



Prototyping: Considerations From the Bread Board for the Final Product

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Prepared For:

DFW Sensor & IoT Technology Meetup

Outline

- About Me
- If I Could Only Tell You 2 Things...
- Breadboarding – The First Step
- Circuit Design/Schematic Capture
- PCB Design
- Final Assembly
- Free Tools
- Design For Manufacture



About Me

Education

- Ph.D. Applied Mathematics, RPI - 2013
- M.S. Mechanical Engineering, UB - 2010
- B.T. Electrical Eng. Tech., Buff. State - 2008
- B.T. Mechanical Eng. Tech., Buff. State - 2007
- A.A.S. Drafting Tech., ECC – 2005

Professional

- UTD ARC - Principal Investigator
- Applied Research Associates –
- Group Leader
- Cameron Compression – Designer
- ATSI – Piping Engineer



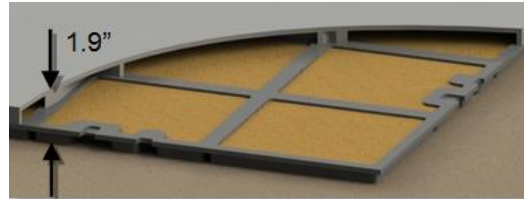
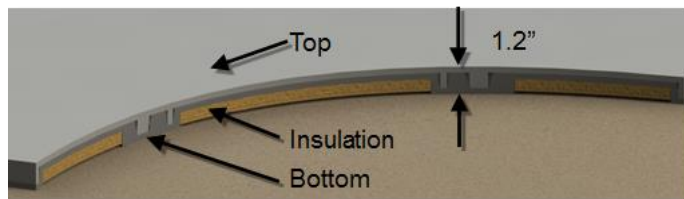
These are a Few of My Recent Projects



Multi-Functional Transcranial Electrical Stimulation System



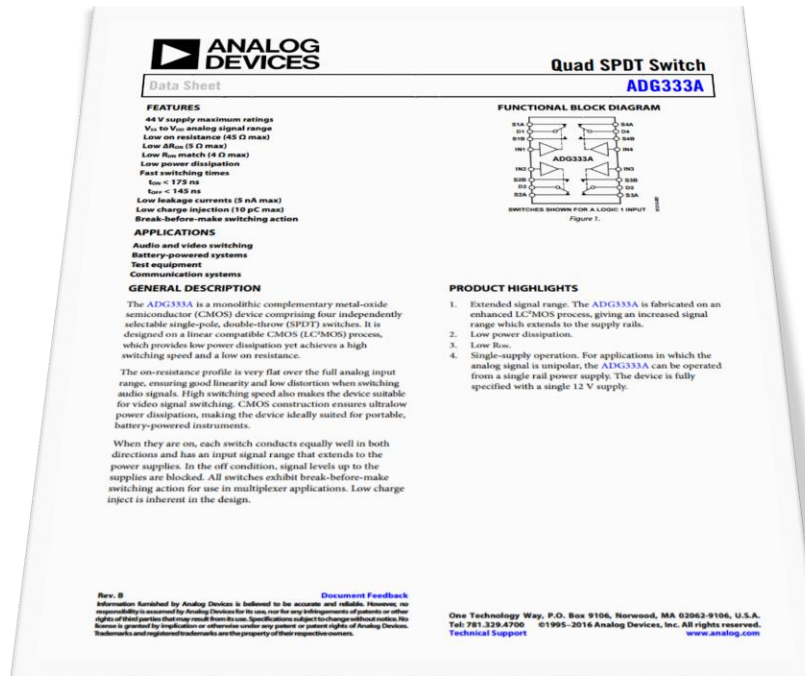
Energy Savings Control Unit



Energy Efficient Expeditionary Flooring




If I Could Only Tell you Two Things... (1)



If I Could Only Tell you Two Things... (2)




LT1637
1.1MHz, 0.4V/ μ s
Over-The-Top Micropower, Rail-To-Rail Input and Output Op Amp

FEATURES

- Operates with Inputs Above V*
- Rail-to-Rail Input and Output
- Micropower: 250 μ A Supply Current Max
- Operating Temperature Range: -55 $^{\circ}$ C to 125 $^{\circ}$ C
- Gain-Bandwidth Product: 1.1MHz
- Slew Rate: 0.4V/ μ s
- Low Input Offset Voltage: 350 μ V Max
- Single Supply Input Range: -0.4V to 44V
- High Output Current: 25mA Min
- Specified on 3V, 5V and \pm 15V Supplies
- Output Shutdown
- Output Drives 4700pF with Output Compensation
- Reverse Battery Protection to 25V
- High Voltage Gain: 800V/mV
- High CMRR: 110dB
- Available in 8-Lead MSOP, PDIP and SO Packages; and a Tiny (3mm \times 3mm \times 0.8mm) DFN Package

APPLICATIONS

- Battery or Solar Powered Systems:
 - Portable Instrumentation
 - Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- MUX Amplifiers
- 4mA to 25mA Transmitters

DESCRIPTION

The LT $^{\circ}$ 1637 is a rugged op amp that operates on all single and split supplies with a total voltage of 2.7V to 44V. The LT1637 has a gain-bandwidth product of 1.1MHz while drawing less than 250 μ A of quiescent current. The LT1637 can be shut down, making the output high impedance and reducing the quiescent current to only 3 μ A. The LT1637 is reverse supply protected; it draws virtually no current for reverse supply up to 25V. The input range of the LT1637 includes both supplies and the output swings to both supplies. Unlike most micropower op amps, the LT1637 can drive heavy loads; its rail-to-rail output drives 25mA. The LT1637 is unity-gain stable into all capacitive loads up to 4700pF when optional 0.22 μ F and 150 Ω compensation is used.

The LT1637 has a unique input stage that operates and remains high impedance when above the positive supply. The inputs take 44V both differential and common mode, even when operating on a 3V supply. Built-in resistors protect the inputs for faults below the negative supply up to 22V. There is no phase reversal of the output for inputs 5V below V_{EE} or 44V above V_{EE}, independent of V_{CC}.

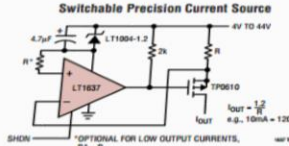
The LT1637 op amp is available in the 8-pin MSOP, PDIP and SO packages. For space limited applications, the LT1637 is available in a 3mm \times 3mm \times 0.8mm dual fine pitch leadless package (DFN).

*V_{CC}, LT, LTC and LTM are registered trademarks of Linear Technology Corporation. Over-The-Top is a registered trademark of Linear Technology Corporation. All other trademarks are the property of their respective owners.

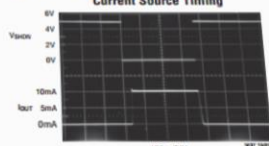
TYPICAL APPLICATION


Over-The-Top $^{\circ}$ Current Source with Shutdown

Switchable Precision Current Source

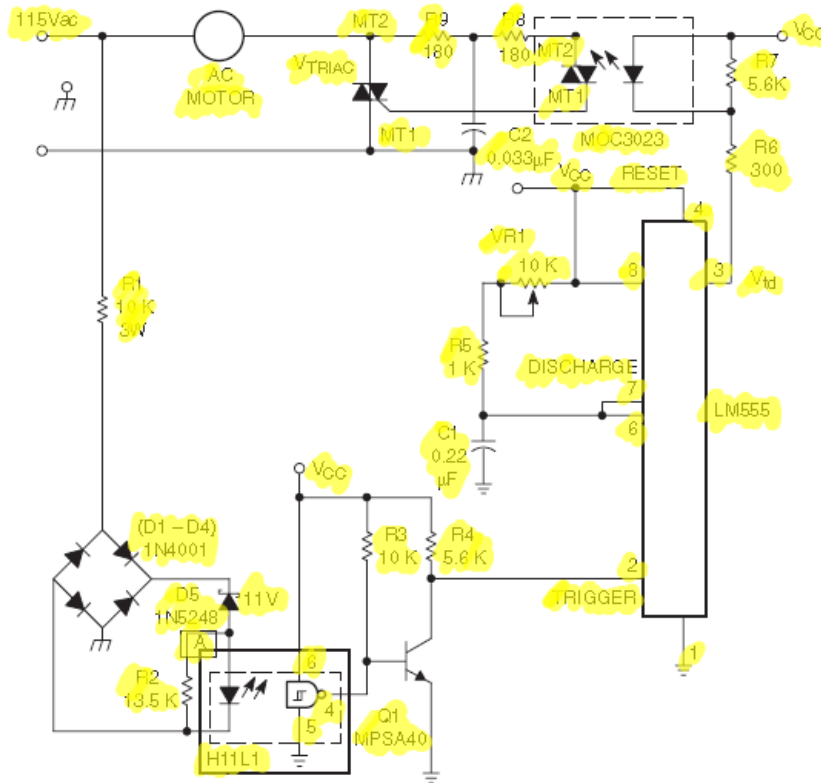


Current Source Timing



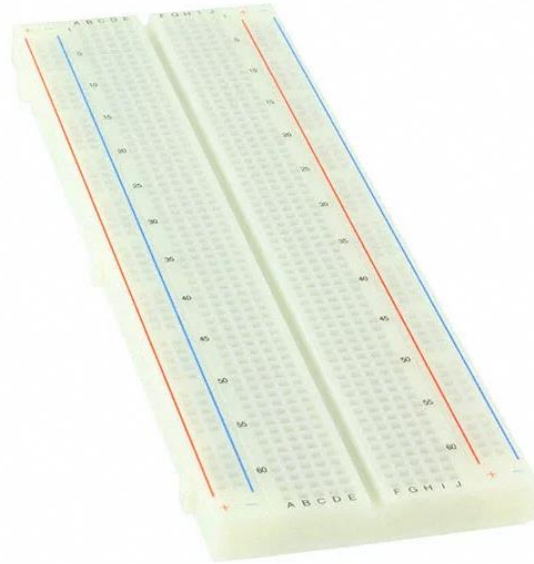

1

If I Could Only Tell you Two Things... (2)



You Will Check. The Only Question is: Do You Check Before or After Something Breaks?

Breadboarding



Always Use an ESD Wrist Strap



Digikey PN

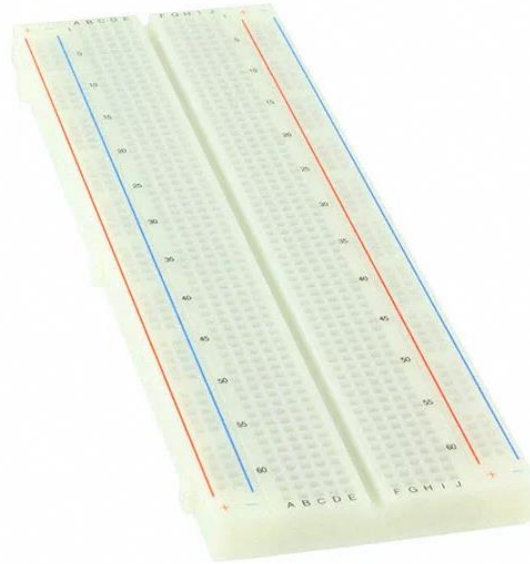
16-1087-ND

You will not always see a spark if an ESD event occurs



Knowing these Breadboard Specs Will Help You Pick the Right Parts

- 100 mil pitch
- Center is 300 mil pitch
- 1.5 A capacity
- Look for parts with lead dia. < 40 mil, length ≥ 138 mil (3.5mm)



Digikey PN

BKGS-830-ND



Use Wire to Board Terminal Blocks If Connecting to Breadboard





Item	Digikey PN
15A 12-30 AWG	277-5911-ND
10A 14-30 AWG (low profile)	277-6270-ND

Rising Edge Cage Clamp



Look for Parts Available in Both DIP and SMT

Compare Parts	Image	Digi-Key Part Number	Manufacturer Part Number	Manufacturer	Description	Quantity Available	Unit Price USD	Minimum Quantity	Packaging	Package / Case	Supplier Device Package
<input type="checkbox"/>		ADG436BRZ-ND	ADG436BRZ	Analog Devices Inc.	IC SWITCH DUAL SPDT 16SOIC	890 - Immediate	6.90000	1	Tube Alternate Packaging	16-SOIC (0.154", 3.90mm Width)	16-SOIC
<input type="checkbox"/>		ADG436BNZ-ND	ADG436BNZ	Analog Devices Inc.	IC SWITCH DUAL SPDT 16DIP	133 - Immediate 2,500 - Factory Stock	7.47000	1	Tube	16-DIP (0.300", 7.62mm)	16-PDIP

Common SMT Packages

SOIC

SWD

QFN

TSSOP

1206

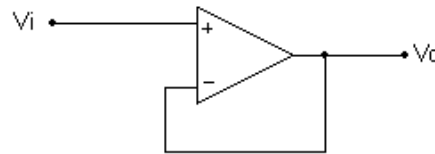
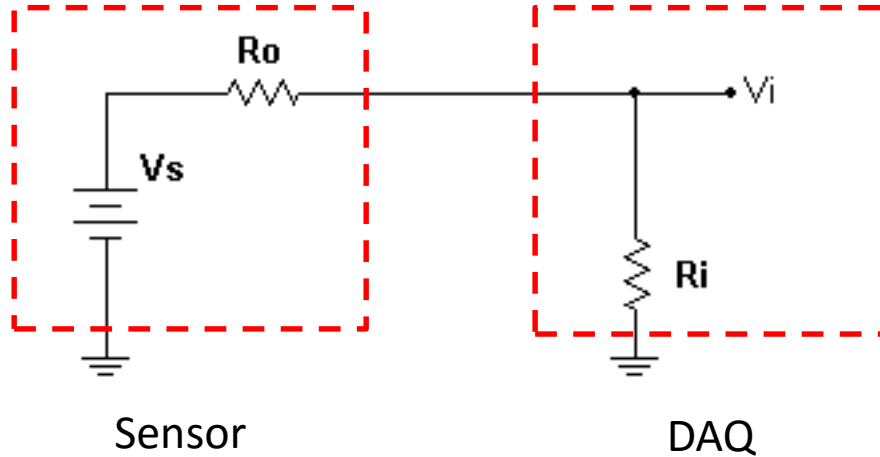
Double Check Your Packaging and Footprints

DIP: Dual In-Line Plastic
SMT: Surface Mount Technology

Avoid Plastic Ball Gated Array (PBGA)



Watch out for Low Input Impedances; Avoid Sensors That Output Voltage

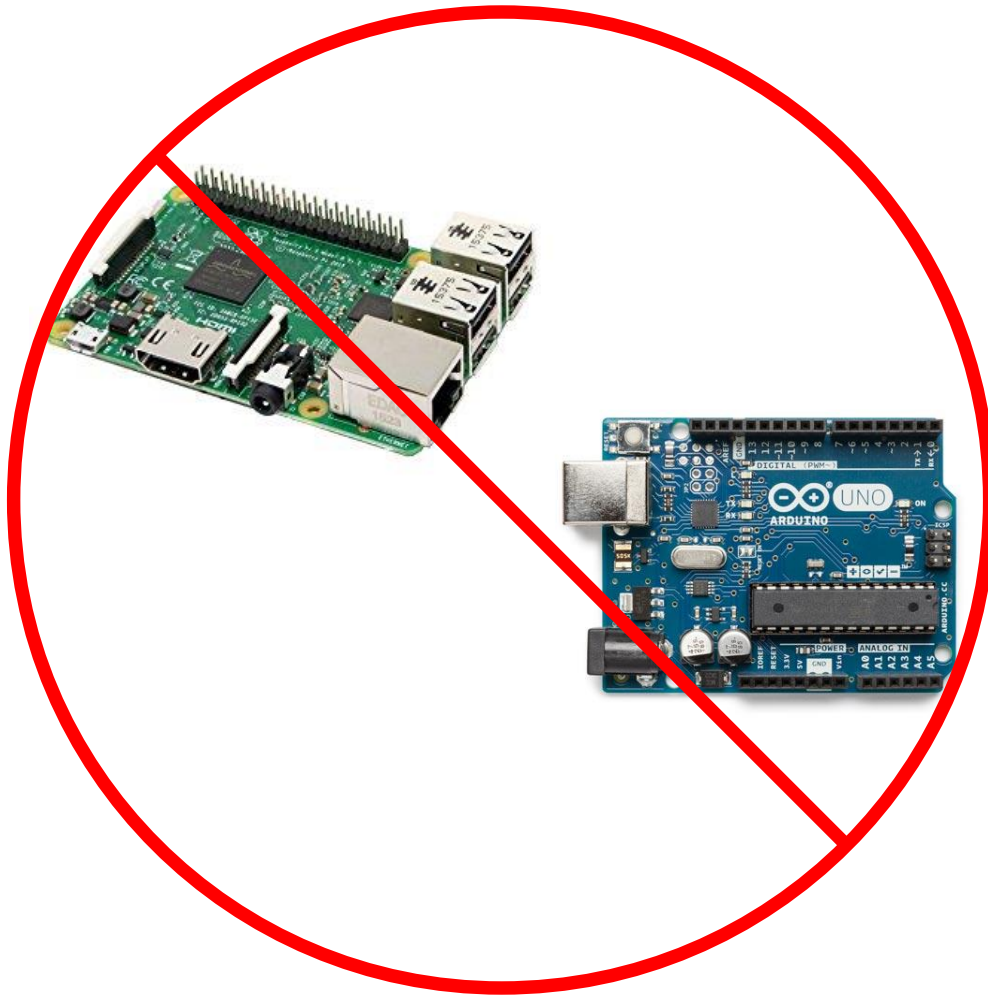


Voltage Follower

**Voltage Follower is one of My Favorite
Circuits; Output Z:Input Z = 1:100**



Avoid Raspberry Pi or Arduino if Trying to Bring a Product to Market



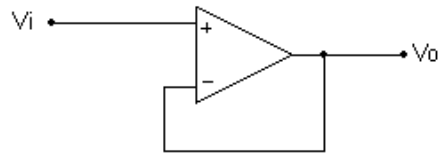
Not Available at MFG Quantities. You Will Have to Port

General Breadboarding Guidelines

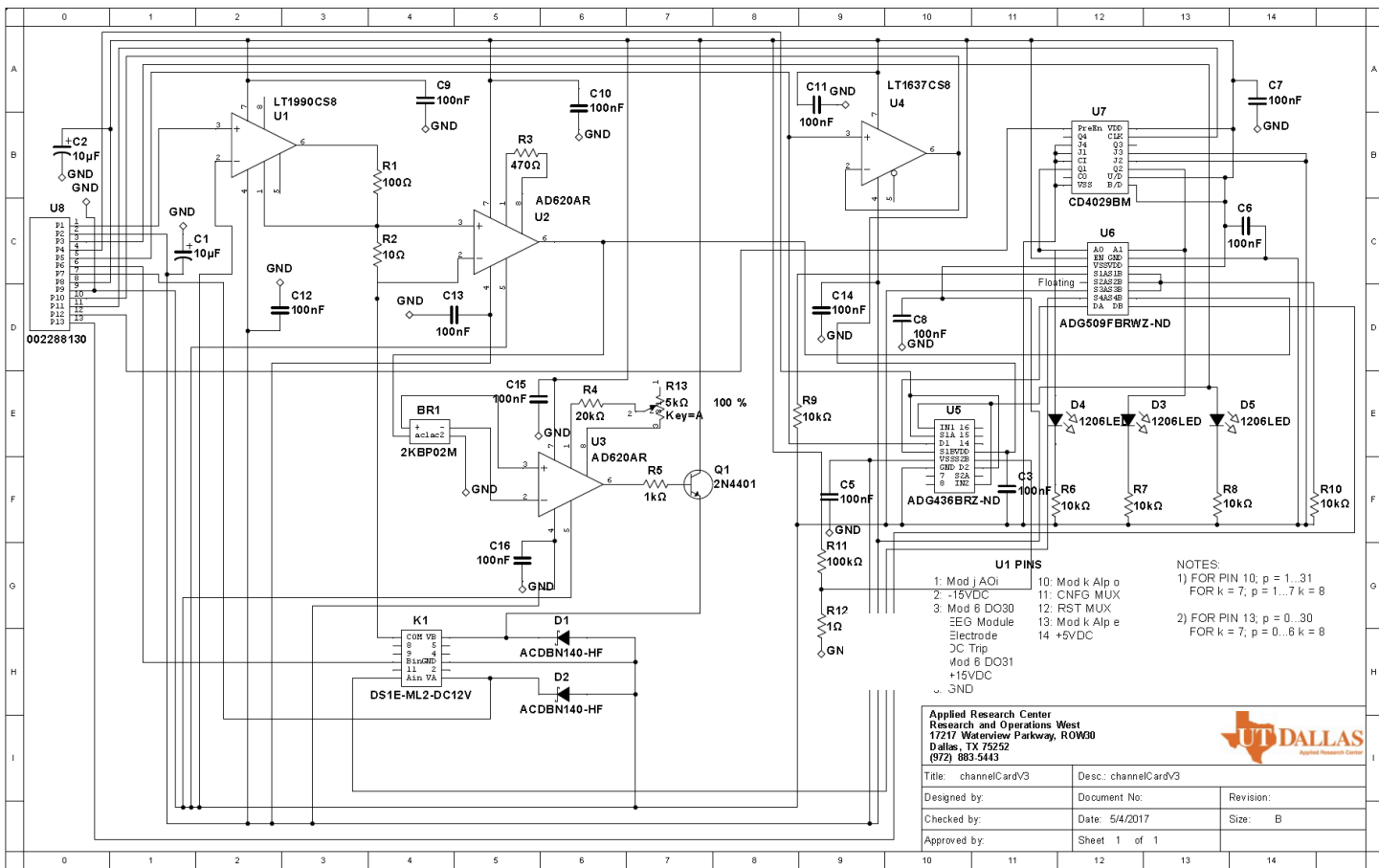
- Avoid Touching Breadboard/Prototypes When Power is On (Even if it is low voltage)
- Set up your measurements first, then power on
- Switch off and unplug
- Order more parts than you need



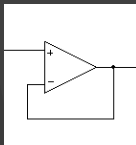
Circuit Design/Schematic Capture



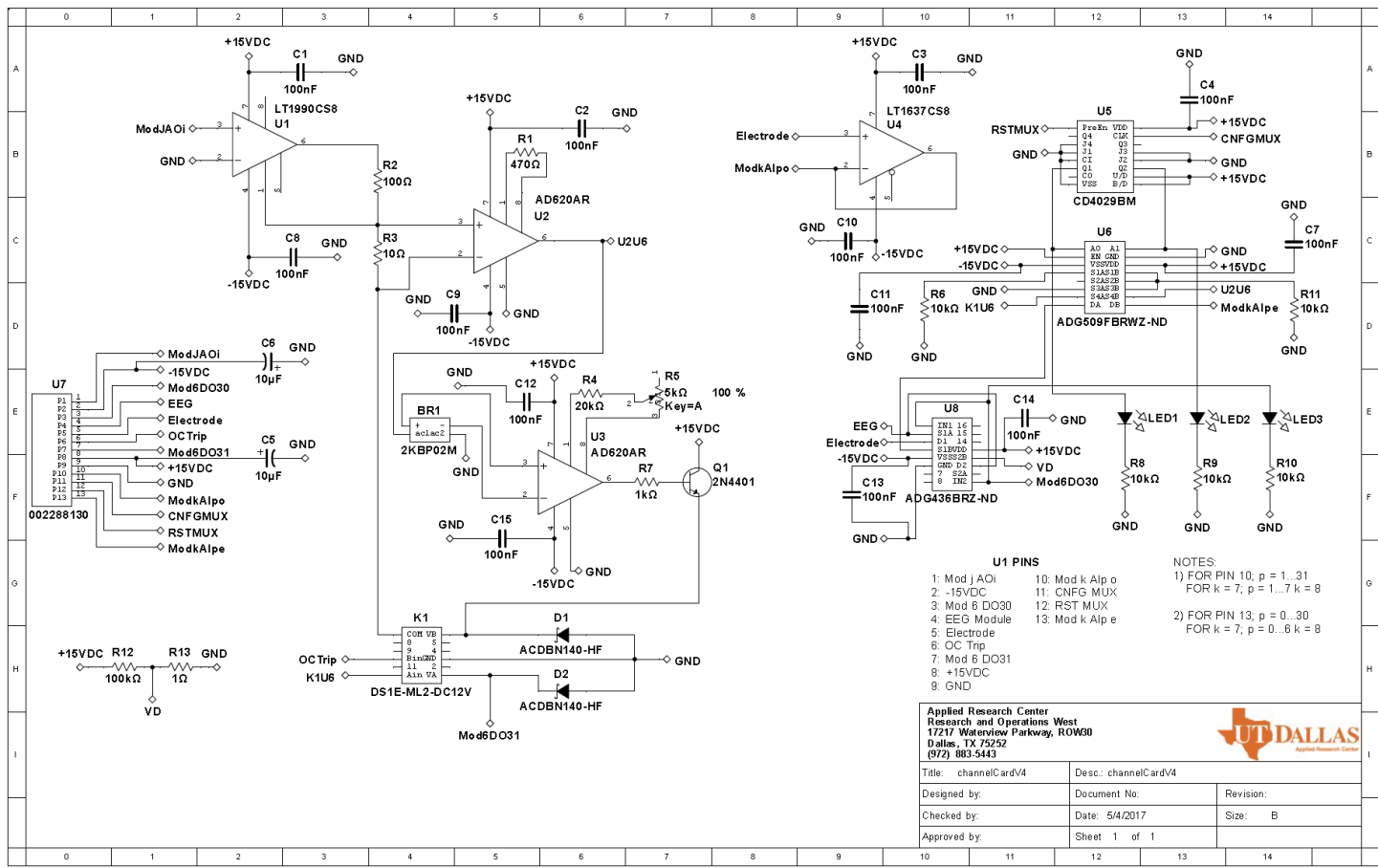
Use Named Nets Instead of Wires on Schematics



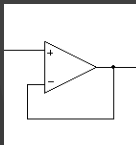
Before



Use Named Nets Instead of Wires on Schematics

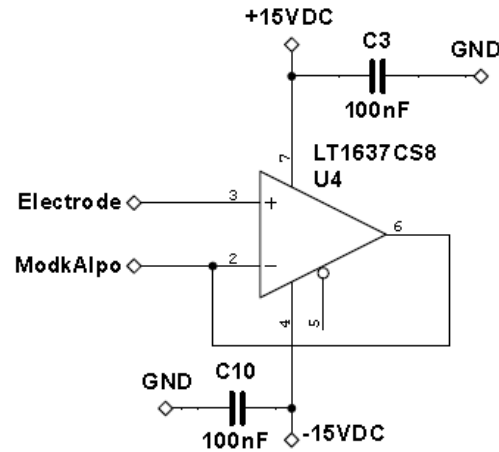


After



Bypass Caps Prevent Damage, and Ensure Proper IC Operation

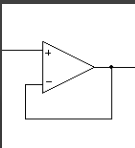
- Every IC gets one
- Dual voltage IC's get two



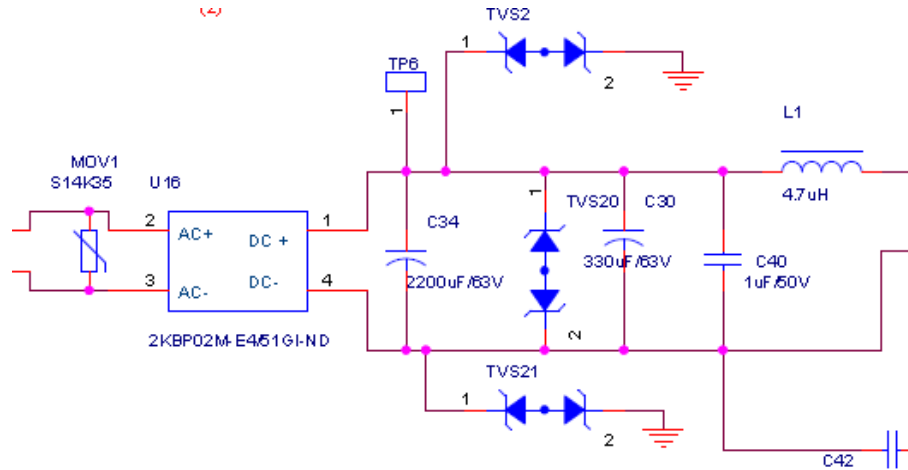
Item	Digikey PN
10 uF Tantalum Cap	PN 399-5152-1-ND
0.1 uF Ceramic Cap	399-1249-1-ND



Good Practice in Prototyping Too



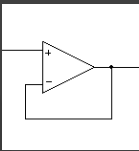
Use TVS Diodes and Chokes



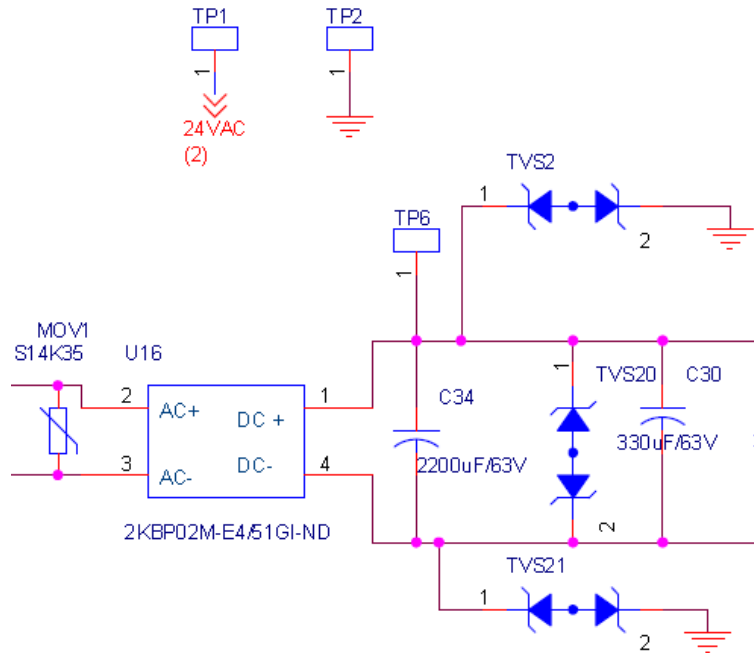
Item	Digikey PN
TVS Diode	296-41842-1-ND
Choke	PM3700-70-RCCT-ND



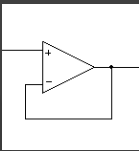
Good Practice in Prototyping Too



You can Never Have Too Many Test Points



Especially ground points (you want to avoid making large loops with scope cables)



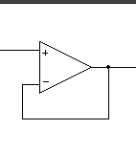
Provide Jumpers to Ground JTAG Lines, Especially Clock, When Using MCUs

Define JTAG

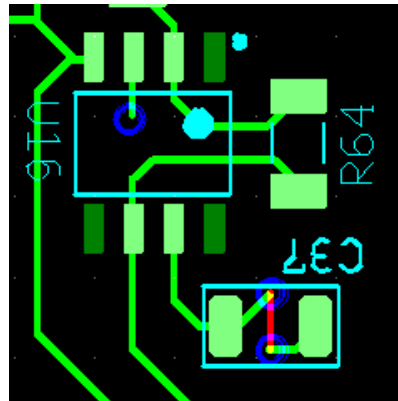


Digikey PN

S3404-ND

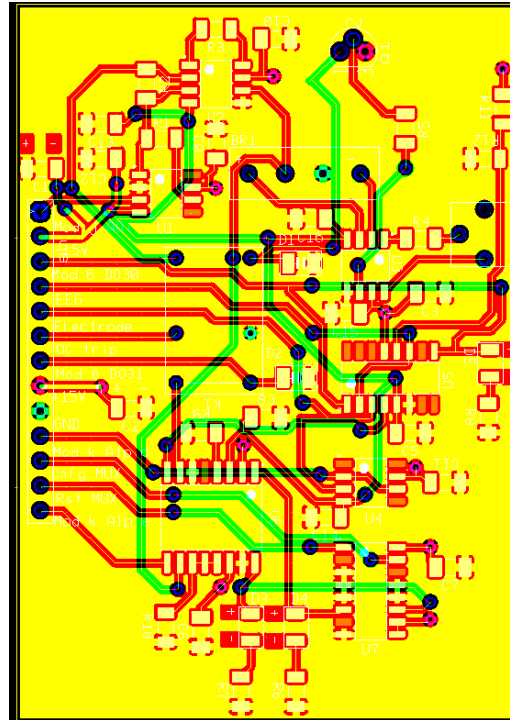


PCB Design

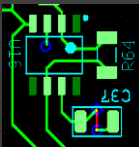


Always Use Copper Planes

- At Least Two – One for Vdd and one for VSS
- Do Not run Copper Planes to Edges

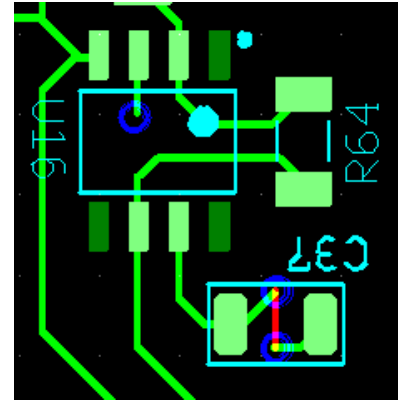
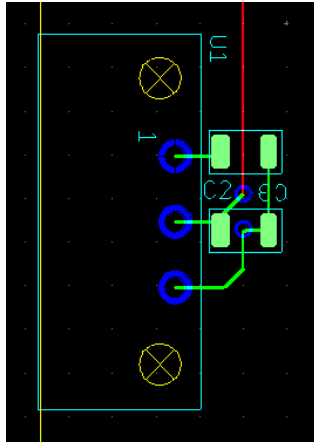


If using a 4 layer board make the two internal layers power and ground plane – No signals on internal layers

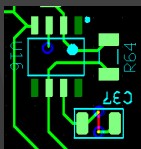


By-Pass Caps Should be as Close to IC's/Power Entry as possible

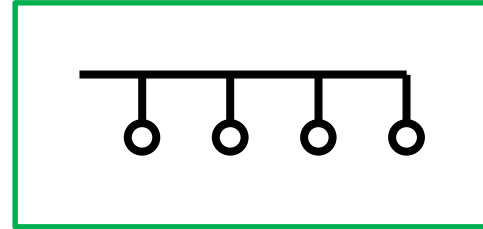
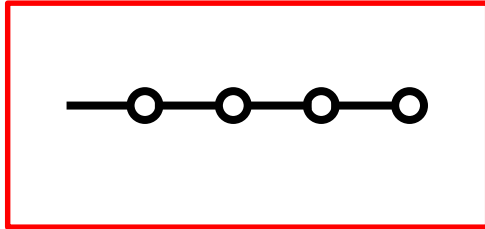
- Every IC gets one
- Dual voltage IC's get two



Item	Digikey PN
10 uF Tantalum Cap	PN 399-5152-1-ND
0.1 uF Ceramic Cap	399-1249-1-ND



Avoid Routing Traces Through Mounting Holes/Pads

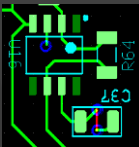


No.

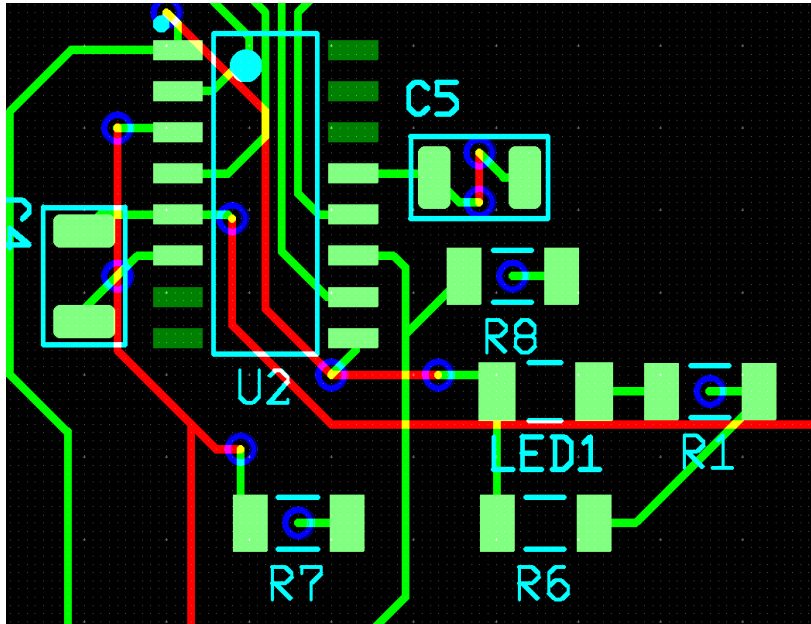
Removing one pad requires two cuts and a bridge. Also, Trace and pads act like a heat sink – harder to solder.

Yes.

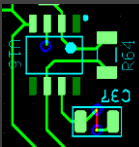
Removing one pad requires one cut.



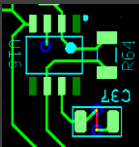
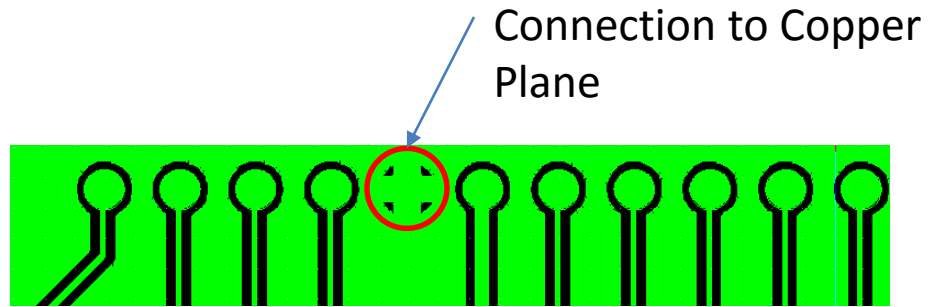
Avoid Placing Vias Under ICs, Esp. For Reflow



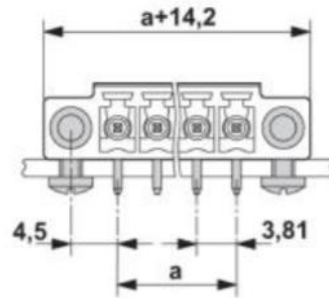
Solder can Bridge and You Will Not Know



Make Sure Copper Plane Connections Have Thermal Relief

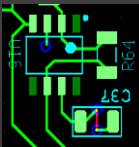


Use Connectors When Connecting Wires to PCB



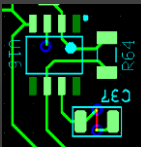
Item	Digikey PN
Male	277-5764-ND
Female	277-5714-ND

Require No Special Tools



These Are Some General PCB Guidelines

- Use double sided board with power and ground planes on top and bottom
- Use Informative Silkscreen Labels Excessively
- If using a 4 layer board make the two internal layers power and ground plane – No signals on internal layers
- Use plated holes connected to ground for mounting holes watch your screw head size though (remember key takeaway #2)
- Hole diameter = 40 mils
- Track width = 10-60 mils (10 mil traces with 10 mil spacing is a good one, beef up any power traces)
- Circular pads = 80-120 mils
- Width/height for rectangular pads = 80-120 mils



Final Assembly



ALWAYS clean your PCB with Alcohol First



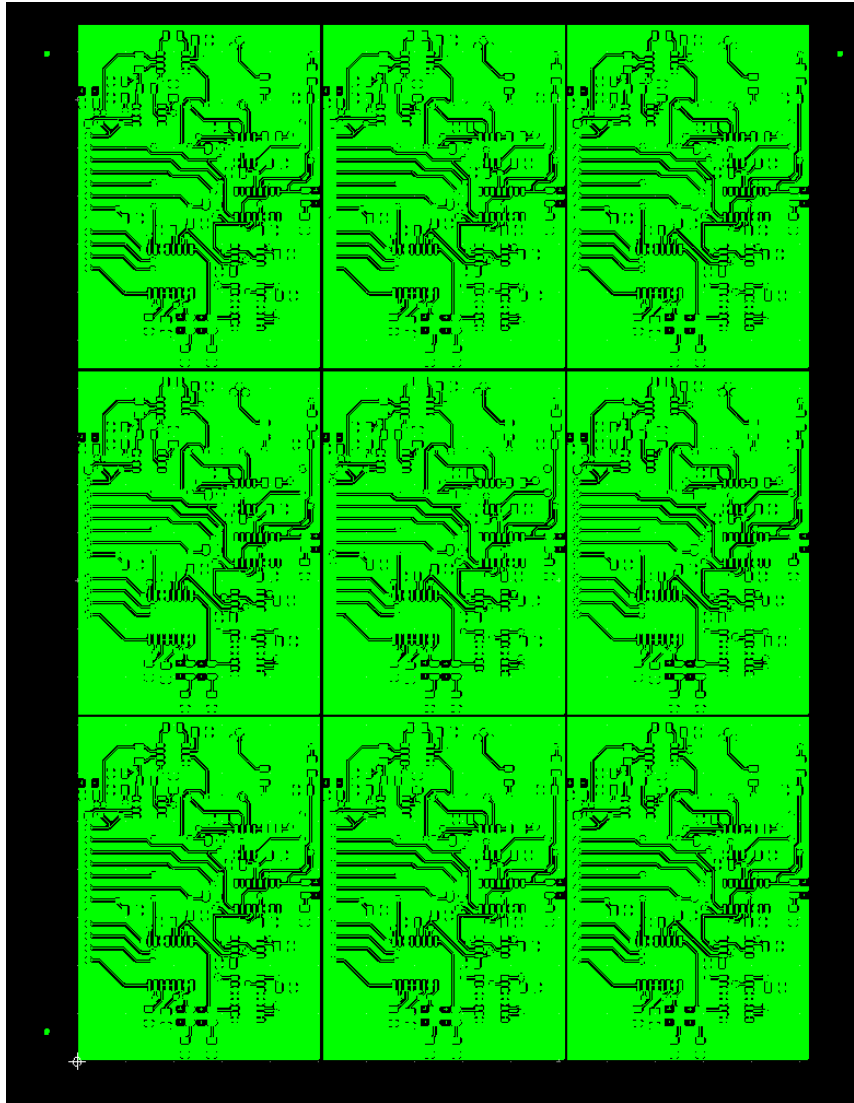
Digikey PN

473-1150-ND

**Don't Touch it After You Clean It. Handle Like a
Record**



For Multiple Boards Consider Panelizing



These are Some Good Solder Choices

- 63/37 RA/RMA for hand soldering
- 42/57.6/0.4 for Reflow Soldering

Item	Digikey PN
63/37 Solder Wire	KE1400-ND
42/57.6/0.4 Solder Paste	SMDLTLFP-ND

Weld	T (deg C)	Minutes
Pre-heat	100	1
Heat	150	1
Melt	170	0.5
Cool	170	-

This Profile Works Well for 42/57.6/0.4 with Single Chamber Reflow Ovens

**Always Store Solder Paste in the Fridge,
Remove 24 Hours Before Use**

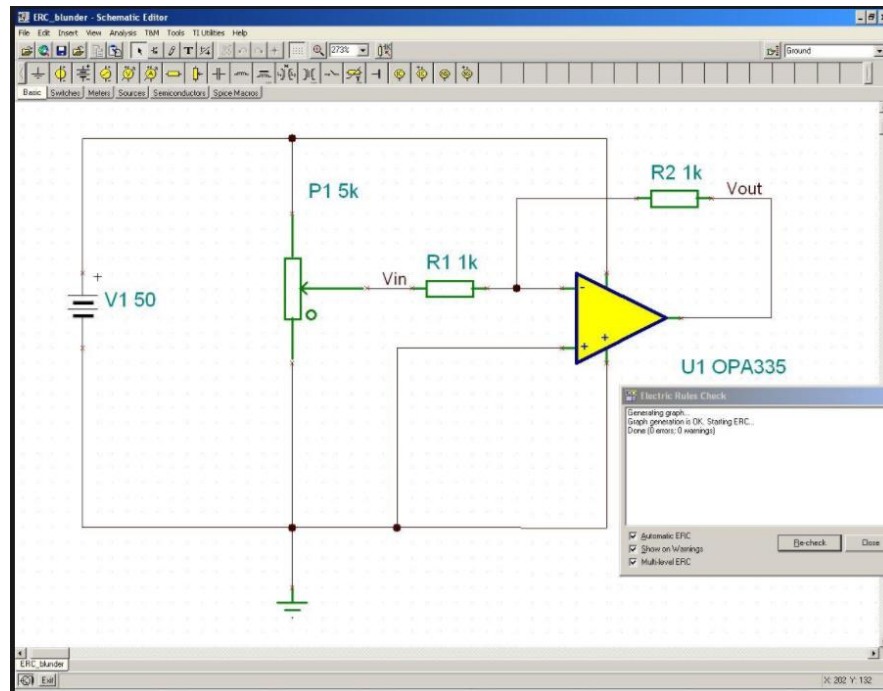


Some Final Comments on ASSM

- You can use conformal coating to “seal” your board after it has been soldered. Protects against conduction and moisture
- Watch your packaging when ordering – reels are a pain if not using P and P

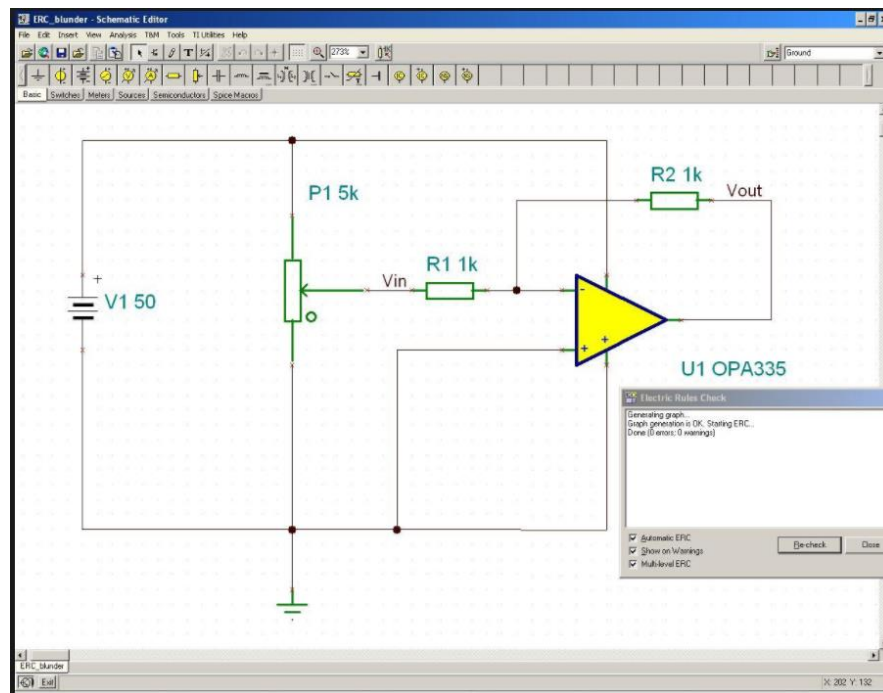


Free Tools

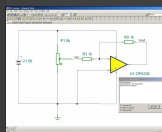


TINA is a Free SPICE-based Analog Simulation Program

- DC, Transient & Frequency Analysis
- Virtual Tools Including Oscilloscope and Probes



<http://www.ti.com/tool/tina-ti>



Webench is an Online Design Tool Power, Lighting, Filtering, Clocking and Sensing Circuits

WEBENCH® Designer *My* Designs

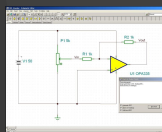
Filters	Sensors	Interface	Reference
Power	FPGA/μP	LED	Clocks

Input Frequency
 MHz

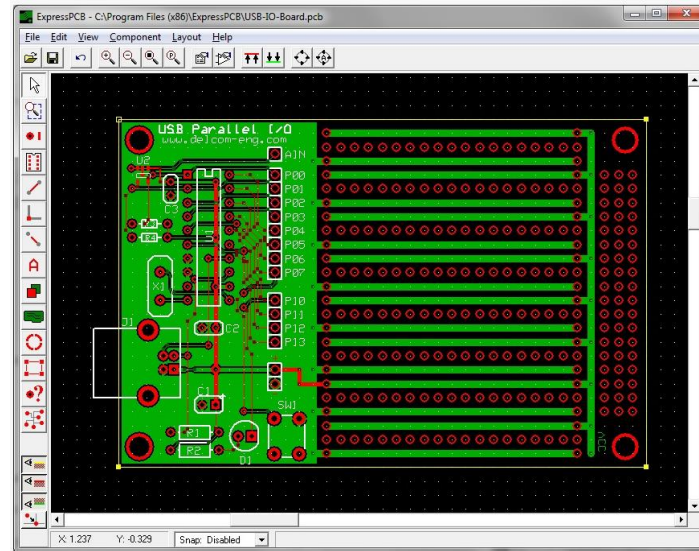
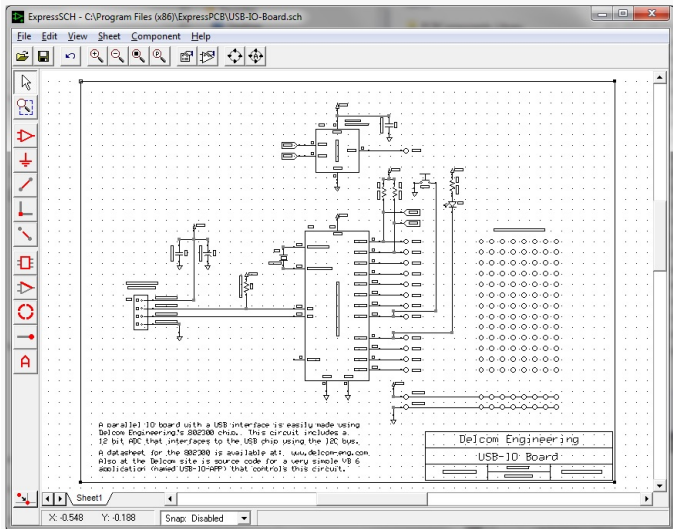
Output Frequency
 MHz
 MHz
 MHz

More Options **Start Design**

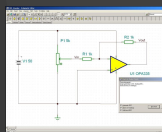
<http://www.ti.com/lstds/ti/analog/webench/overview.page>



Express PCB is A PCB MFG That Makes Cheap Boards, Provided They're Designed with Their Tool



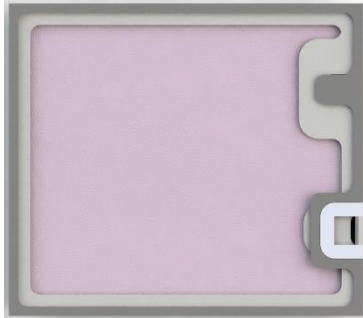
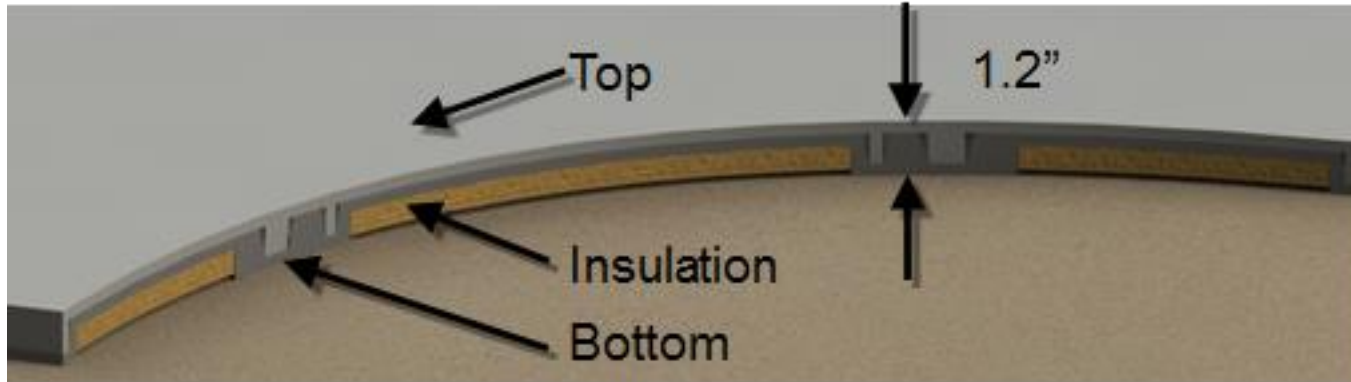
<https://www.expresspcb.com/free-cad-software/>



Design For Manufacture



Make sure you have fillets, drafts, clearances, tolerances



Gemini Plastics, Inc. is a great plastic manufacturer

<http://www.gplastics.com/index.html>

Jeremy O'Connell 920-336-2525

joconnell@gplastics.com

Communicate with your potential manufacturer ahead of time to get a sense of what their tools can and cannot do



These are My Best Practices

Your best practices depend on what you do, in your work there are elements just like this.

Think through your work process to save yourself time and money

Questions?