Open Hardware: Breadboard to PCB

Jenner Hanni

Open Source Bridge 2014

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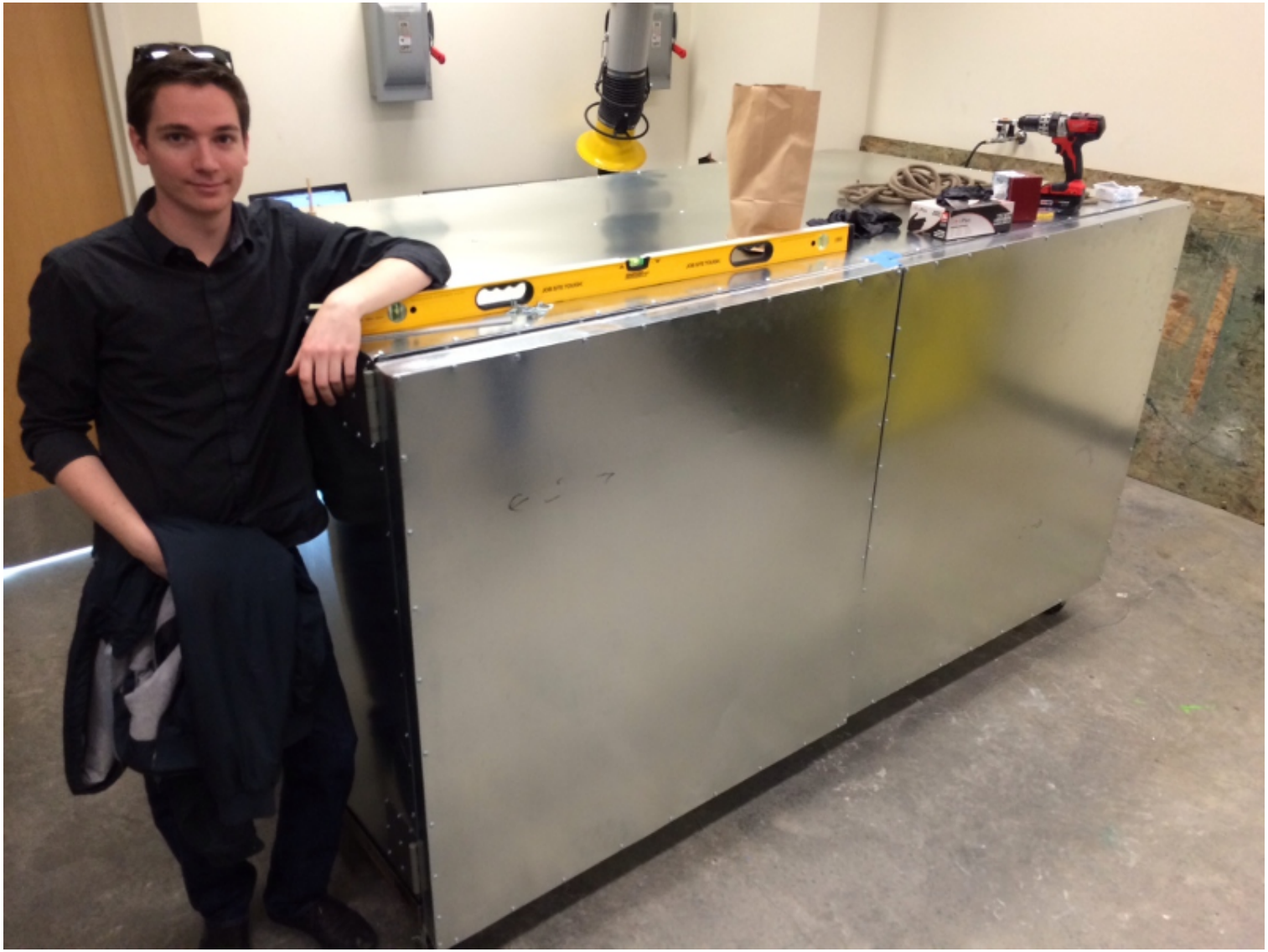
July 11, 2014

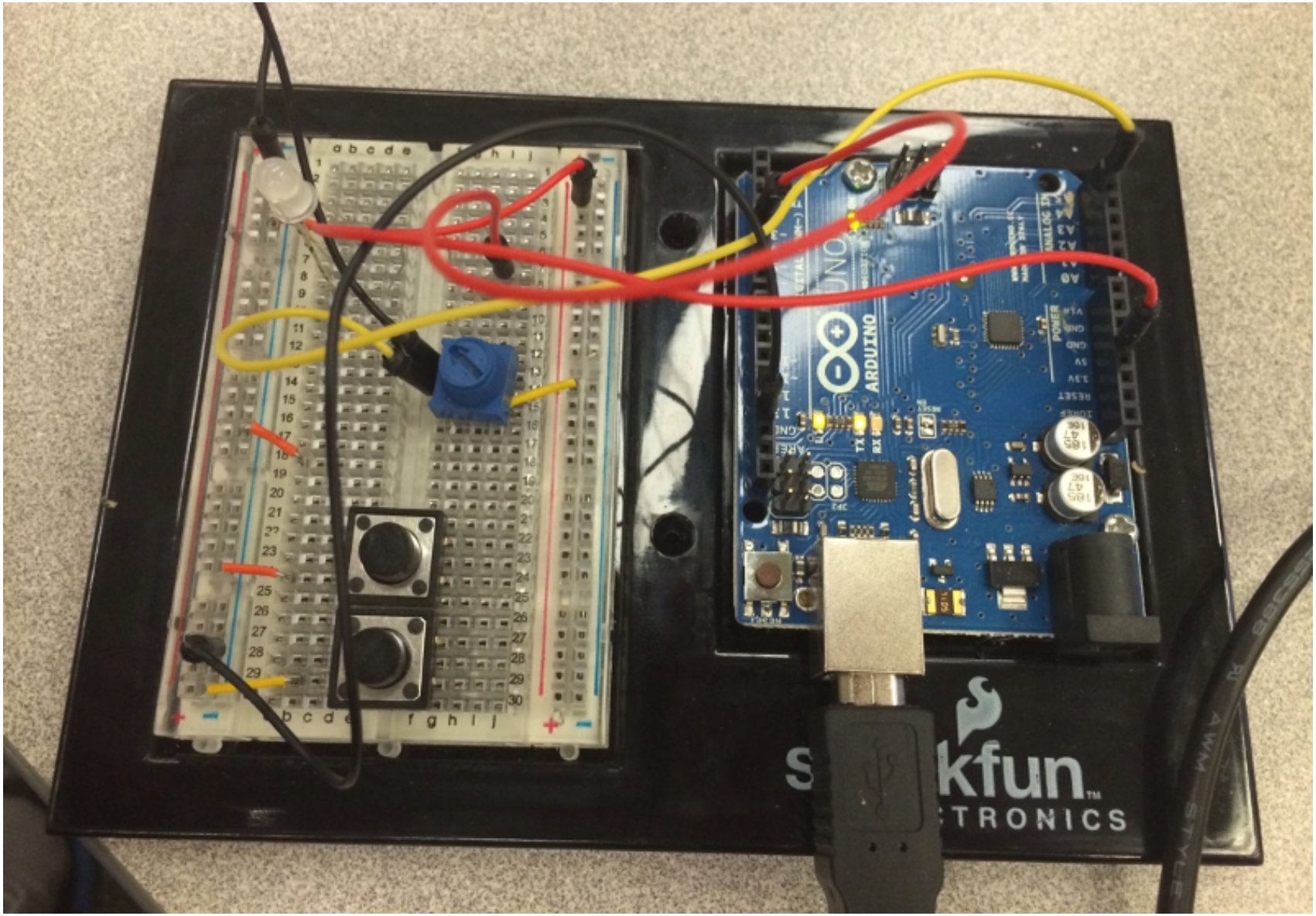
Overview

Portland State Aerospace Society

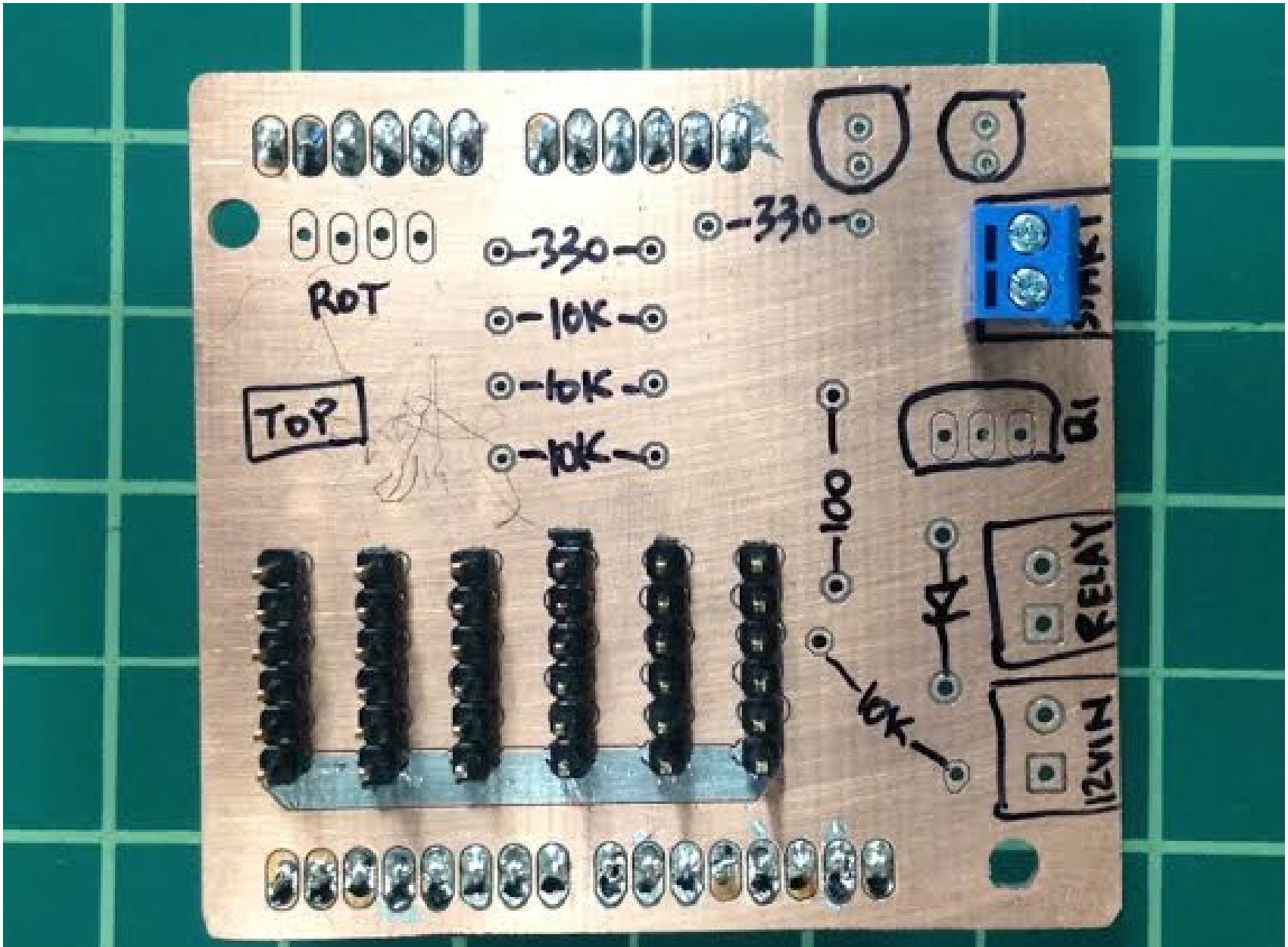
"We built you an oven!"



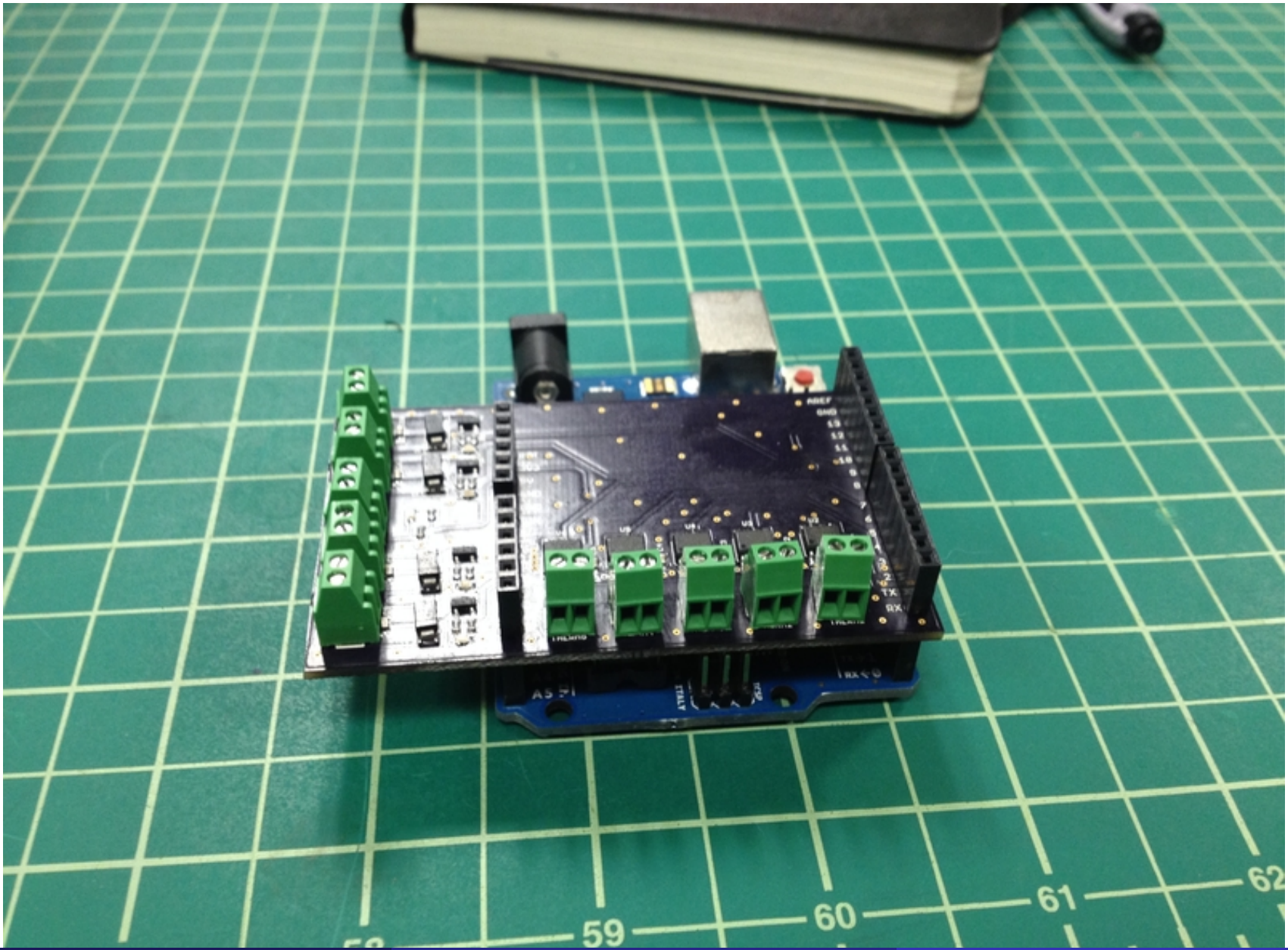
"... here are the electronics!"



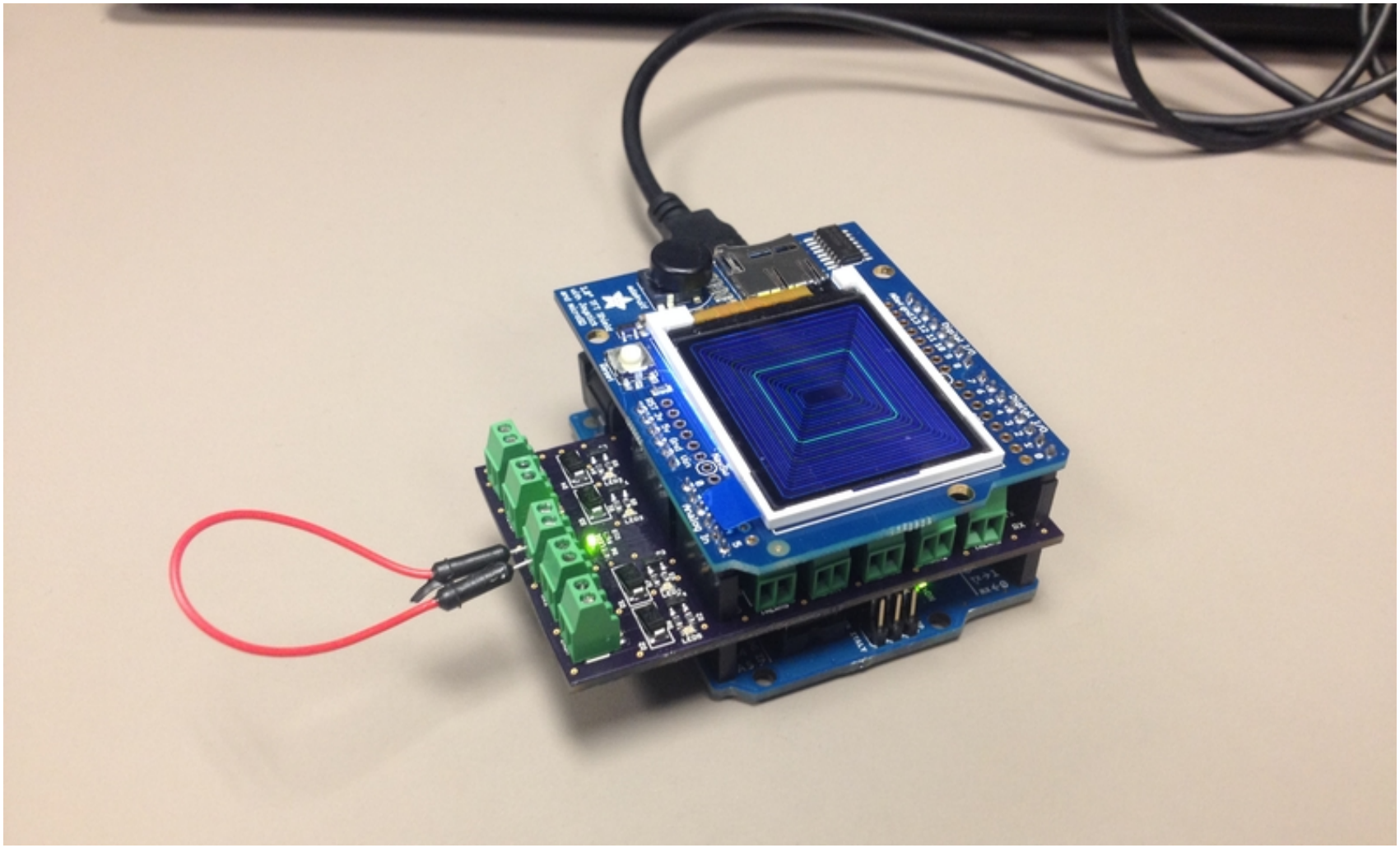
Through-hole Arduino Shield



Surface-mount Arduino Shield

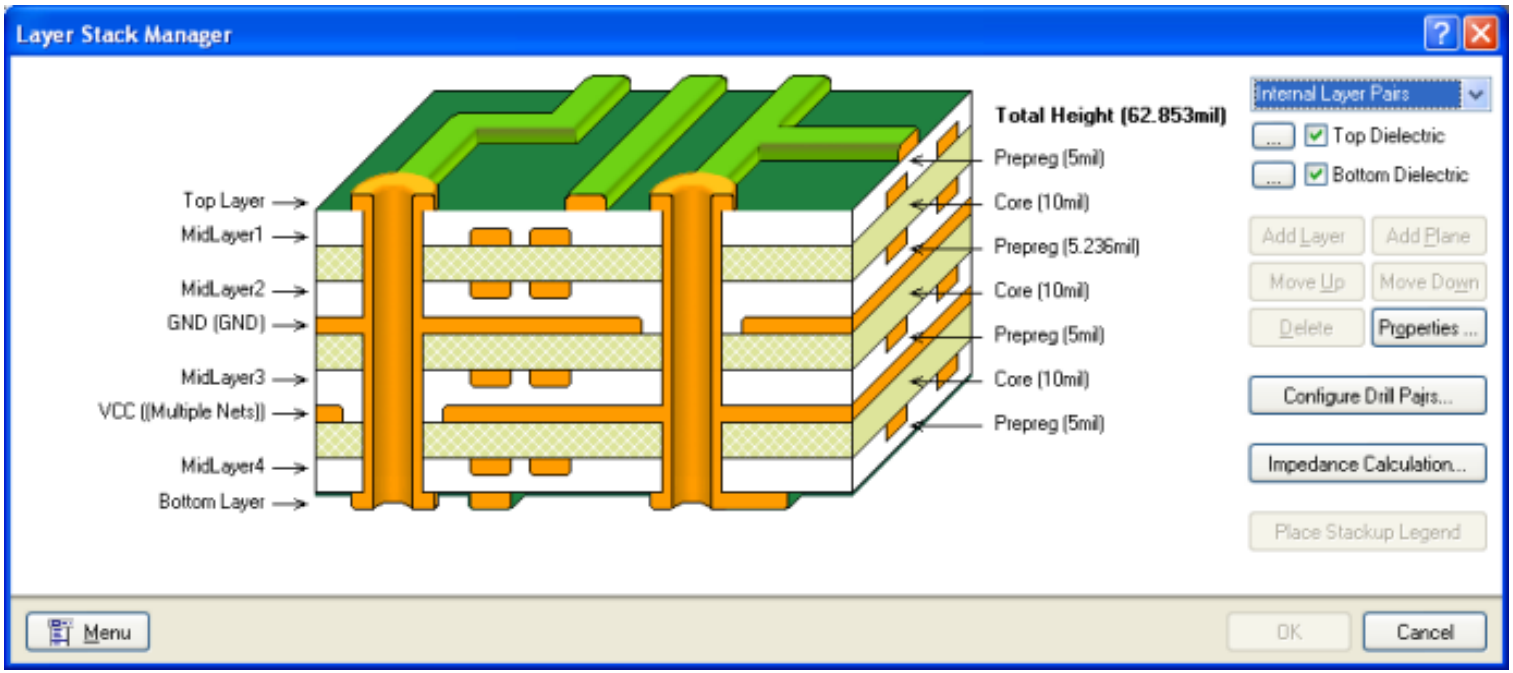


Finished product



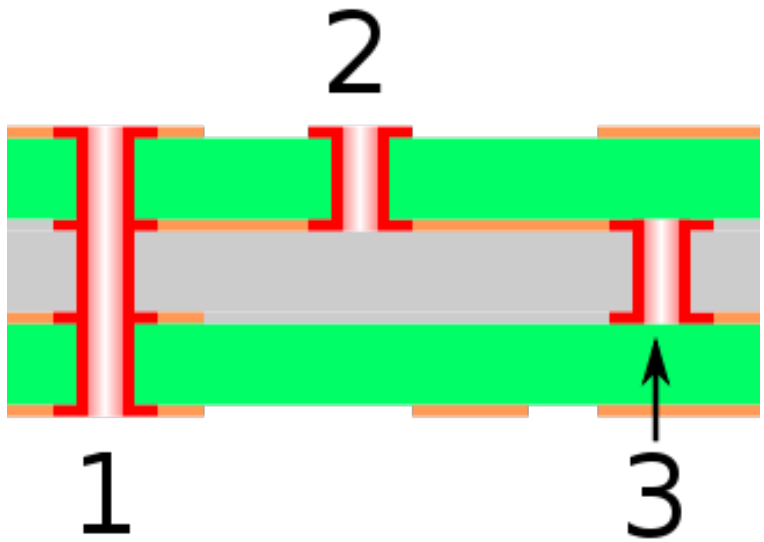
Terminology

Layer Stackup

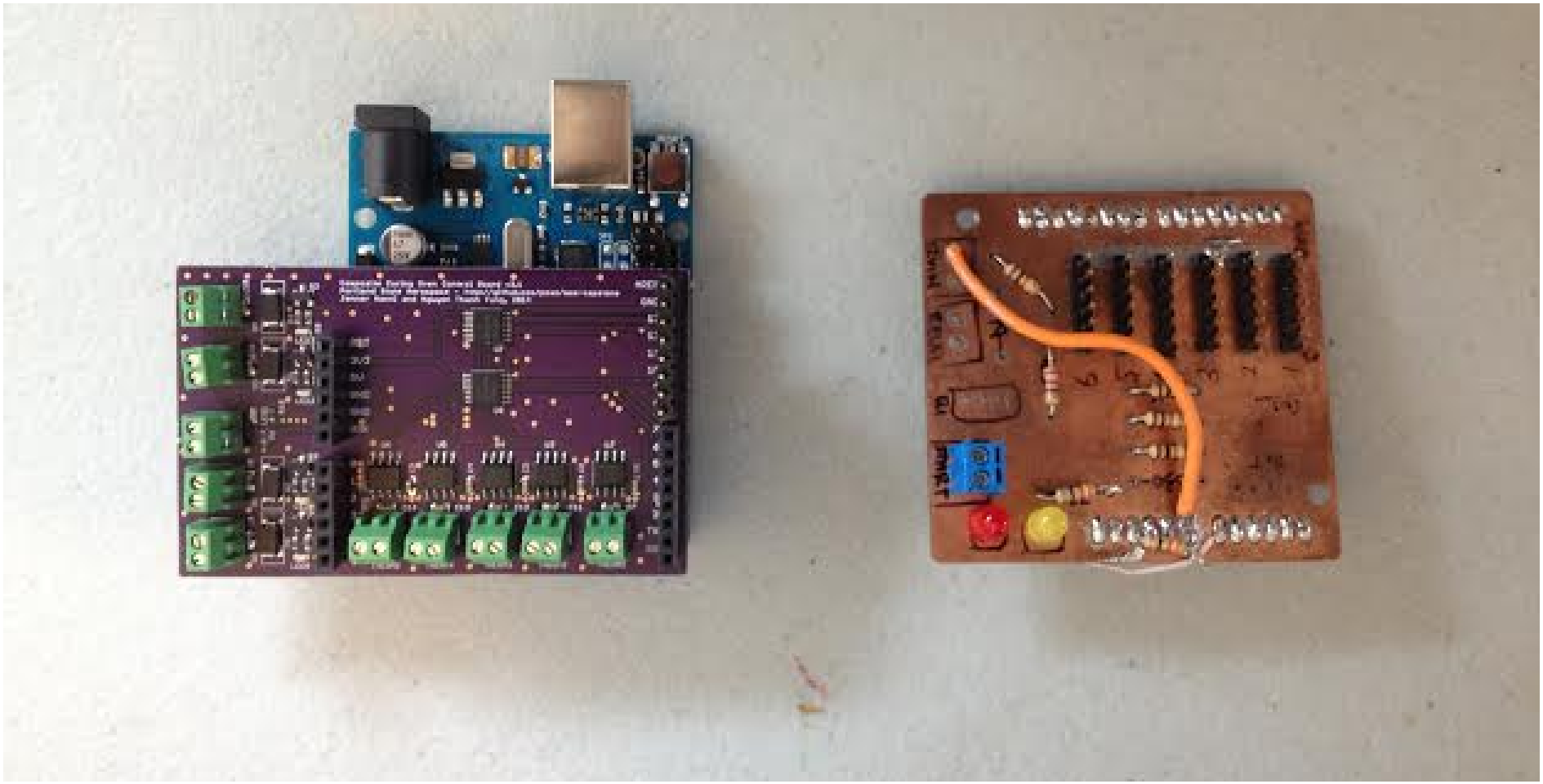


Vias

1. Through-hole
2. Blind
3. Buried



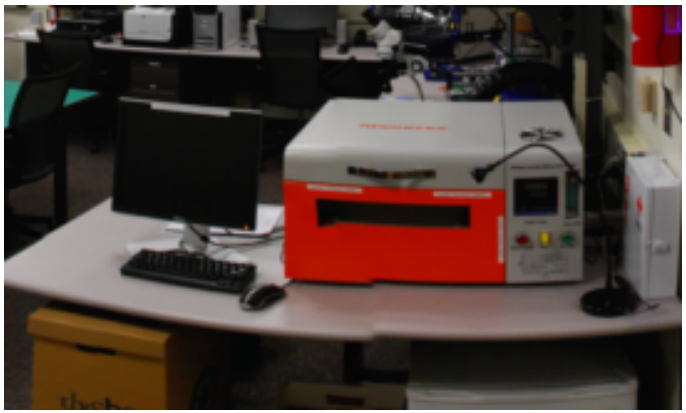
Soldermask



Reflow

Reflow Profile

1. Leaded
2. Non-leaded



Let's make a printed circuit board.

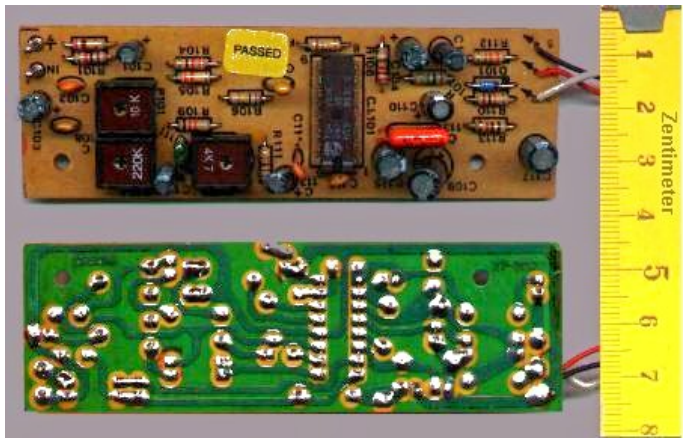
Process

1. Make decisions
2. Choose parts
3. Draw schematic
4. Draw layout
5. Buy parts
6. Fab the board
7. Assemble the board
8. Test the board

Making Decisions

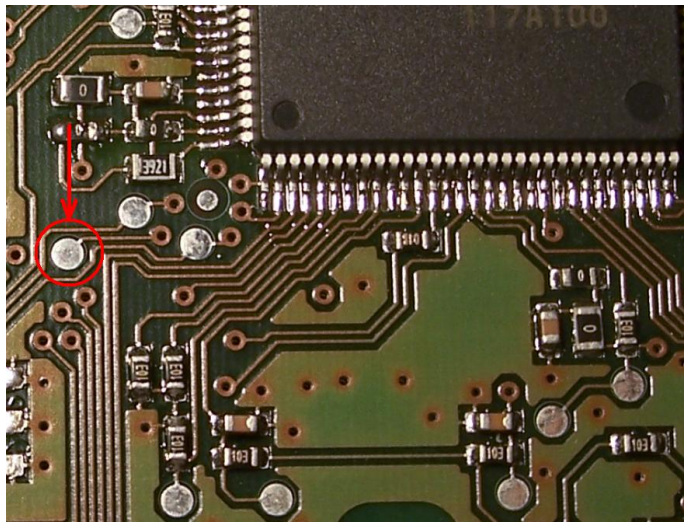
Making Decisions: Parts and Assembly

Through-hole



Solder by hand

Surface-mount

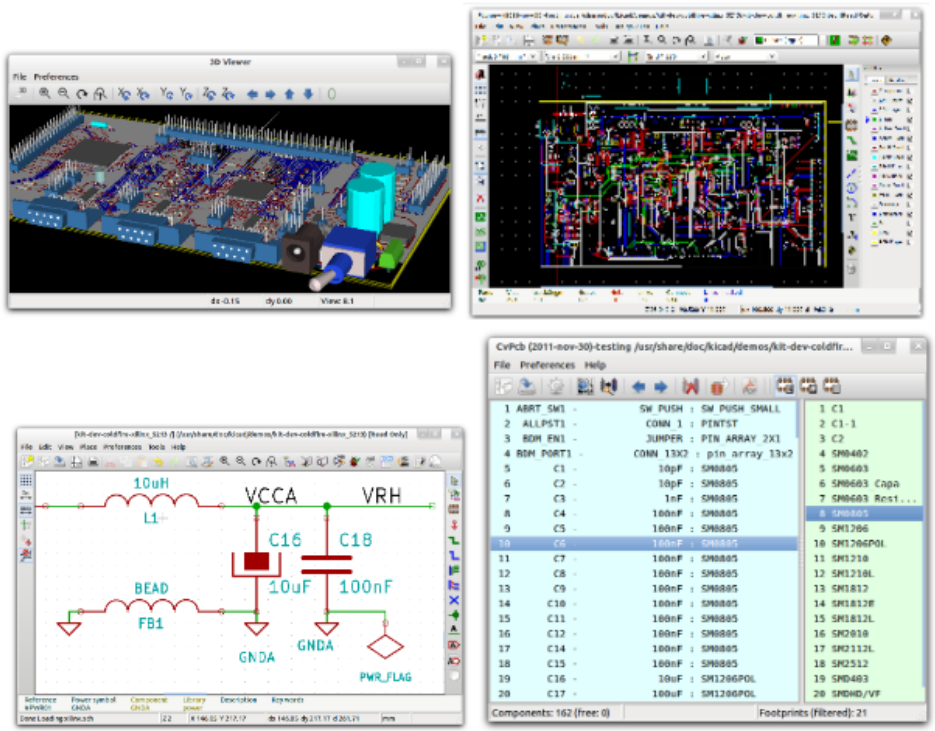


Stencil, Reflow

Making Decisions: Design Tool

1. Altium
2. DxDesigner/PADS
3. Eagle
4. gEDA
5. KiCad

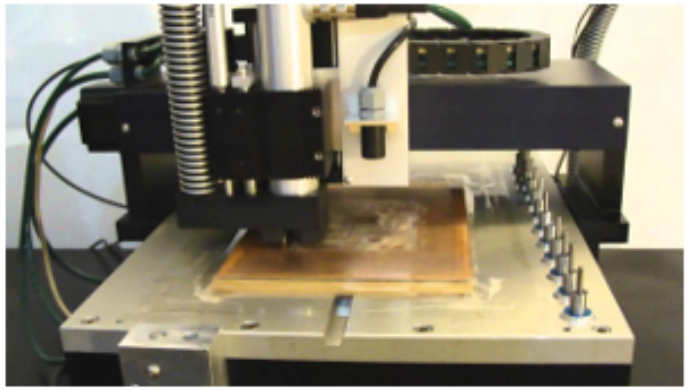
KiCad

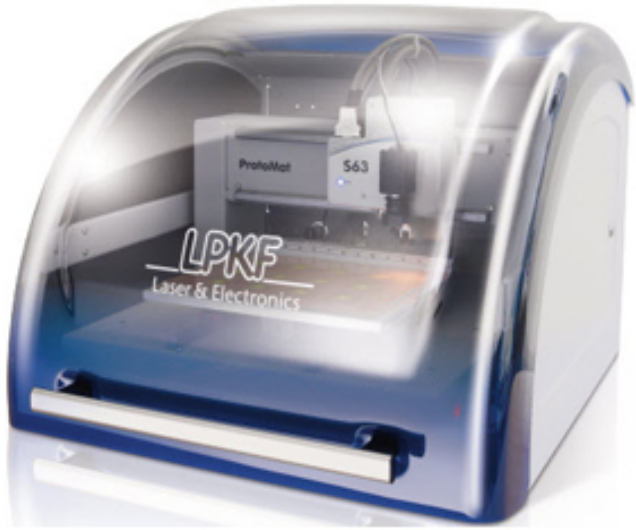


Making Decisions: Fab House

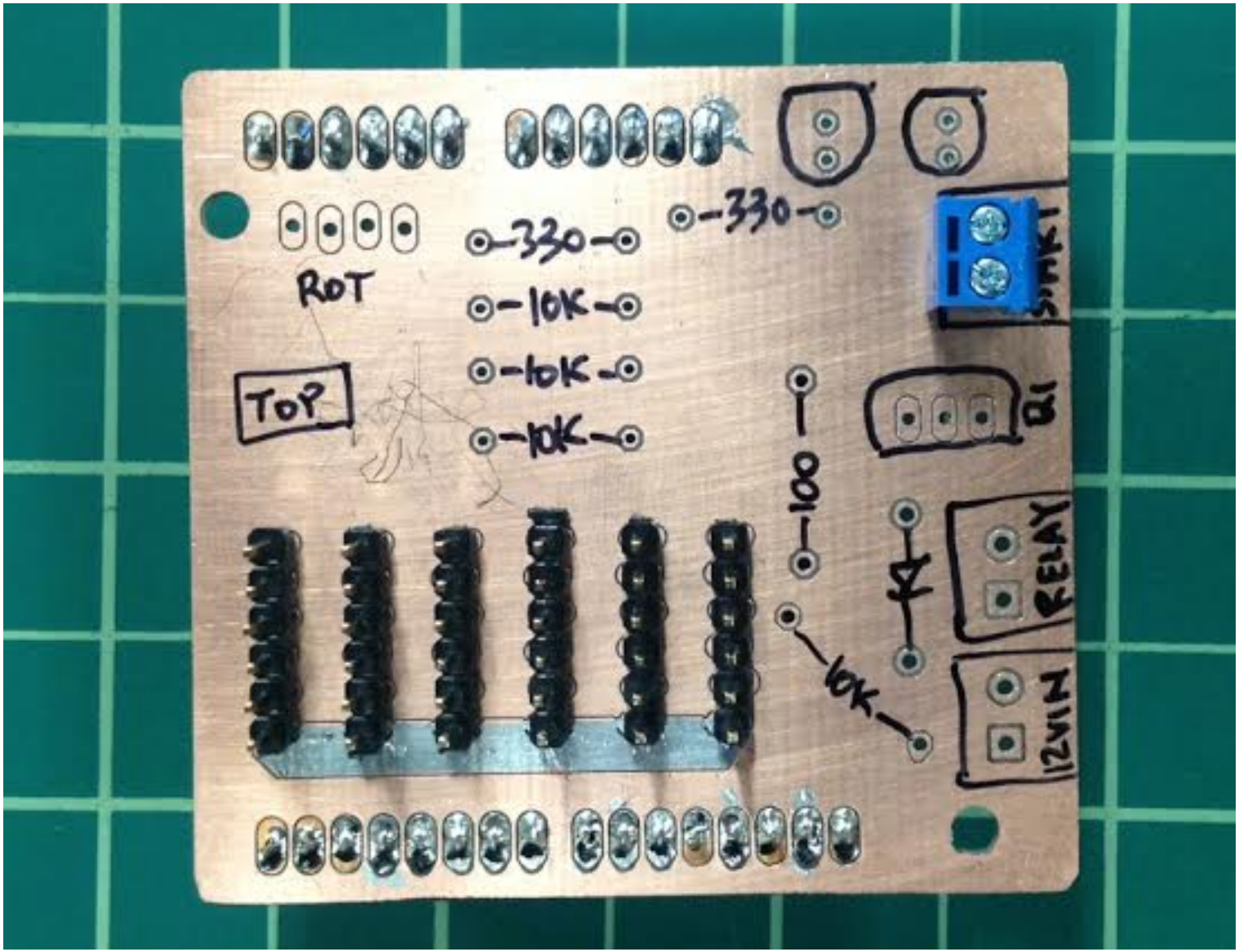
ADVANCED CIRCUITS

seeed
Open Hardware Facilitator

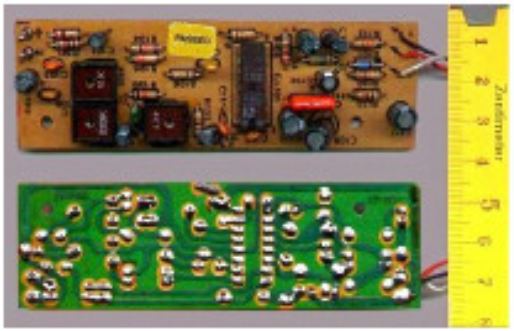




Oven Board v1



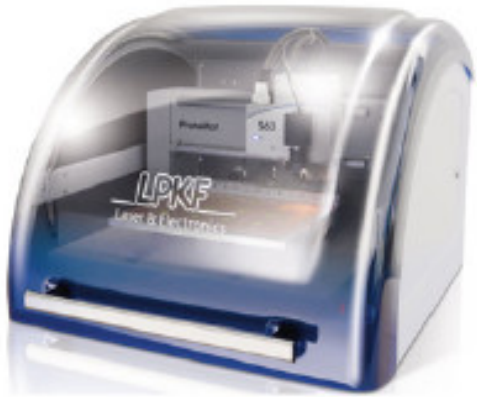
v1 Decisions



Through-hole
Solder by hand

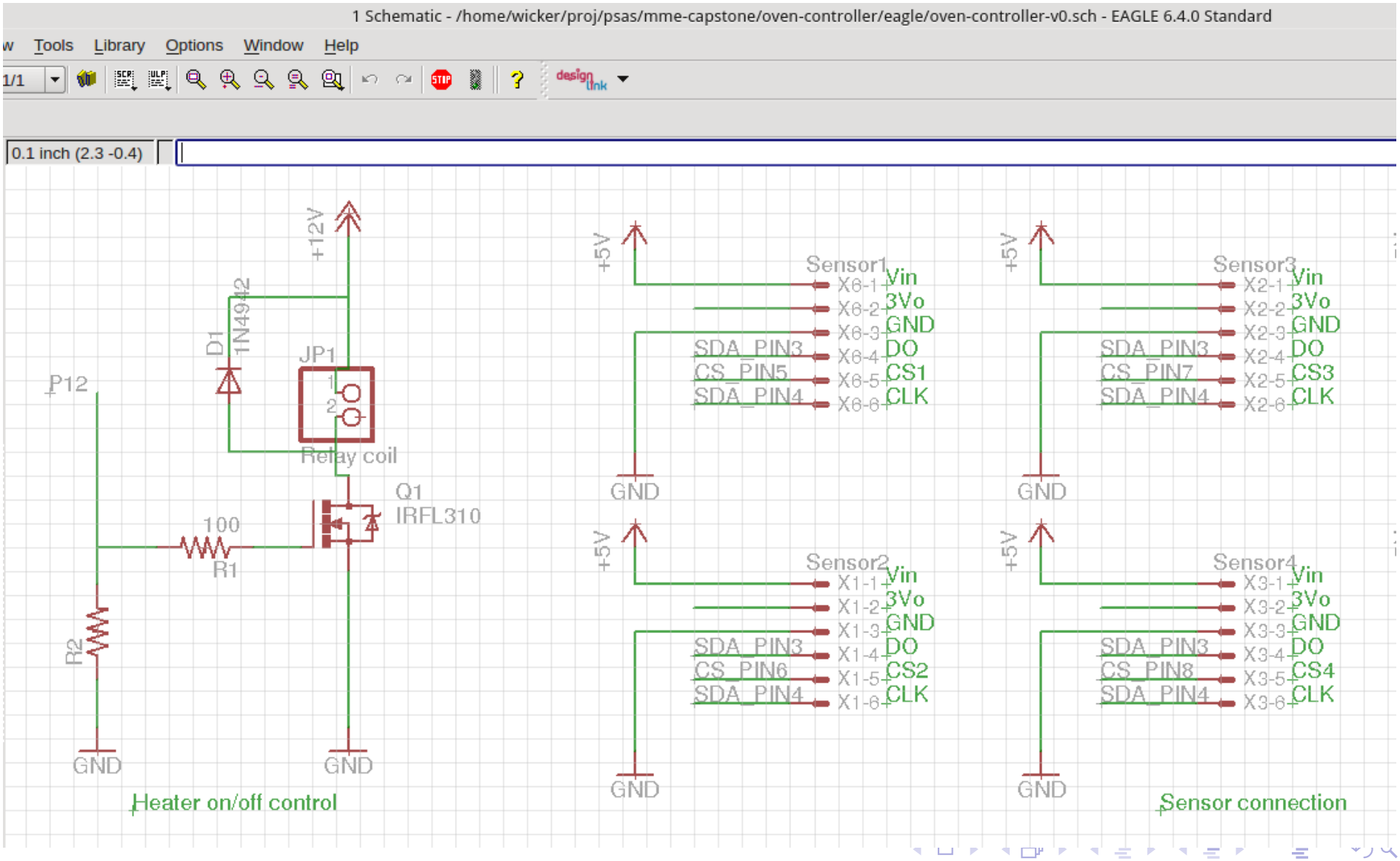
EAGLE®
www.cadsoft.de

- Eagle

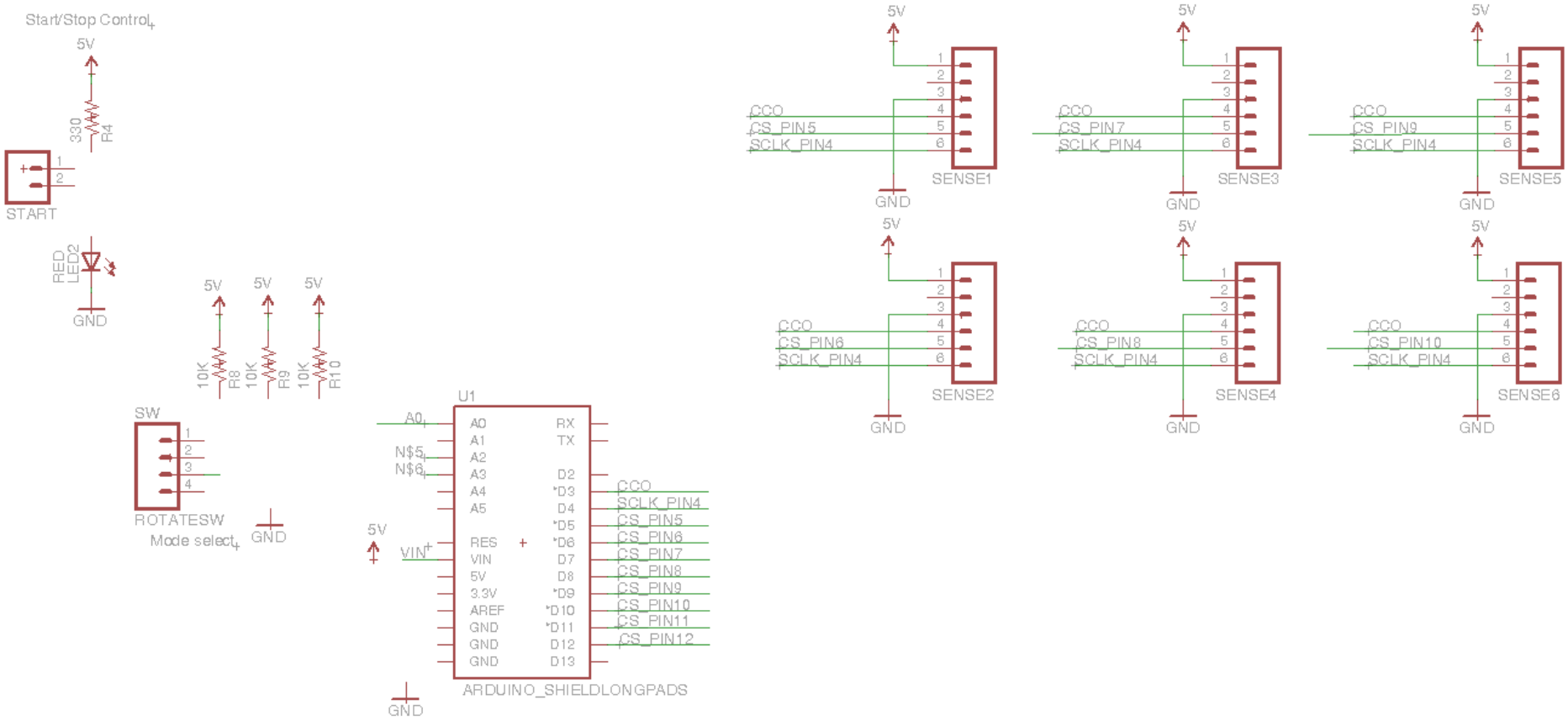


Grid

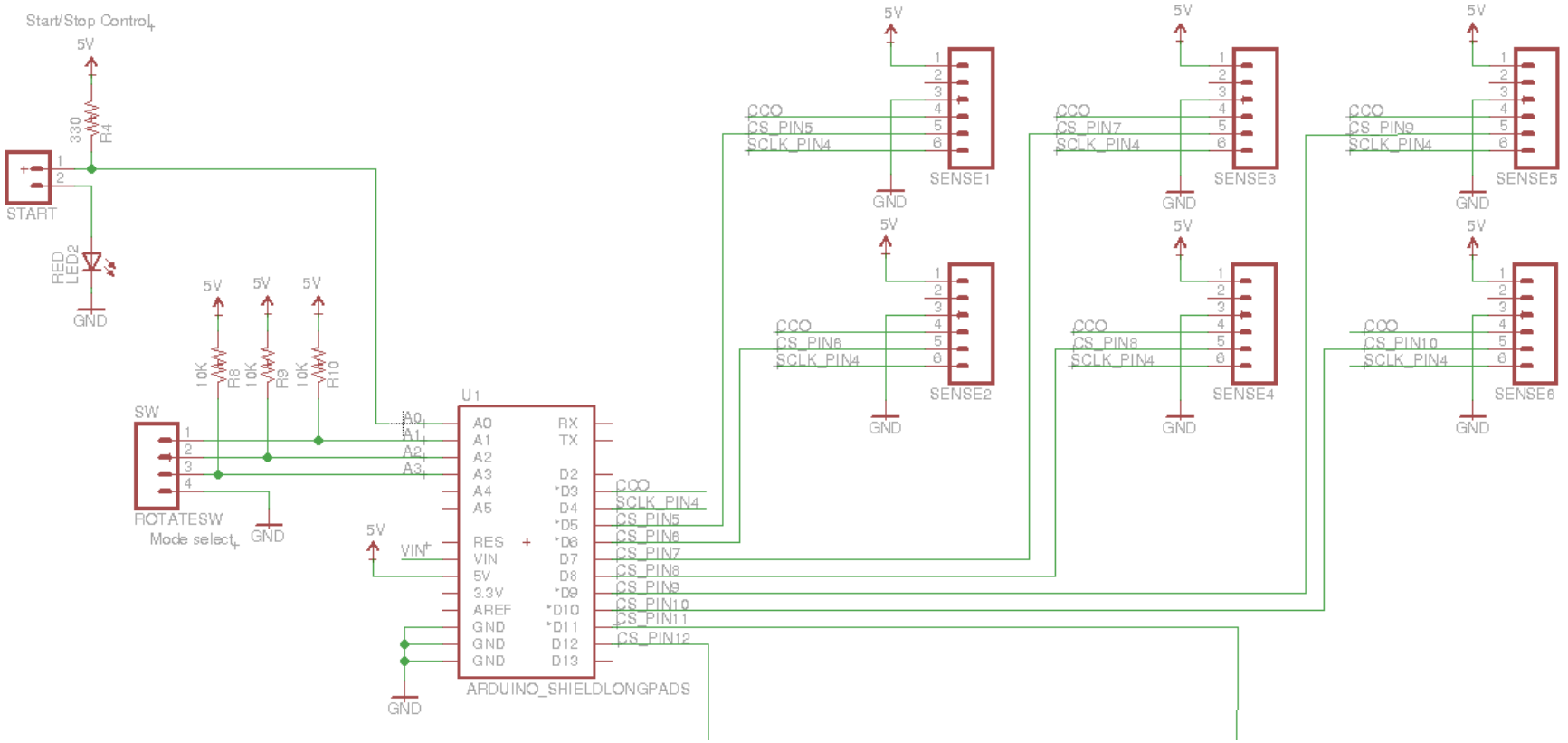
0.001” = one thousandth of an inch = 1 mil != 1 millimeter



Place symbols with pins



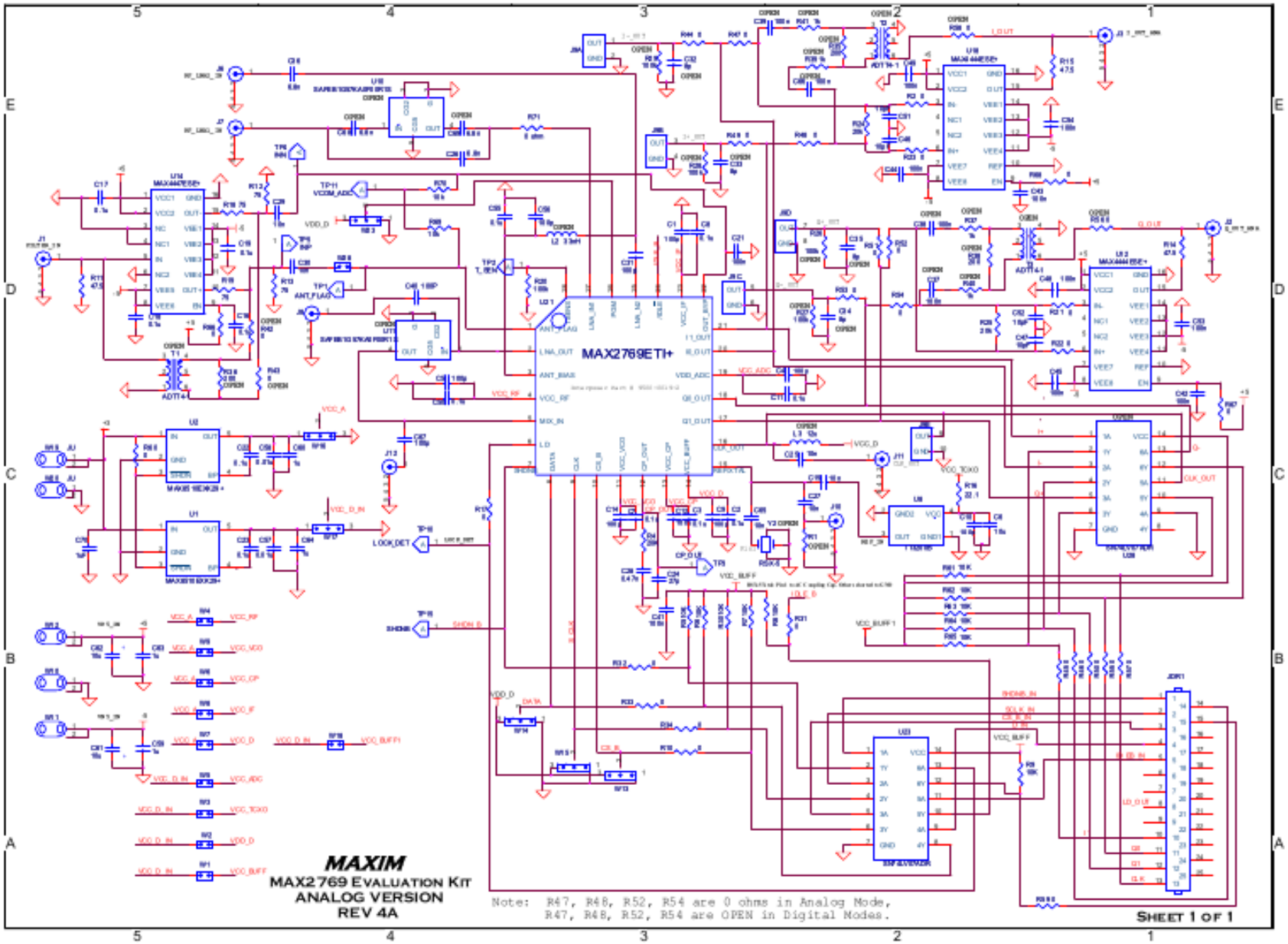
Show connections!



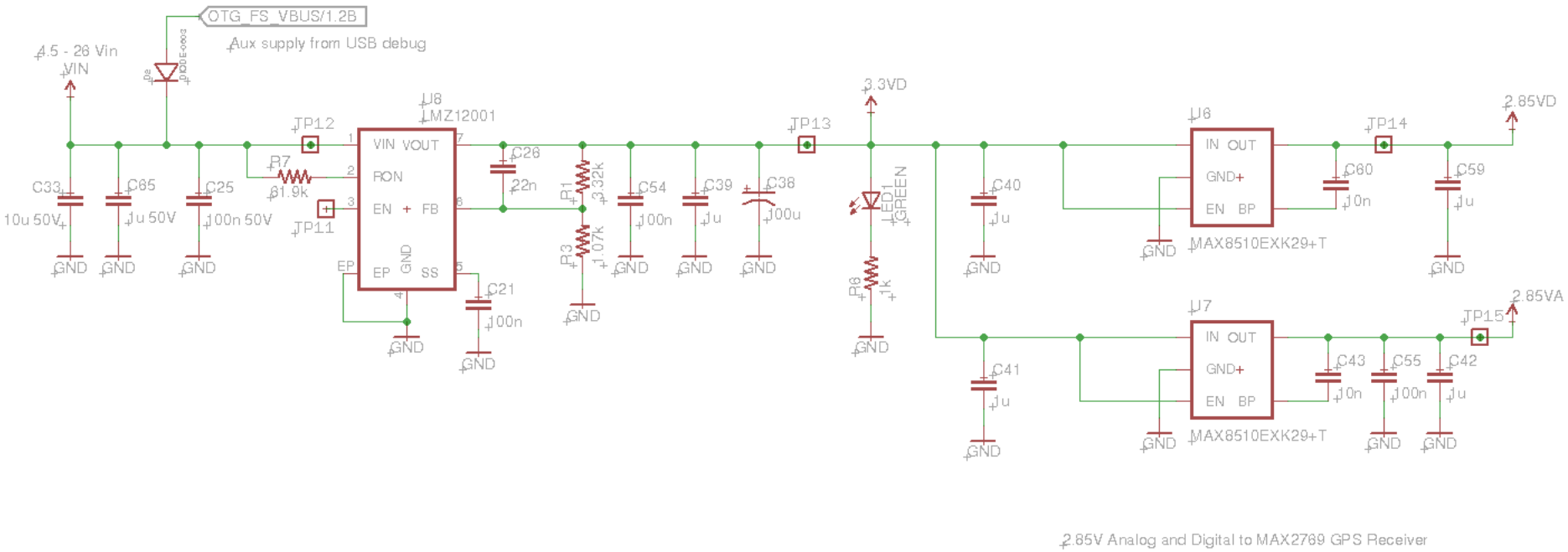
Things to think about

1. Signal flow left to right
2. Power and ground
3. Symbol layout doesn't have to look like the footprint
4. Net names for traceability
5. Boxes around sections to show options or functionality
6. Multiple pages for a complicated circuit
7. Text to give more information - are you the layout person?

Bad Example: MAX2769 Eval Board



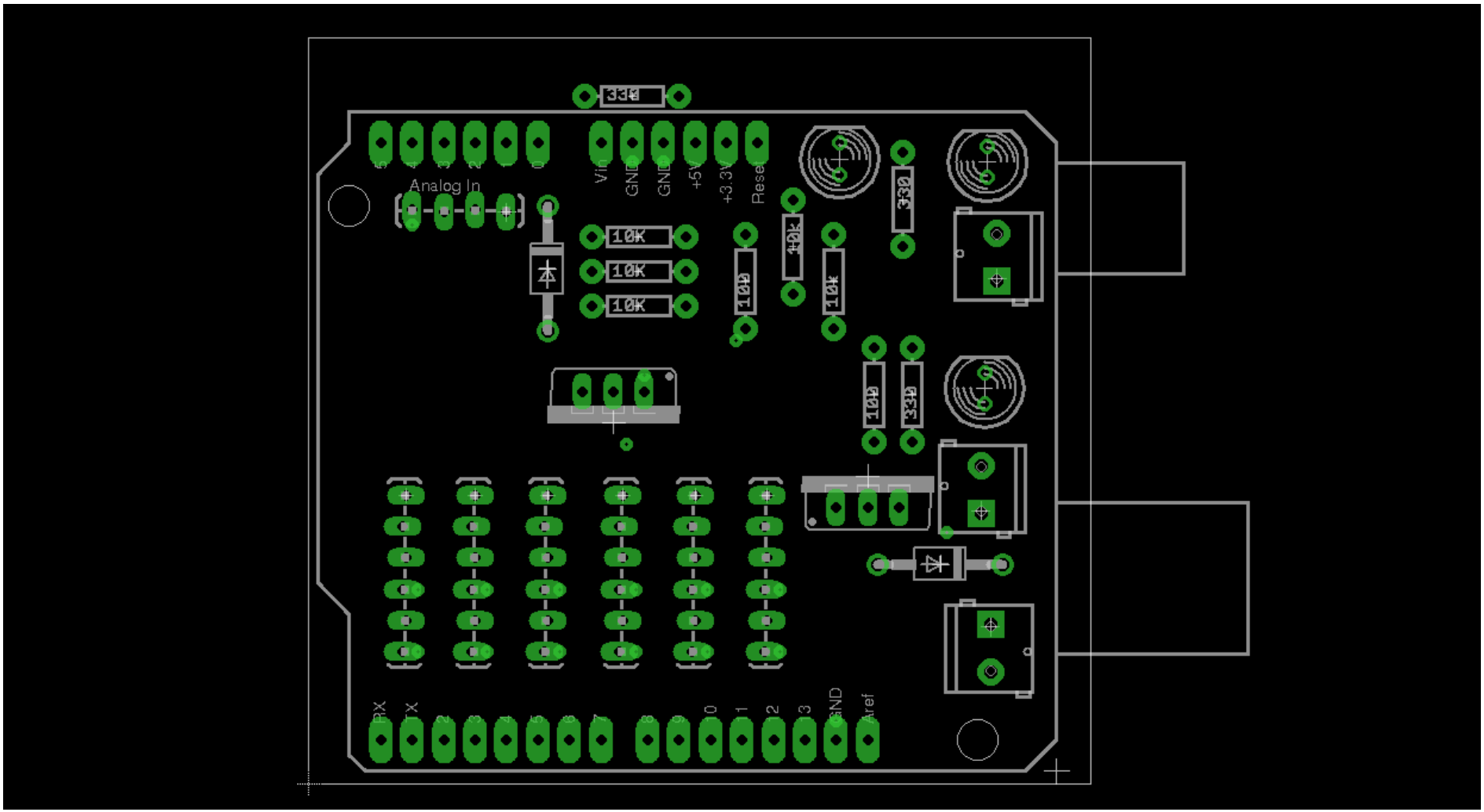
Good Example: GPS RF Front-end Board



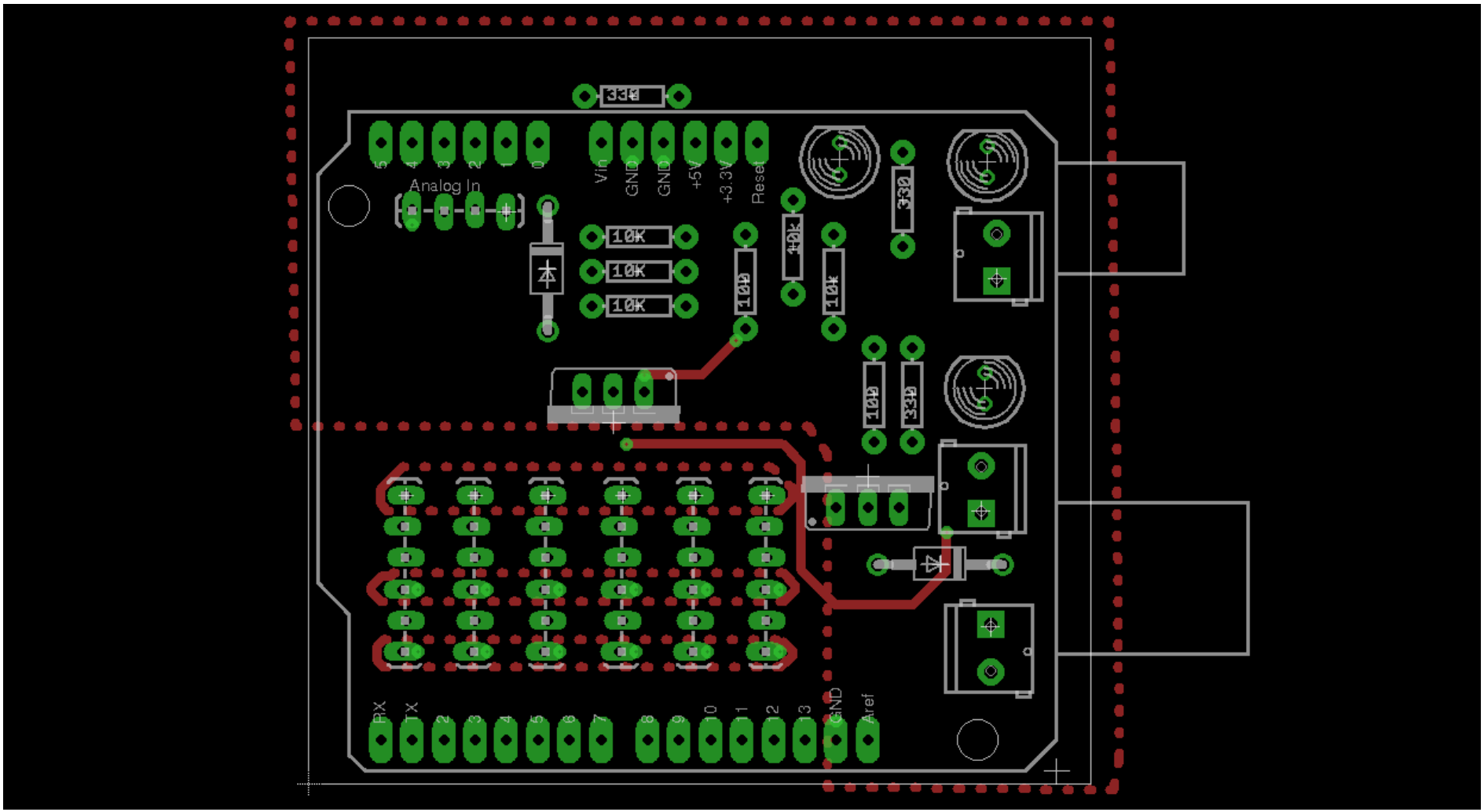
Okay, now what?

1. Design Review
2. Notebook
3. Remember, don't make this a waterfall process

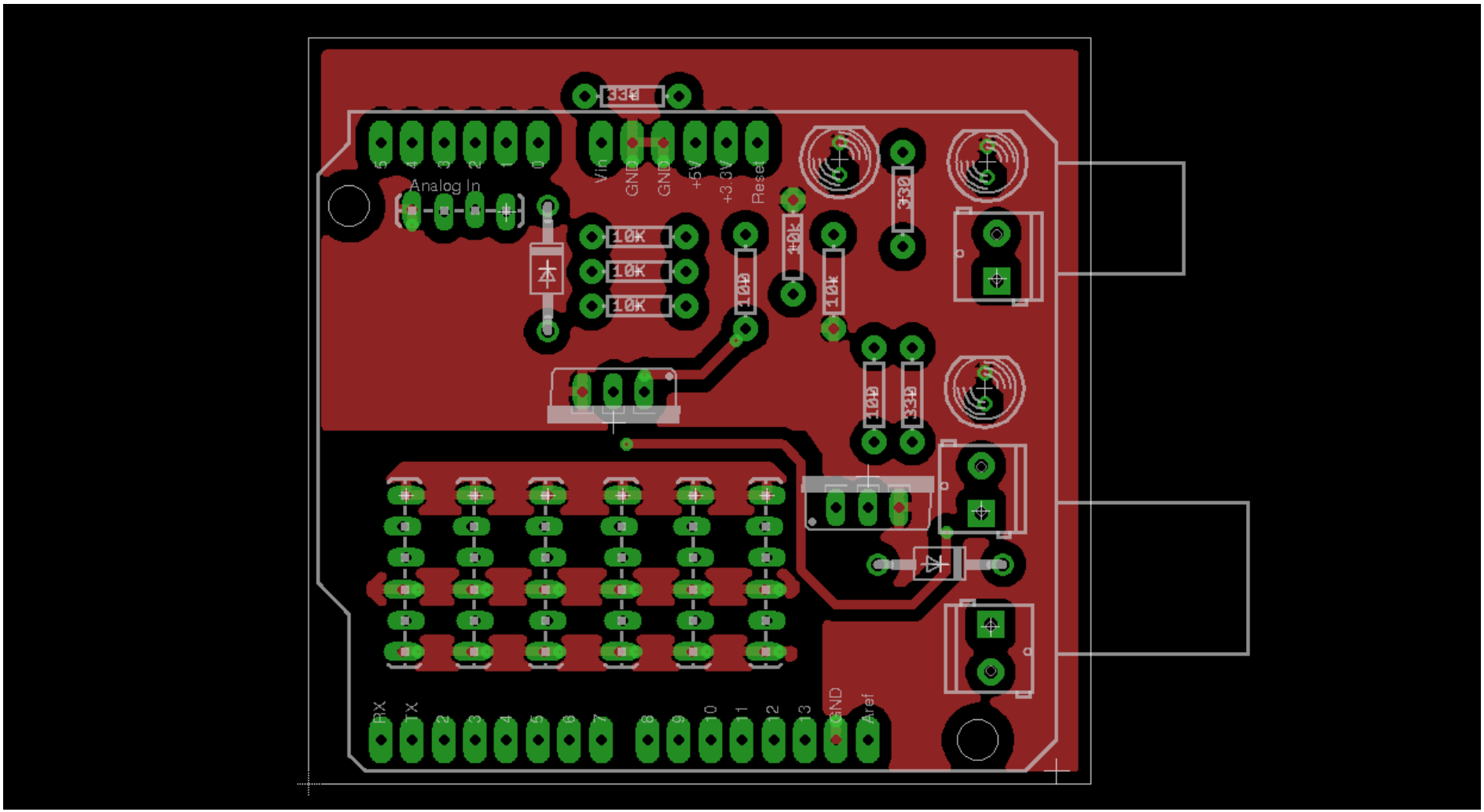
Board Layout



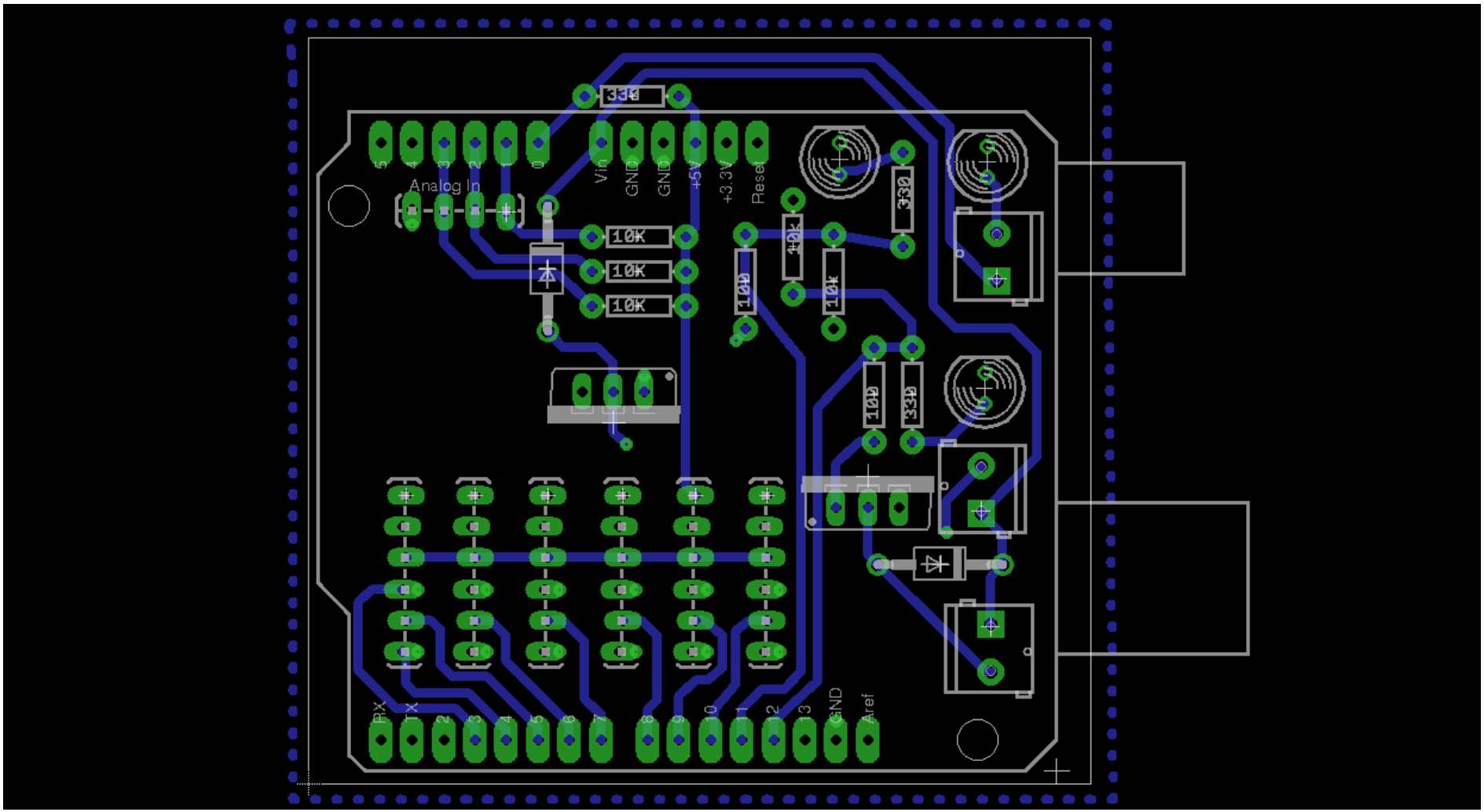
Board Layout



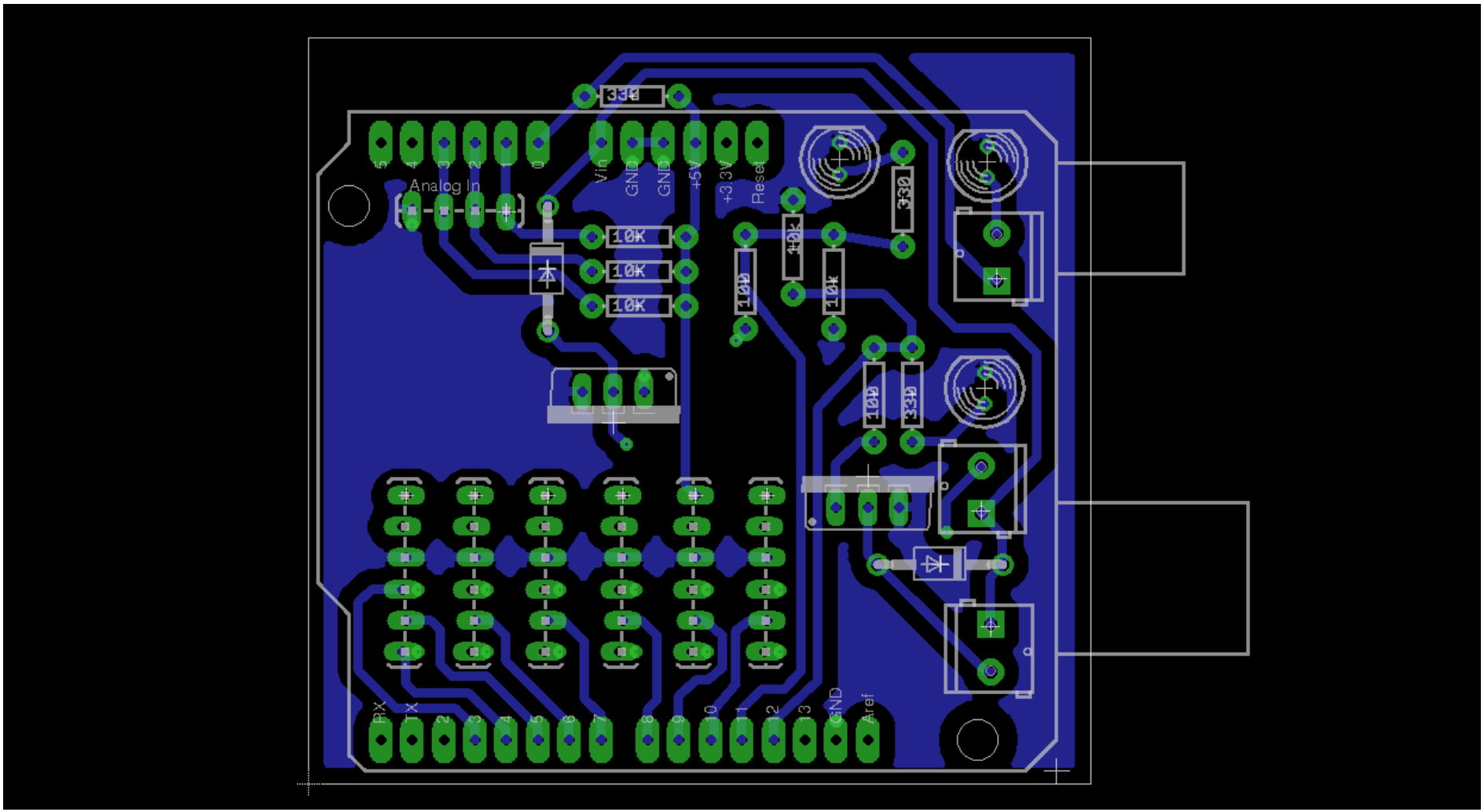
Board Layout



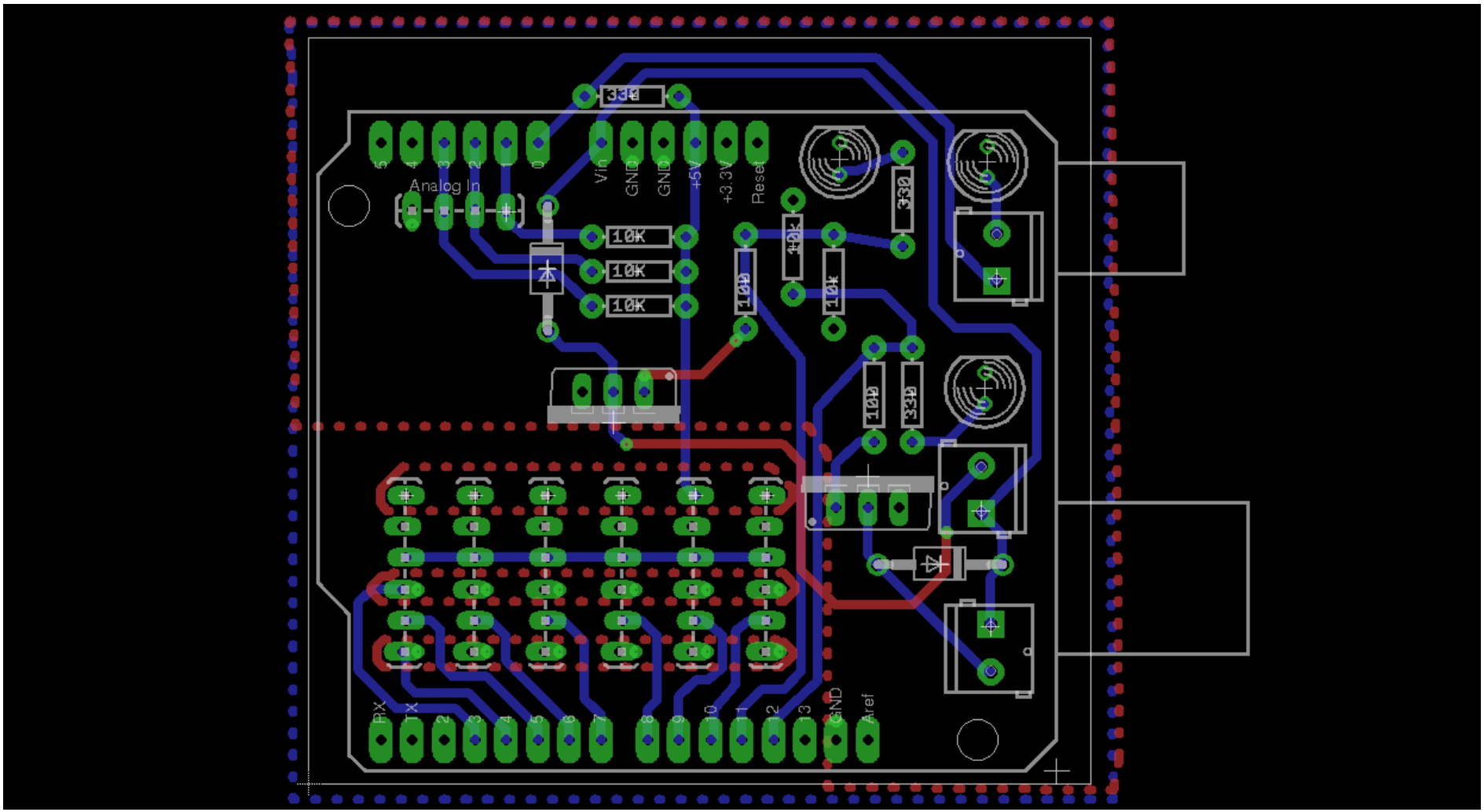
Board Layout



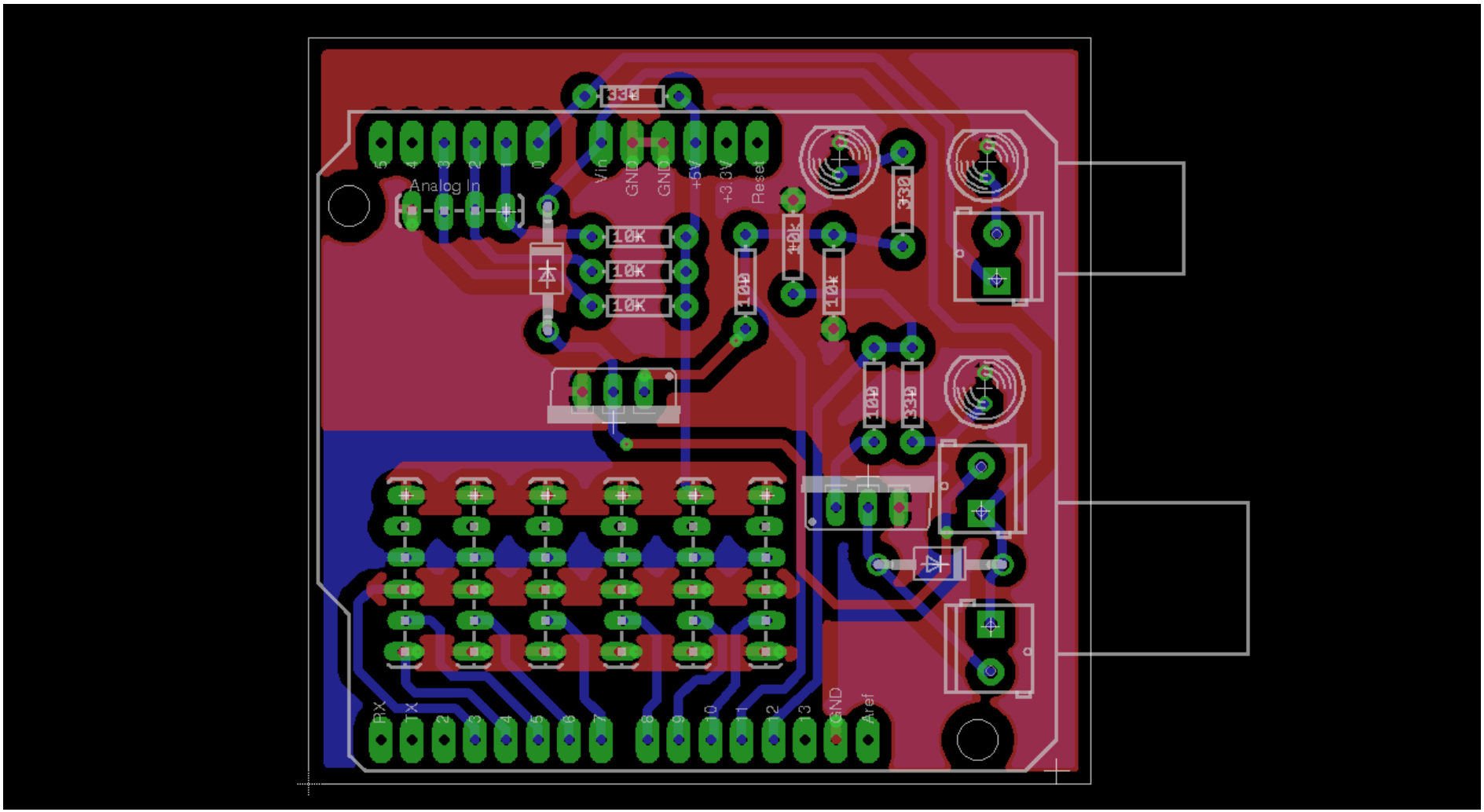
Board Layout



Board Layout

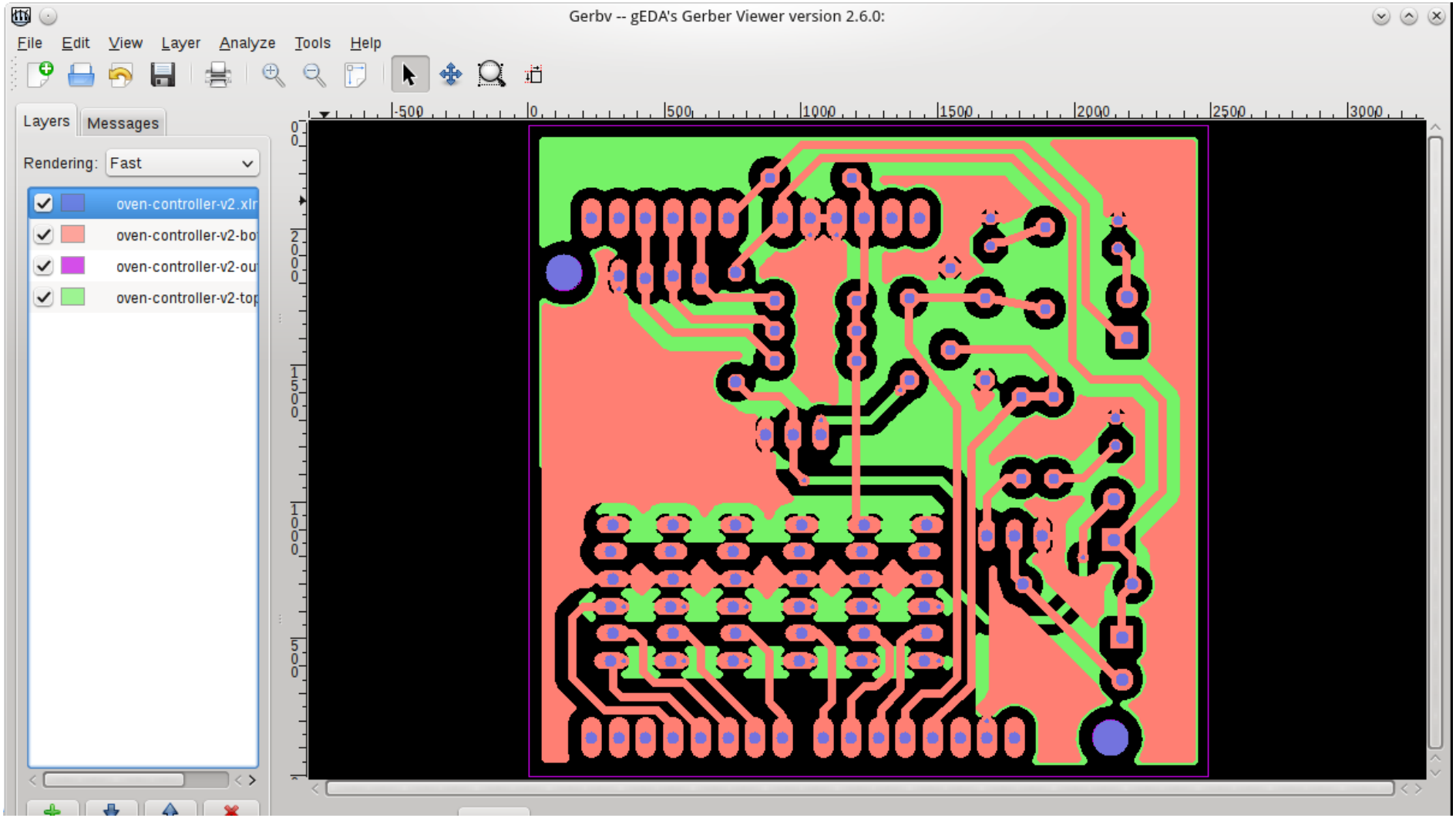


Board Layout

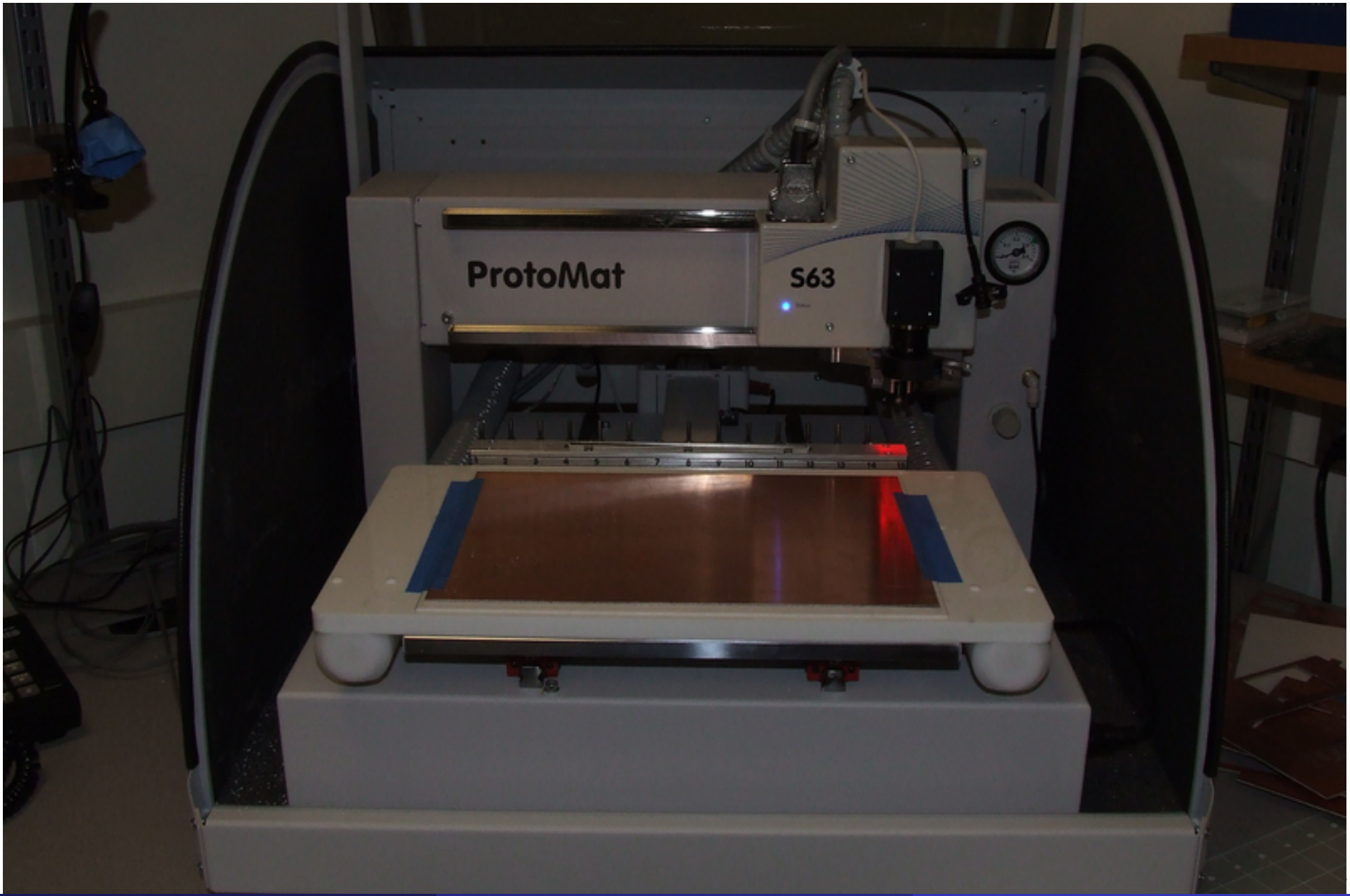


Gerbers

Board Outline, Top, Bottom, Drills



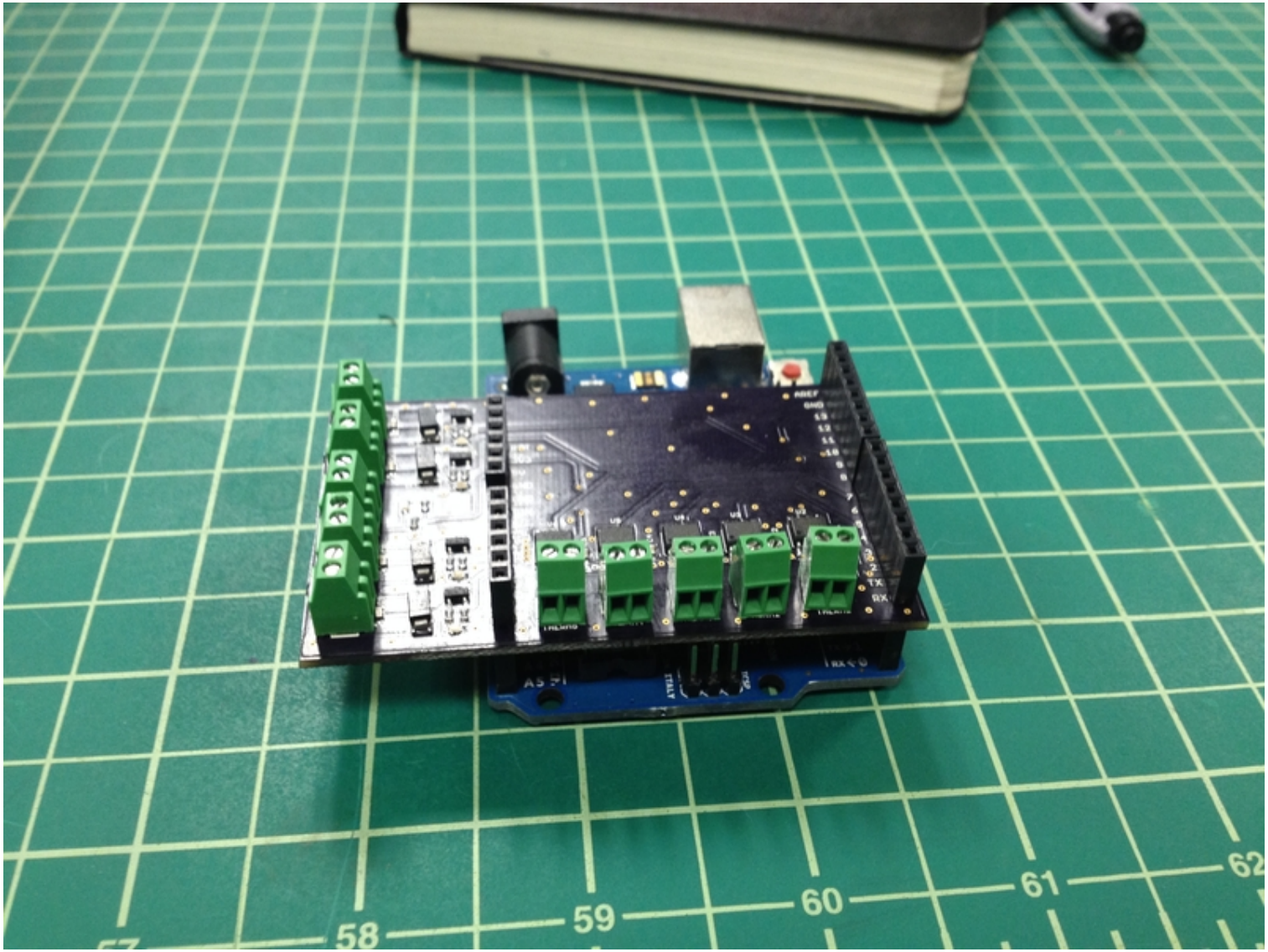
Fabricate with the LPKF



Get the board back... now what?

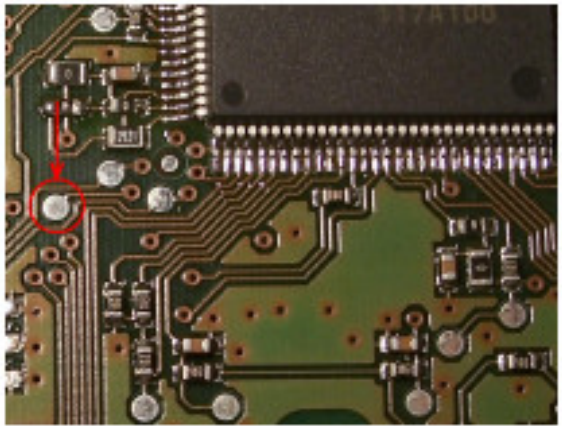
1. Inspect, test with a multimeter
2. Solder in parts
3. Test with a multimeter
4. Power it up

Oven Board v3



v3 Decisions

Surface-mount



Stencil, Reflow

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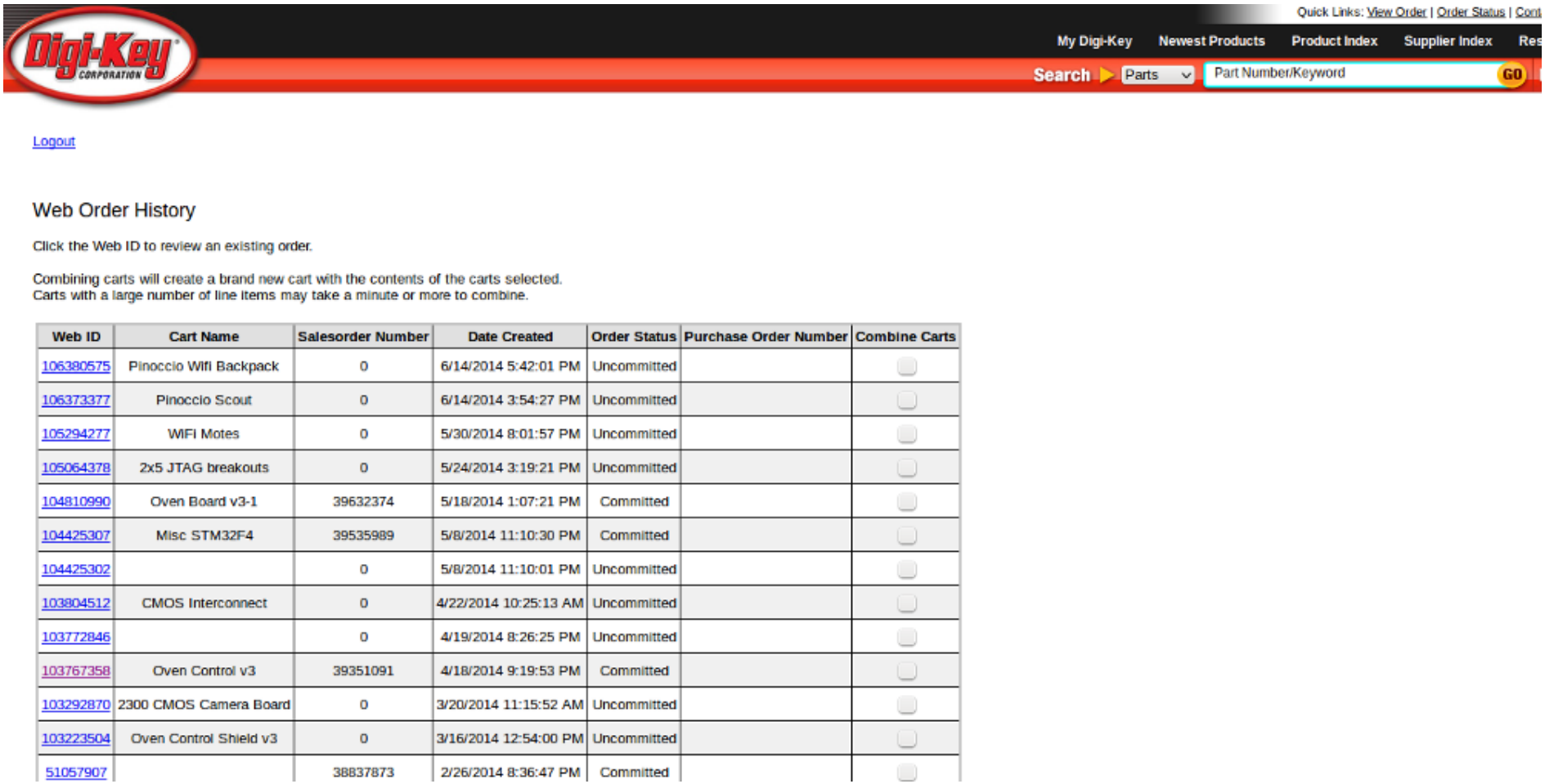
- Eagle

Using Digikey



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Click the Web ID to review an existing order.

Combining carts will create a brand new cart with the contents of the carts selected.
Carts with a large number of line items may take a minute or more to combine.

Web ID	Cart Name	Salesorder Number	Date Created	Order Status	Purchase Order Number	Combine Carts
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105294277	WIFI Motes	0	5/30/2014 8:01:57 PM	Uncommitted		
105064378	2x5 JTAG breakouts	0	5/24/2014 3:19:21 PM	Uncommitted		
104810990	Oven Board v3-1	39632374	5/18/2014 1:07:21 PM	Committed		
104425307	Misc STM32F4	39535989	5/8/2014 11:10:30 PM	Committed		
104425302		0	5/8/2014 11:10:01 PM	Uncommitted		
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103772846		0	4/19/2014 8:26:25 PM	Uncommitted		
103767358	Oven Control v3	39351091	4/18/2014 9:19:53 PM	Committed		
103292870	2300 CMOS Camera Board	0	3/20/2014 11:15:52 AM	Uncommitted		
103223504	Oven Control Shield v3	0	3/16/2014 12:54:00 PM	Uncommitted		
51057907		38837873	2/26/2014 8:36:47 PM	Committed		

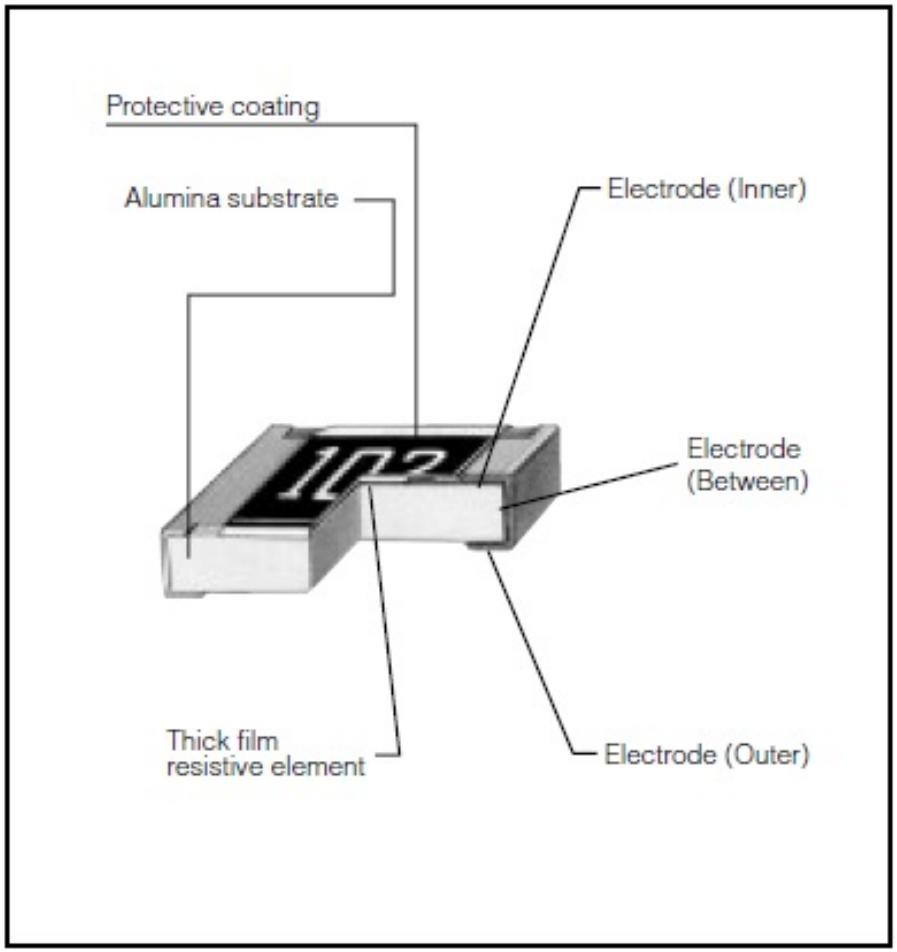
Using Digikey

All prices are in US dollars.

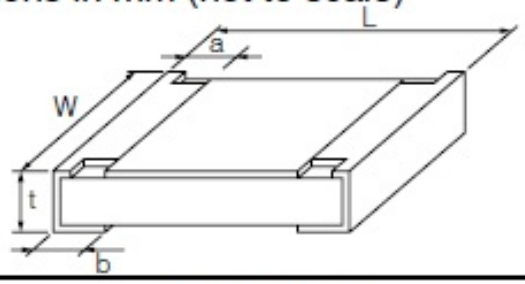
Index	Quantity	Image	Part Number	Description	Customer Reference	Available Quantity	Backorder Quantity	Unit Price	Extended Price
1	250		1276-3485-1-ND	RES 10K OHM 1/10W 1% 0603		250 Immediate	0	0.00444	$1.11
2	250		1276-3484-1-ND	RES 1K OHM 1/10W 1% 0603		250 Immediate	0	0.00444	$1.11
3	10		FDV305NCT-ND	MOSFET N-CH 20V 0.9A SOT-23		0 Immediate	**10** Lead Time	0.41300	$4.13
4	25		516-3074-1-ND	LED CHIP GAP HER DIFFUSED TOP MT		25 Immediate	0	0.32640	$8.16
5	10		MAX31855KASA+-ND	IC CONV THERMOCOUPLE-DGTL SOIC		0 Immediate	**10** Lead Time	4.27500	$42.75
6	50		A98333-ND	TERM BLOCK 2POS SIDE ENT 2.54MM		50 Immediate	0	0.72420	$36.21
7	100		399-1091-1-ND	CAP CER 10000PF 50V 10% X7R 0603		100 Immediate	0	0.00900	$0.90

Panasonic Thick Film Chip Resistors

■ Construction



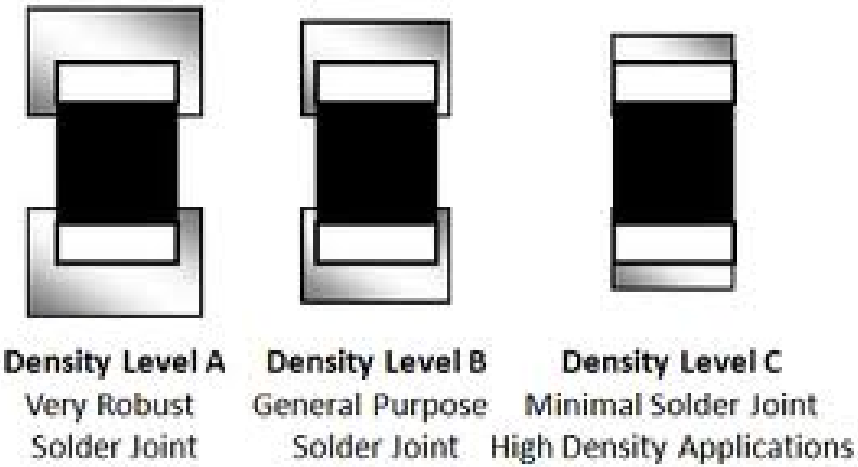
■ Dimensions in mm (not to scale)



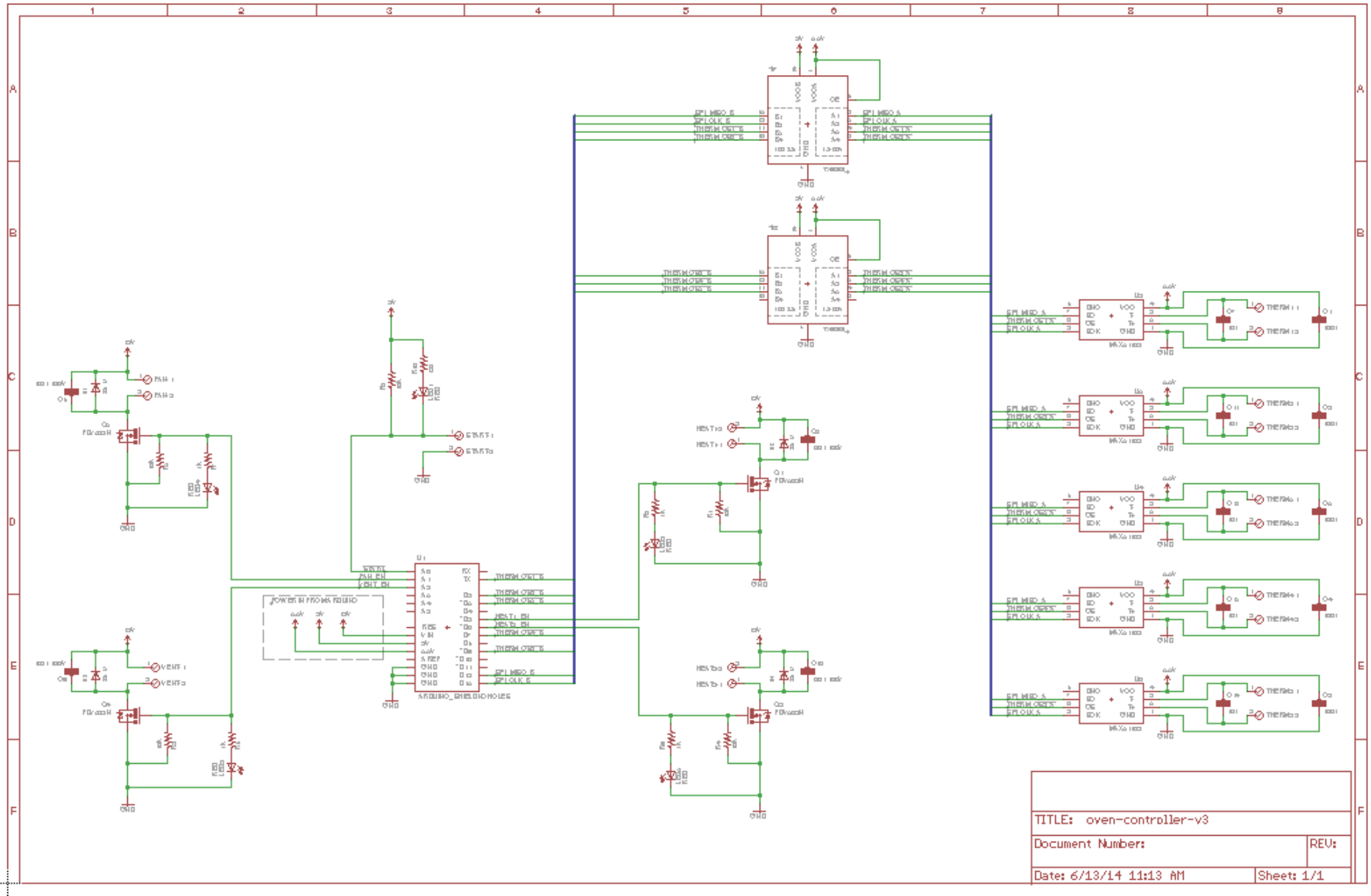
Type (inches)	Dimensions (mm)					Mass (Weight) (g/1000 pcs.)
	L	W	a	b	t	
ERJXG (01005)	$0.40^{\pm0.02}$	$0.20^{\pm0.02}$	$0.10^{\pm0.03}$	$0.10^{\pm0.03}$	$0.13^{\pm0.02}$	0.04
ERJ1G (0201)	$0.60^{\pm0.03}$	$0.30^{\pm0.03}$	$0.10^{\pm0.05}$	$0.15^{\pm0.05}$	$0.23^{\pm0.03}$	0.15
ERJ2G (0402)	$1.00^{\pm0.05}$	$0.50^{\pm0.05}$	$0.20^{\pm0.10}$	$0.25^{\pm0.05}$	$0.35^{\pm0.05}$	0.8
ERJ3G (0603)	$1.60^{\pm0.15}$	$0.80^{+0.15}_{-0.05}$	$0.30^{\pm0.20}$	$0.30^{\pm0.15}$	$0.45^{\pm0.10}$	2
ERJ6G (0805)	$2.00^{\pm0.20}$	$1.25^{\pm0.10}$	$0.40^{\pm0.20}$	$0.40^{\pm0.20}$	$0.60^{\pm0.10}$	4
ERJ8G (1206)	$3.20^{+0.05}_{-0.20}$	$1.60^{+0.05}_{-0.15}$	$0.50^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	10
ERJ14 (1210)	$3.20^{\pm0.20}$	$2.50^{\pm0.20}$	$0.50^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	16
ERJ12 (1812)	$4.50^{\pm0.20}$	$3.20^{\pm0.20}$	$0.50^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	27
ERJ12Z (2010)	$5.00^{\pm0.20}$	$2.50^{\pm0.20}$	$0.60^{\pm0.20}$	$0.60^{\pm0.20}$	$0.60^{\pm0.10}$	27
ERJ1T (2512)	$6.40^{\pm0.20}$	$3.20^{\pm0.20}$	$0.65^{\pm0.20}$	$0.60^{\pm0.20}$	$0.60^{\pm0.10}$	45

Working with Parts

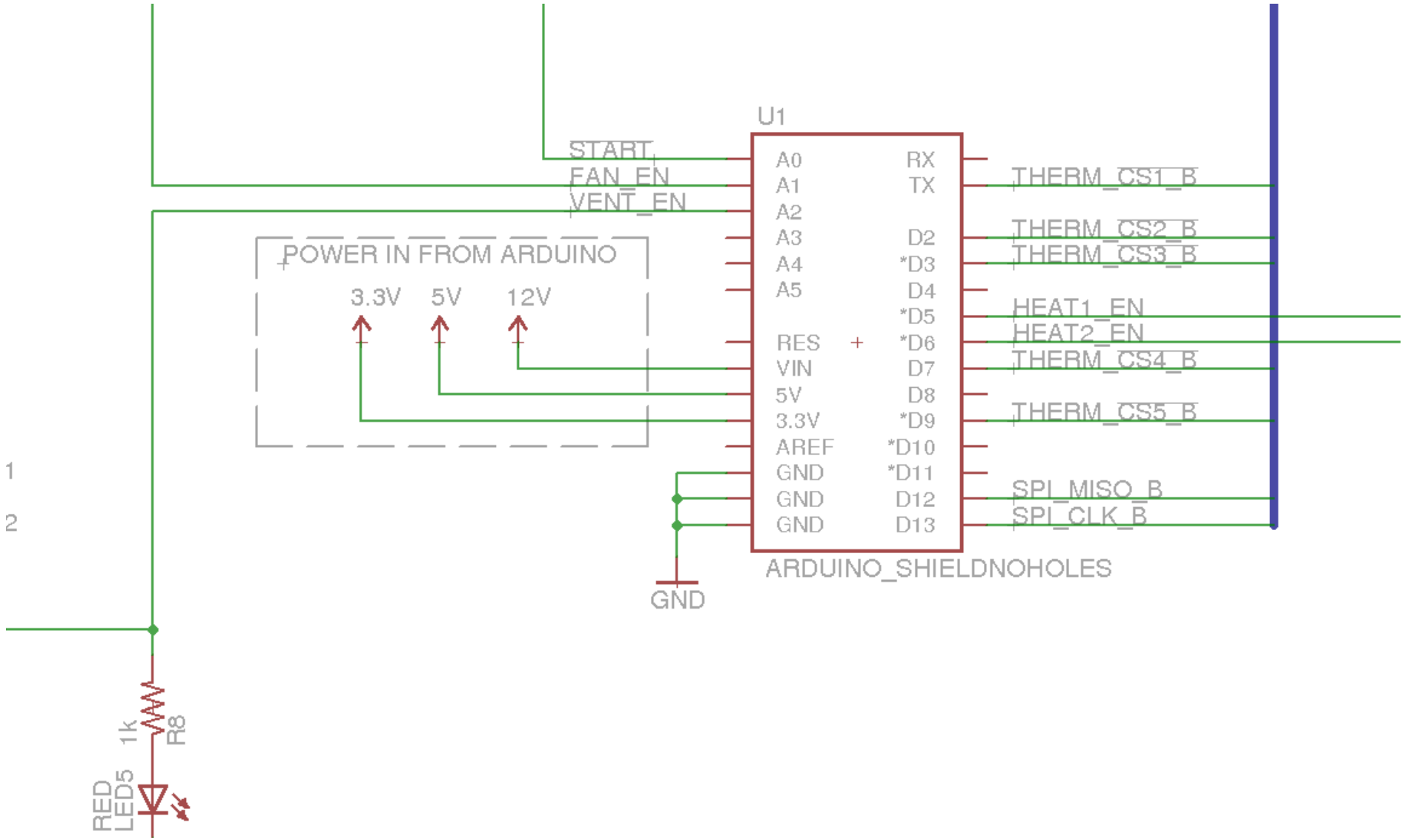
1. Temperature Coefficients
2. Storage (ESD, boxes)
3. Heat and humidity



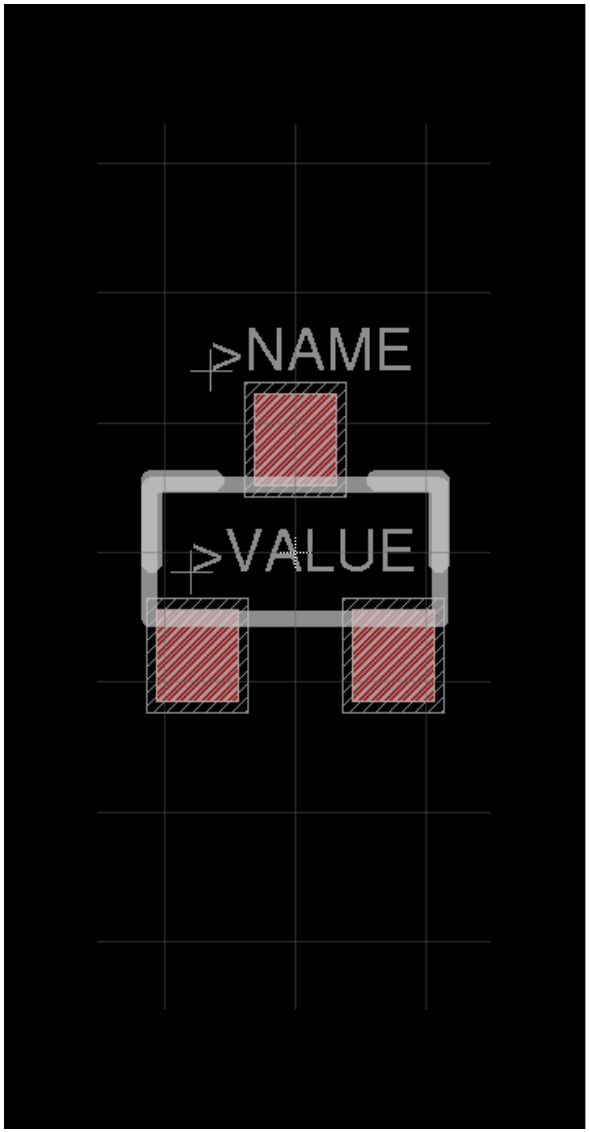
Update the circuit

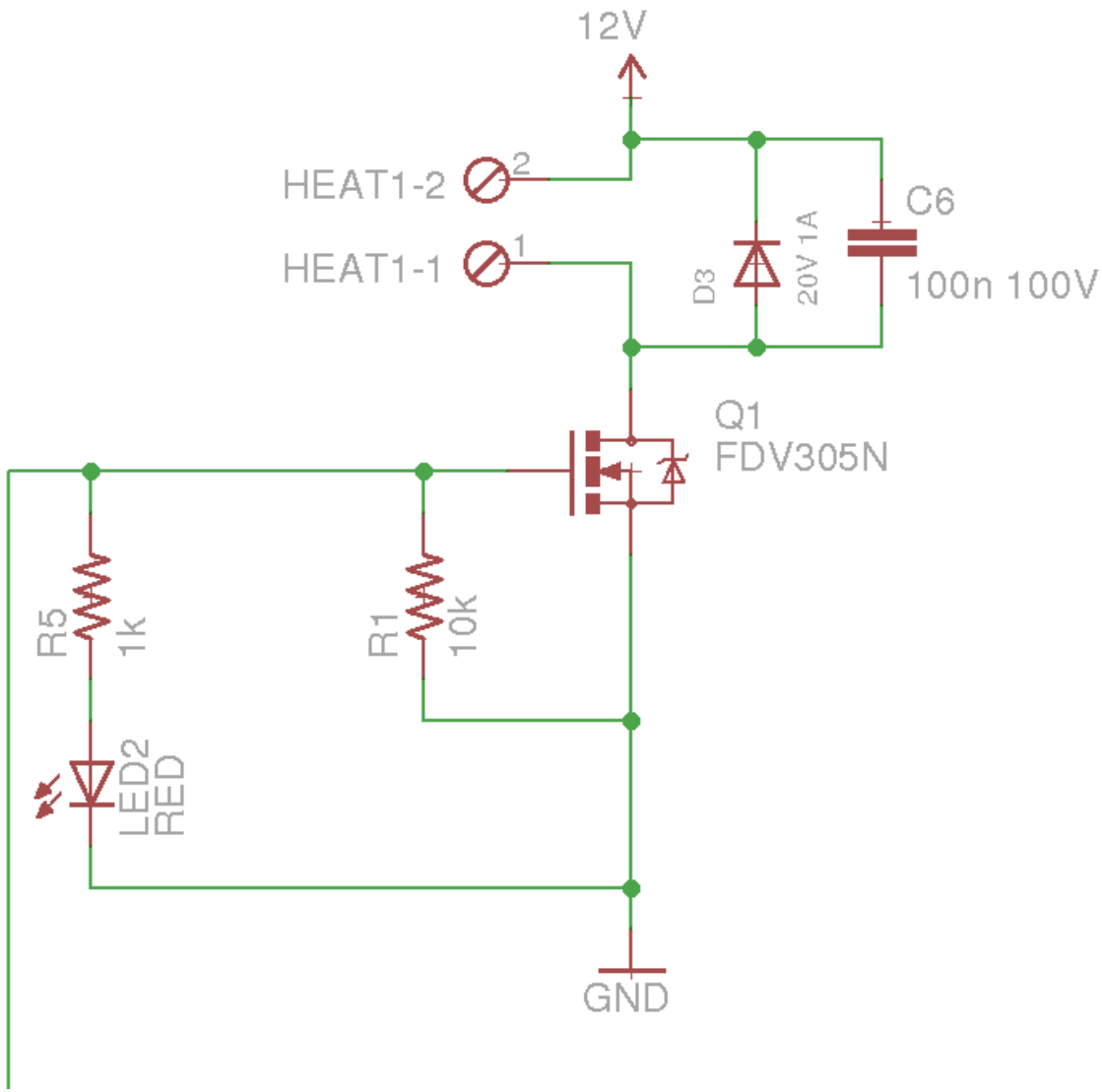


Update the circuit



Example: FDV305N





The footprint is a lie

Land pattern

FAIRCHILD SEMICONDUCTOR®

January 2003

FDV305N

FDV305N

20V N-Channel PowerTrench® MOSFET

General Description

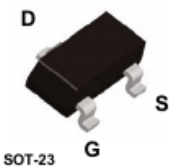
This 20V N-Channel MOSFET uses Fairchild's high voltage PowerTrench process. It has been optimized for power management applications.

Applications

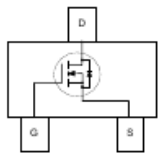
- Load switch
- Battery protection
- Power management

Features

- 0.9 A, 20 V $R_{DS(ON)}$ = 220 mΩ @ V_{GS} = 4.5 V
  $R_{DS(ON)}$ = 300 mΩ @ V_{GS} = 2.5 V
- Low gate charge
- Fast switching speed
- High performance trench technology for extremely low $R_{DS(ON)}$



SOT-23



Absolute Maximum Ratings T_A=25°C unless otherwise noted

Symbol	Parameter	Ratings	Units
V_{DSS}	Drain-Source Voltage	20	V
V_{GSS}	Gate-Source Voltage	± 12	V
I_D	Drain Current – Continuous	0.9	A
	– Pulsed	2	
P_D	Maximum Power Dissipation	0.35	W
T_J, T_{STG}	Operating and Storage Junction Temperature Range	–55 to +150	°C

Thermal Characteristics

$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	357	°C/W

Package Marking and Ordering Information

Device Marking	Device	Reel Size	Tape width	Quantity
305	FDV305N	7"	8mm	3000 units

FDV305N

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
Off Characteristics						
BV_{DSS}	Drain–Source Breakdown Voltage	V_{GS} = 0 V, I_D = 250 µA	20			V
$\frac{\Delta BV_{DSS}}{\Delta T_J}$	Breakdown Voltage Temperature Coefficient	I_D = 250 µA, Referenced to 25°C		15		mV/°C
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 16 V, V_{GS} = 0 V			1	µA
I_{GSSF}	Gate–Body Leakage, Forward	V_{GS} = 12 V, V_{DS} = 0 V			100	nA
I_{GSSR}	Gate–Body Leakage, Reverse	V_{GS} = –12 V, V_{DS} = 0 V			–100	nA
On Characteristics (Note 2)						
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 250 µA	0.6	1	1.5	V
$\frac{\Delta V_{GS(th)}}{\Delta T_J}$	Gate Threshold Voltage Temperature Coefficient	I_D = 250 µA, Referenced to 25°C		–3		mV/°C
$R_{DS(on)}$	Static Drain–Source On–Resistance	V_{GS} = 4.5 V, I_D = 0.9 A V_{GS} = 2.5 V, I_D = 0.7 A V_{GS} = 4.5V, I_D = 0.9 A, T_J = 125°C		164 235 220	220 300 303	mΩ
$I_{D(on)}$	On–State Drain Current	V_{GS} = 4.5V, V_{DS} = 5 V	1			A
g_{FS}	Forward Transconductance	V_{DS} = 5V, I_D = 0.9 A		3		S
Dynamic Characteristics						
C_{iss}	Input Capacitance	V_{DS} = 10 V, V_{GS} = 0 V, f = 1.0 MHz		109		pF
C_{oss}	Output Capacitance			30		pF
C_{rss}	Reverse Transfer Capacitance			14		pF
Switching Characteristics (Note 2)						
$t_{d(on)}$	Turn–On Delay Time	V_{DD} = 10 V, I_D = 1 A, V_{GS} = 4.5 V, R_{GEN} = 6 Ω		4.5	9	ns
t_r	Turn–On Rise Time			7	14	ns
$t_{d(off)}$	Turn–Off Delay Time			8	16	ns
t_f	Turn–Off Fall Time			1.4	2.8	ns
Q_g	Total Gate Charge	V_{DS} = 10 V, I_D = 0.9 A, V_{GS} = 4.5 V		1.1	1.5	nC
Q_{gs}	Gate–Source Charge			0.26		nC
Q_{gd}	Gate–Drain Charge			0.26		nC
Drain–Source Diode Characteristics and Maximum Ratings						
I_S	Maximum Continuous Drain–Source Diode Forward Current				0.29	A
V_{SD}	Drain–Source Diode Forward Voltage	V_{GS} = 0 V, I_S = 0.29 A		0.75	1.2	V
t_{rr}	Diode Reverse Recovery Time	I_F = 0.9 A, d_F/d_t = 100 A/µs		7.4		nS
Q_{rr}	Diode Reverse Recovery Charge			2.2		nC

Notes:

1. Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%

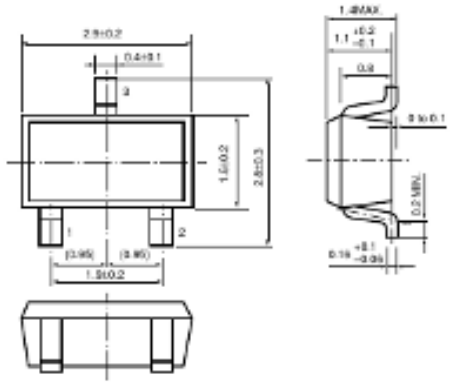
FDV305N Rev D (W)

Land pattern

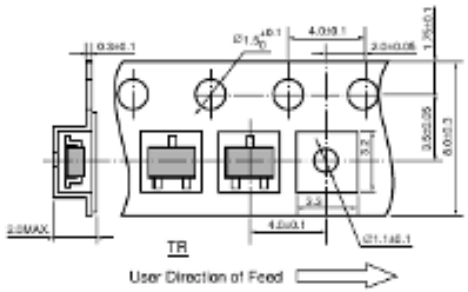
• SOT-23-3 (SC-59A)

Unit: mm

PACKAGE DIMENSIONS



TAPING SPECIFICATION (T1: Standard Type)



PACKAGE INFORMATION PE-SOT-23-3-0510

POWER DISSIPATION (SOT-23-3)

This specification is at mounted on board. Power Dissipation (P_D) depends on conditions of mounting on board.
This specification is based on the measurement at the condition below:
(Power Dissipation (SOT-23-3) is substitution of SOT-23-6.)

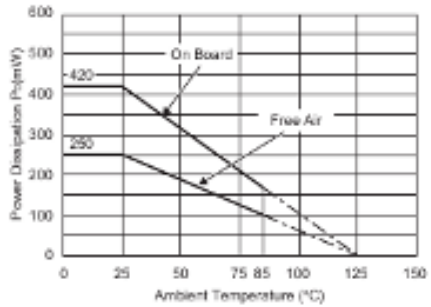
Measurement Conditions

	Standard Land Pattern
Environment	Mounting on Board (Wind velocity=0m/s)
Board Material	Glass cloth epoxy plastic (Double sided)
Board Dimensions	40mm × 40mm × 1.6mm
Copper Ratio	Top side : Approx. 50% , Back side : Approx. 50%
Through-hole	φ0.5mm × 44pcs

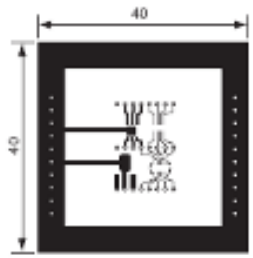
Measurement Result

(Ta=25°C,Tjmax=125°C)

	Standard Land Pattern	Free Air
Power Dissipation	420mW	250mW
Thermal Resistance	θja=(125–25°C)/0.42W=263°C/W	400°C/W



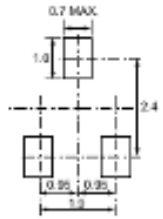
Power Dissipation



Measurement Board Pattern

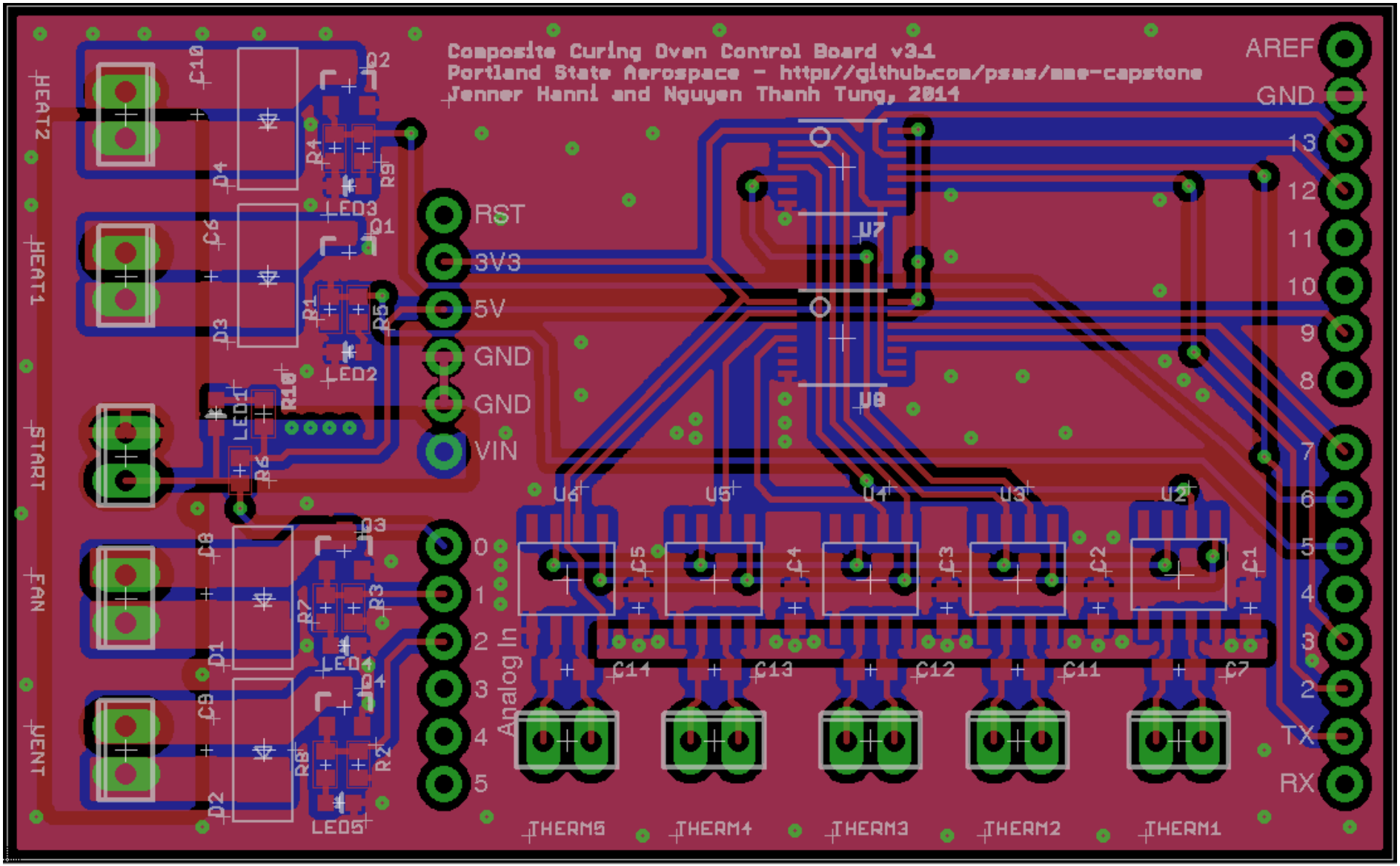
IC Mount Area Unit : mm

RECOMMENDED LAND PATTERN (SOT-23-3)

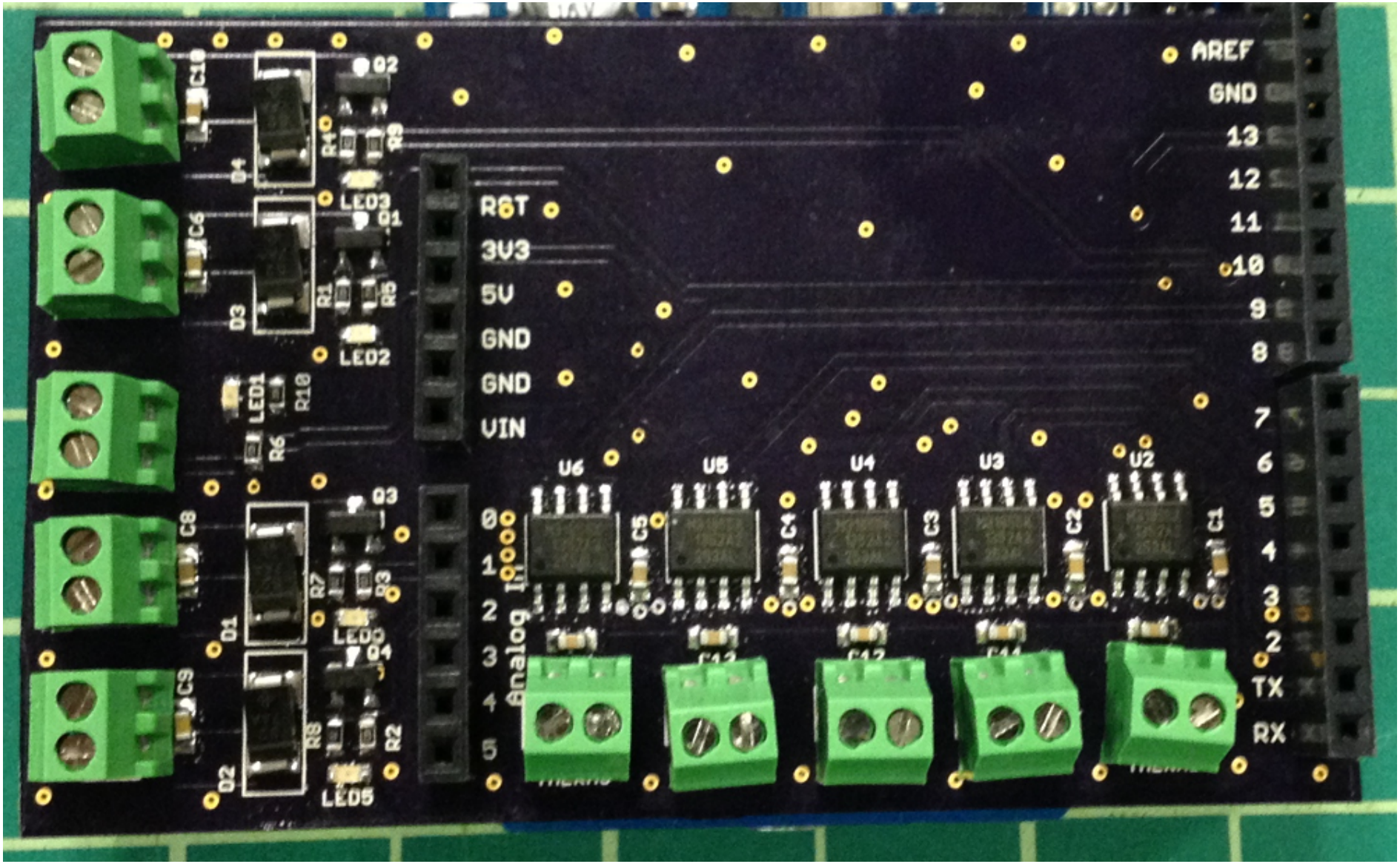


(Unit: mm)

Oven Board v3 Layout



Silkscreen


AREF
GND
13
12
11
10
9
8
7
6
5
4
3
2
TX
RX
RST
3V3
5V
GND
GND
VIN
Analog In
0
1
2
3
4
5
U6
U5
U4
U3
U2
LED3
LED2
LED1
LED0
LED5
Q1
Q2
Q3
Q4
D1
D2
D3
D4
R1
R2
R3
R4
R5
R6
R7
R8
R10
C1
C2
C3
C4
C5
C6
C8
C9
C10

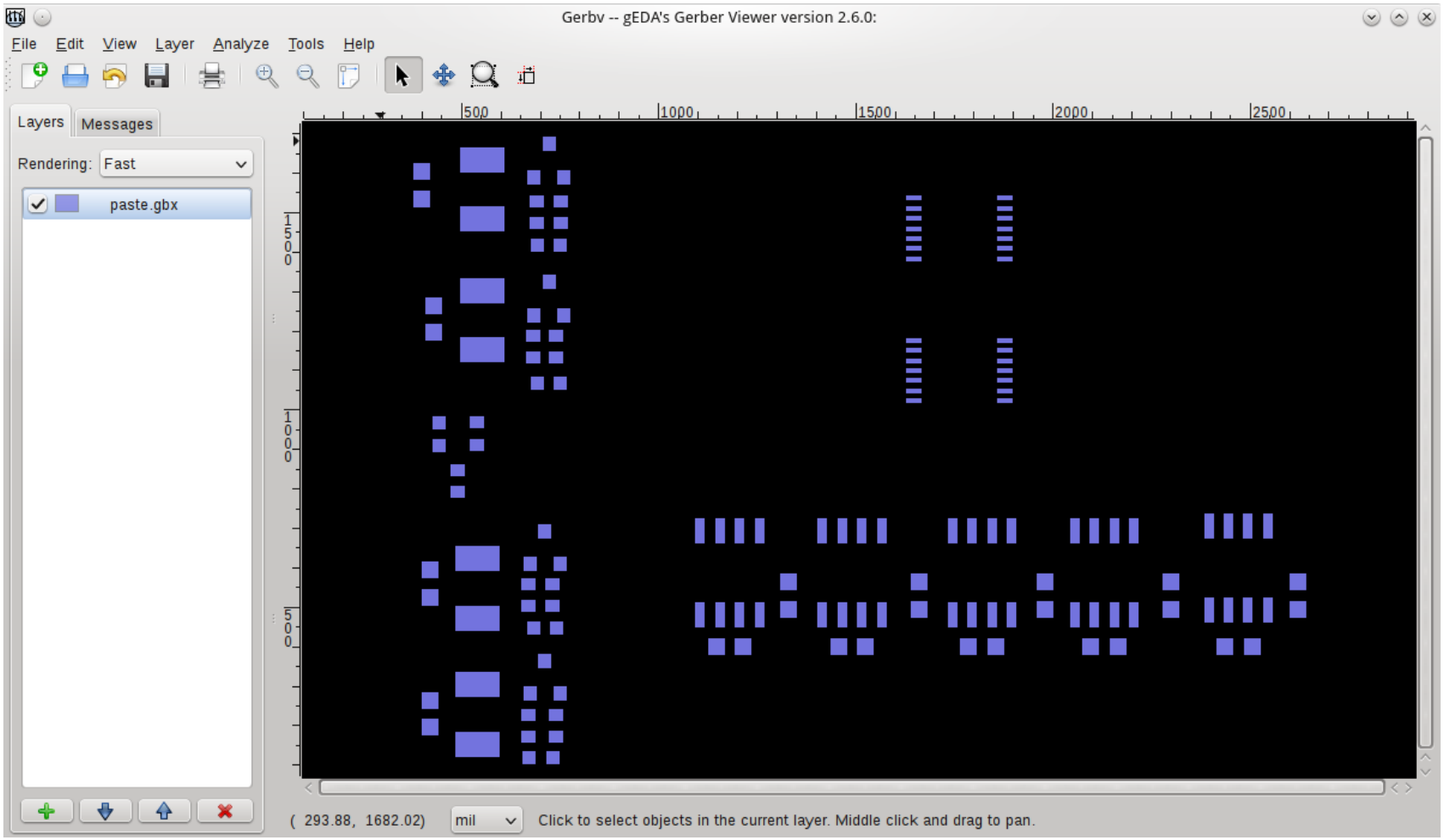
Fab

Order parts, then order the board.

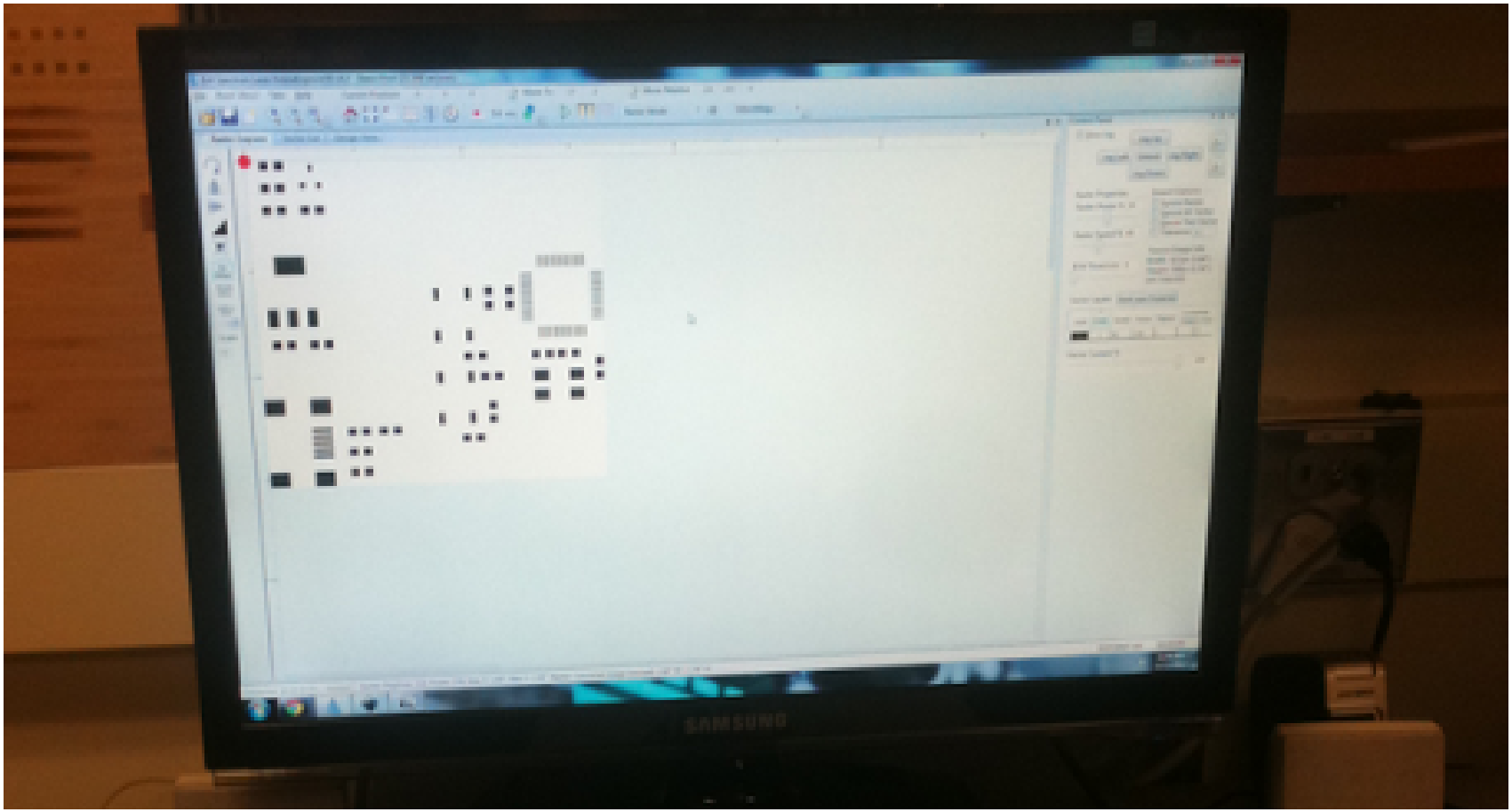
Assembly

1. Make a stencil
2. Secure board in a jig
3. Place stencil on the jig
4. Spread solder paste
5. Remove the stencil
6. Prepare the parts
7. Place the surface mount parts
8. Place in the oven
9. Reflow the board
10. Test the board
11. Hand solder the through-hole parts

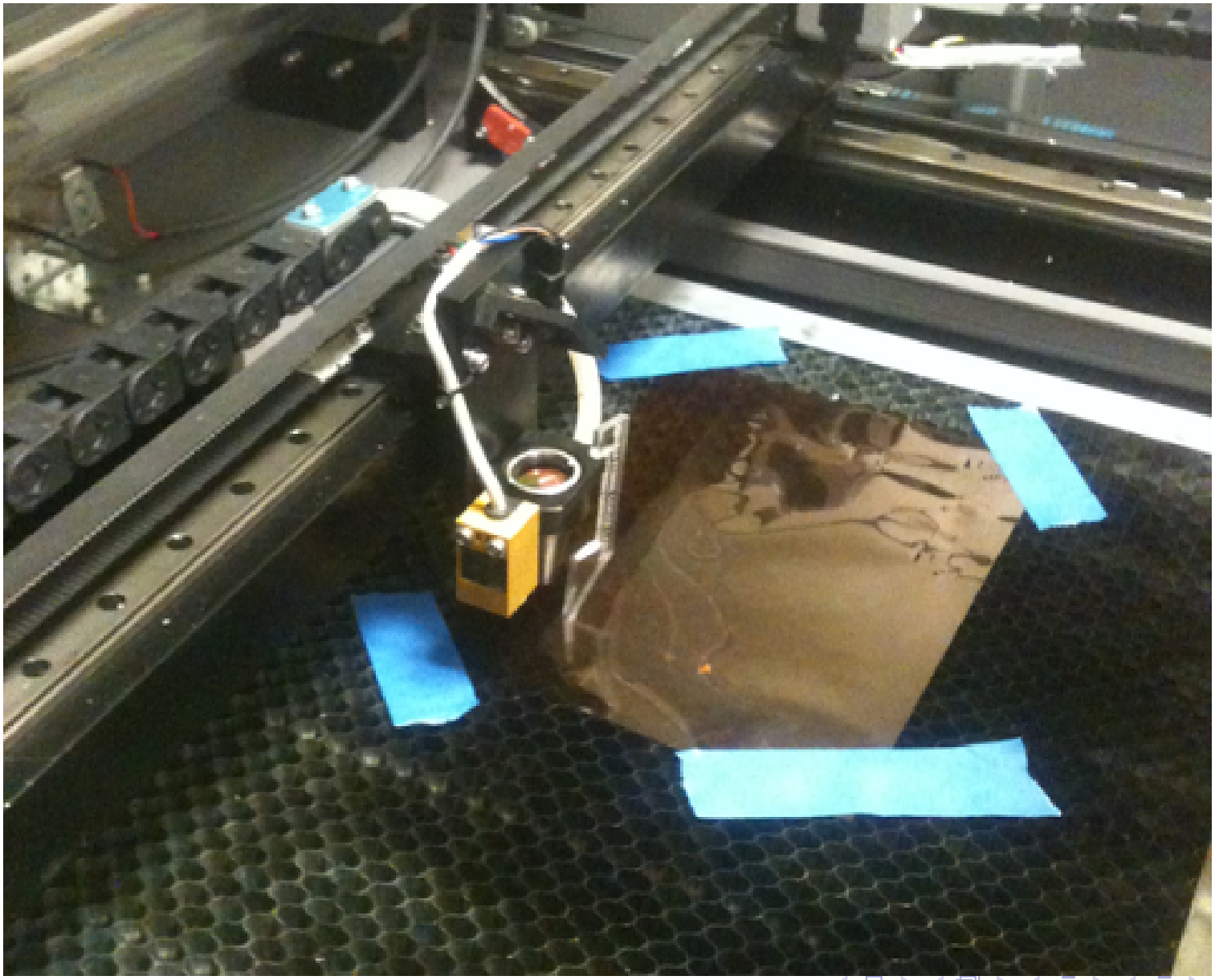
Assembly: Paste Layer



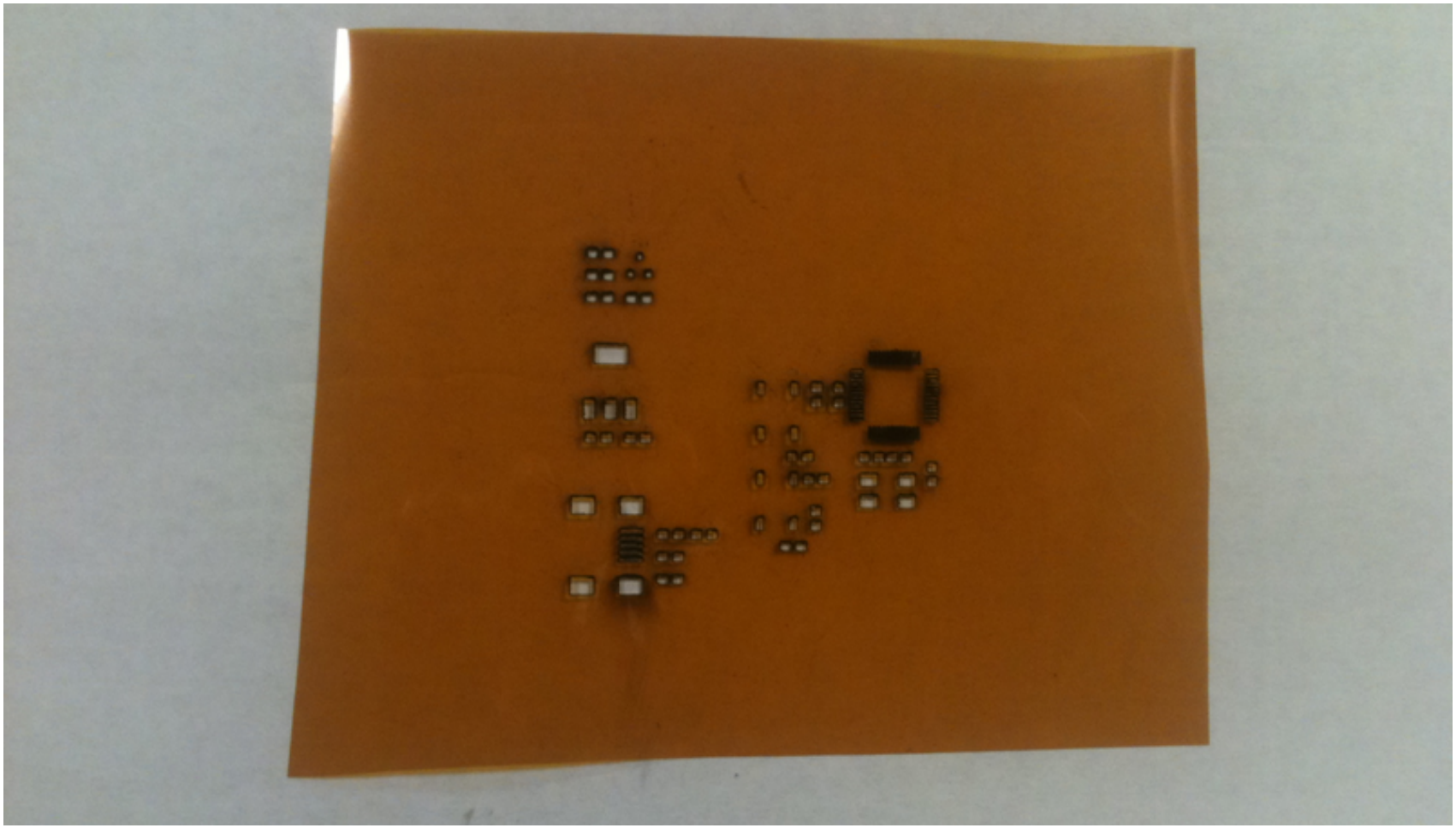
Assembly: Make a Stencil



Assembly: Make a Stencil



Assembly: Make a Stencil

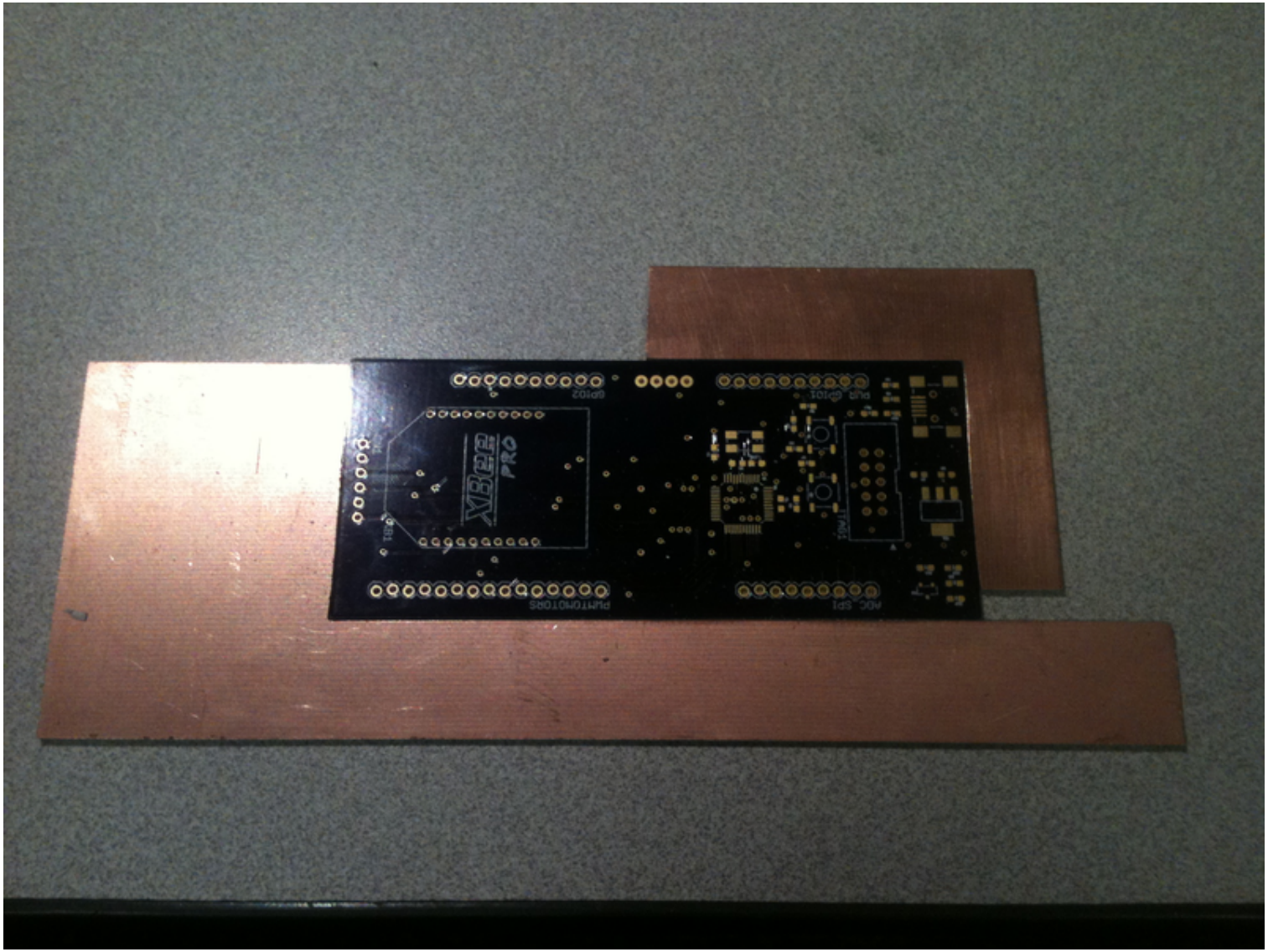


Assembly: Make a Stencil

Assembly: Gather Parts

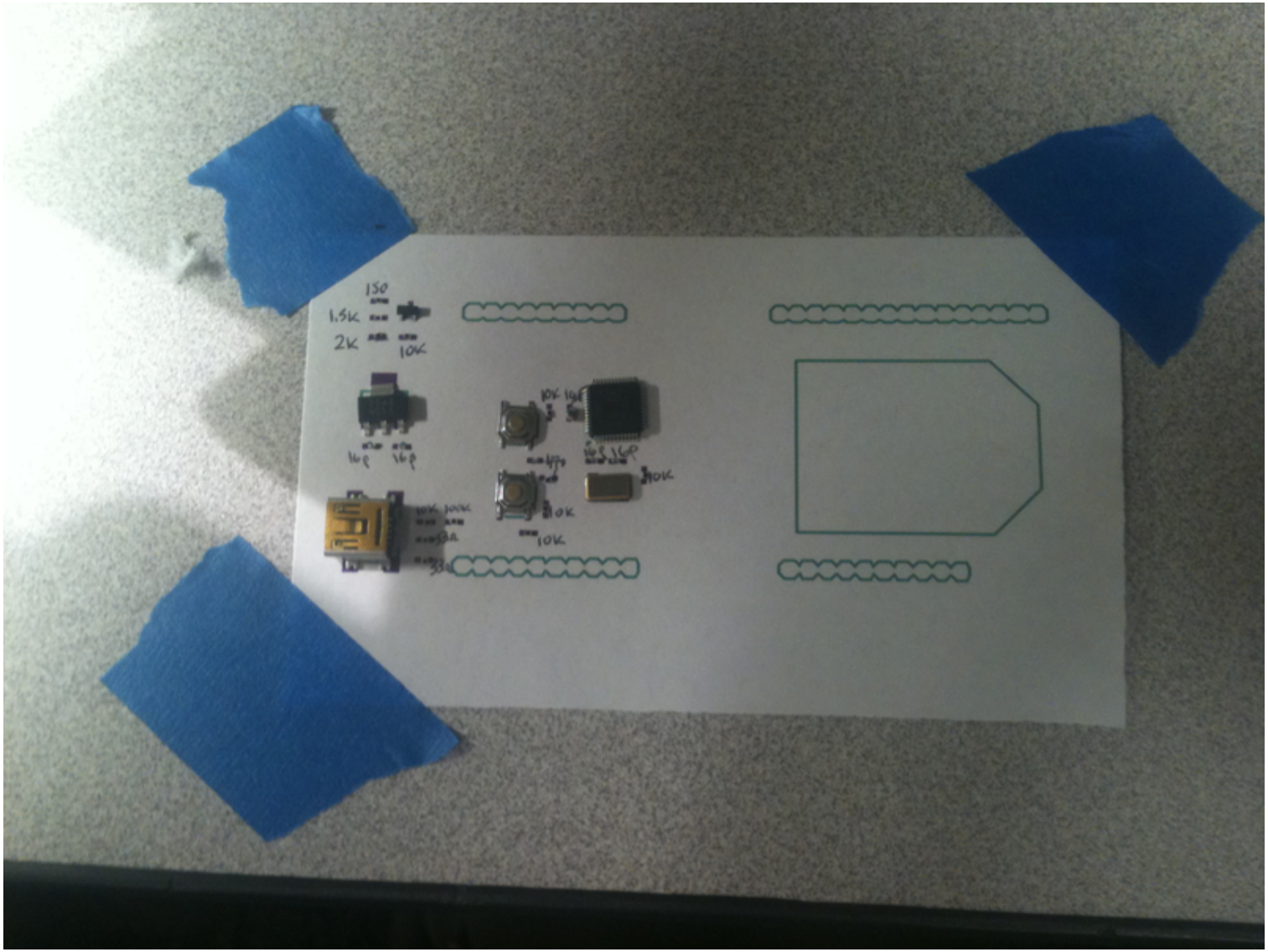
Assembly: Prepare the Board

Assembly: Secure the Board

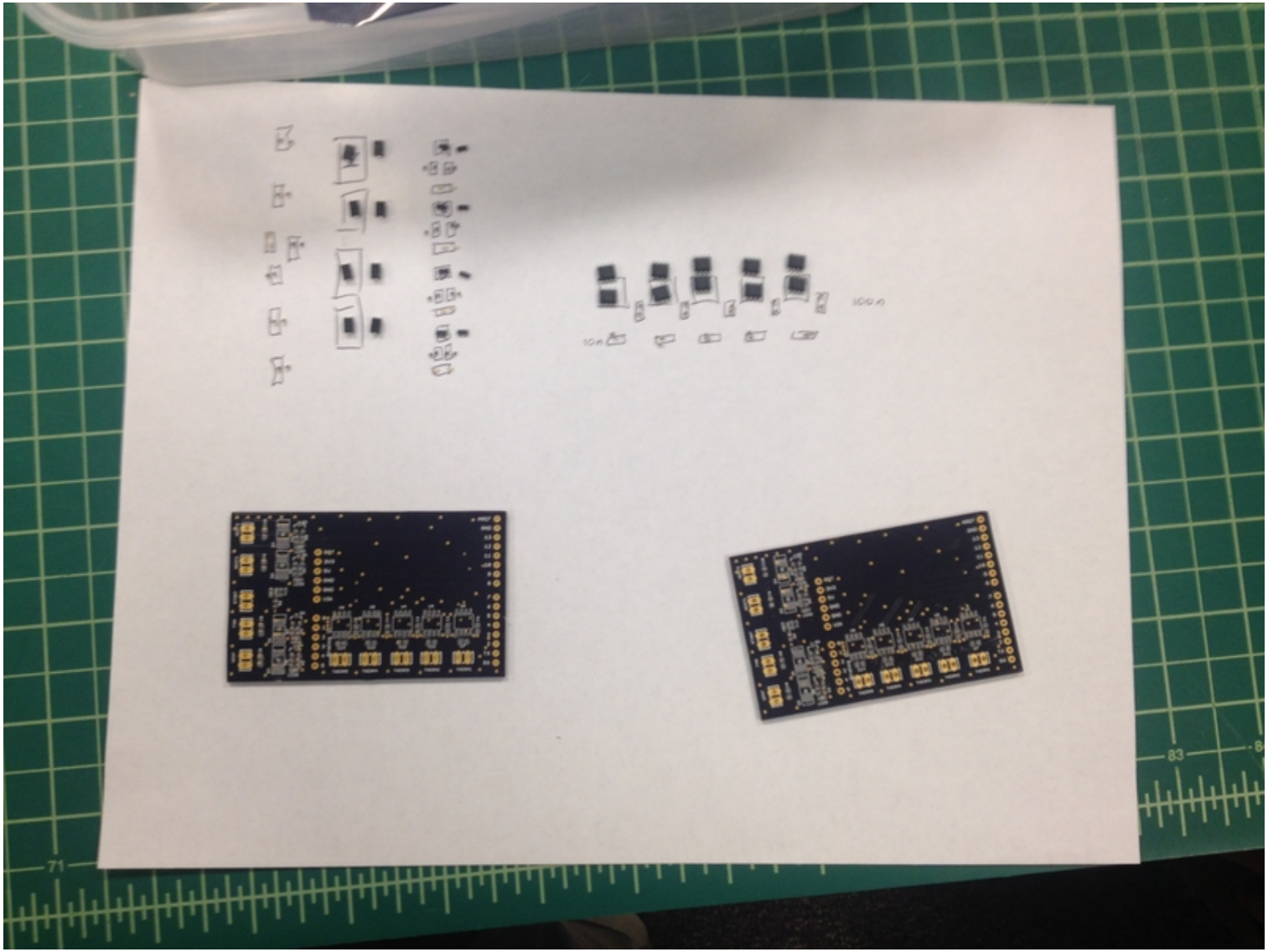


Assembly: Solder Paste

Assembly: Prepare Parts

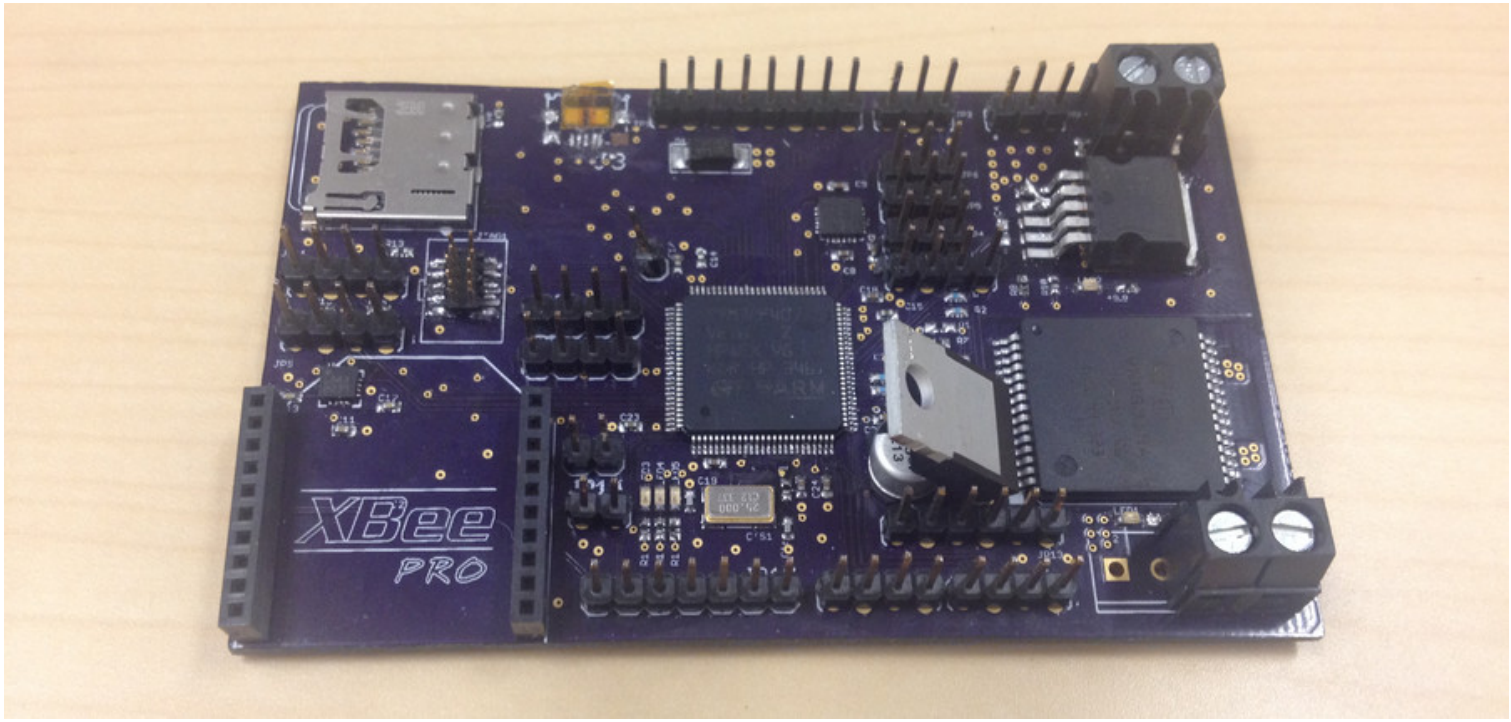


Assembly: Place Parts and Reflow



Assembly: Place Parts and Reflow

Assembly: Place Parts and Reflow



Rework

Wick, flux, solder sucker, vacuum, hot air gun.

All the things

1. IPC-A-610D: Acceptability of Electronics Assemblies
2. Henry Ott's Electromagnetic Compatibility Engineering

3. Sparkfun: http://learn.sparkfun.com
4. Adafruit: http://learn.adafruit.com
5. Oshpark: http://oshpark.com
6. PSU Electronics Prototyping Lab: http://psu-epl.github.io

7. Me: http://jennerhanni.net
8. My Github: http://github.com/wicker

The End