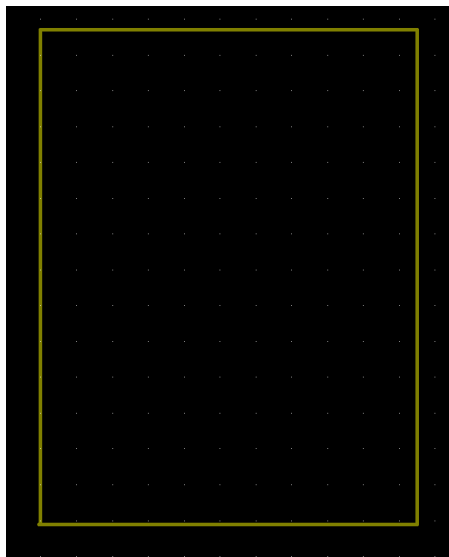
Top Solder mask



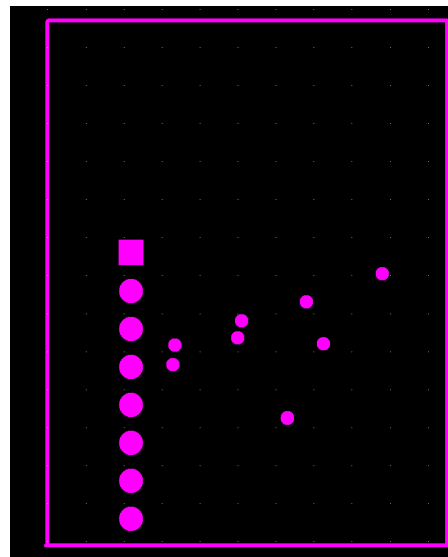
Top Copper



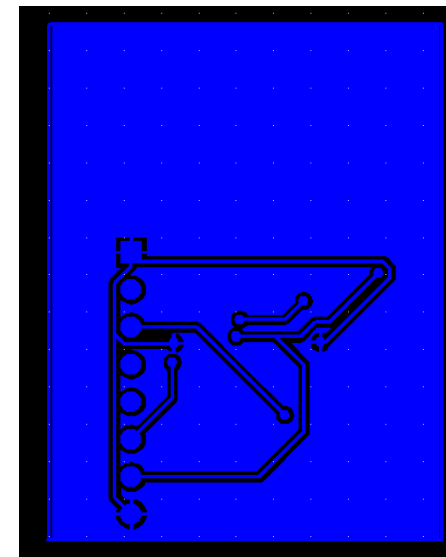
Bottom Silkscreen



Bottom Solder mask



Bottom Copper



HOLD NOTICE / FreeDFM CHECK

View sample FreeDFM report below.

Potential Show Stoppers

[Missing Soldermask Clearance \(112 violations\)](#)

[1](#) [2](#) [3](#) [4](#) [5](#)

Problems Automatically Fixed

[Insufficient SMT Soldermask Clearance \(15 violations\)](#)

[1](#) [2](#) [3](#) [4](#) [5](#)

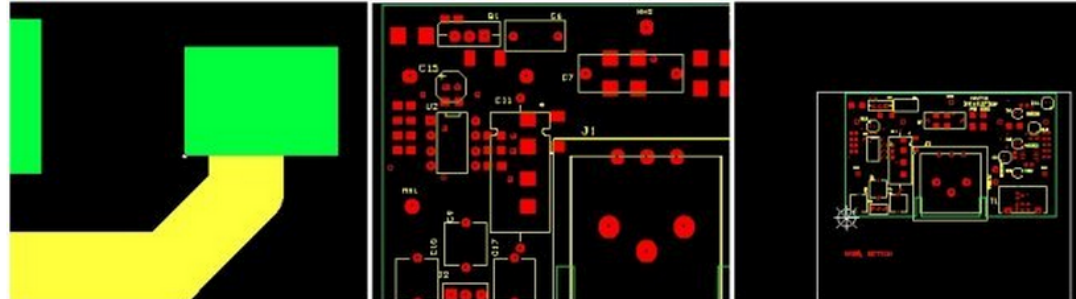
[Insufficient Soldermask Clearance \(466 violations\)](#)

[1](#) [2](#) [3](#) [4](#) [5](#)

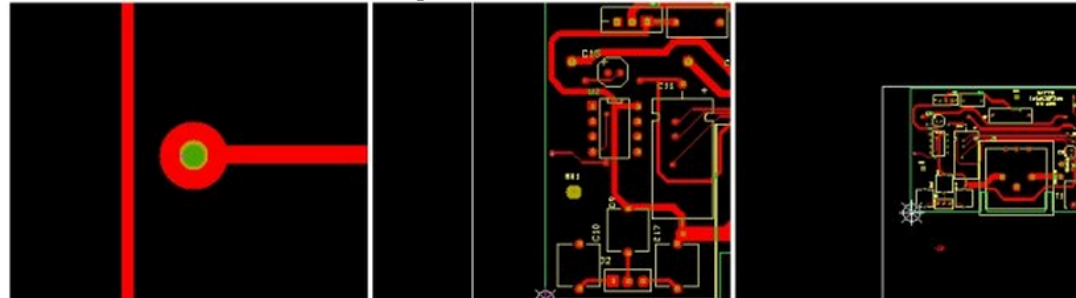
[Insufficient Silkscreen Line Width \(515 violations\)](#)

[1](#) [2](#) [3](#) [4](#) [5](#)

Three zoom view of Insufficient SMT Soldermask Clearance.



Three zoom view of Insufficient Annual Ring.

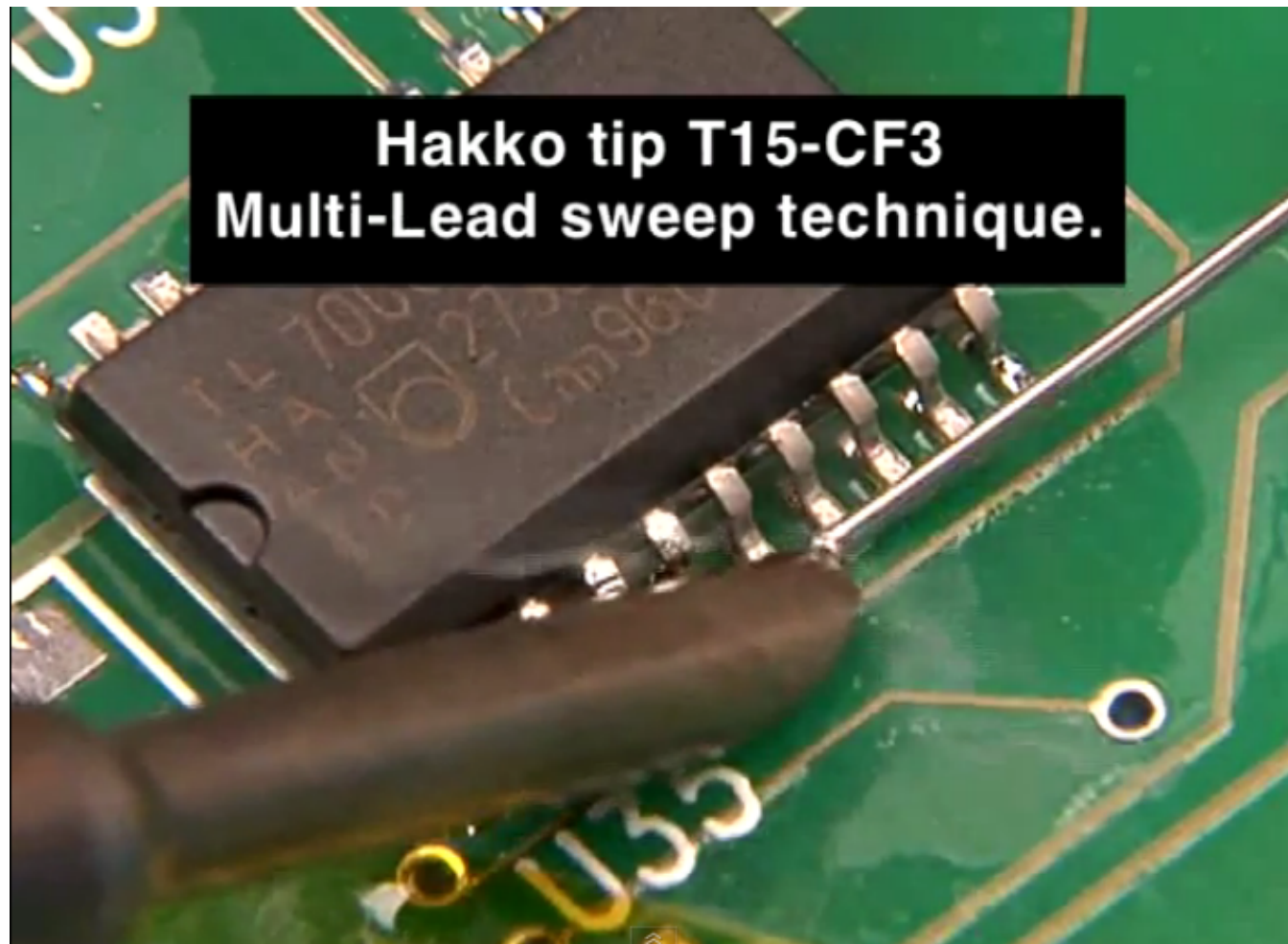


* Based on time of order to time of shipment.

PCB Assembly

- Things you need to know
 - Soldering
 - De-soldering
 - Re-flow
 - Small to medium quantity manufacturing
 - Pick and Place Machine
 - Reflow oven

Soldering



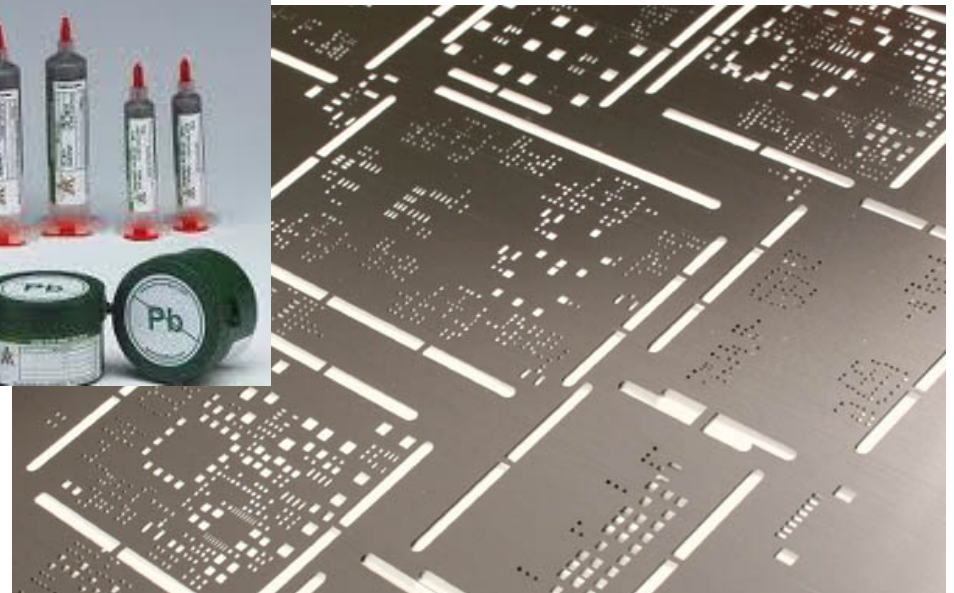
<http://www.youtube.com/watch?v=5uiroWBkdFY&feature=related>

Soldering

- **Solder size**
 - Depending of size of the part
- **Solder paste**
 - For SMD components
- **Solder tips**



http://store.curiousinventor.com/guides/Surface_Mount_Soldering/Tools/



De-soldering and Re-flow



- **Flux** - chemical cleaning agent, flowing agent, or purifying agent
- **Solder Sucker or Solder-wick**



Before

After

Hot air station

for removing quad flat packages (where there are too many leads to properly de-solder it without)



Infrared Rework Station

Same idea with the hot air station, The only difference is it won't blow away tiny parts



PCB manufacturing and assembly

<http://www.custompcb.com/>

starting at \$18 each

<http://www.advancedcircuits.com/>

\$33/board (student)

<http://www.streamlinecircuits.com/>

Need to know

1. Board layers
2. Material (FR4)
3. Trace width
4. Solder mask and silkscreen color
5. Thickness
6. Panel?



Home File Formats FAQ Shipping Tech Spec E-test Sample Online Order Policies Contact Us



PCB made to order!

We are a PCB manufacturer that specializes in PCB prototype and low volume PCB production. Our fabrication services offer high level of customization to suit all price and requirements.

Founded in summer of 2000 in Ames, Iowa, we have grown from our humble beginnings as garage PCB lab, to a full fledged high-tech PCB factory with 4 mil process and multilayer PCB capability.

Our PCB fabrication facility is located at Kuala Lumpur, Malaysia.

Instant **PCB Price** Quote

PCB width	2	inch
PCB height	2	inch
Quantity	100	pcs

[Quote Now](#)

Setup Unit Cost

Rates for 2 layers 0.062" FR4 1 oz copper, Green Soldermask, White Legend, 2 weeks turn

PCB Prototypes
starting at **\$18⁰⁰** each

[Quote & Order](#)

Specifications

Process	7 mil trace/space 14 mil hole
Layers	1 to 2 layers
Material	FR4 0.062" FR4 1 oz
Finishing	HASL
Soldermask	Green LPI SMDBC
Silkscreen	White
Lead time	1 week

- Maximum 6.3"x4.0 area for 1 or 2 layers
- Smaller boards can be panelized for additional cost of just \$0.50 per piece.
- Additional charge for bottom silkscreen.
- 1 week leadtime

PCB Production
as low as **13¢** /inch²

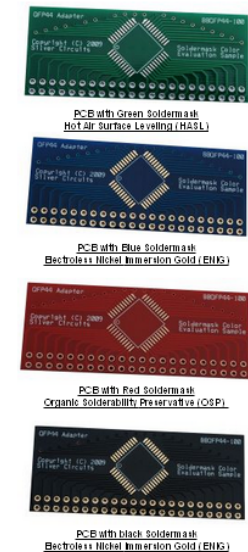
[Quote & Order](#)

Build Options

Process	7 mil trace/space 14 mil hole
Layers	1 to 6 layers
FR4 thickness	0.032", 0.062", 0.096", 124"
Finishing	HASL, ENIG, OSP, RoHS HAL
Soldermask	Green, Red, Blue, Black, White
Copper Weight	1oz / 2oz / 3 oz
Lead time	1 week, 2 weeks

Example Unit Cost in US Dollars
2 layers 0.062" FR4 1 oz copper, SM SLK.

Size	50	100	250	500
2"x2"	1.40	1.17	0.94	0.80
4"x3"	2.80	2.31	1.84	1.68
5"x3"	3.24	2.65	2.17	2.01
8"x6"	6.20	5.40	4.92	4.76



PCB Design cost calculator - <http://www.ladyada.net/library/pcb/costcalc.html>

Width (inches)	Length (inches)	Quantity (minimum)	Size (square inches)
3 inches	3 inches	100 PCBs	9 square inches

Calculate Costs

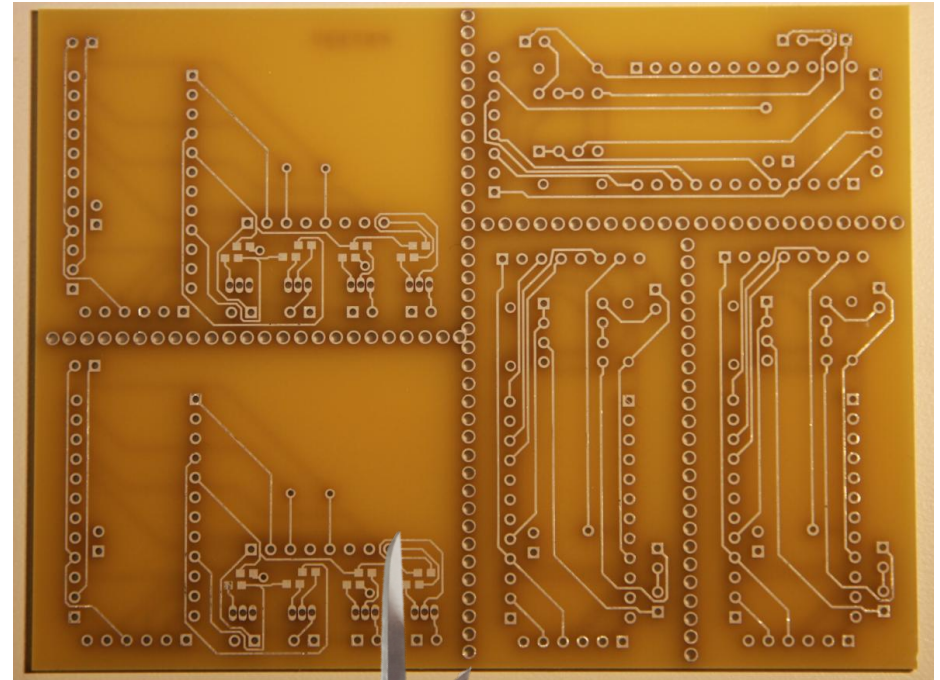
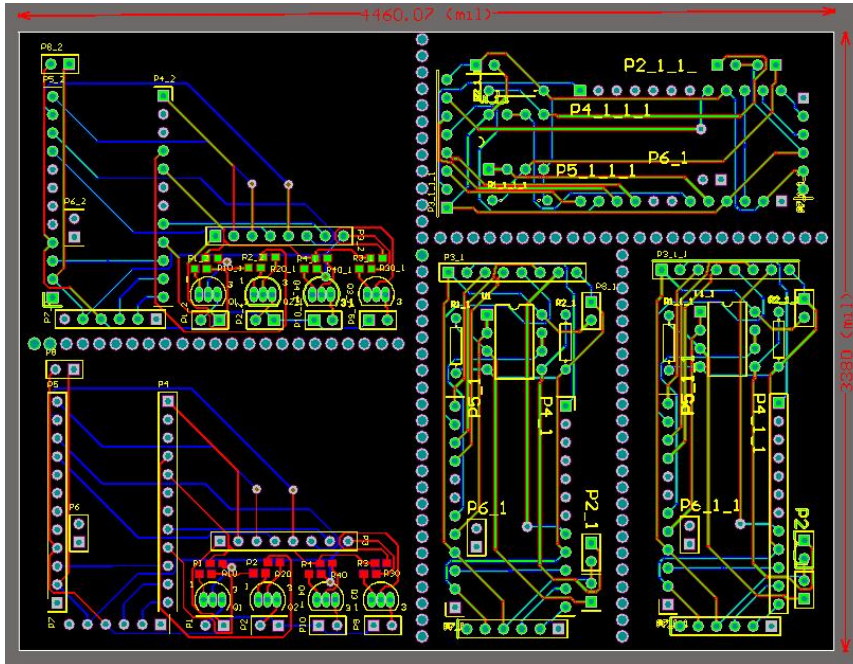
Prototype PCBs, no soldermask or silkscreen, usually 1-3 day turn.

PCB Manufacturer	# PCBs	Cost Per	Cost	Shipping	Total	Notes
Barebones PCB	<input type="text" value="100"/>	<input type="text" value="4.47"/>	<input type="text" value="447"/>	<input type="text" value="20"/>	<input type="text" value="467"/>	Can deduct cost from future production orders
PCB express El	<input type="text" value="100"/>	<input type="text" value="7.15"/>	<input type="text" value="715"/>	Free	<input type="text" value="715"/>	Preset #'s of PCBs
APcircuits basic	Haven't quite been able to figure out their calculator algorithm. Try it here.					

Prototype PCBs, with 2 sides green mask and 1 or 2 sides silkscreen, usually 3-10 day turn

[illegible]

Cheap way to test your circuit design – barebones PCB without solder mask



Cheap way to get more boards made from the same order

Put via everywhere so you can separate different designs!

Break the board with a bender



Board assembly

- <http://www.protoexpress.com/>
- <http://www.advancedcircuits.com/>
- <http://www.spinpcb.com/>
- <http://www.leaflabs.com>
- <http://www.suntroncorp.com>
- <http://www.rapidboard.com/>
- <http://www.pcacorporation.com/>
- <http://www.pcbassemblydepot.com/>
- <http://www.flexone.com/>

INFO needed for a quote -

- Board quantity
- Unique parts
- Both Sides?
- Lead-free?
- # of SMT parts
- # of through hole
- # of fine pitch / QFM items
- Jumper wire? (if you made mistakes)

GENERATE YOUR PCB ASSEMBLY QUOTE

1 Tell us about your board so we can generate your quote.

FULL PROTO ?

SIMPLE PROTO ?

SHORT-RUN ?

DETAILED SERVICE COMPARISON ▶

Benefits:

- Our **entry-level** prototype assembly service
- Great for saving money on **simple SMT & Thru-Hole only** designs
- **Up to 50 boards** assembled in **10 days**

Requirements:

- SMT & Thru-Hole parts only
- SMT parts 0402 or larger
- 1-Sided assembly only
- Kitted only (*no Turn-Key service*)
- Files & payment due on order submission

BOARD DETAILS

Desired board quantity ?

Total unique parts (# BOM line items) ?

SMT on 2-Sides? ? ☐ Yes ☒ No

Lead-Free processing? ? ☐ Yes ☒ No

Class III Inspection? ? ☐ Yes ☒ No

PLACEMENTS ON BOARD

SMT ?

Thru-Hole ?

Fine Pitch ?

BGA / QFN / Leadless ?

2 Select your desired **assembly** quantity and turnaround time.

RE-CALCULATE

! • Assembly configuration has changed, please recalculate.

		10 Day
TY	50	<input type="radio"/> \$889.80

How to order PCB assembly

- You can ask them to order the parts or you can send them the parts.
- Files needed -
 - Bill of Materials(BOM)
 - Centroid data
 - Centroid data (aka Insertion or Pick-and-place or XY data) - This is the machine file, which should include: X, Y, Theta, Side of Board (Top or Bottom), and Reference Designator.
- The BOM from Eagle is not the format that they like.

Footprint	Comment	LibRef	Designator	Description	Quantity	Distributor	Distributor part ID
1608[0603]	100nF	Cap Semi	C11, C14, C17, C20, C34, C35, C51, C62, C63	Capacitor	9	Digi-key	490-1524-6-ND

For generating Centroid data, see

<http://www.screamingcircuits.com/services/how-it-works.aspx#eagle>

Pick and Place



http://www.youtube.com/watch?v=S8qkaTsr2_o&feature=related

