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# Schematics, Prototyping and Soldering Lecture



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# Schematic Diagrams

Schematic diagrams represent an electronic circuit in symbolic form.

A schematic need not depict the actual physical arrangement of the components





# Schematic Symbols Cont.

## *Wires and wire connections*

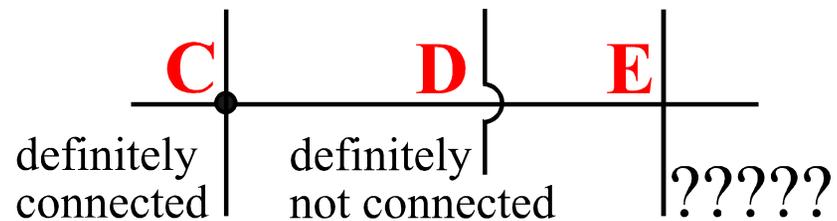
single wire



connected wires



intersecting wires



### ***Current practice:***

Either **A** or **B** is acceptable

**D** is seldom used

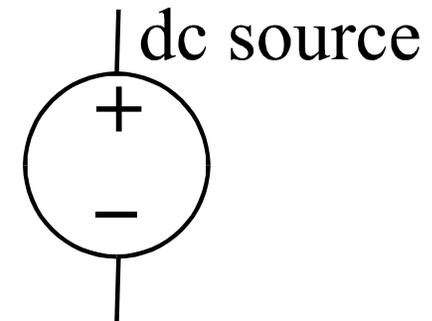
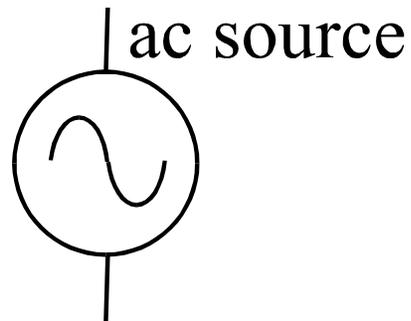
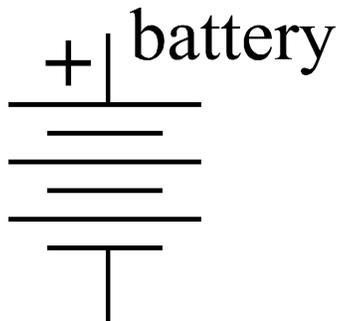
**C** is the preferred style

**E** is interpreted as a non-connection



# Schematic Symbols Cont.

*Power sources (V) common connections (GND)*



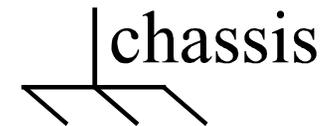
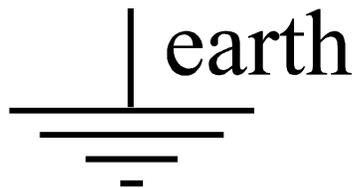
- The “+” sign may not always appear on a battery symbol. By convention, the longer horizontal line represents the positive terminal
- Note that no polarity is shown for the ac source



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# Schematic Symbols Cont.

## *Common connections (GND)*



- “Earth” means an actual connection to a conductor driven into the soil.
- “Chassis” means a bonded electrical connection to the metallic case of chassis of a device.



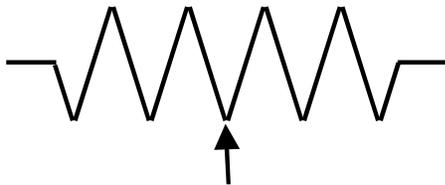
# Schematic Symbols Cont.

## *Resistors (R) and Capacitors (C)*

tapped resistor

or

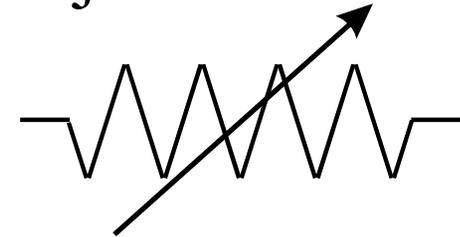
potentiometer



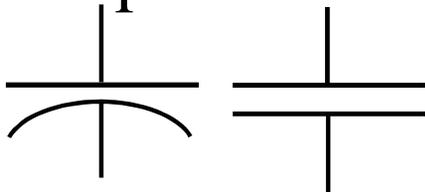
resistor



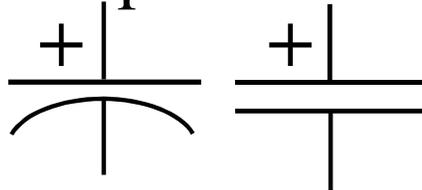
adjustable resistor



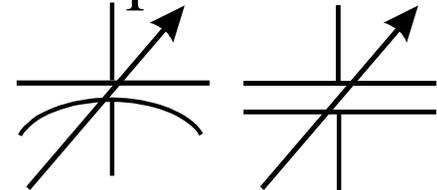
unpolarized  
capacitors



polarized  
capacitors



adjustable  
capacitors





# Schematic Symbols

## *Inductors (L) and Transformers (T)*

simple  
inductors



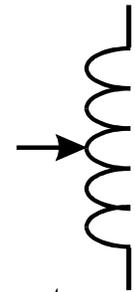
adjustable



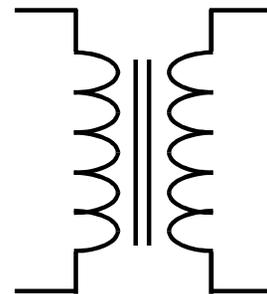
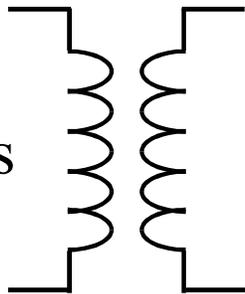
adjustable



tapped



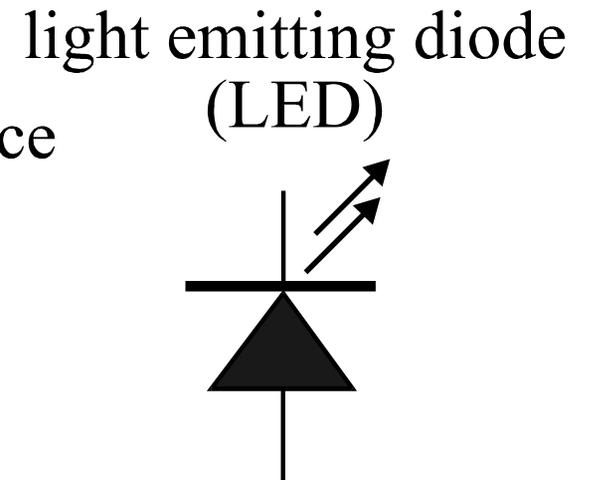
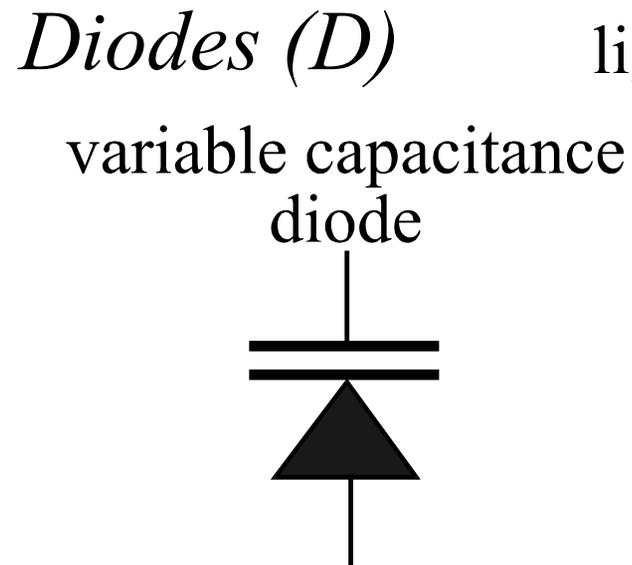
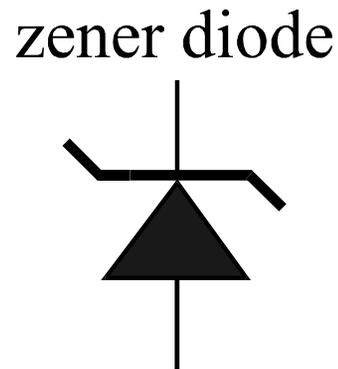
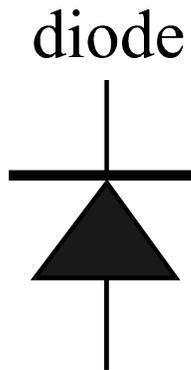
transformers



*The two parallel lines indicate that the inductor is wound on a core of iron, iron powder, or ferrite material.*



# Schematic Symbols



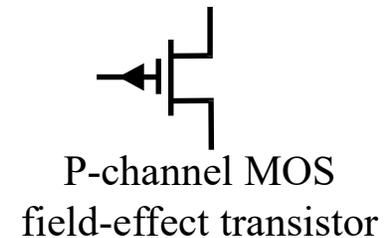
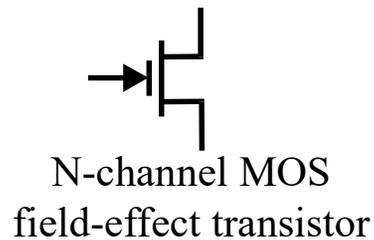
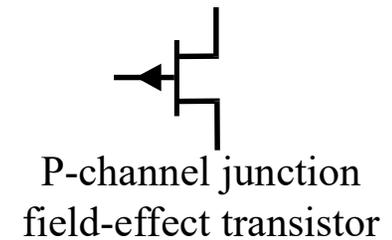
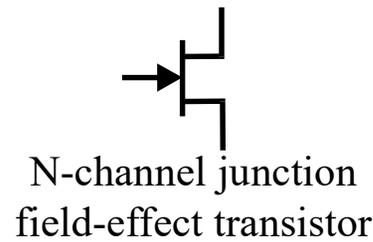
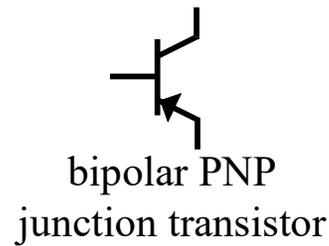
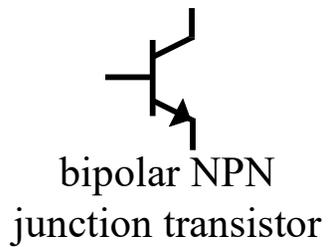
*The arrow points in the allowed direction of conventional (positive charges) current flow.*

*The bar represents the cathode, marked with a band on most parts.*



# Schematic Symbols

## *Transistors (Q)*

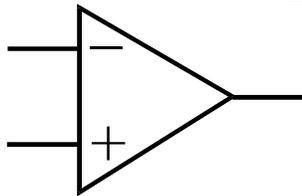




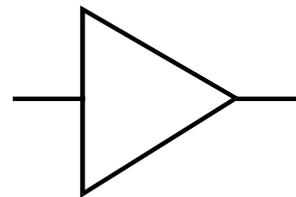
# Schematic Symbols

## *Integrated circuits (U)*

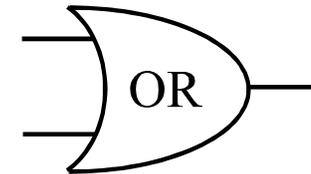
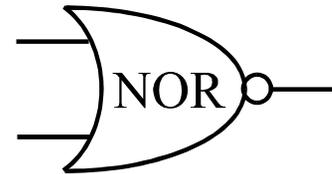
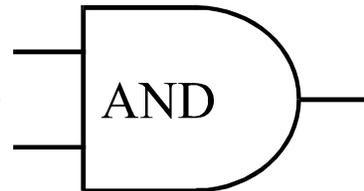
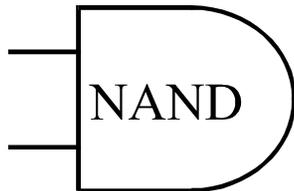
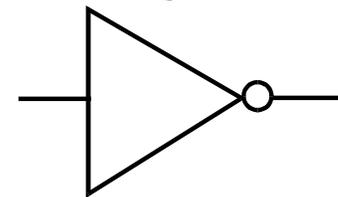
operational amplifier



buffer



inverting buffer



*Most complex integrated circuits are represented on schematic diagrams as a rectangular block symbol, with pin numbers and, usually, pin functions indicated; but many logic integrated circuits have special symbols that identify their function.*



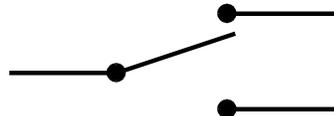
# Schematic Symbols

## *Switches (S) and Relays (K)*

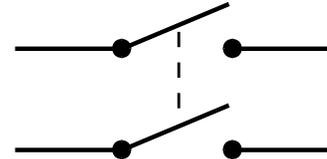
single pole single throw  
SPST



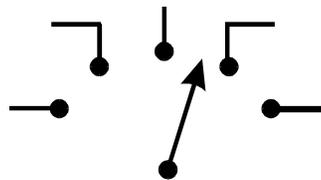
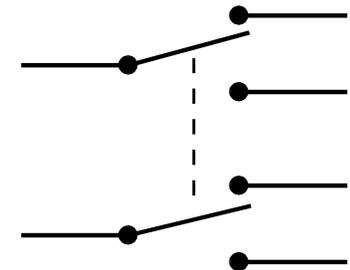
single pole double throw  
SPDT



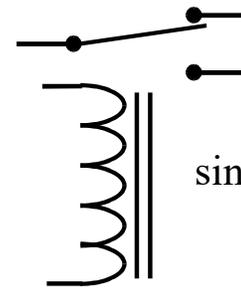
double pole single throw  
DPST



double pole double throw  
DPDT



rotary switch  
1 pole, 5 position



single pole double throw  
relay



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# Drawing Schematic Diagrams

You can use one of the many *schematic capture* programs available on the internet for free. The *SkeeterSat* schematic shown earlier was prepared with ExpressPCB.

## Schematic Capture Programs

- **ExpressPCB** <http://www.expresspcb.com/>
- **Eagle** <http://www.cadsoftusa.com/freeware.htm>

*Schematic capture* is a step in the design cycle where the electronic diagram of the electronic circuit is created by a designer.



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# Building a prototype

- Solderless breadboards
- Perfboards or Protoboards
- *Manhattan* Construction
- *Dead Bug* Construction
- Etched Circuit Boards



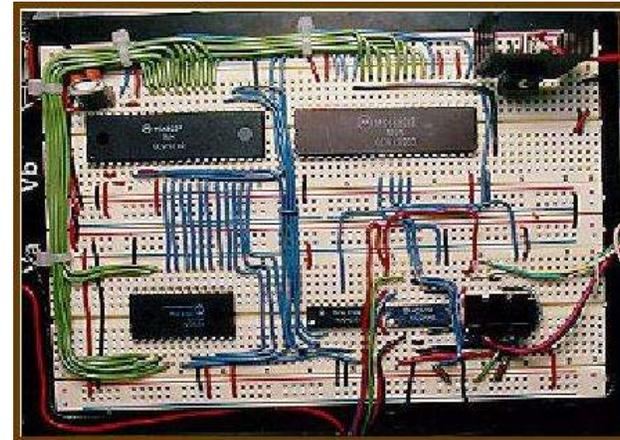
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# Solderless Breadboards

The term *breadboard* originated in the early days of radio, when many experimenters actually built circuits on the wooden boards used in their mother's kitchen for rolling out bread dough.

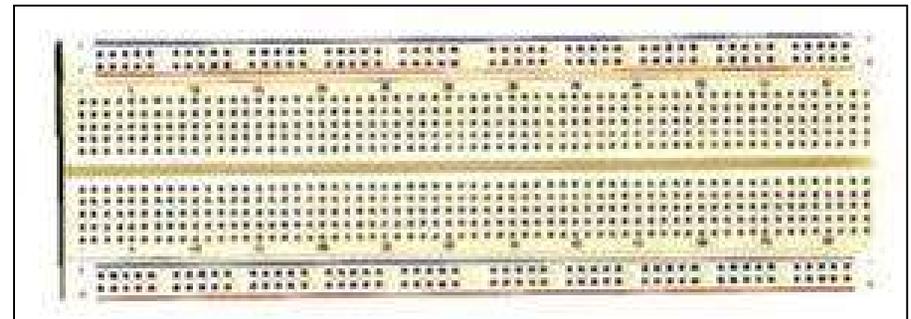


A ham radio transmitter circa 1930



Modern solderless breadboards

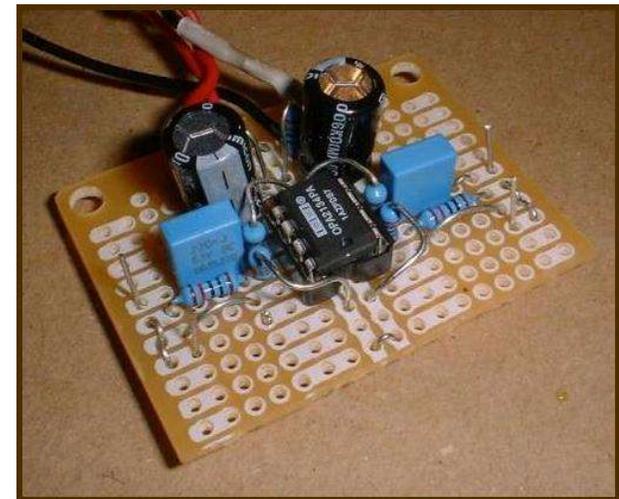
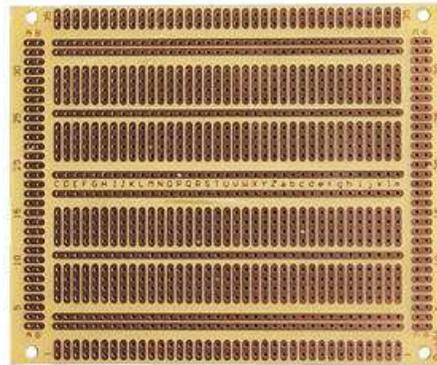
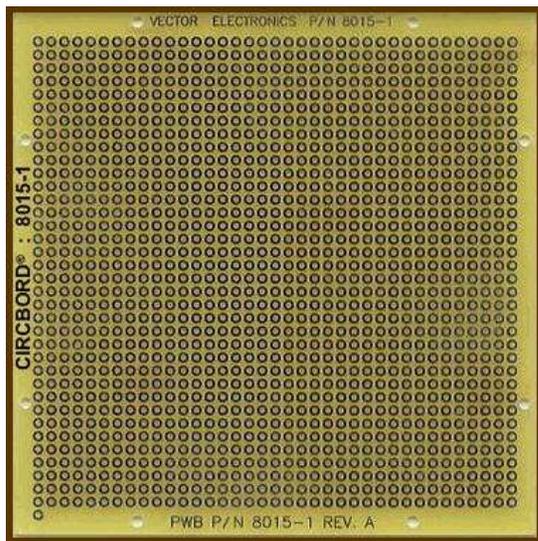
Best thing to come along since sliced bread!





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# *Perfbord or Protoboard*



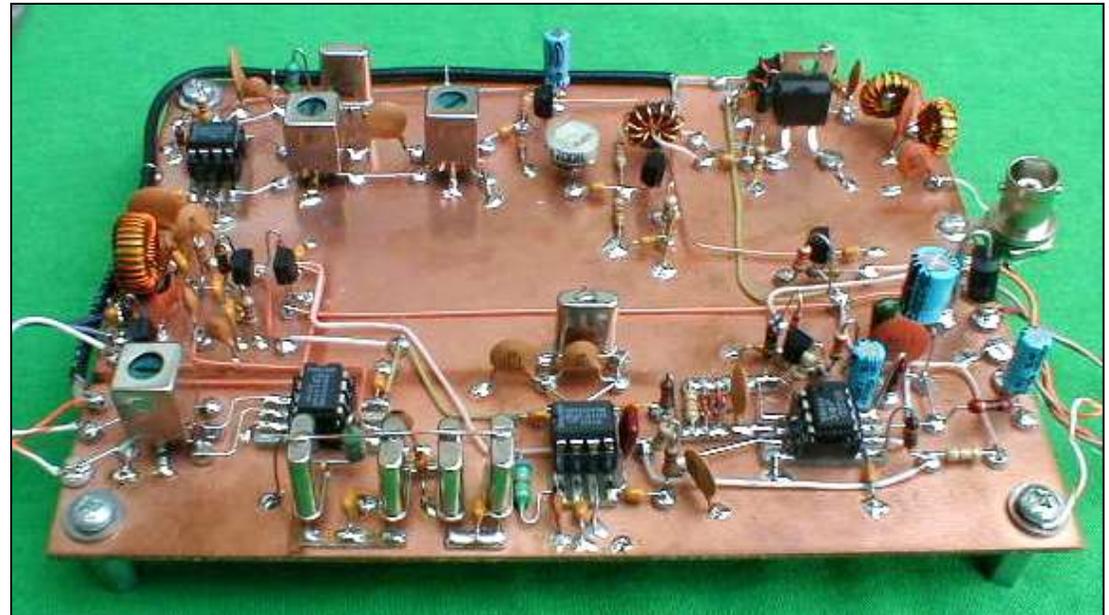
Components are soldered to the board, with connections made using a combination of short pieces of wire and the copper traces already present on some versions of these boards.



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# *Manhattan* Construction

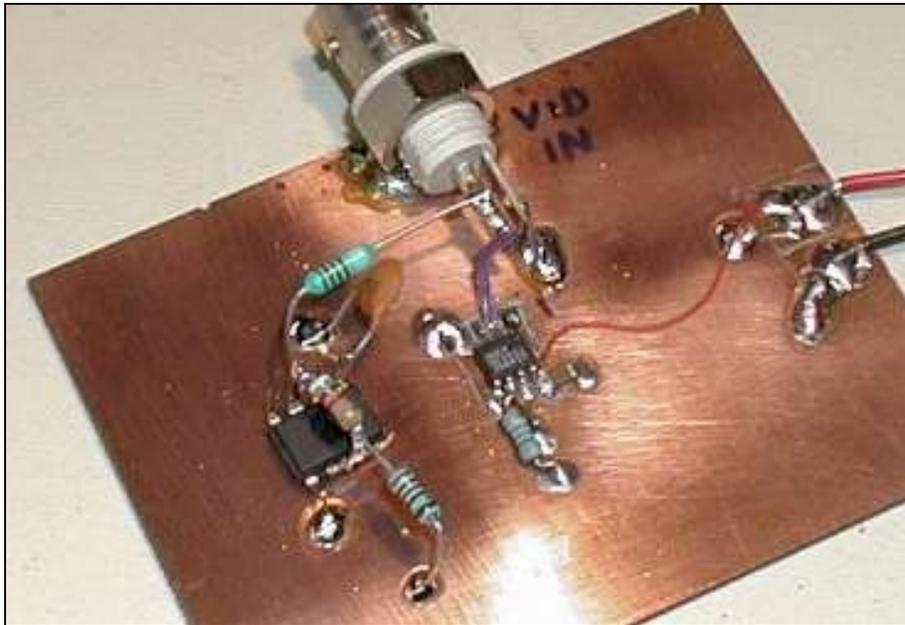
Manhattan Style  
uses little “islands”  
of PCB material  
glues to a substrate  
ties points for  
components.





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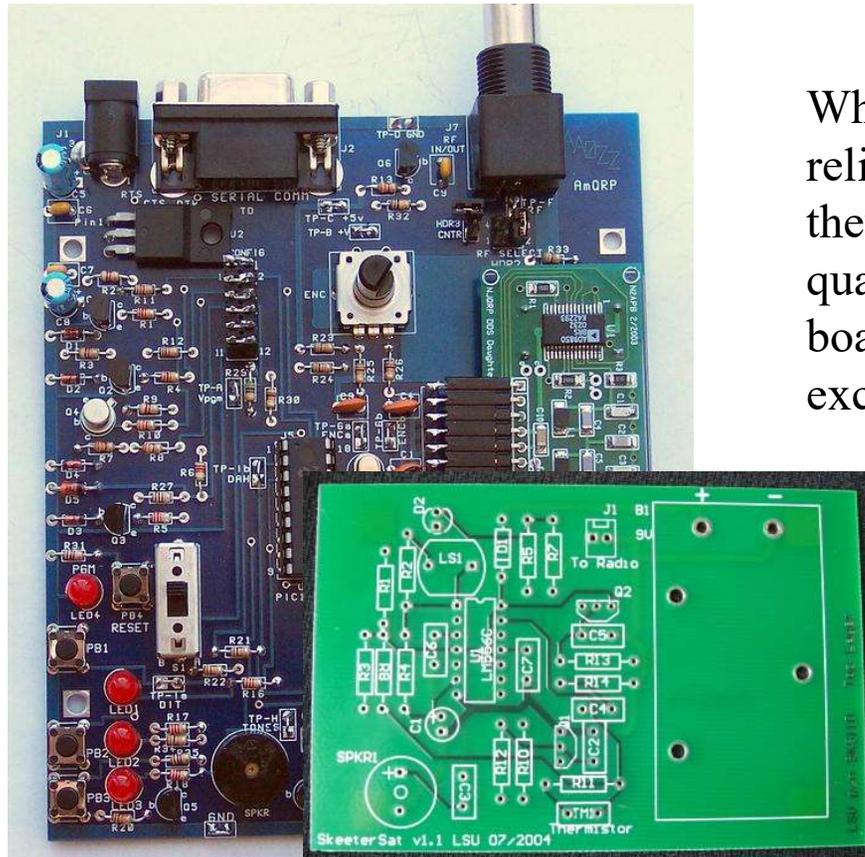
# *Dead Bug* Construction



“*Dead bug*” style is a type of board design with the integrated circuits (IC’s) flipped upside-down with their pins sticking up into the air like a dead insect. While it is messy-looking, it can be used to make more compact circuits than other methods.



# Etched Circuit Boards



While etched boards are the most reliable method of circuit construction, they can be expensive in small quantities (\$300+ per board). Cost per board drops rapidly when quantities exceed 25 or so.



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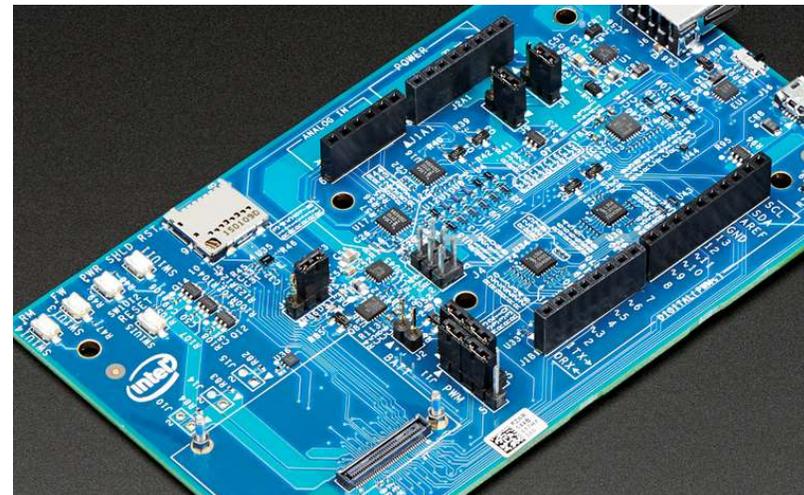
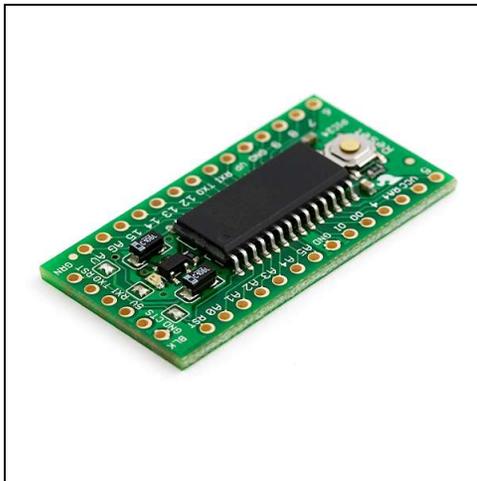
# Prototyping with Surface Mounted Device (SMD) components

- Difficult to prototype SMD components without a PCB board
- Can solder wires directly to the leads
  - However, this requires a fair amount of precision and handling to accomplish. May unintentionally damage component if mishandled
  - Some devices are sensitive to electrostatic discharge (ESD) and can be destroyed by touching them.



# Breakout Boards

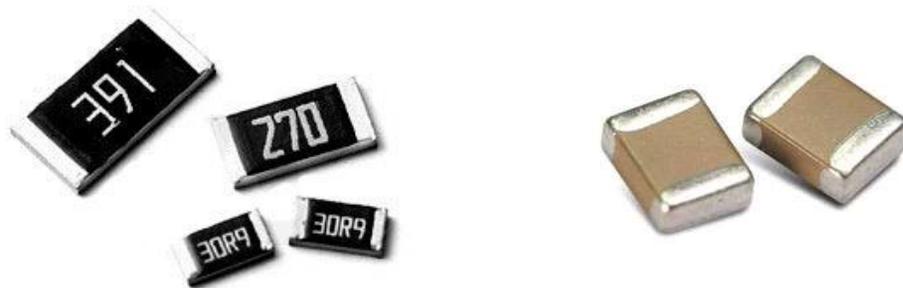
- Common method for testing specific chips is to make or buy a board that draws out all the desired leads to terminals that are easier to interface with.





# Two-terminal SMD

- Resistors and Capacitors
  - Case Code usually reported in **XXYY** format where **XX** is the length and **YY** in the width in mm or inches
  - **VERY** important not to mix up imperial and metric values! Ex. 0603 can be 0.6mm x 0.3 mm OR 0.06 x 0.03 in
- Other two terminal devices such as LEDs have their own package sizes and dimensions
- Dimensions are always listed on the **DATASHEET**





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# Multi-terminal SMD

- Wide variety of packages and footprints available
- Many manufacturers will adhere to standard package sizes common throughout the industry
  - This is not true for all components
- Types of SMD footprints
  - Small outline transistors (SOT), Small outline integrated circuit (SOIC), Dual Flat No-Lead (DFN), Ball Grid Array (BGA)



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# Soldering Tutorial

Soldering – fastening metal objects together using molten metal (solder) as the glue.

Three requirements

- Low melting point metal (wire solder)
- Heat source (soldering iron)
- Flux (to prevent surfaces from oxidizing)



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# Types of Solder

## **Tin-Lead solders**

60% Tin, 40% Lead - solid at  $361^{\circ}\text{F}$ , liquid at  $374^{\circ}\text{F}$

63% Tin, 37% Lead - eutectic point is  $361^{\circ}\text{F}$

*no "pasty" range so joint movement less a problem*

## **Silver-bearing Solder**

62% Tin, 36% Lead, 2 % Silver - solid at  $354^{\circ}\text{F}$ ,

liquid at  $372^{\circ}\text{F}$

*often used for surface mount components whose contacts contain trace amounts of silver*



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# Soldering Irons

## **Constant wattage**

Iron is continuously “ON” and eventually reaches equilibrium temperature

20 to 25 watt iron sufficient for circuit board assembly

## **Constant temperature**

Tip incorporates a thermostatic element to maintain desired tip temperature

650 – 750 ° F appropriate for circuit board assembly

**But wait.....even better...**



Weller® 30 watt iron



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# Soldering Irons

## Temperature Controlled Solder Station

Feedback control maintains tip at desired temperature

Adjustable, often with analog or digital temperature display

Many have grounded tip to help prevent ESD damage



Weller® solder station



# Types of Flux

- Rosin Flux

Type R – ordinary rosin – most common

Leaves a residue that can be removed for cosmetic reasons if desired.

Type RMA – mildly activated rosin

Type RA – activated rosin – use with care

RMA and RA fluxes leave a slightly corrosive residue that generally should be removed (with a solvent) after soldering

- Acid Flux – **NEVER, EVER** use this for electronics

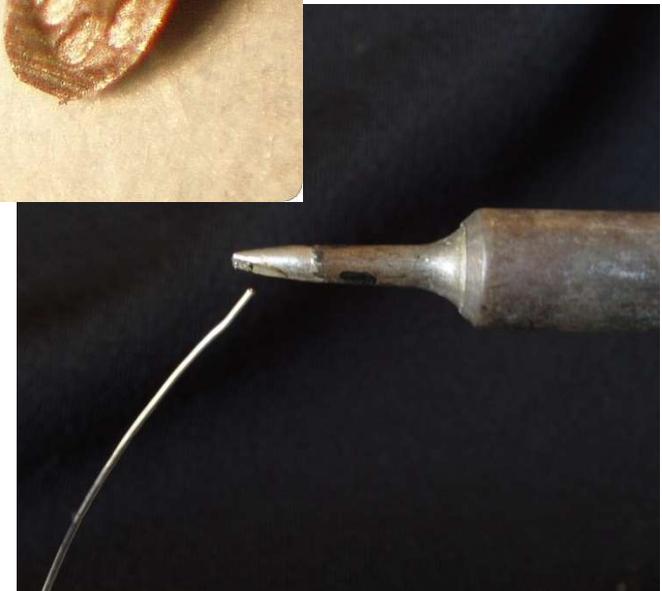


# Flux-core solder

Most solder used for electronics assembly is in wire form, with the flux incorporated inside the solder.

*Multi-core* solder has several (usually five) separate flux channels within the solder.

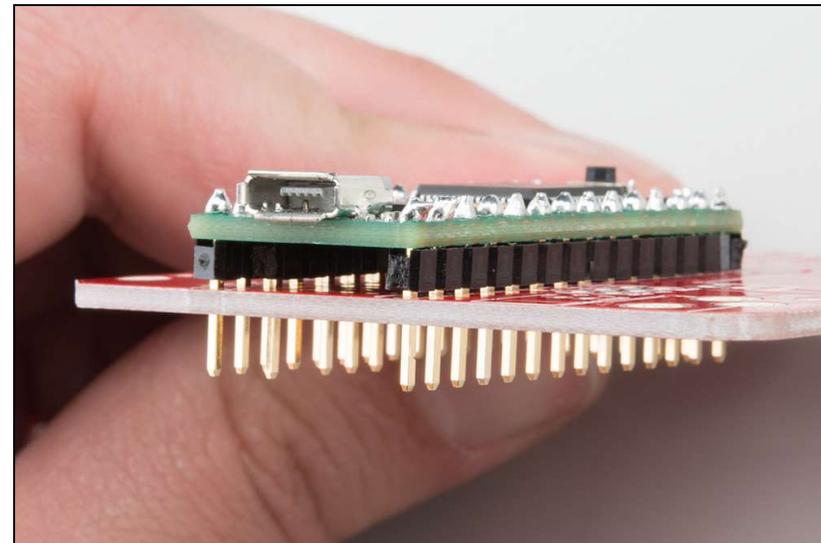
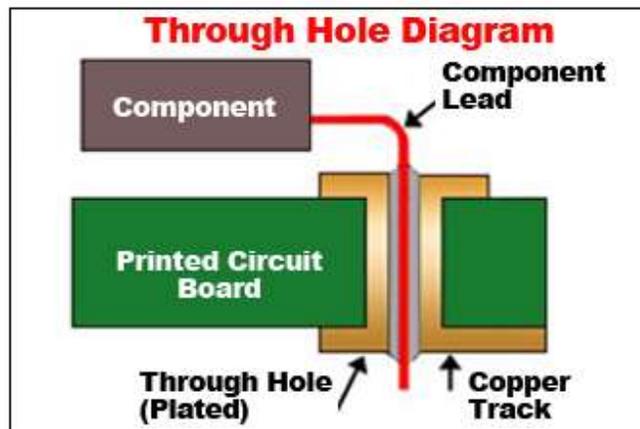
For circuit board assembly use wire solder with a diameter of about 0.025 inch or less





# Two Types of Soldering

- 1<sup>st</sup> type: Through Hole  
Component has metal leads that goes through the board.

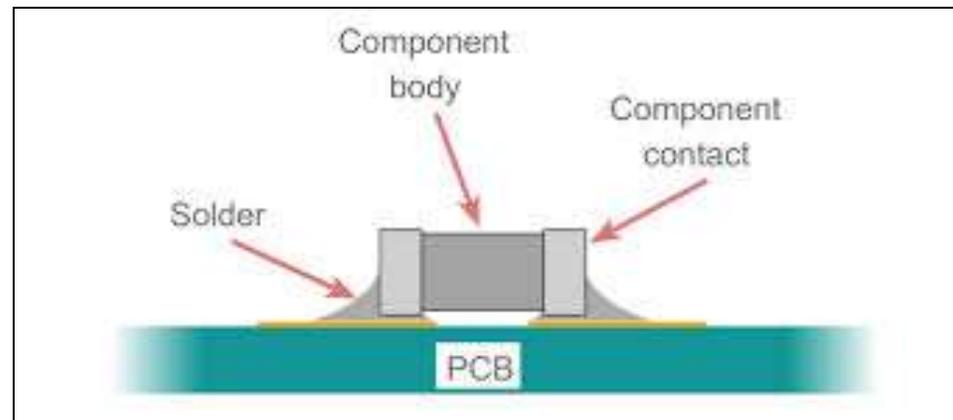
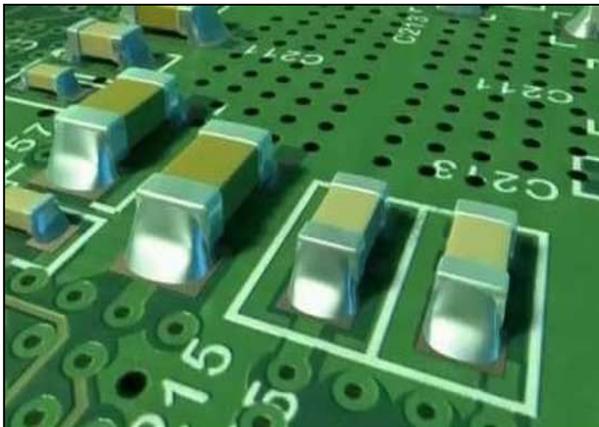




# Two Types of Soldering

- 2<sup>nd</sup> type: Surface Mount.

Component has metal pads that rest on top of board.





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# Activities



A03.01 Use the supplied assortment of components and practice soldering them to the perfboard.