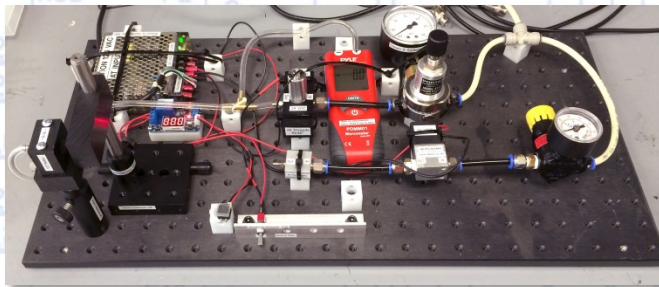
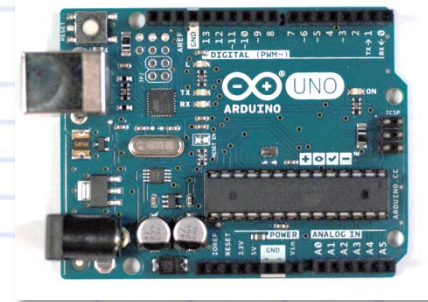
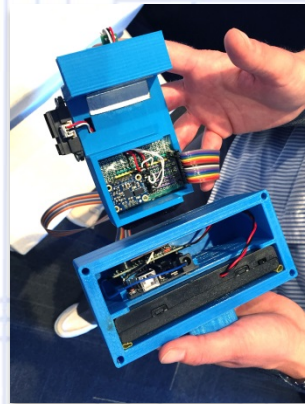
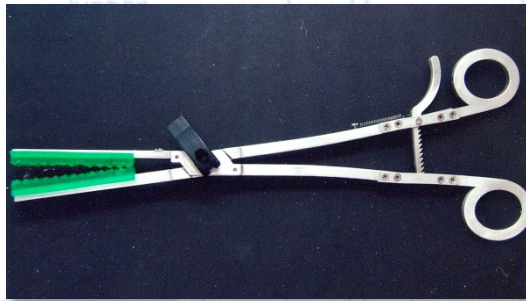


Introductory Medical Device Prototyping

Fabricating Electronic Circuits

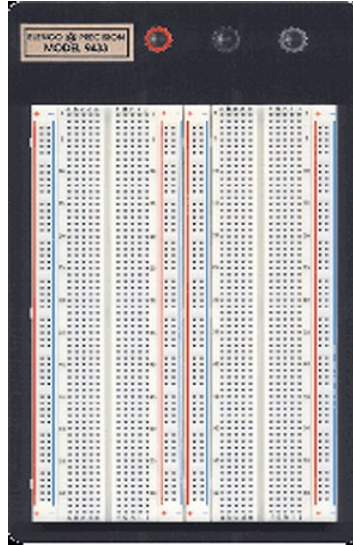
Prof. Steven S. Saliterman, <http://saliterman.umn.edu/>
Department of Biomedical Engineering, University of Minnesota



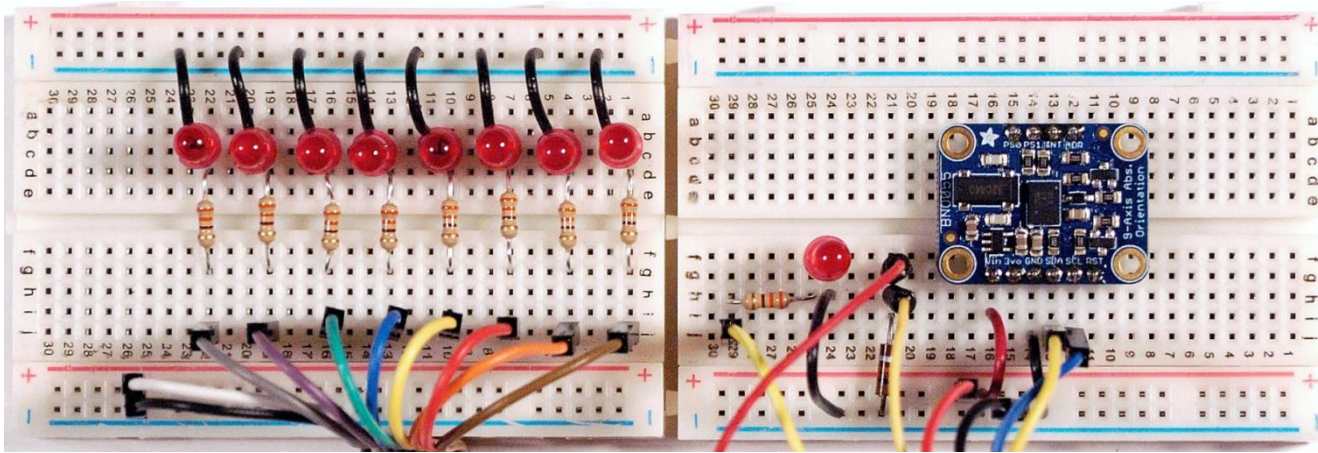
Topics

- Approaches to creating a prototype
 - Breadboard, wire-wrap and soldered
- Making circuit boards
 - Design and production
- Multimeters other test equipment
 - Voltage, resistance, current and capacitance
 - Oscilloscopes and function generators
- Connectors and cables
- Power supplies

Course Workstations

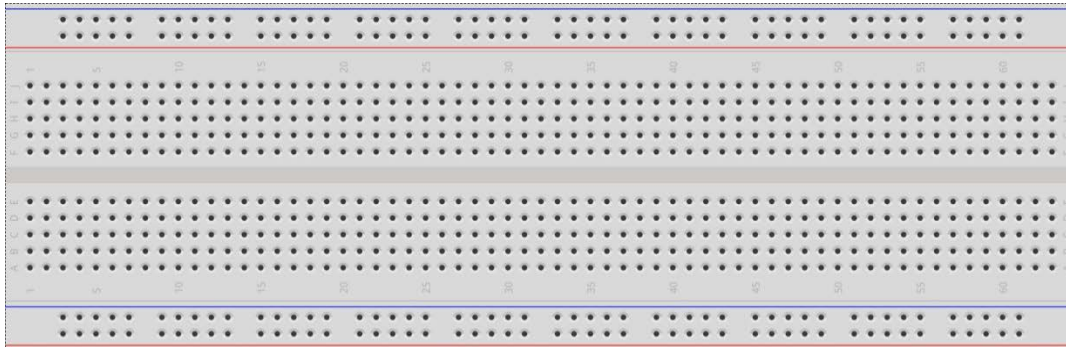


Breadboarding Your Designs

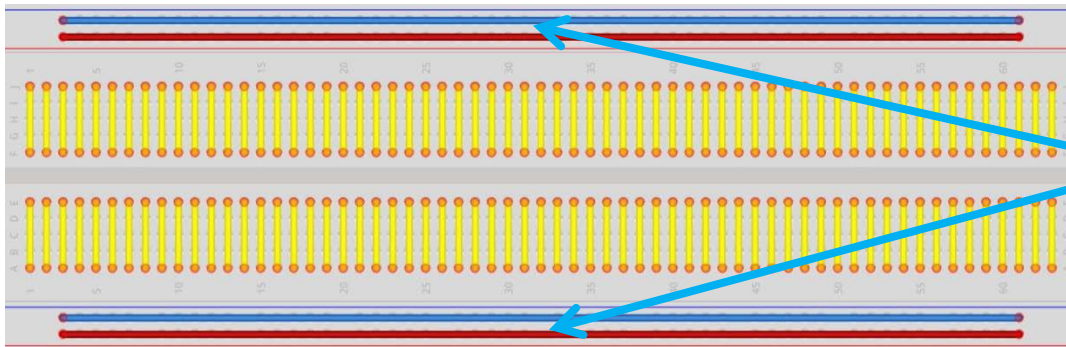


Solderless Breadboards...

Components and Wiring Top Side



Unseen Interconnections Bottom Side



Typical Use

DC Power Gnd or Neg. Rail ↔
DC Power Positive Rail ↔

Component Bus

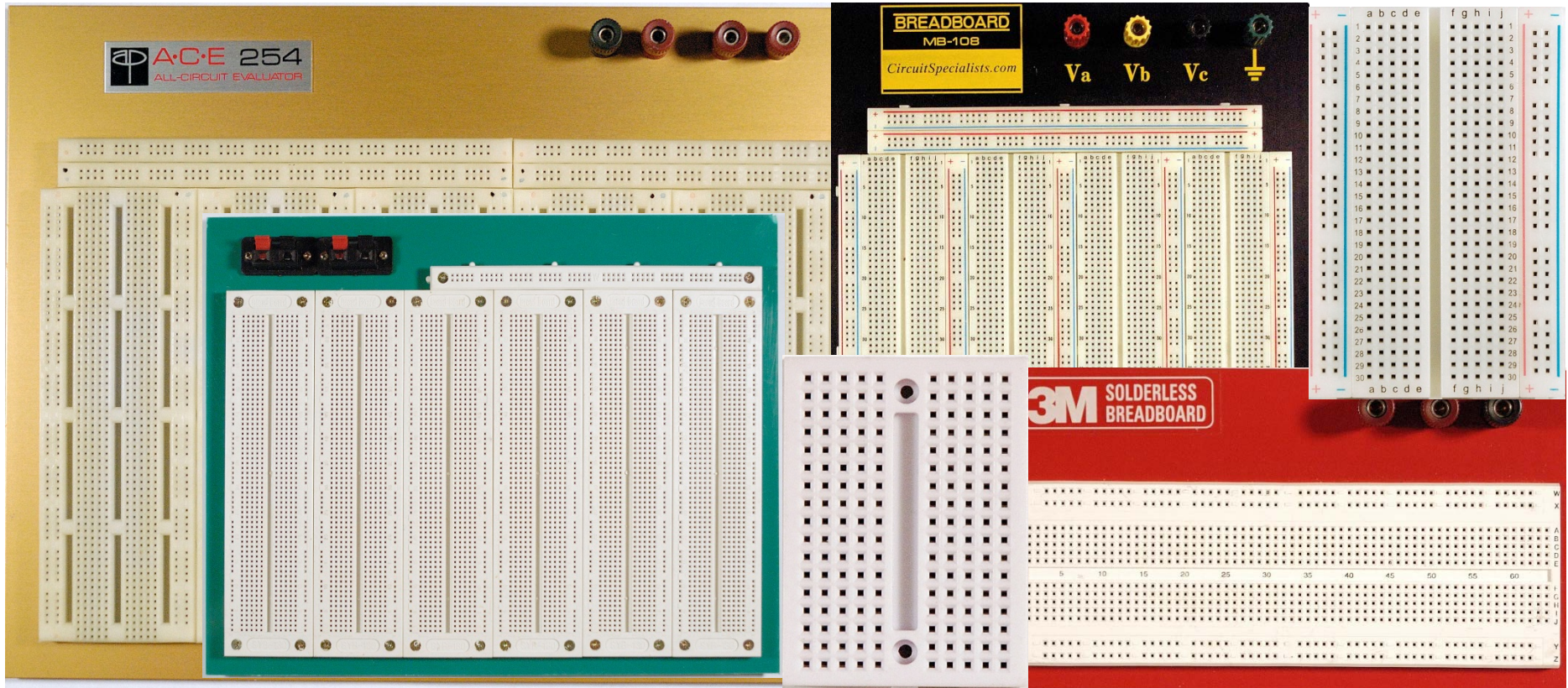
Component Bus

DC Power Gnd or Neg. Rail ↔
DC Power Positive Rail ↔

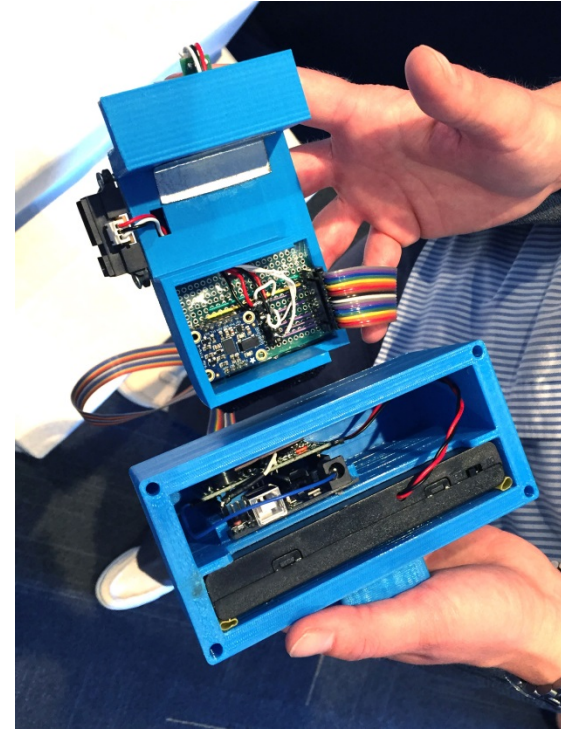
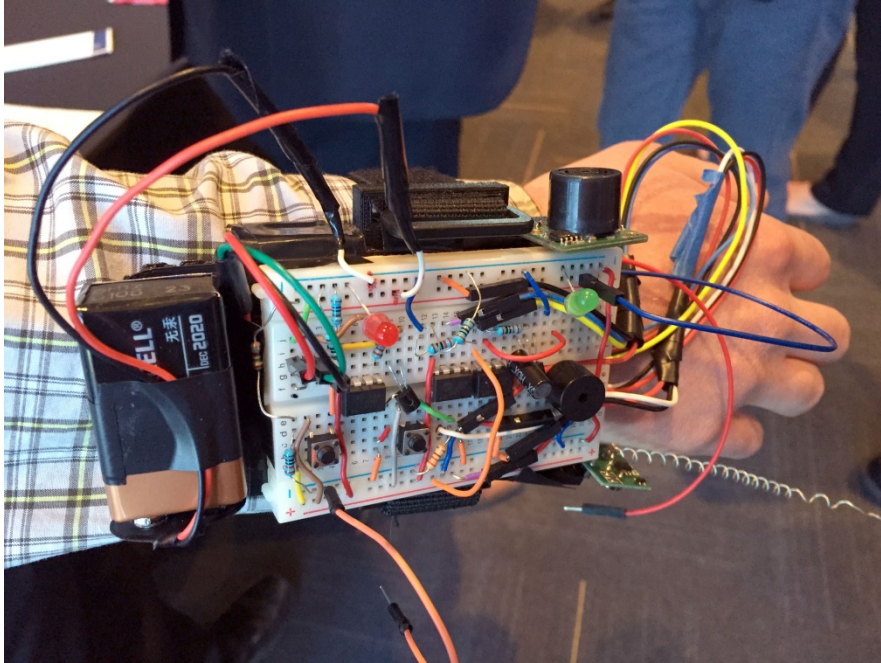
22 gauge solid wire works best for interconnections.

Caution, rails may need jumping at midway points on some boards.

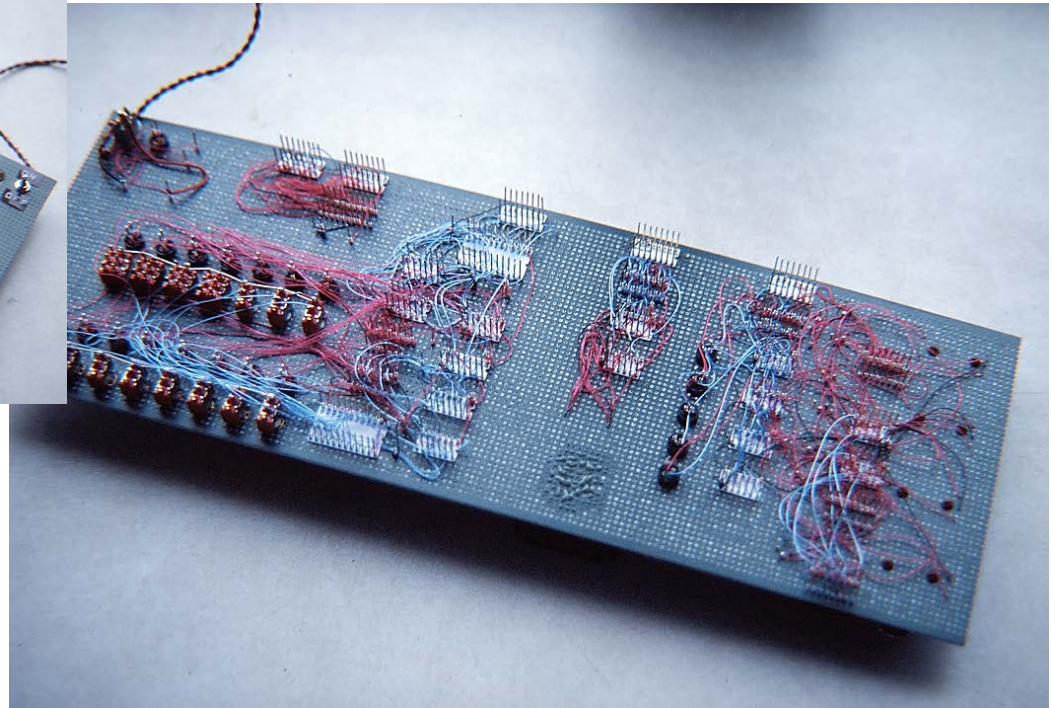
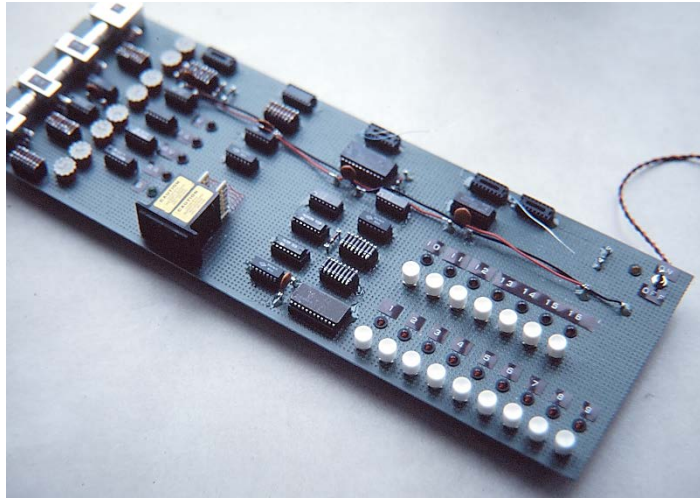
All Sizes & Shapes...



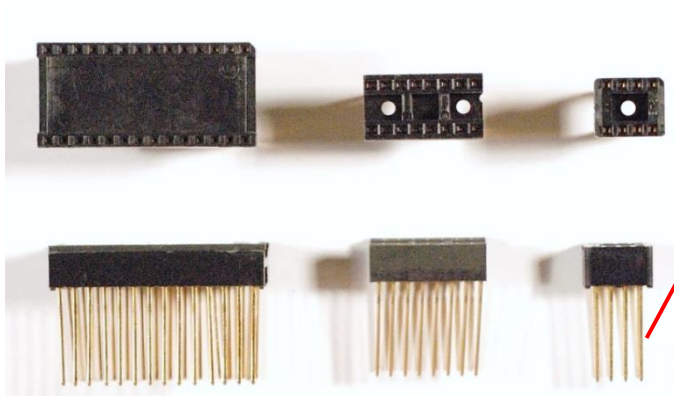
Alternative Approaches



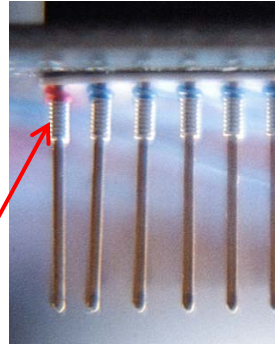
Wire-Wrap Prototyping...



Wire-Wrap Sockets, Header, Wire & Tools...



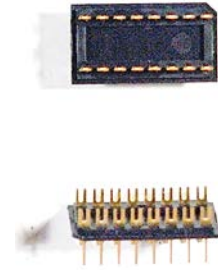
Sockets



Wrap



Wire-wrap gun



Header



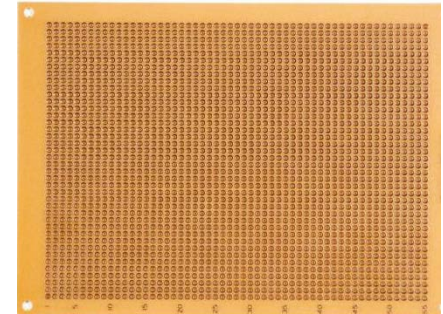
Precision Wire Stripper



Wire



Pre-cut wire

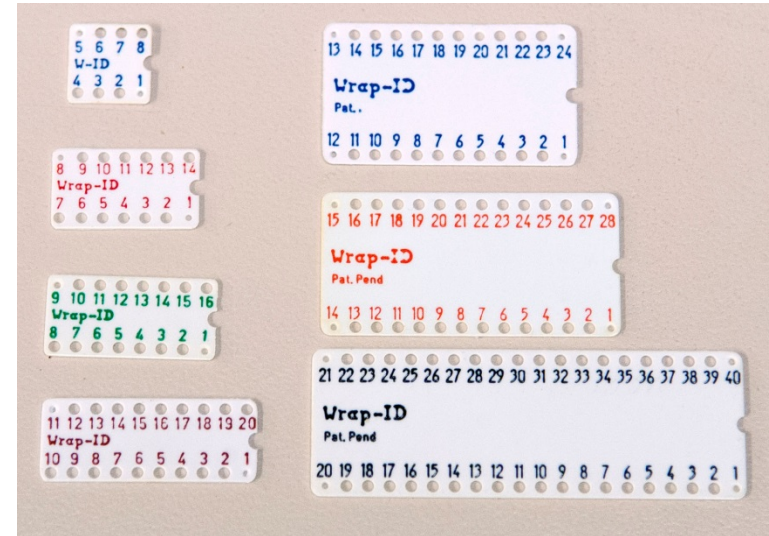


Perf board

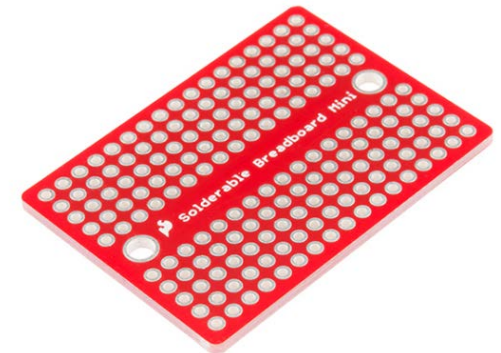
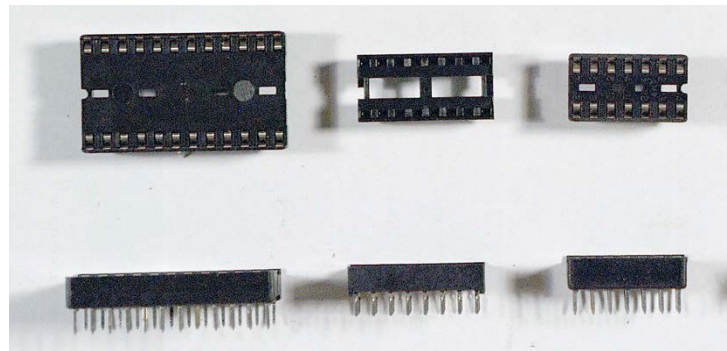
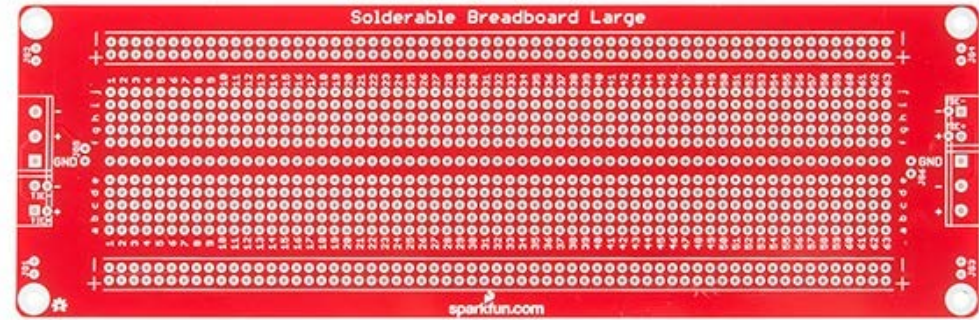
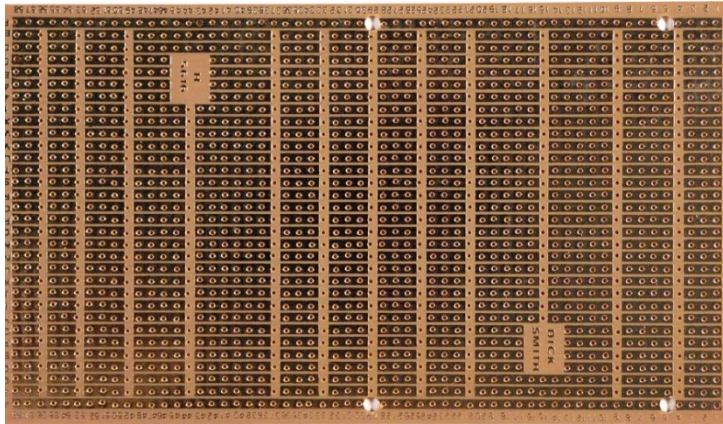
Wire-Wrap Socket Assortment...



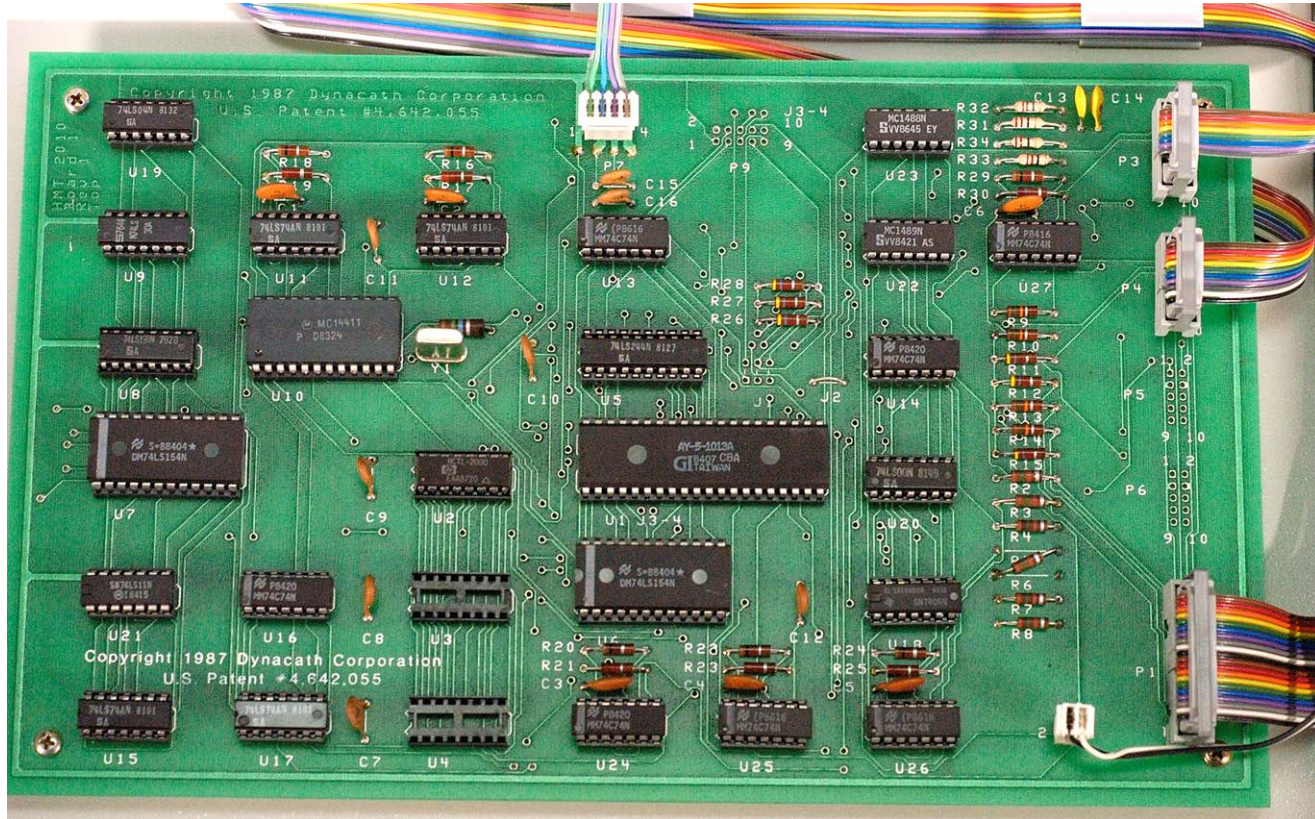
Wire-Wrap Socket ID Labels...



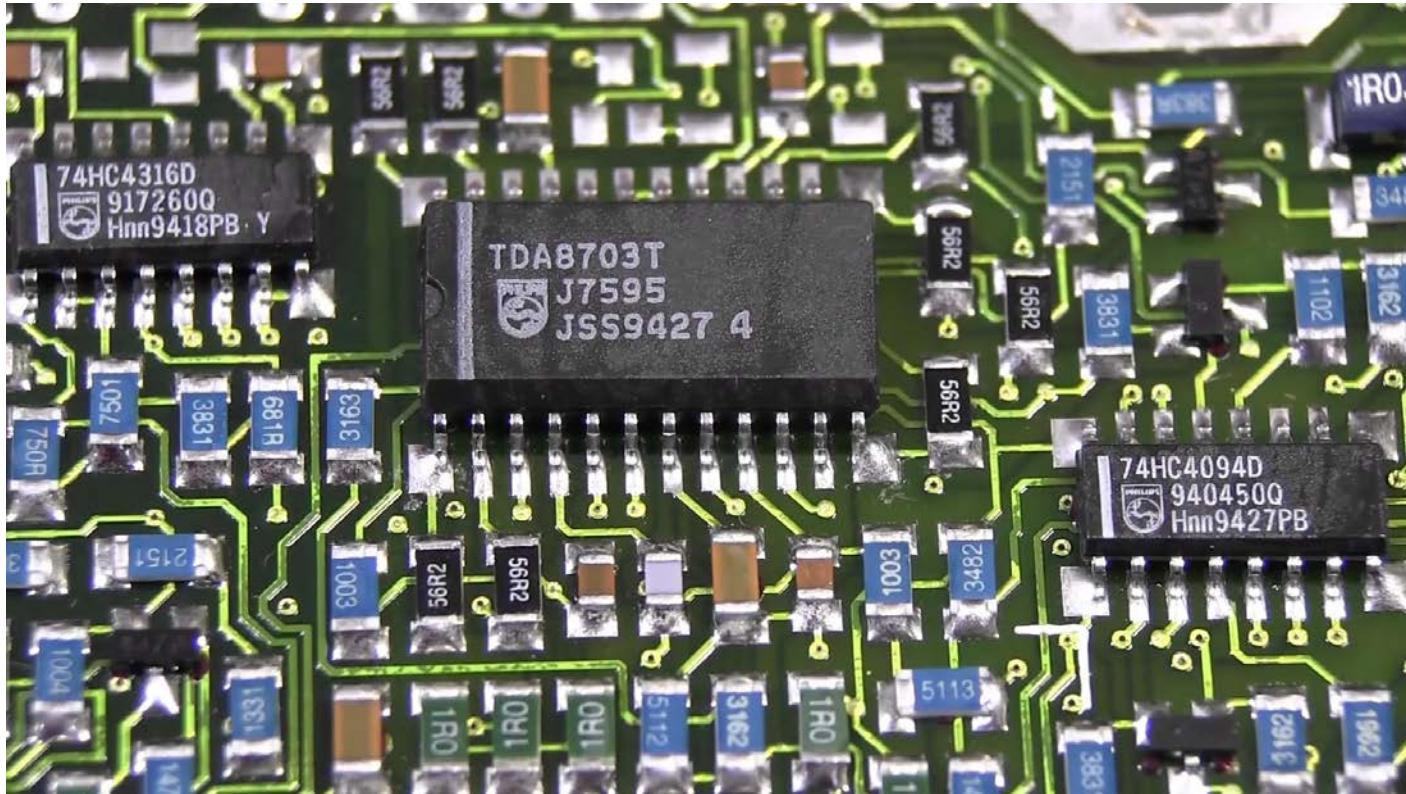
Solder Boards & Sockets...



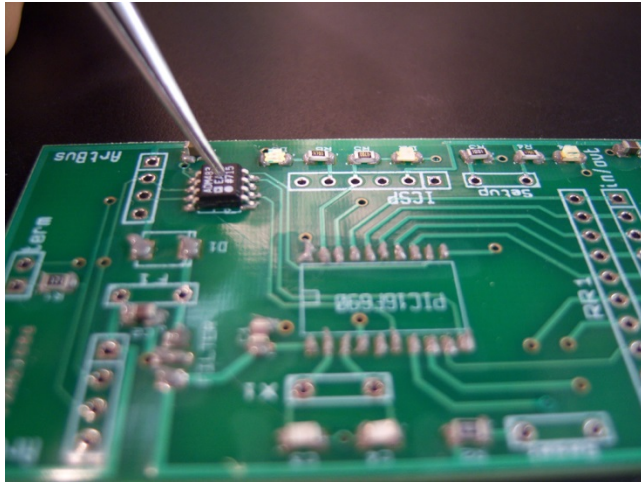
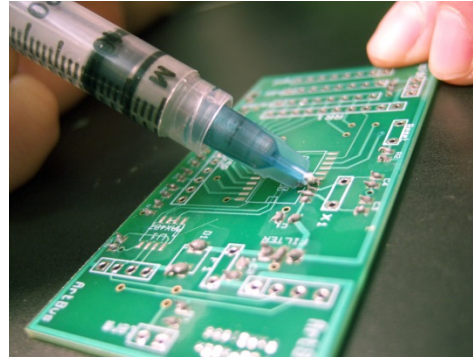
Circuit Board, 2-Sided, Thru-Board...



Surface Mount, Wave Soldered...



Surface Mount, Flux Pen & Solder Paste...



Apply flux to the solder pads, then a small amount of solder paste. Place each part with a tweezers. Heat or bake at a controlled temperature and duration. (See the website below for more information.)

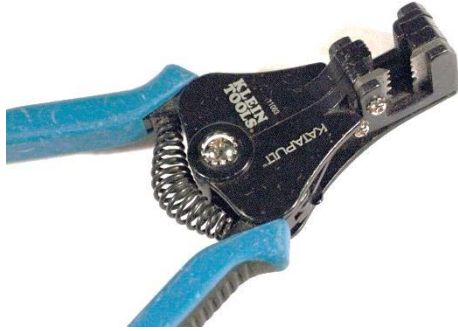
Soldering Tools



Surface Mount, Fine Point & Hot Air



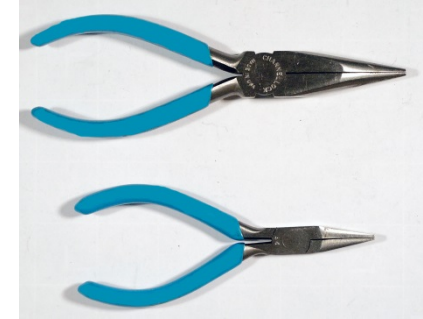
Other Useful Tools



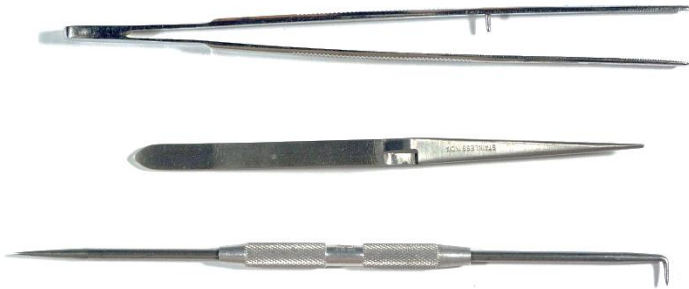
Wire stripper



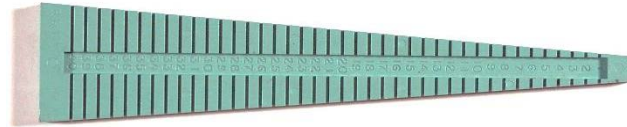
Dupont Connector Crimper



Needle Nose Pliers



Tweezers & Probe

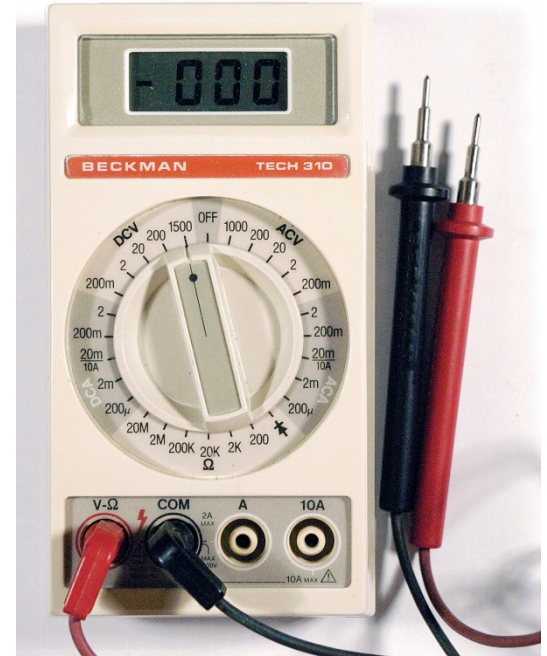


Precision lead bender



Cable-tie gun

Handheld Multimeters

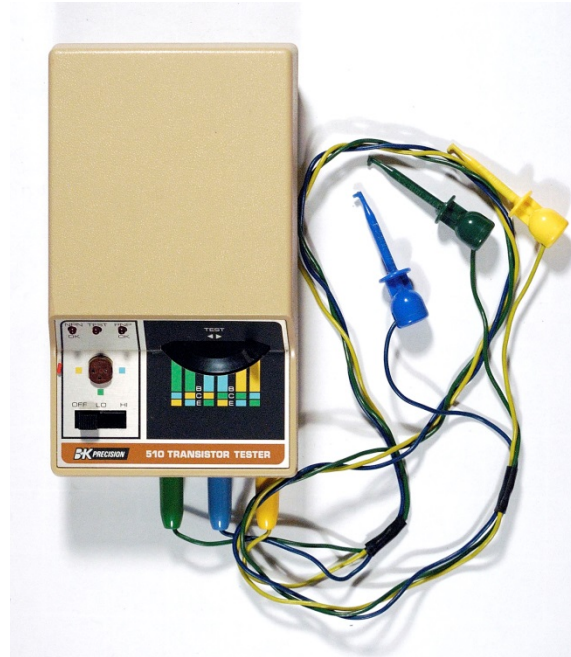


Volt-Ohm-Amperage- Diode-Capacitance

Special Function Meters...



LCR: Impedance-
Capacitance-Resistance

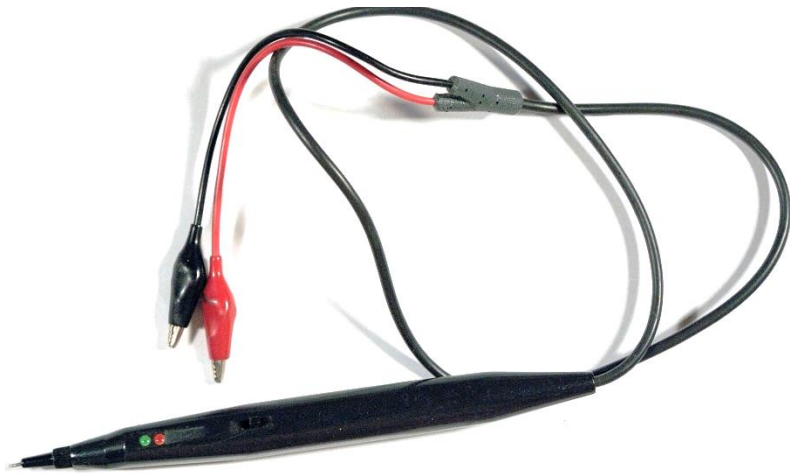


Transistor Tester



Temperature & Probe

Logic Probe & Smart Tweezer...



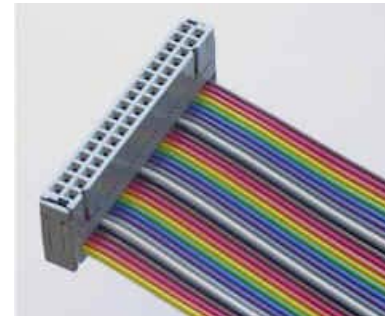
Contact Point HIGH/LOW Tester



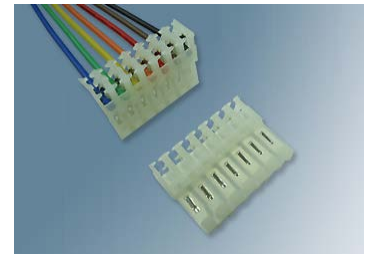
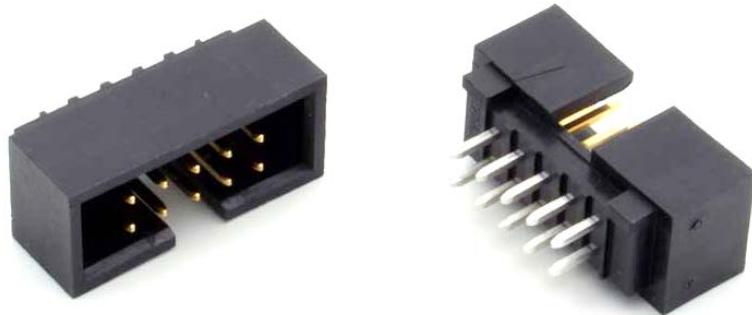
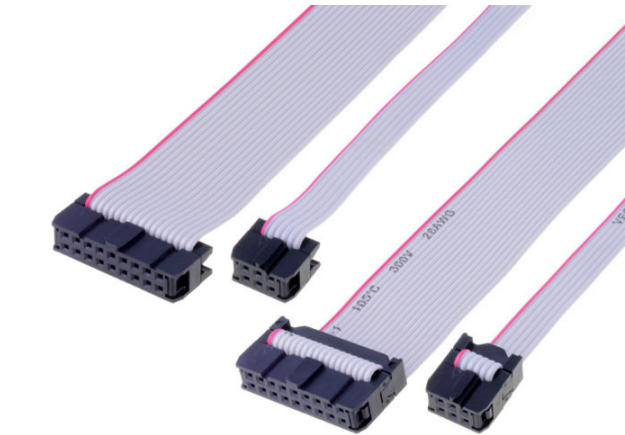
Multimeter for Surface Mount Devices

Connectors & Cables

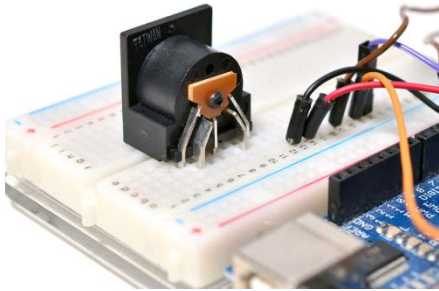
- Connectors
 - DIN & Mini-DIN
 - Sub-D
 - Edge
 - IDC (insulation-displacement contact) and Headers
 - Dupont Connectors
- Cable & wire
 - Breadboard jumpers
 - Microcontroller jumpers
 - Ribbon cable
- Shrink tubing



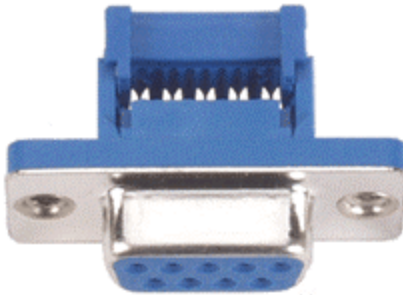
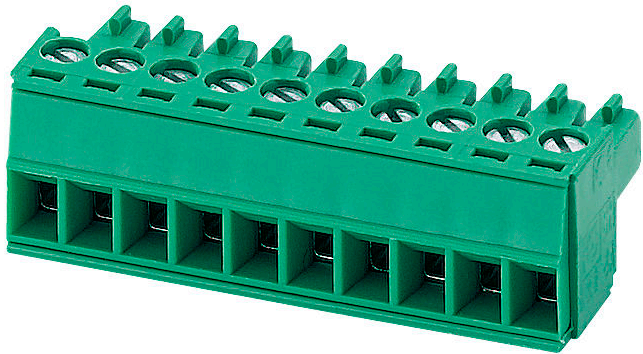
IDC Connectors



DIN & Mini-DIN Connectors



Other Connectors



Various Headers...



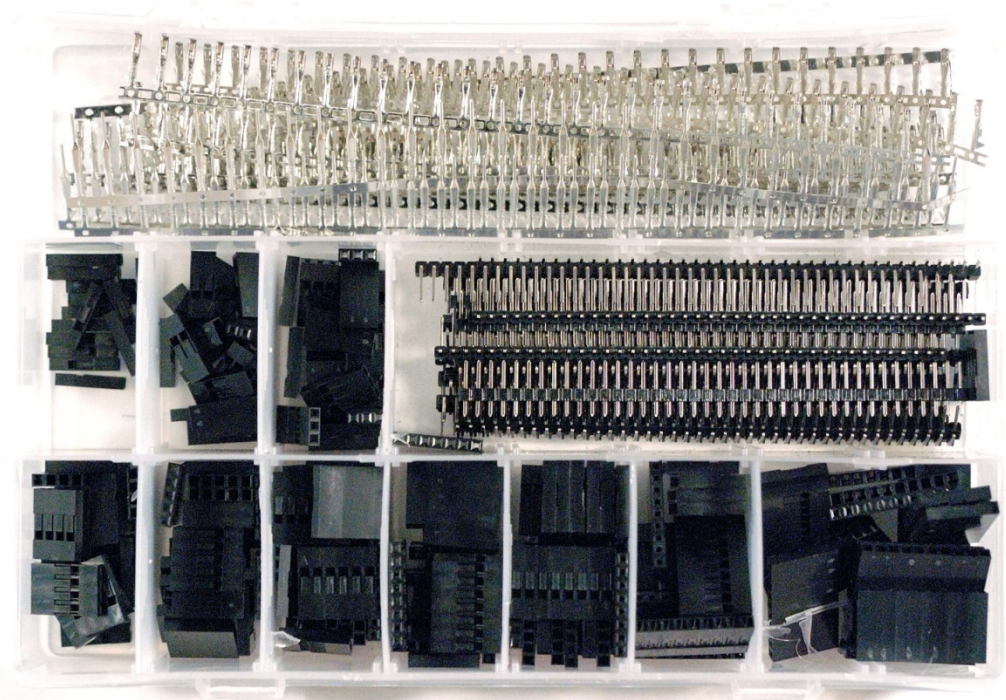
Dupont Connector Kit...

HILTCHI[®]

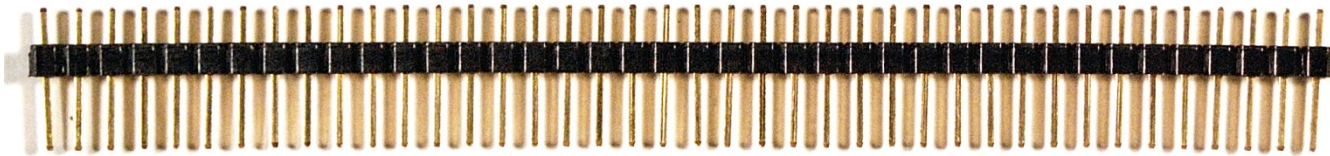
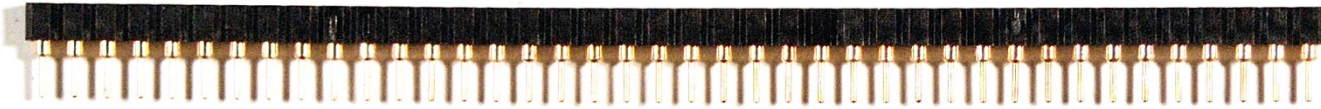
Dupont Pin Connector Kit

Total: 515 Pcs

1. 2.54 mm 1x1P Dupont Connector Housing Female x 20Pcs
2. 2.54 mm 1x2P Dupont Connector Housing Female x 20Pcs
3. 2.54 mm 1x3P Dupont Connector Housing Female x 20Pcs
4. 2.54 mm 1x4P Dupont Connector Housing Female x 20Pcs
5. 2.54 mm 1x5P Dupont Connector Housing Female x 20Pcs
6. 2.54 mm 1x6P Dupont Connector Housing Female x 20Pcs
7. 2.54 mm 1x7P Dupont Connector Housing Female x 20Pcs
8. 2.54 mm 1x8P Dupont Connector Housing Female x 20Pcs
9. 2.54 mm 1x9P Dupont Connector Housing Female x 15Pcs
10. 2.54 mm 1x10P Dupont Connector Housing Female x 20Pcs
11. Dupont Jumper Wire Cable Female Pin Connector x 150Pcs
12. Dupont Jumper Wire Cable Male Pin Connector x 150Pcs
13. 10Pcs x 40 Pin 2.54mm Single Row Male Headers
14. 10Pcs x 40 Pin 2.54mm Single Row Right Angle PCB Pin Headers.

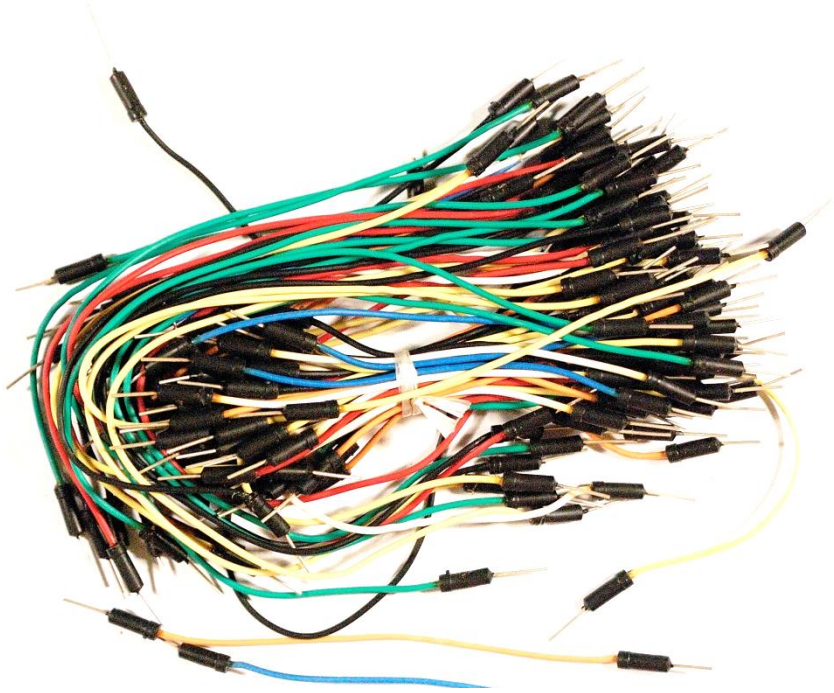


Board Stacking Connectors...



Break-away female and male, single and double row.

Breadboard and Dupont-Style Jumpers...



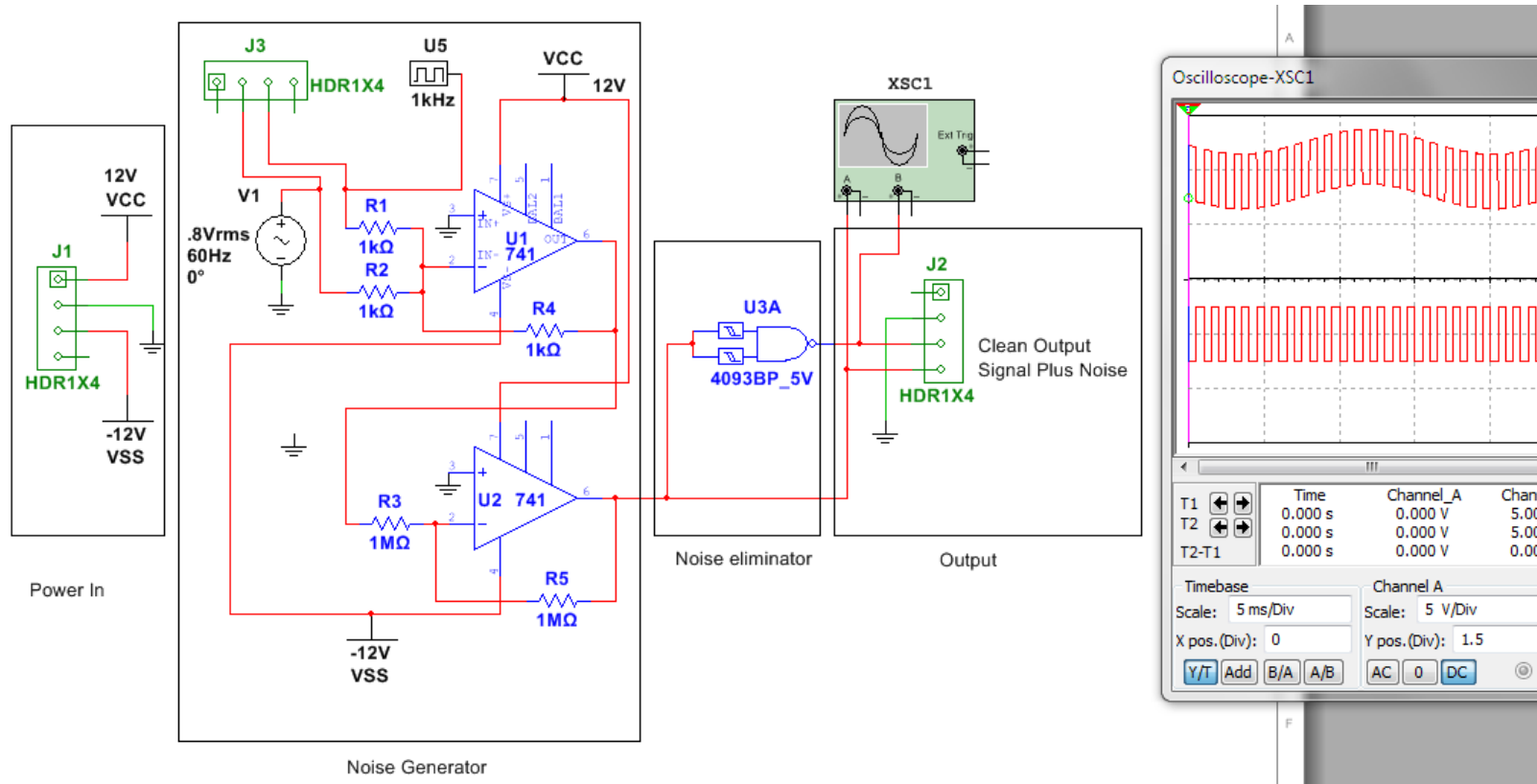
Potentiometer Kit...



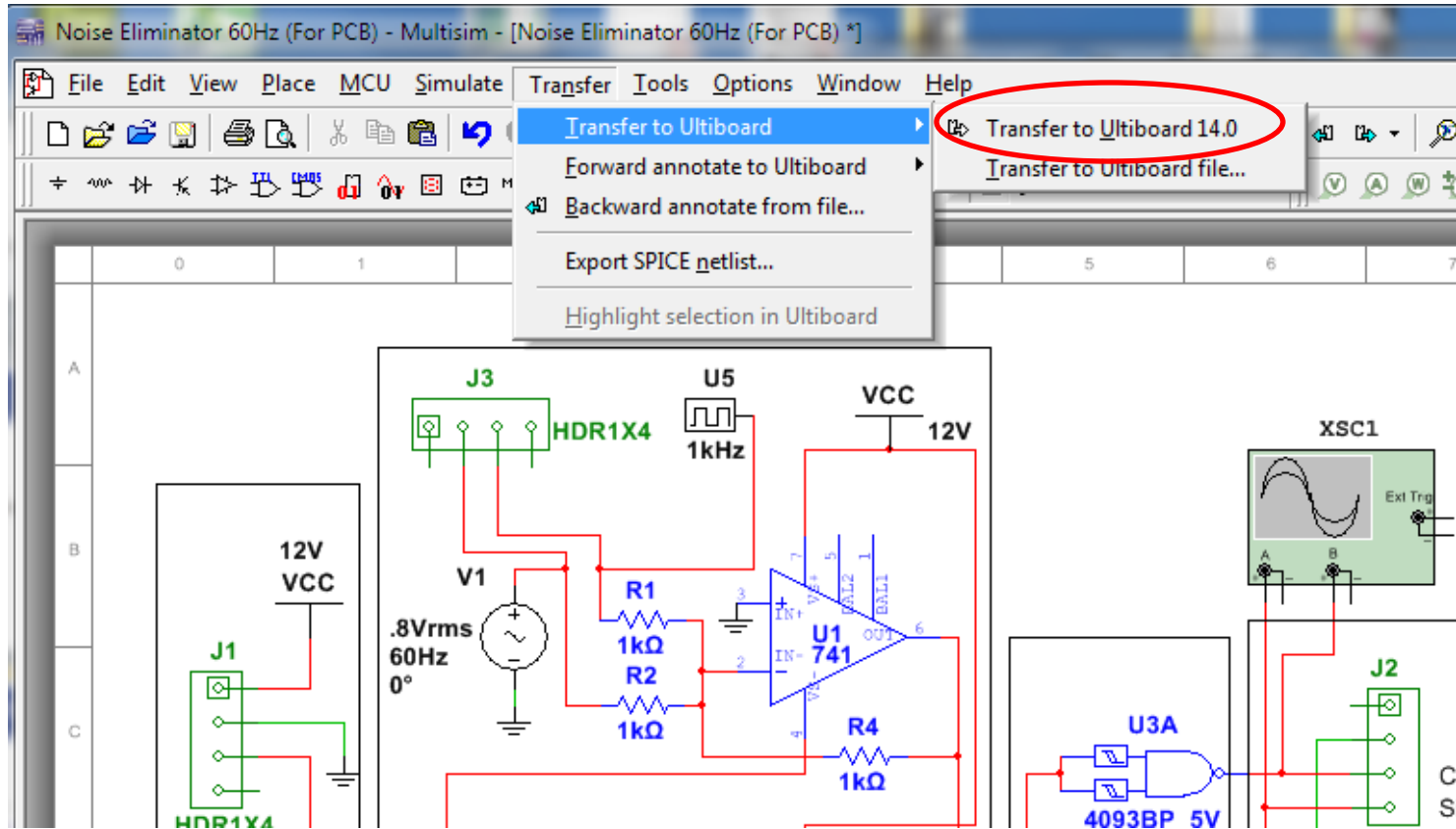
Circuit Boards

- Considerations
 - Overall dimensions
 - Number of layers
 - Production time
 - Quality
 - Cost
- PCB Design
 - NI Ultiboard
 - Many vendors also offer design packages
- Build it yourself
 - Masks and chemical etching
 - Using XY router table
- Vendors

Creating a Board from the “Noise Eliminator” Circuit...



Transfer to Ultiboard...



Netlist is Automatically Created...

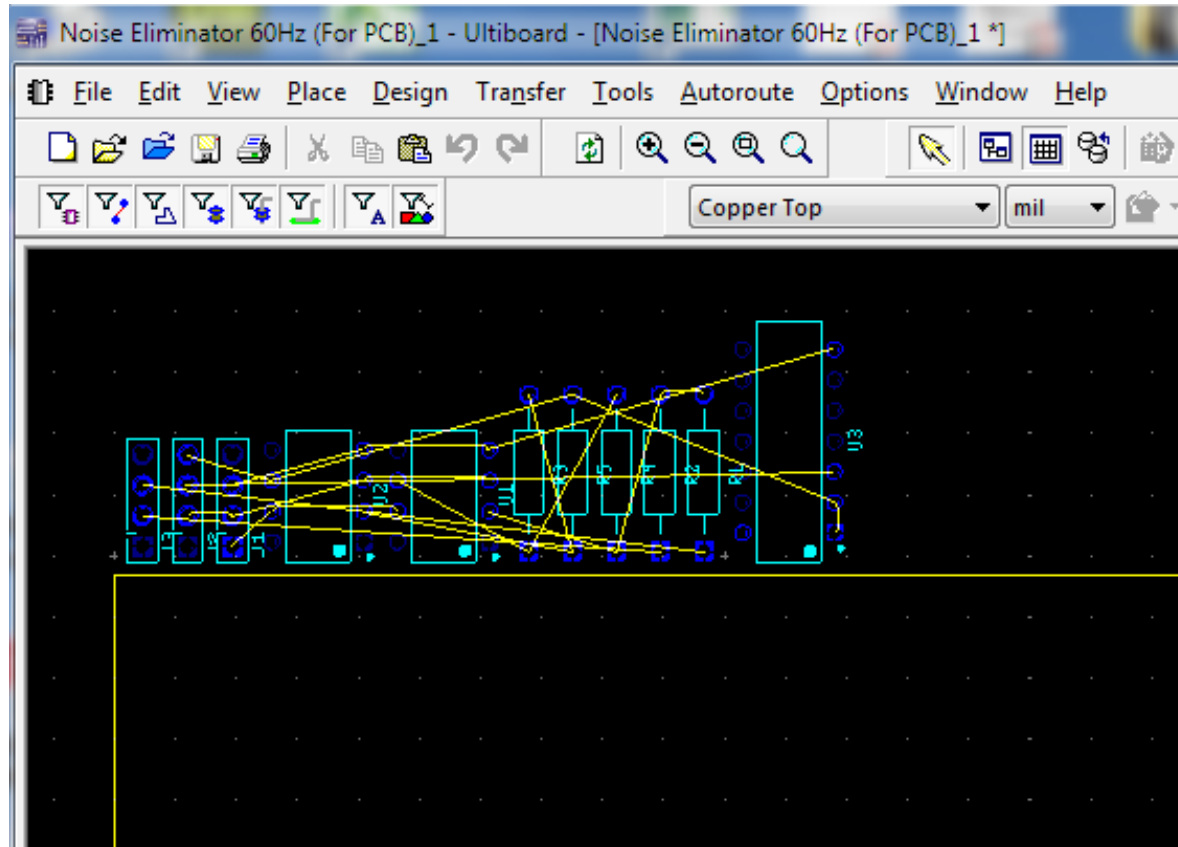
Design Toolbox

- PCB**
 - Copper Top
 - Copper Inner 1
 - Copper Inner 2
 - Copper Bottom
 - Keep-in/keep-out
 - Board Outline
 - Silkscreen Top
 - Silkscreen Bottom
 - 3D-Info Top
 - 3D-Info Bottom
 - Solder Mask Top
 - Solder Mask Bottom
- Board assembly**
 - Paste Mask Top
 - Paste Mask Bottom
 - Glue Mask Top
 - Glue Mask Bottom
- Information**
 - Ratsnest
 - Design Rule Check
 - Comment
- Mechanical**
 - Mechanical 1
 - Mechanical 2

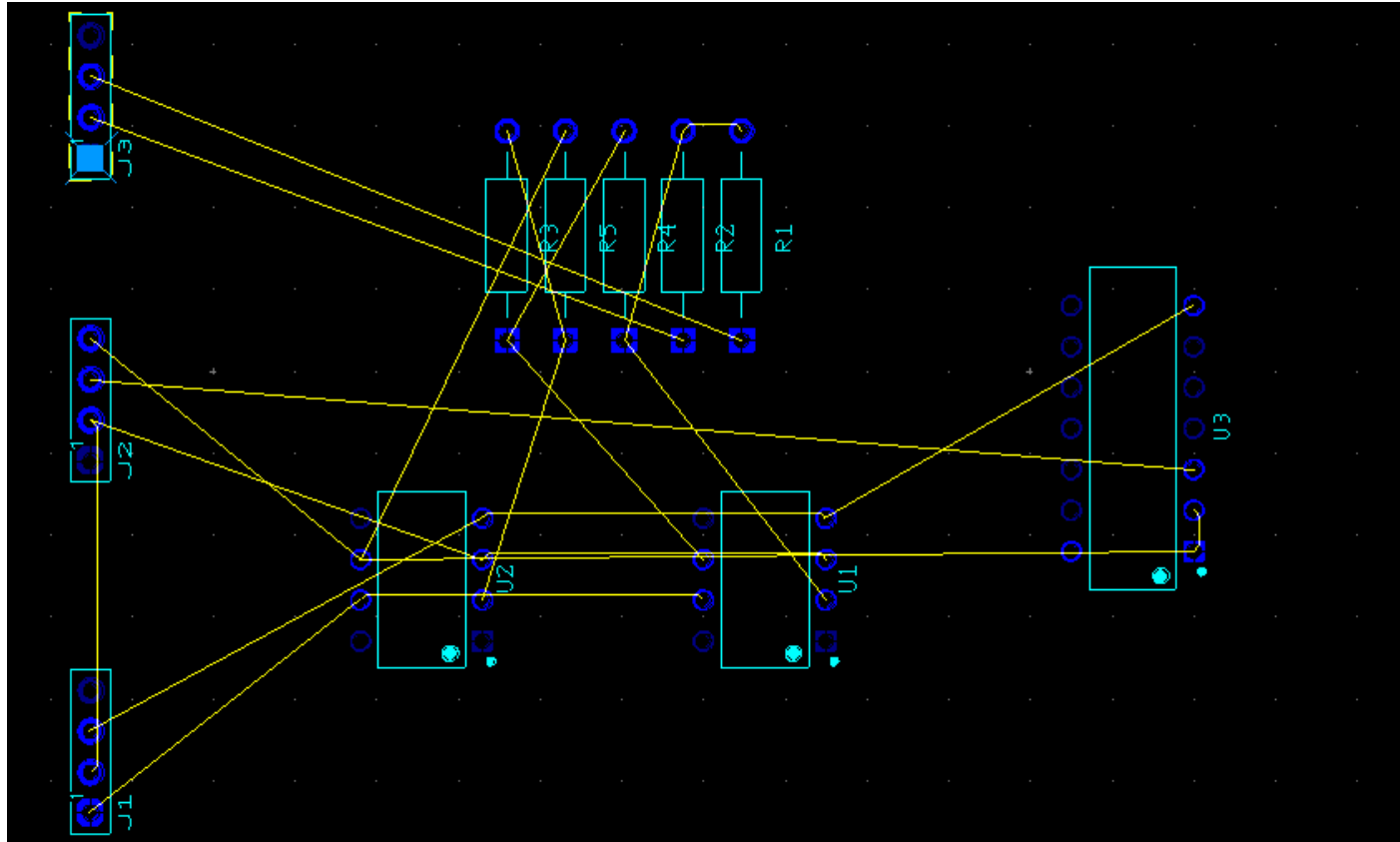
Import Netlist

Item	Action in Layout	Status
Layers Copper Bottom, Copper Top	Add layers Copper Bottom, Copper Top	
Net 0	Add net 0	
Net 0	Add U1 pin 3 to net 0	
Net 0	Add U2 pin 3 to net 0	
Net 0	Add J1 pin 2 to net 0	
Net 0	Add J2 pin 2 to net 0	
Net 4	Add net 4	
Net 4	Add U1 pin 2 to net 4	
Net 4	Add R1 pin 2 to net 4	
Net 4	Add R2 pin 2 to net 4	
Net 4	Add R4 pin 1 to net 4	
Net 6	Add net 6	
Net 6	Add U3 pin 3 to net 6	
Net 6	Add J2 pin 3 to net 6	
Net 14	Add net 14	
Net 14	Add U1 pin 6 to net 14	
Net 14	Add R4 pin 2 to net 14	
Net 14	Add R2 pin 1 to net 14	

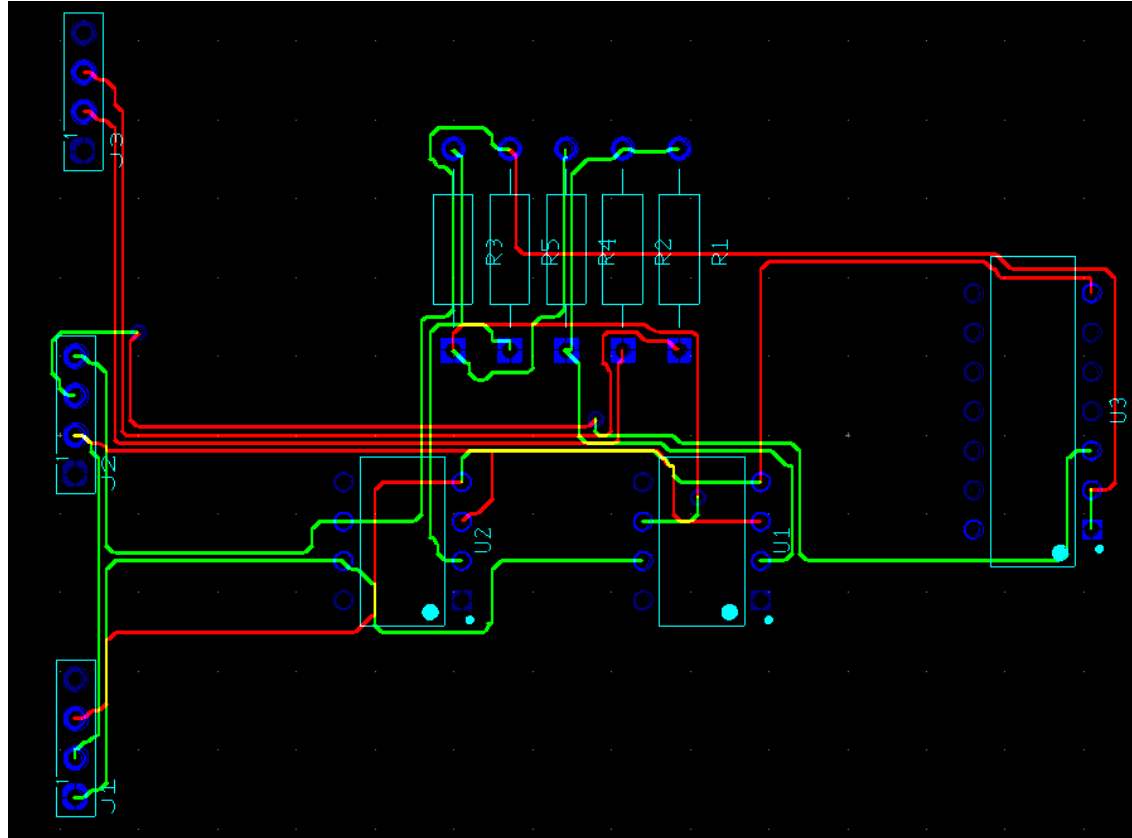
Parts with Footprints are Automatically Imported...



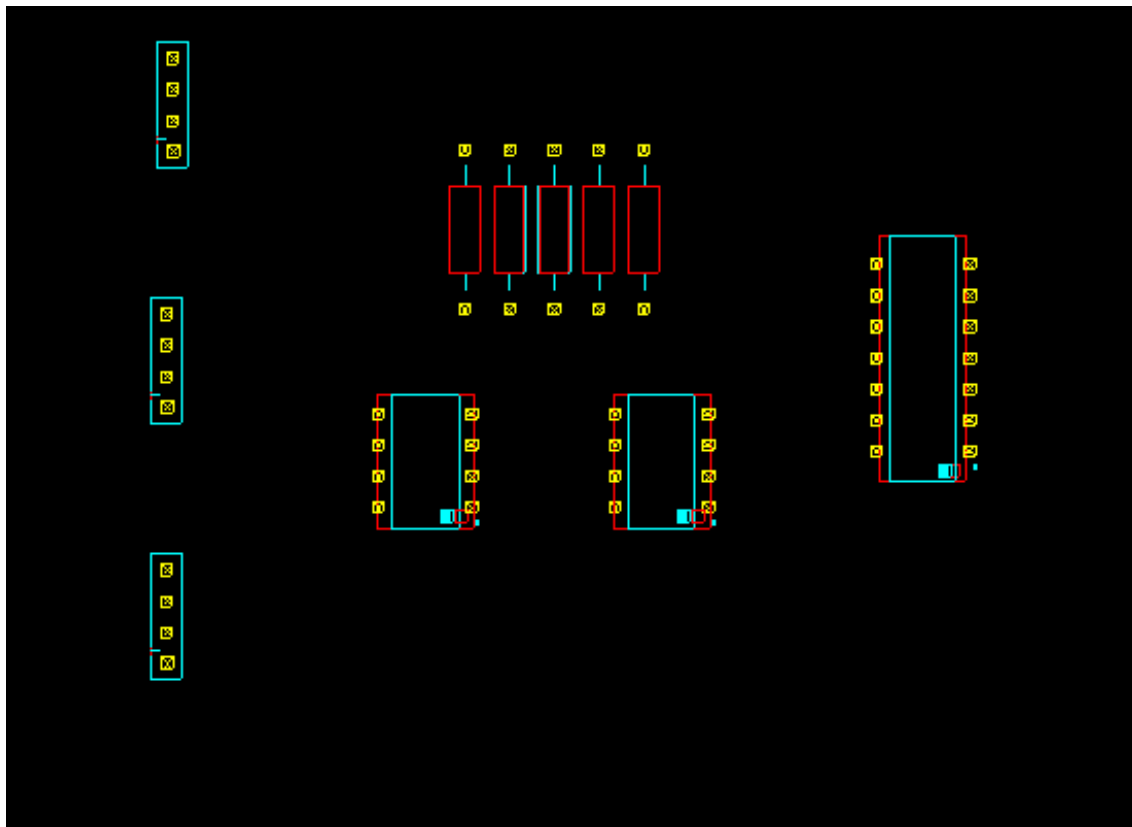
Drag and Place Parts onto the Board...



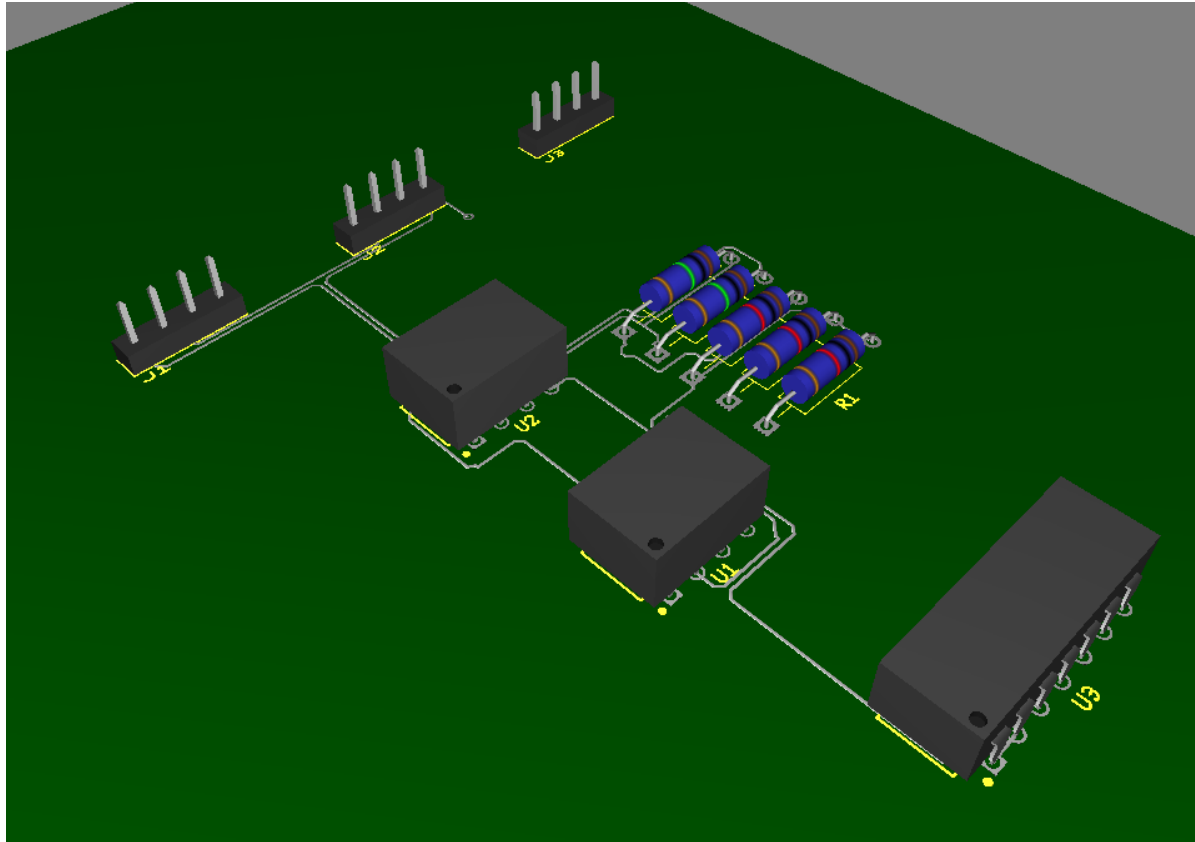
Select Autoroute...



Bird's Eye View...



3D Simulation...



Project Power Supplies

● Batteries

- Disposable vs. rechargeable
- Voltage and current
- Amp hours

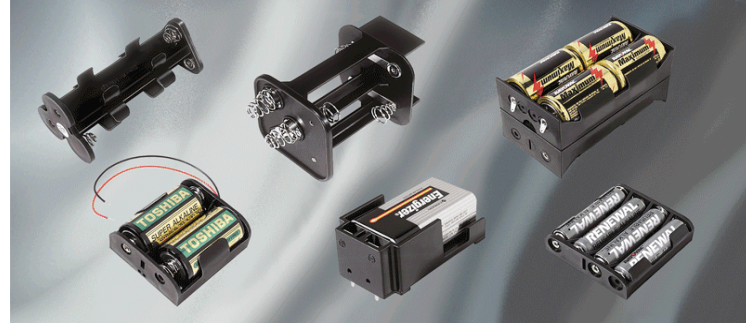


Image courtesy of Battery Holders.com

● AC Power

- Always ground your circuits.
- Use circuit breakers and fuses
- Cover 115 VAC connections.
- Use proper machine tool wire and connectors for voltage/current.



Part Vendors

- Axman Surplus, 1639 University Ave.
 - Highly recommended!
- Online
 - Digi-Key Electronics
 - <http://www.digikey.com/>
 - Adafruit
 - <https://www.adafruit.com/>
 - Sparkfun
 - <https://www.sparkfun.com/>
 - eBay
 - Amazon

Fabrication Vendors

- Gold Phoenix
 - <http://www.goldphoenixpcb.com/>
- Sunstone Circuits
 - <http://www.sunstone.com/>
- Fritzing
 - <http://fab.fritzing.org/fritzing-fab>

Summary

- Approaches to creating a prototype
 - Breadboard, wire-wrap and soldered
- Making circuit boards
 - Design and production
- Multimeters & other test equipment
 - Voltage, resistance, current and capacitance
 - Oscilloscopes and function generators
- Connectors and cables
- Power supplies

Appendix – MDC Parts *Resistors...*



Capacitors...



Diodes, Transistors LEDs...



Digital 7400 Series...



Linear #1...

Linear Integrated Circuits

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LF411CN	Front	23018	
LF412CN	Back	23026	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM1458N	Front	23131	
LM1488N	Back	23157	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM1489N	Front	23181	
LM301N	Back	23392	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM308N	Front	23464	
LM311N	Back	23528	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM317T	Front	23579	
LM324N	Back	23683	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM337T	Front	23819	
LM339N	Back	23851	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM358N	Front	23966	
LM386N-1	Back	24125	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM386N-3	Front	24133	
LM393N	Back	24281	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM555CN	Front	27422	
LM556N	Back	24328	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
NE5532	Front	27385	
TL072CP	Back	33195	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LMC555CN	Front	126797	
MAX232CPE	Back	24811	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
LM723CN	Front	24467	
LM741CN	Back	24539	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
TL074CN	Front	33216	
TL082CP	Back	33241	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
TL084CN	Front	33267	
ULN2003A	Back	34278	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
ULN2803A	Front	34315	
7805T	Back	51262	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
7808T	Front	51300	
7812T	Back	51334	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
7815T	Front	51377	
78L05	Back	51182	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
78L12	Front	51203	
7905T	Back	51457	

JAMECO® 1-800-831-4242			
Linear Integrated Circuits			
Value	Location	Reorder No.	
7912T	Front	51481	
7915T	Back	51502	

Linear #2...



Headers...



Fasteners...



Heat Shrink Tubing...

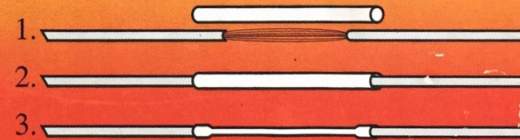
3M Heat Shrink Tubing Kit **FP-301** Multipurpose Flexible Polyolefin

IMPORTANT NOTICE: Before using this product, you must evaluate it and determine if it is suitable for your intended application. You assume all risks and liability associated with such use.

Warranty; Limited Remedy; Limited Liability.

This product will be free from defects in material and manufacture at the time of purchase. **3M MAKES NO OTHER WARRANTIES INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.** If this product is defective within the warranty period stated above, your exclusive remedy shall be, at 3M's option, to replace or repair the 3M product or refund the purchase price of the 3M product. **Except where prohibited by law, 3M will not be liable for any indirect, special, incidental or consequential loss or damage arising from this 3M product, regardless of the legal theory asserted.**

1. Cut tubing to length (allow 10% for shrinkage in length).
2. Position tubing over area to be insulated.
3. Working from the center outward, apply heat evenly around the circumference until it has recovered tightly.



**3M Electrical
Markets Division**
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Austin, TX 78726-9000
www.3m.com/electrical
Made in U.S.A.
34-7058-2326-7