Designing Your Own PC Board

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RVTEC 2020
Zoomland – ver 1.3

Stony Brook University
School *of* Marine and Atmospheric Sciences

Standard Disclaimers

Unless otherwise noted:

- Mention of a company in this presentation does not constitute an official endorsement by the State of New York, the State University of New York, or the School of Marine and Atmospheric Sciences.
- The presenter has no ownership interest in any commercial entity mentioned.

Special Open Ocean Rated "No Chop-Busting" Disclaimers

- The presenter has never dated anyone connected to any mentioned company, nor is this ever likely. Neither have those folks plied him with treats, trinkets, or fancy food and drink.

Anyone who implies otherwise is asking for trouble.

SAFETY, SAFETY, SAFETY

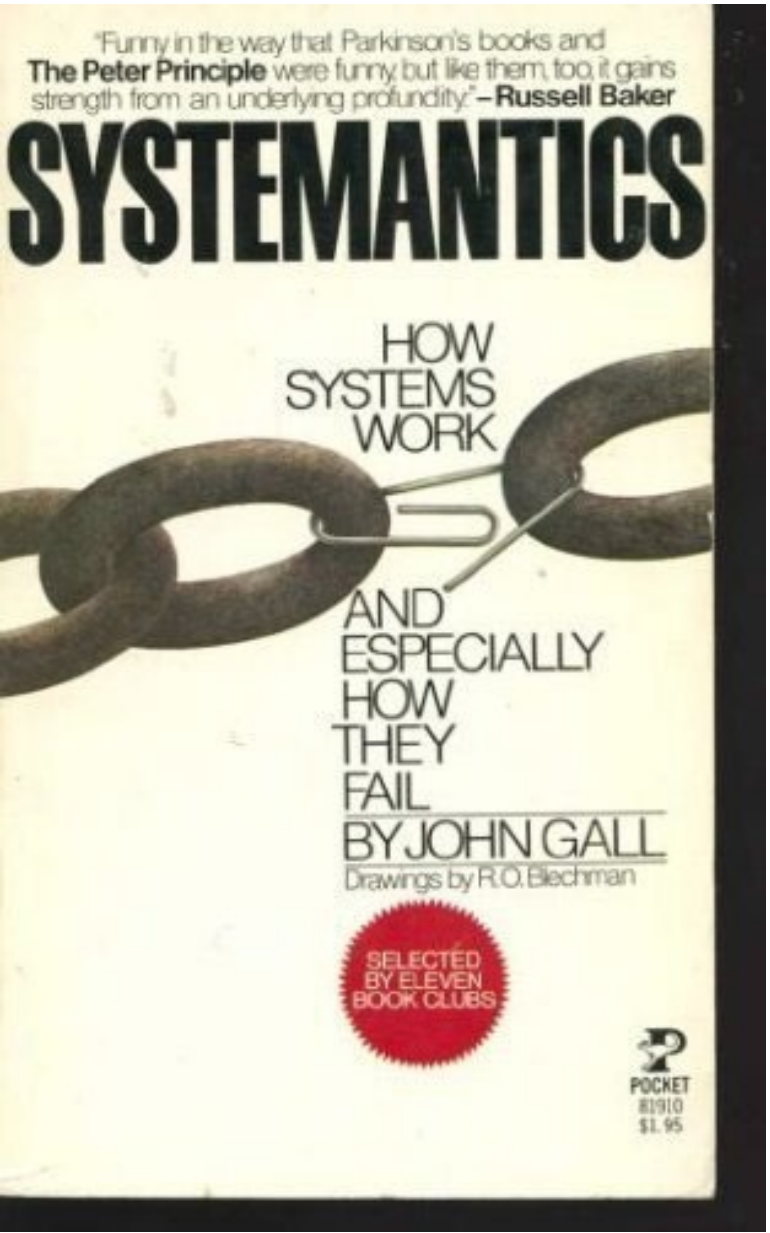
TEST all designs through as wide a range of input conditions as possible.

USE CAUTION with high voltage and high power.

CONSIDER redundant dumb limit controls and other fail safe features.

NOT for human safety applications.

GALL'S LAW



"A complex system that works is invariably found to have evolved from a simple system that worked."

-John Gall (1925-2015)

Pediatrician and author of "Systemantics" (1975)

Large and complex electronic systems are combinations of smaller and less complex electronic systems.

This has many parallels to programming. Well designed electronic subsystems are like programming subroutines, with defined inputs and outputs (and hopefully sanity checks and safety limits).

5:00

Electronic troubleshooting is like code debugging: work down from the total system to locate the specific subsystem that is malfunctioning.

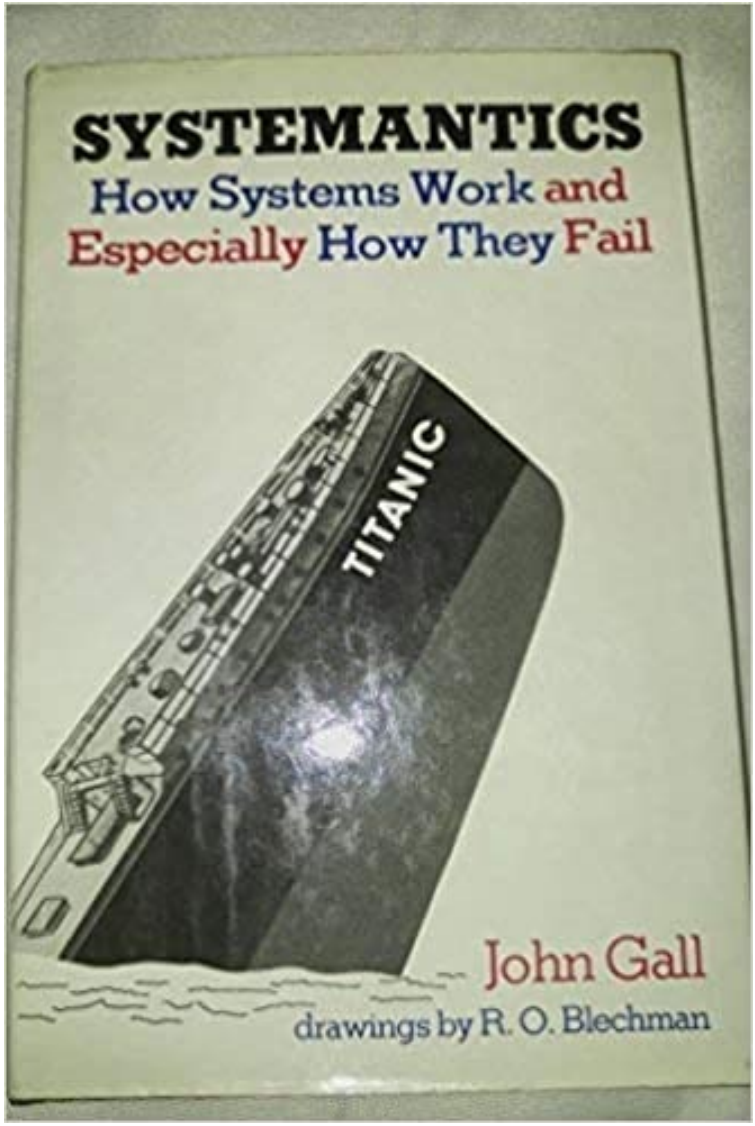
Electronic design is like code writing: design simple, robust, tested subsystems, then combine them to achieve a large and complex result.

If you can learn to write good programs,
You can learn to design electronics!

GALL'S LAW (part 2)

15:00

"A complex system designed from scratch never works and cannot be patched up to make it work. You have to start over, beginning with a working simple system."



Step 1: Make a Design

Getting Started in Electronic Design

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https://www.unols.org/sites/default/files/2018inm_Wilson_Tom_ElectronicDesign_101818.pdf

"THIS IS IT - THE TIME TO FINISH YOUR NOVEL"

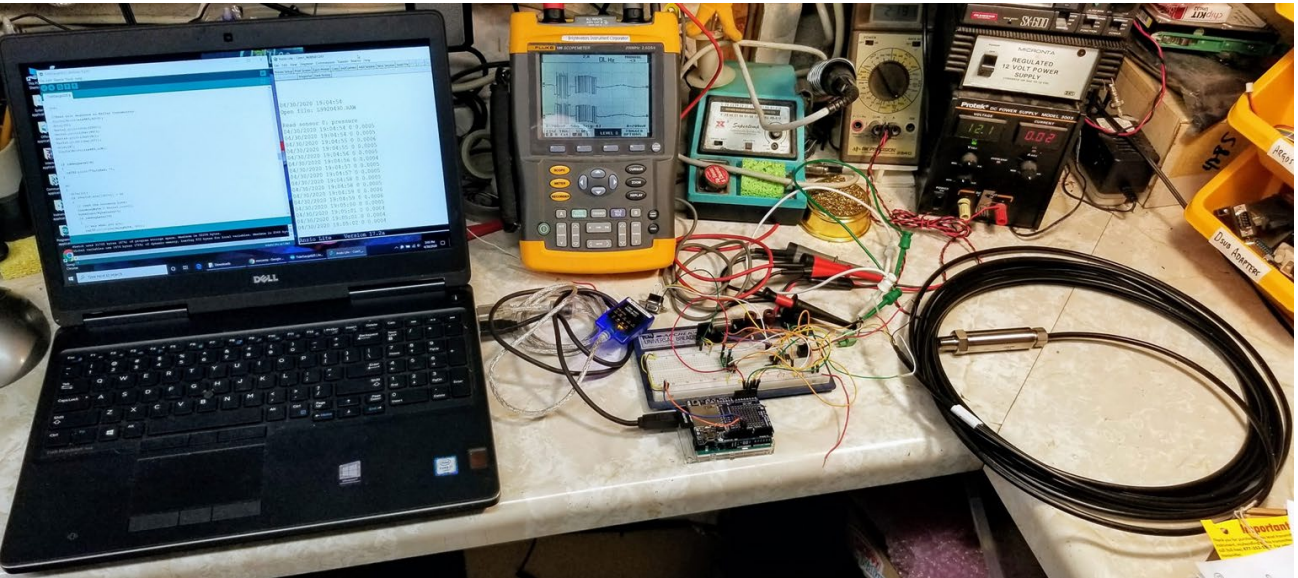
Caption of *The New Yorker* Daily Cartoon, April 29, 2020 by Hilary Allison

Tom's Pandemic Novel
"The Really Useful Datalogger Board"

High Level Specifications

- Arduino based (no single point of failure in the supply chain).
- Real time clock.
- Temperature and humidity sensor to monitor enclosure.
- SD card data storage.
- Wide range input voltage.
- Battery check circuit.
- Operable from solar power.
- Multiple RS232 interfaces.
- RS485 interface with switched sensor power.
- Switched power channels for external equipment (e.g. telemetry).
- 100% Parts I could actually get during a pandemic.
- Completed on budget and in time for inclusion in 5 new environmental stations deploying in summer 2020.

April 2020 in my basement workshop - aka “The Dungeon”

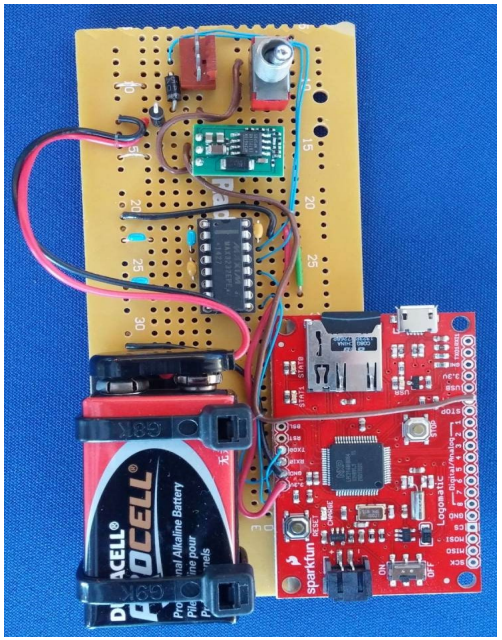


Protoboard
Proof of Concept

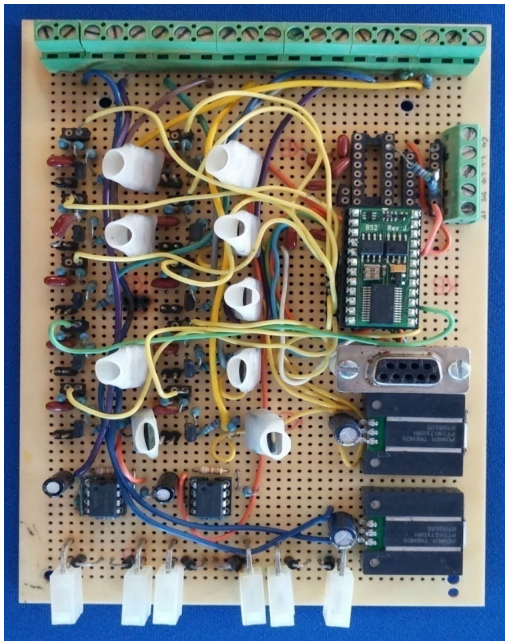
10:00

Option 2a - Hand Wiring

GPS logger



Met buoy power control



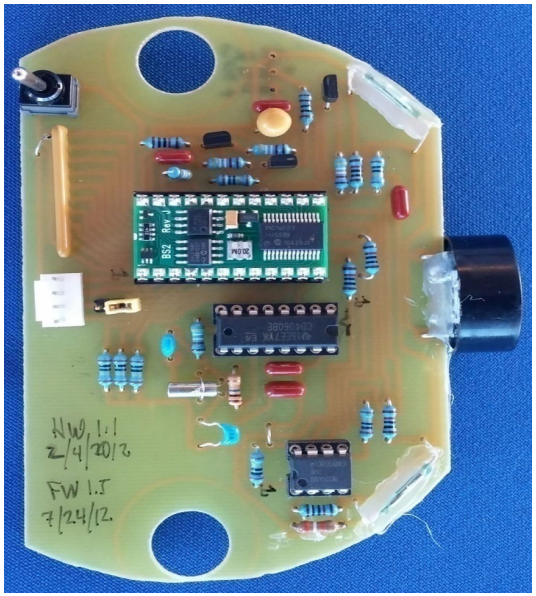
Do not disrespect hand wiring.
It's not a prototype, it's a one-off!
But the problem comes when you need a second "one-off" (field damage), and then a third, and so on.
In my experience, the breakeven point for designing a PCB versus hand wiring is somewhere between 2 and 3 boards.

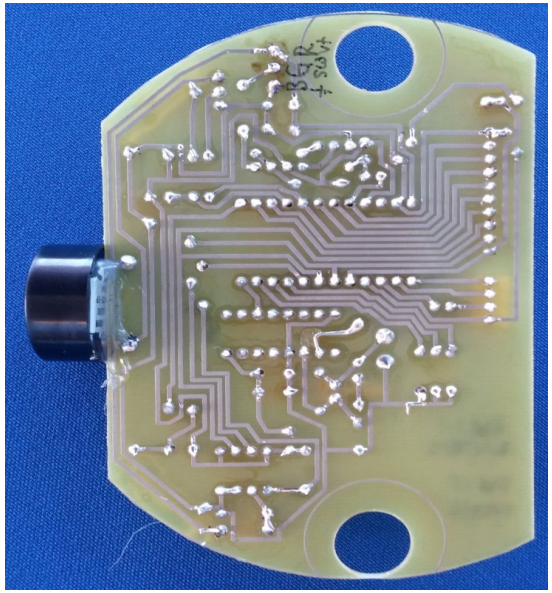
Option 2b - In-house PC Boards

“Desktop PCB Fabrication” – RVTEC 2004

https://www.unols.org/sites/default/files/200411rvtap37.pdf

Challenger deep sea pump replacement timer board





In-house PCBs time has passed.

Double sided boards are a pain.

It takes chemicals, time, and practice to develop the skill set.

You also need to work at odd hours so your spouse/significant other doesn’t see what you are doing in the kitchen sink.

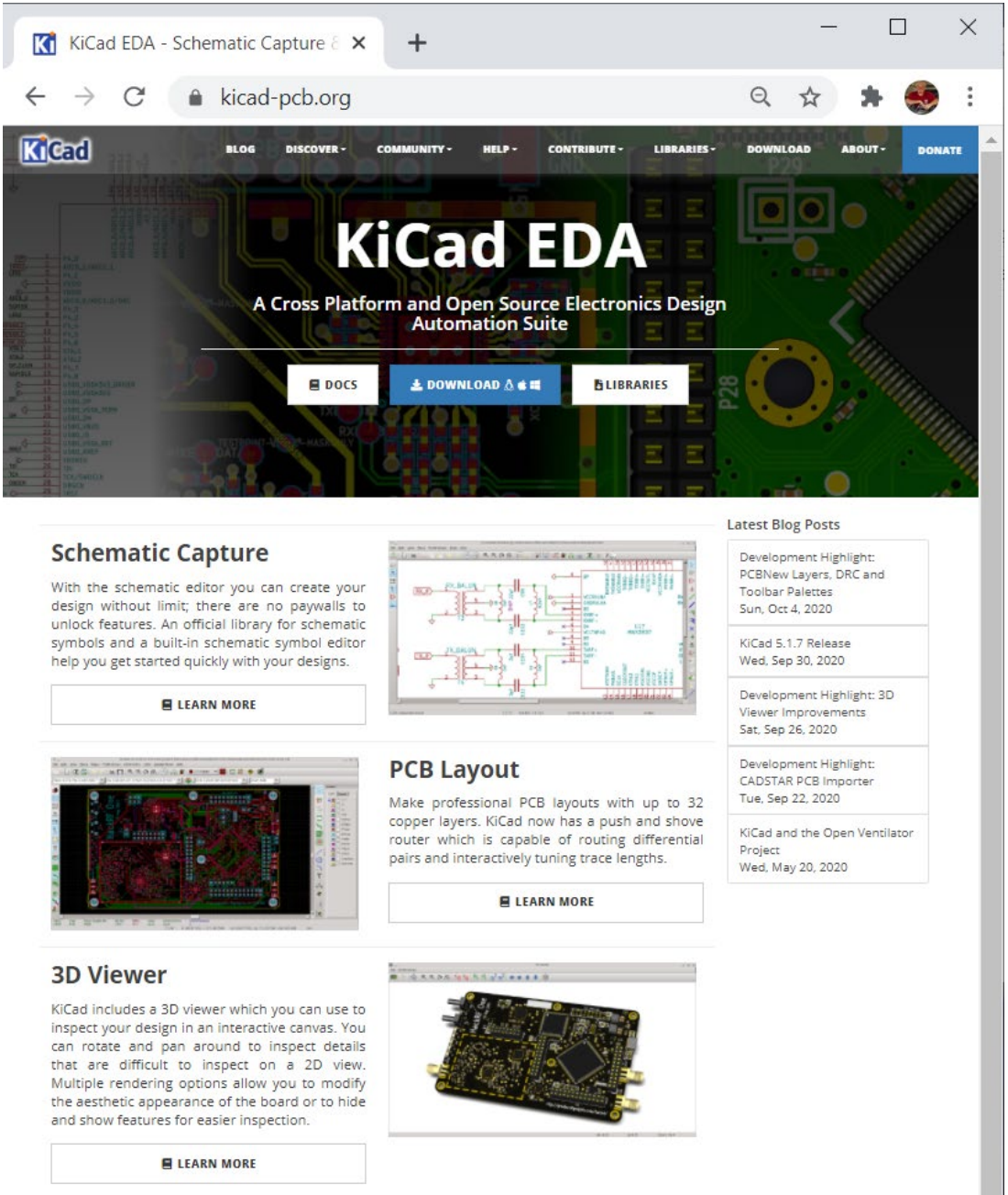
Option 2c - Commercial Board House

**Many manufacturers now offer online ordering,
low minimums, and quick turnaround.**

Multilayer boards, plated through holes, solder mask, and silk screen.

**Today's lesson: 2 layer bare boards, through hole components (mostly).
SMT and assembled boards left as an "exercise for the student."**

Electronics Design Automation (EDA) Software



KiCAD: kicad-pcb.org

Cross platform, open source, community supported, FREE.

EAGLE: from AutoDesk.com

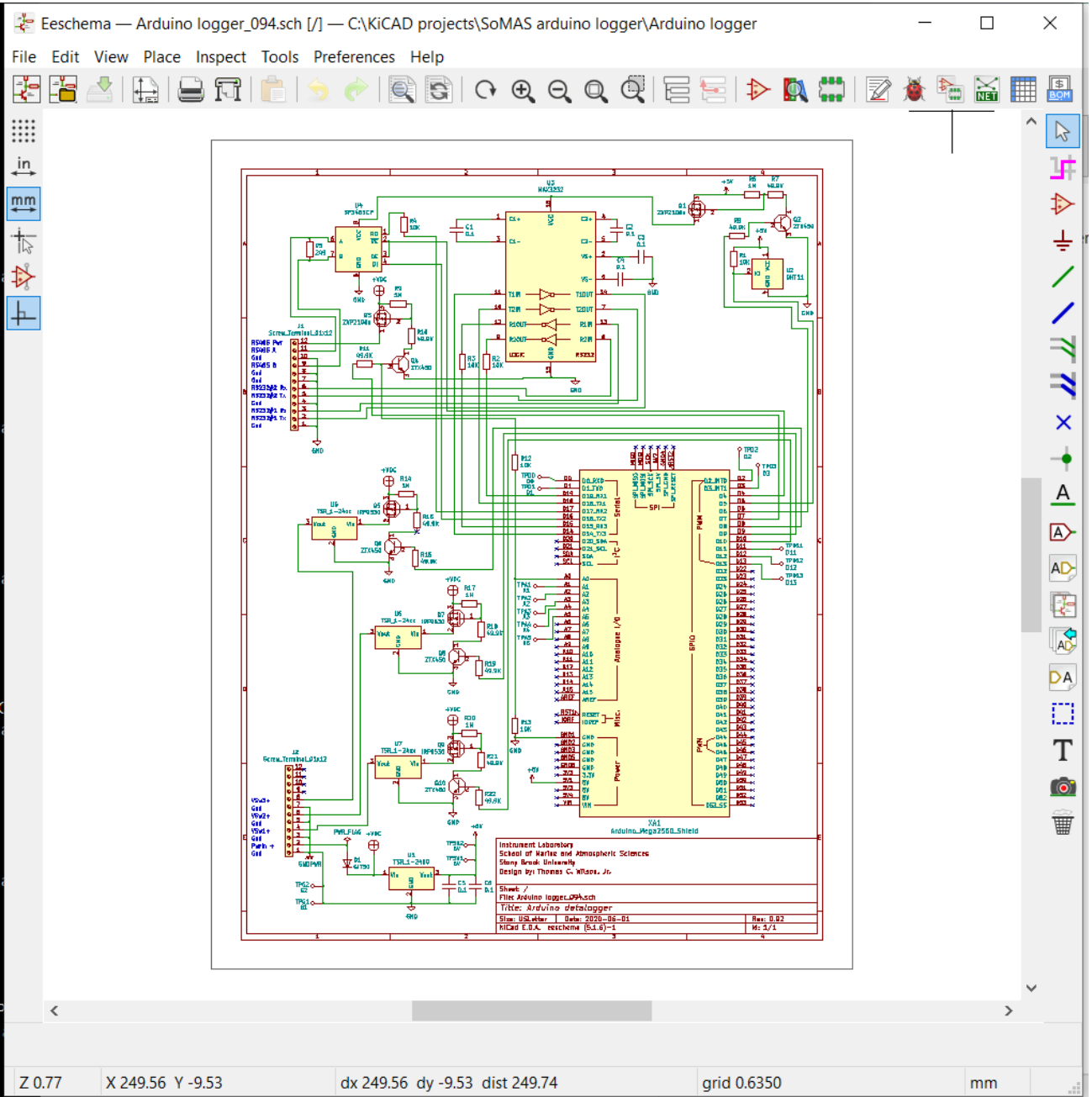
Commercial standard

Free version: 2 layers, 12 in^2 board

Full version: $60/month, $495/yr.

Beware of "free PCB design" software offered by a PCB vendor - it usually traps your files with that vendor.

Schematic Layout

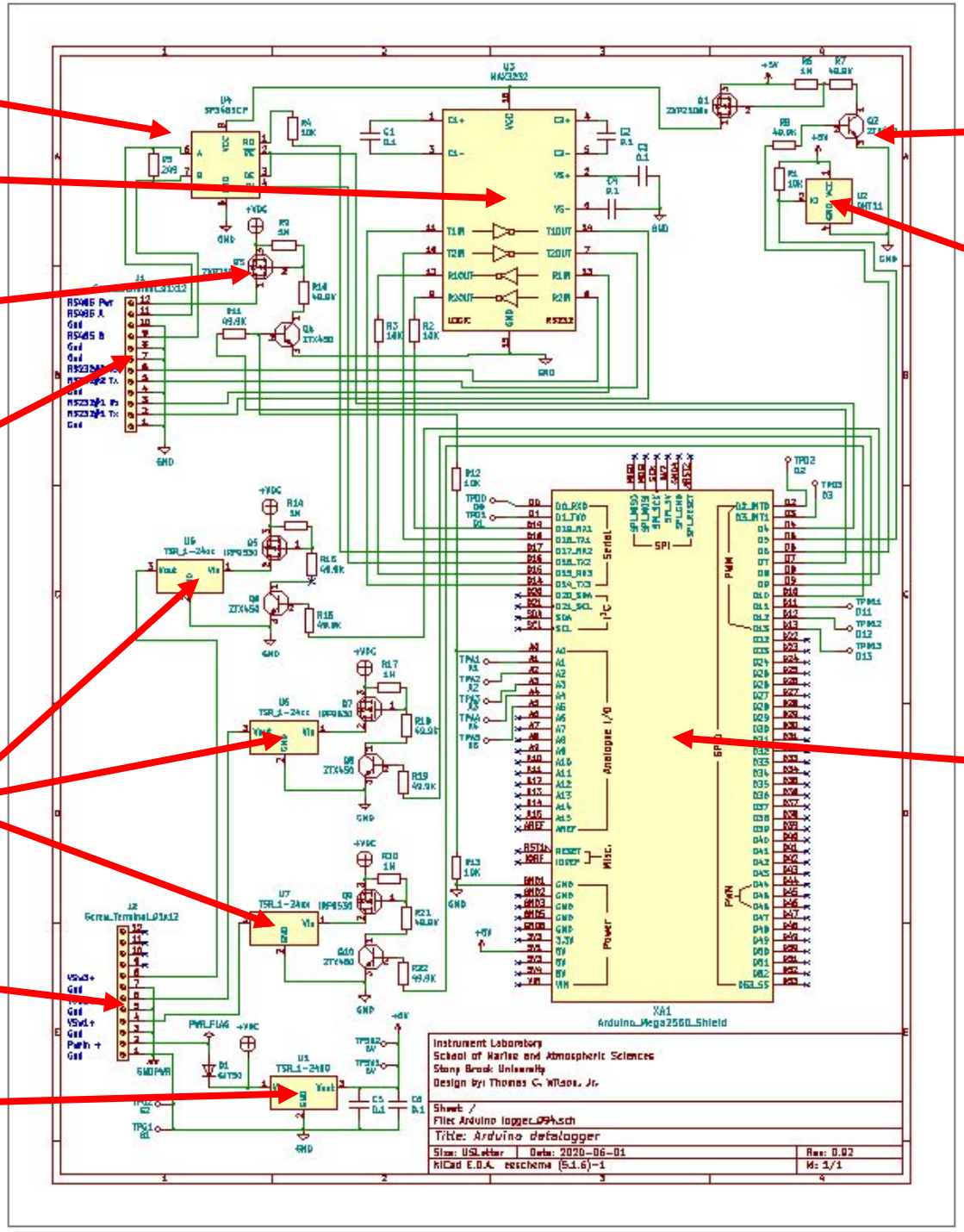


Guaranteed to impress your supervisor!

(presuming they said you could work on it)

Does it look a little scary? Remember Gall's Law!

15:00



A COMPLEX SYSTEM MADE UP OF TWELVE SIMPLER SYSTEMS

Not shown:
Off-the-shelf Real Time Clock + SD memory card "shield"
(OK, those are simpler systems 13 and 14)

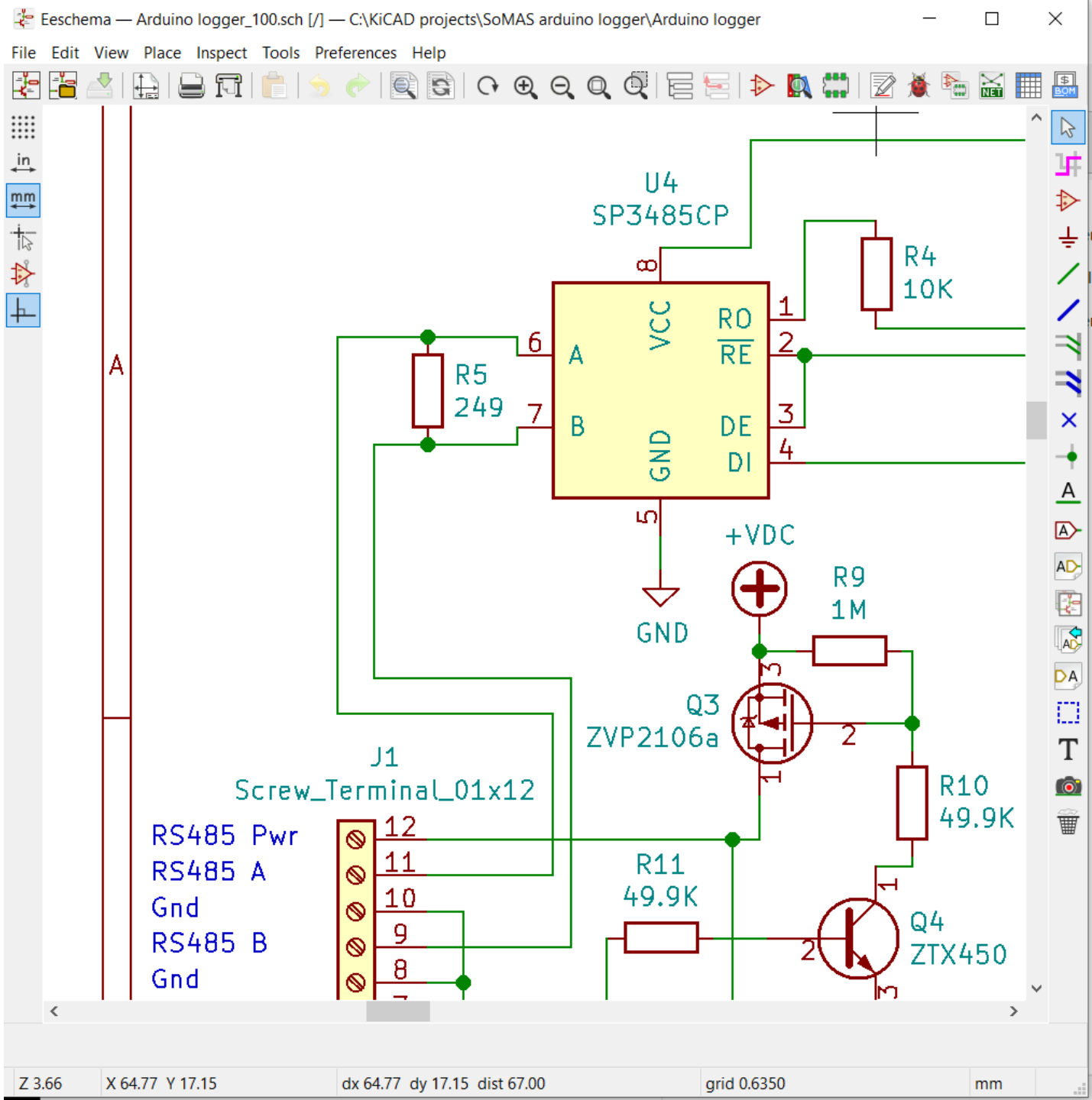
Each component includes

Designator
(U4, Q3, R9, R10)

Identification or value
(SP3485CP,
ZVP2106a, 1M, 49.9K)

If appropriate,
pin definitions
(Vcc, GND)

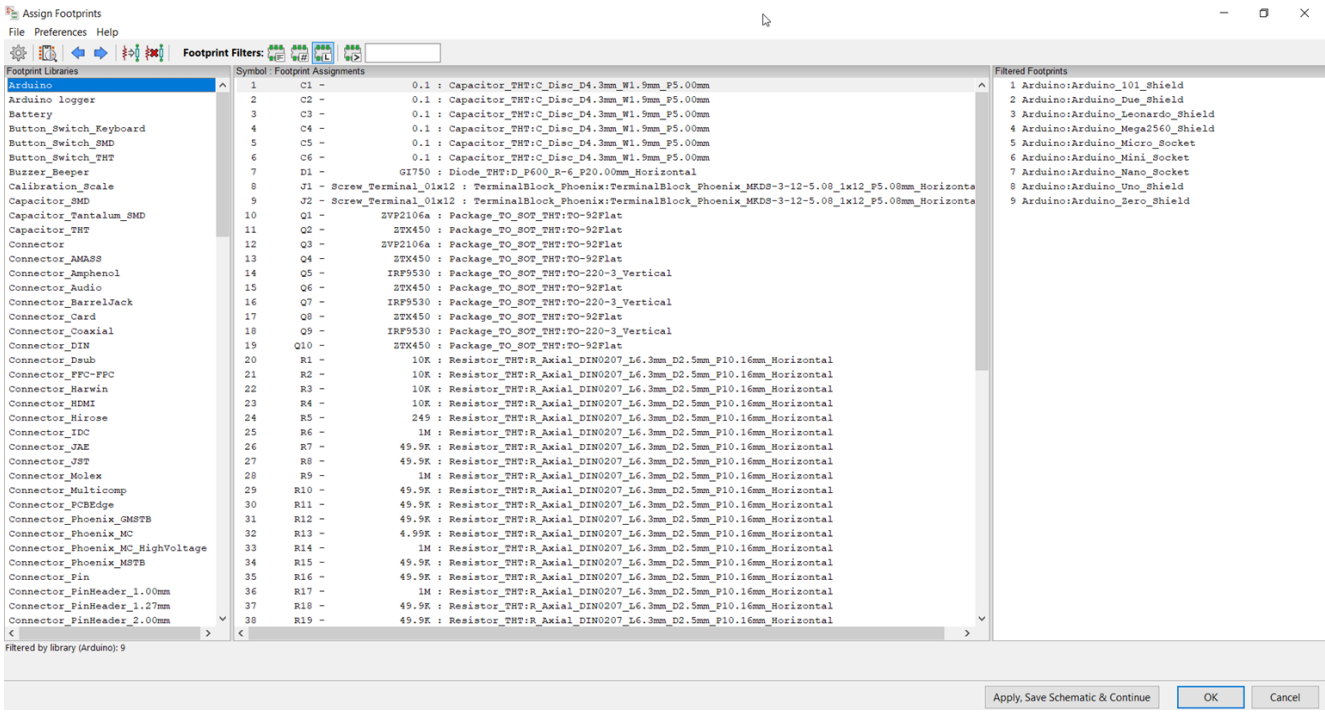
Select components
from the standard
libraries
or
define your own



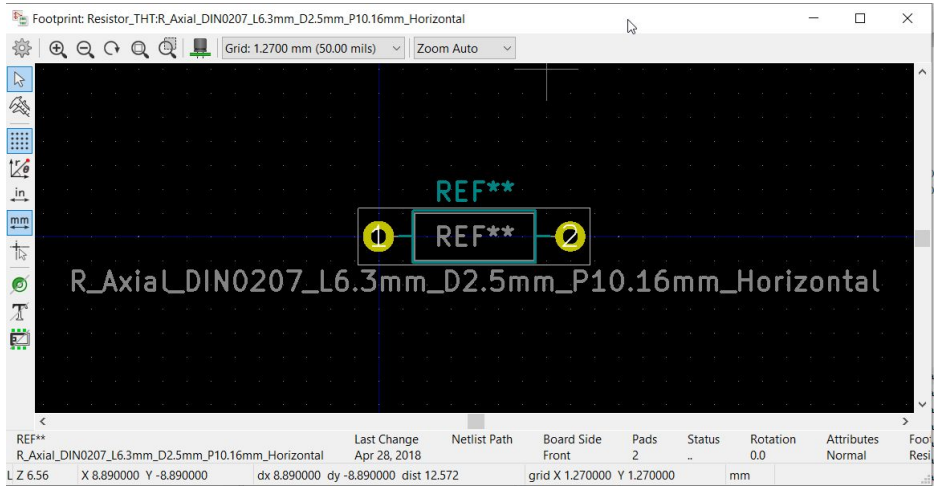
Assign Footprints

Is that 10K resistor ¼ watt or 1 watt, surface mount or through hole?

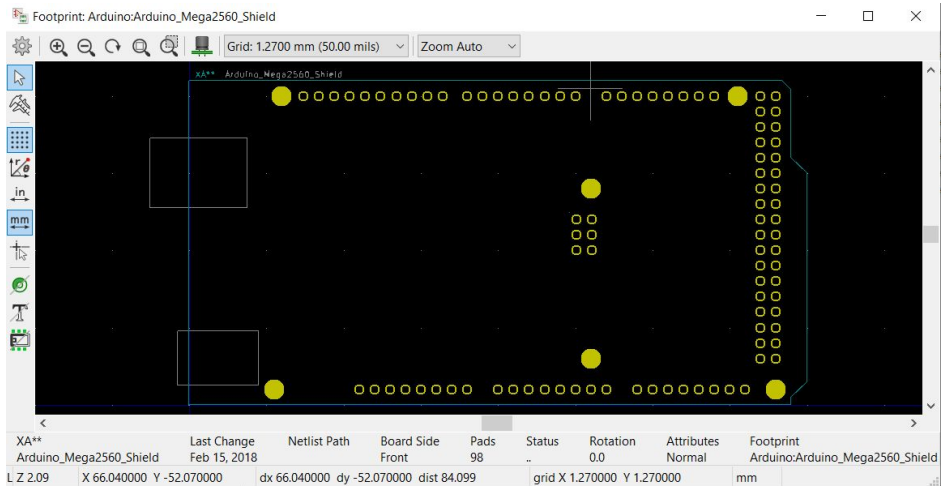
Assign footprints for each component from the standard libraries or define your own. Footprints, like components, can be simple or complex.



¼ watt axial resistor, through hole, horizontal



Arduino Mega 2560 shield



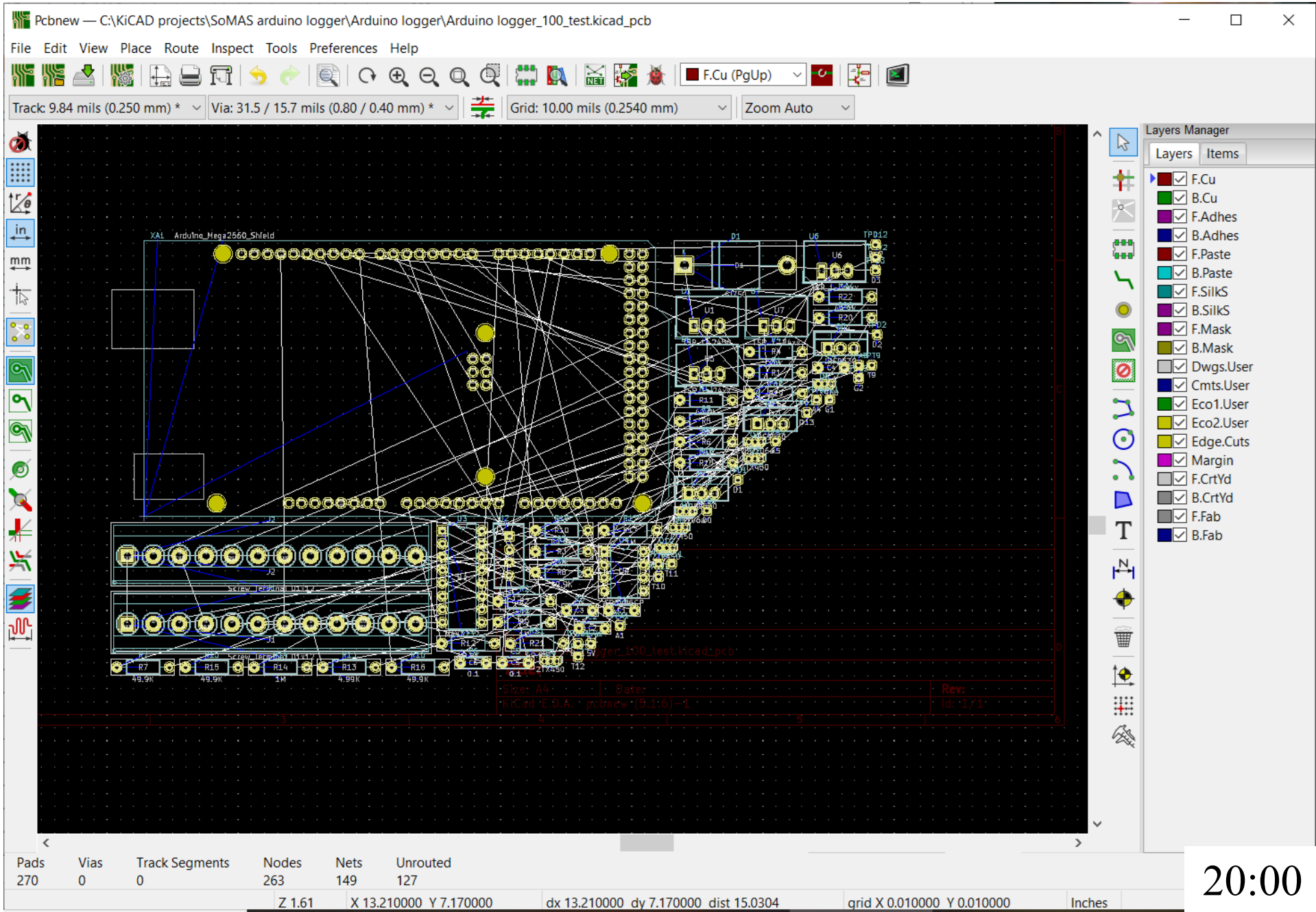
Generate the Netlist

- The Netlist is a file listing all components, the associated physical footprints, and all interconnections.
- Export the Netlist, save your schematic (you have been doing that all along, haven't you?), and exit the schematic editor with a feeling of accomplishment.

Import the Netlist

- Start the PCBoard editor.
- Take a deep breath, intone "Fear is the mind killer", and
- IMPORT THE NETLIST.

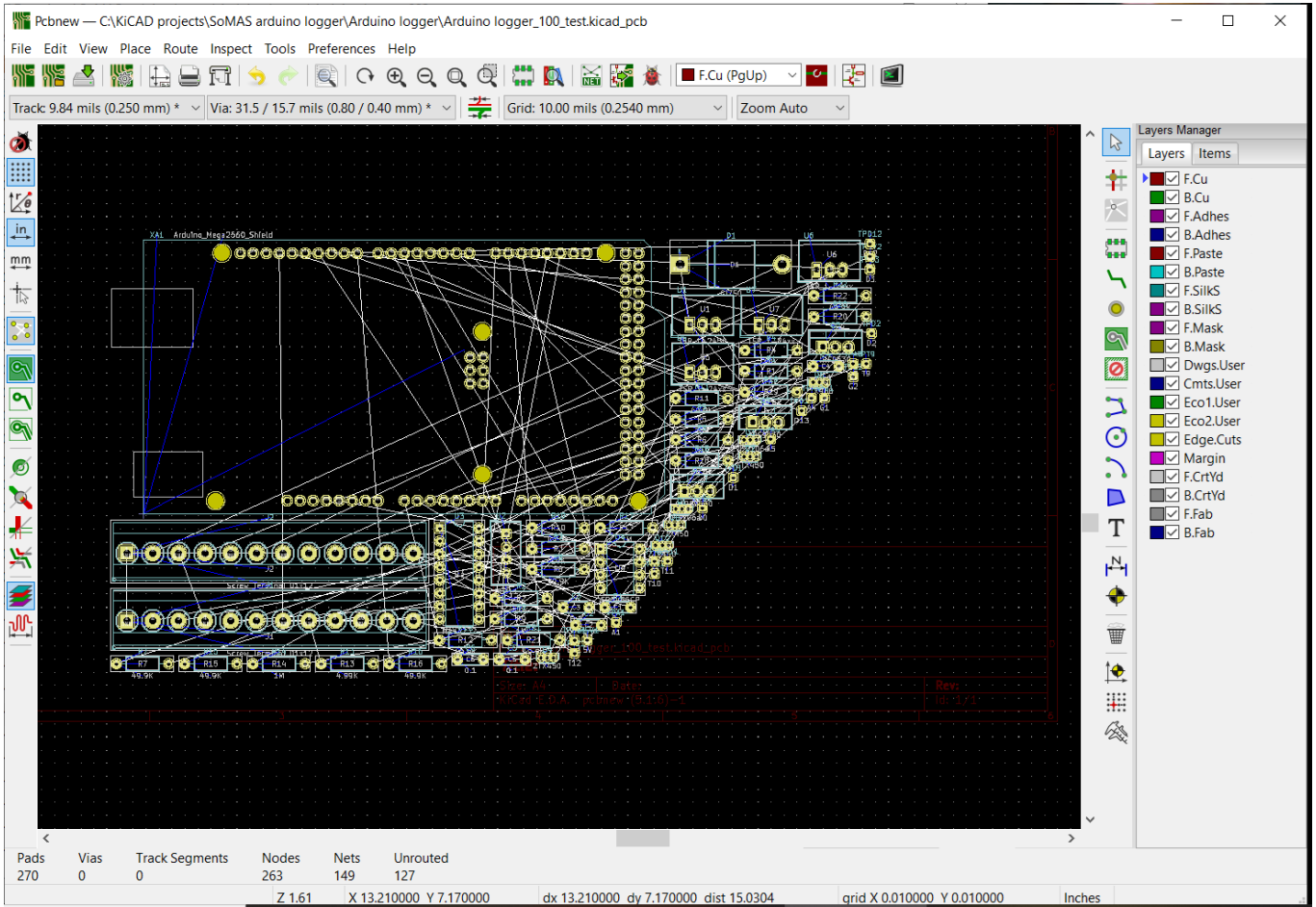
Welcome to the Rat Nest



20:00

Welcome to the Rat Nest

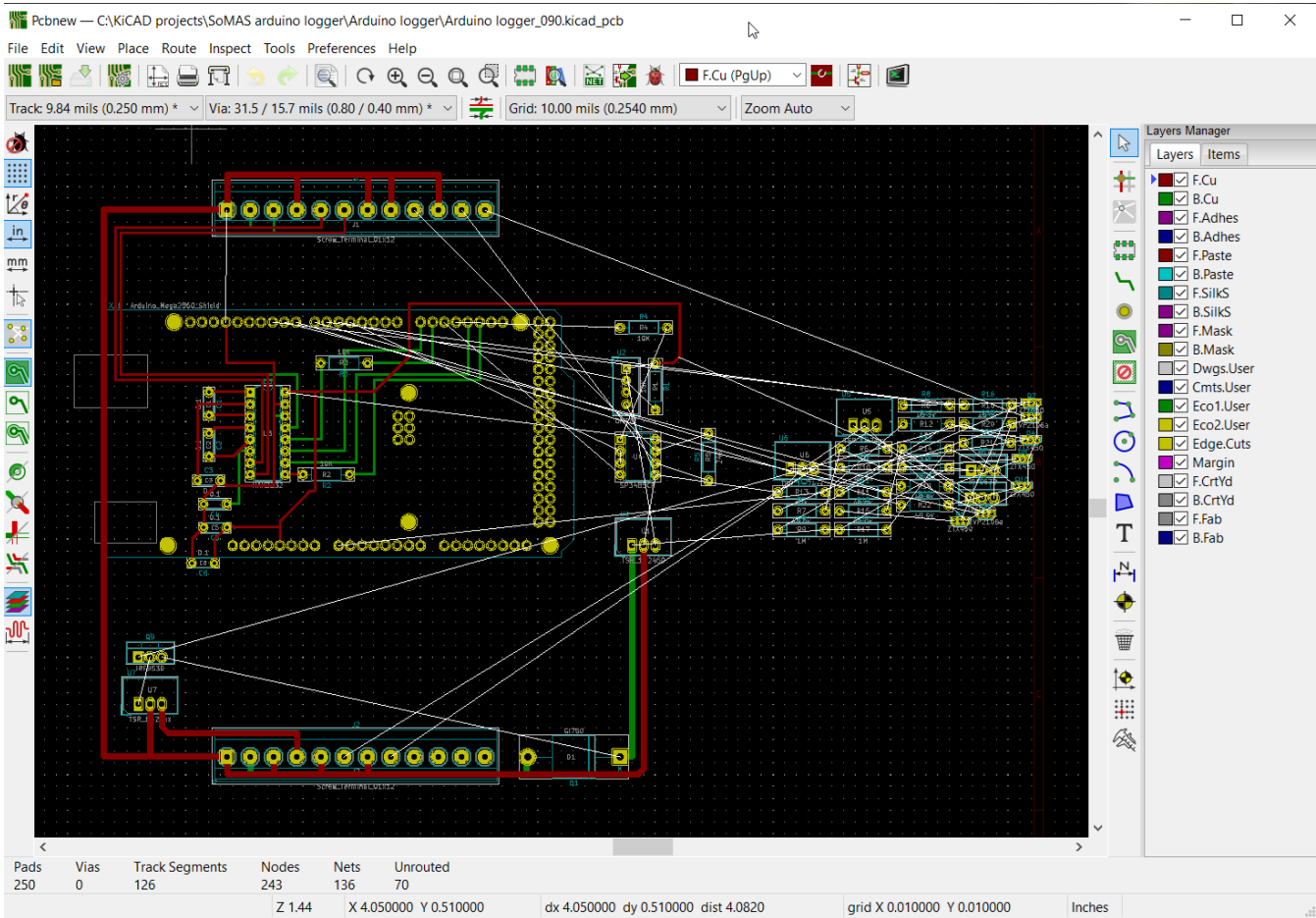
- The PCBoard editor just jams all the components onto the board, then draws a “rat nest” of little white lines between all the pads that need connections.
- YOU get to figure out where to place 69 components, then how to route 127 traces between them.
- Yes, some PCB software purports to “auto place” and “auto route.” Those with the money to buy these high end packages tell me they don’t work so well.
- HEAR ME, HUMANS - this is something we can still do better than a computer!



Layout

- Put on some groovy music - Parliament / Funkadelic works for me.
- If you have a board size constraint, draw “edge cuts”, otherwise leave that to the end.
- If you have components that have to go somewhere (buttons, displays, terminal strips) place them first.
- Group related components together, then start routing traces.

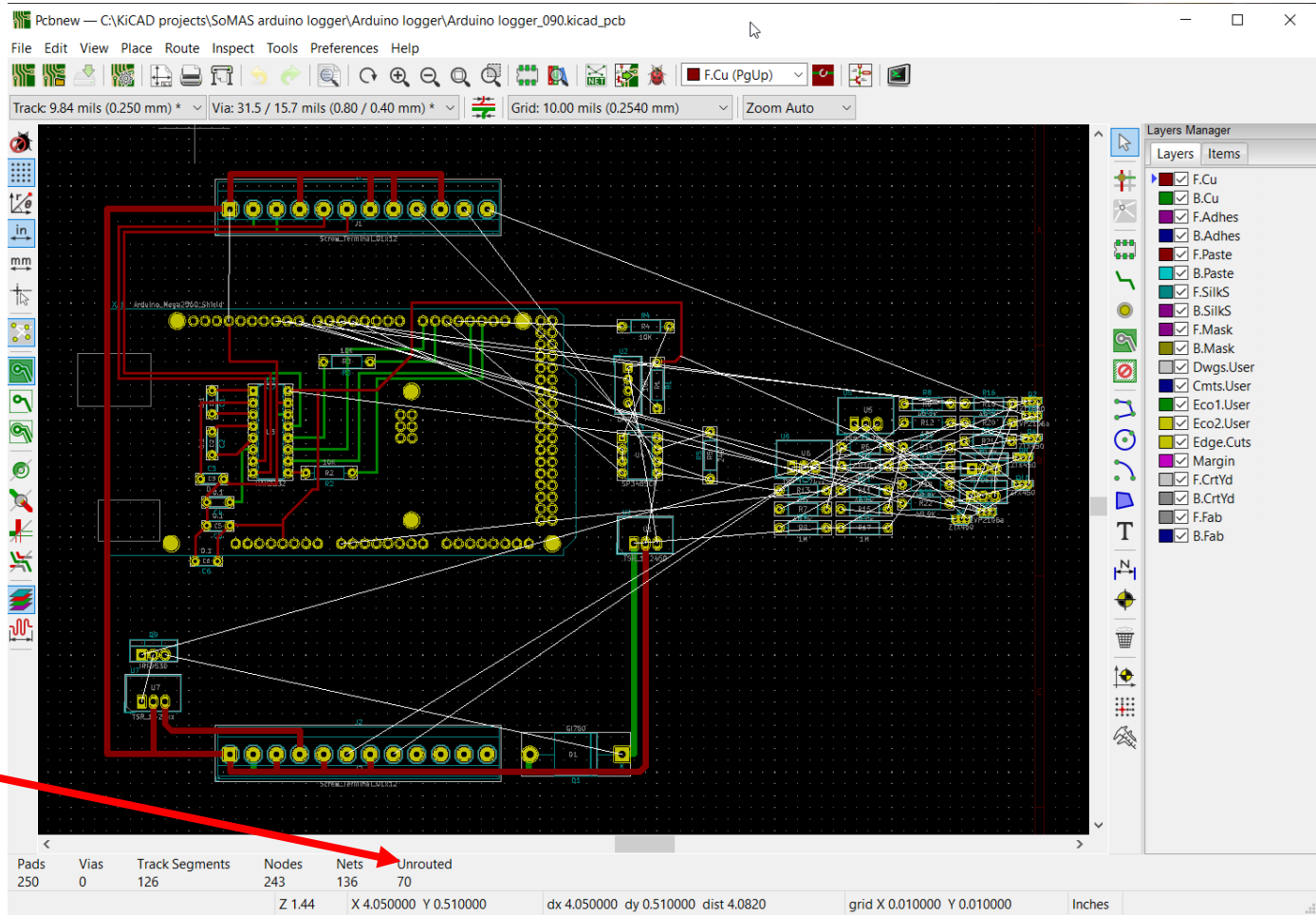
- If two traces have to cross, go from top to bottom to top using a component pad, or add a “via.”



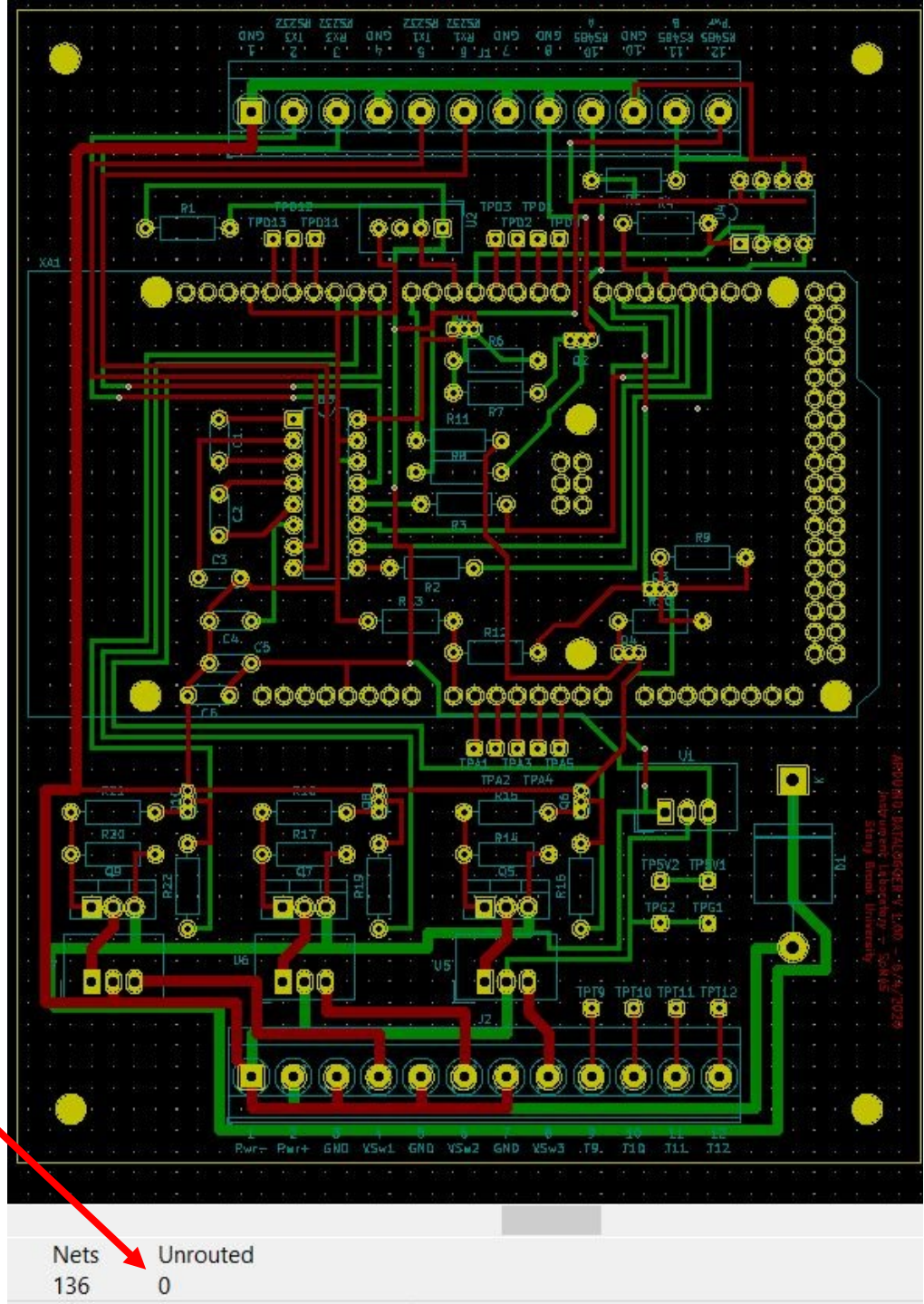
Layout Tips

- Line width and spacing - I like wide traces and lots of spacing.
- Supposedly the program will not let you inadvertently short two nets together. If you cannot make a trace you know needs to be there, go back and double check your schematic. If you made a schematic error, go back and correct it in the schematic editor, generate a new netlist, then update the netlist in your PCB.
- SAVE A LOT, SAVE NEW VERSIONS A LOT so if you mess up you can back up, not start over.

Every successful trace lowers the "Unrouted" count toward the magical number of ZERO.

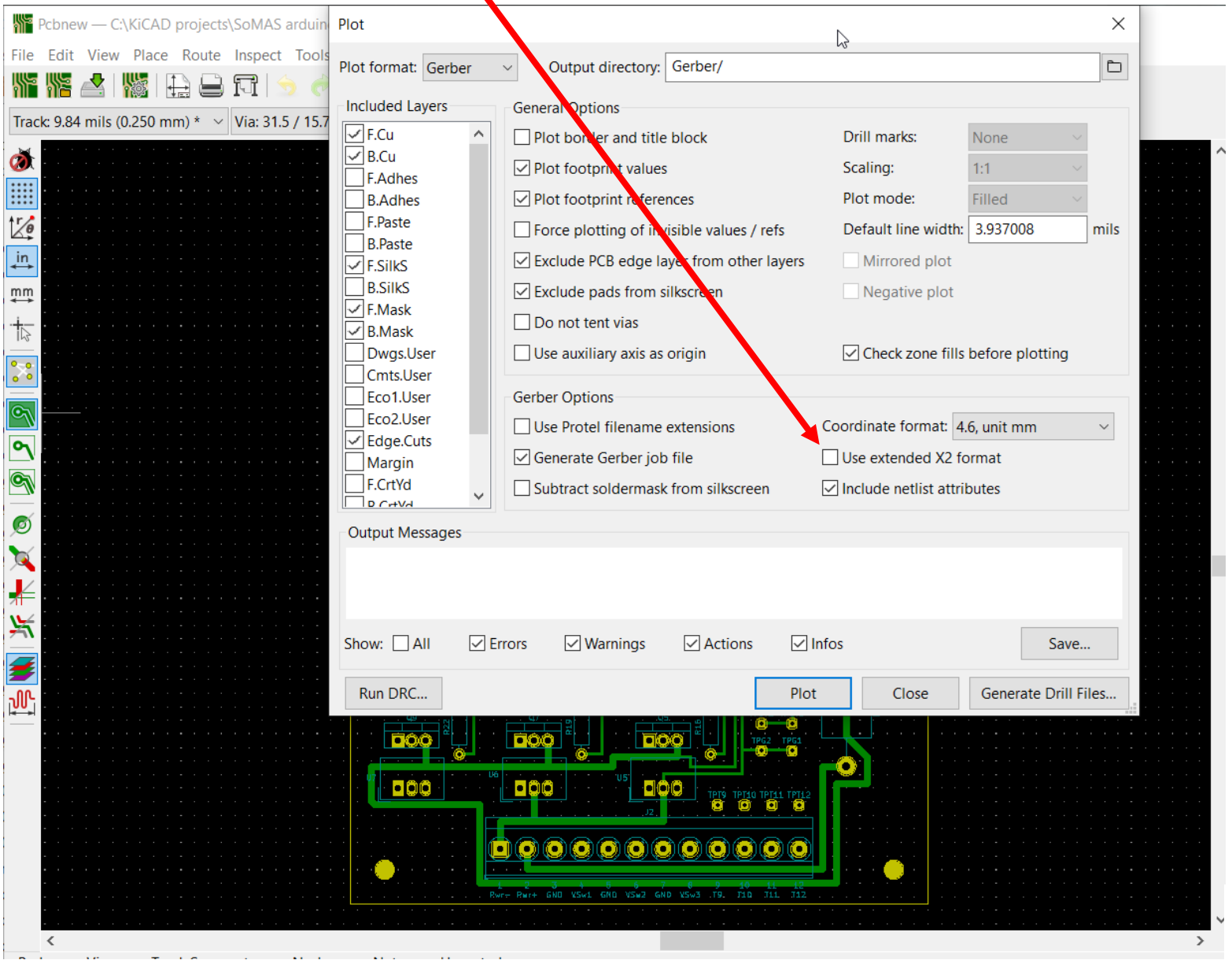


Eventually Nirvana (version 1.00) is Reached!



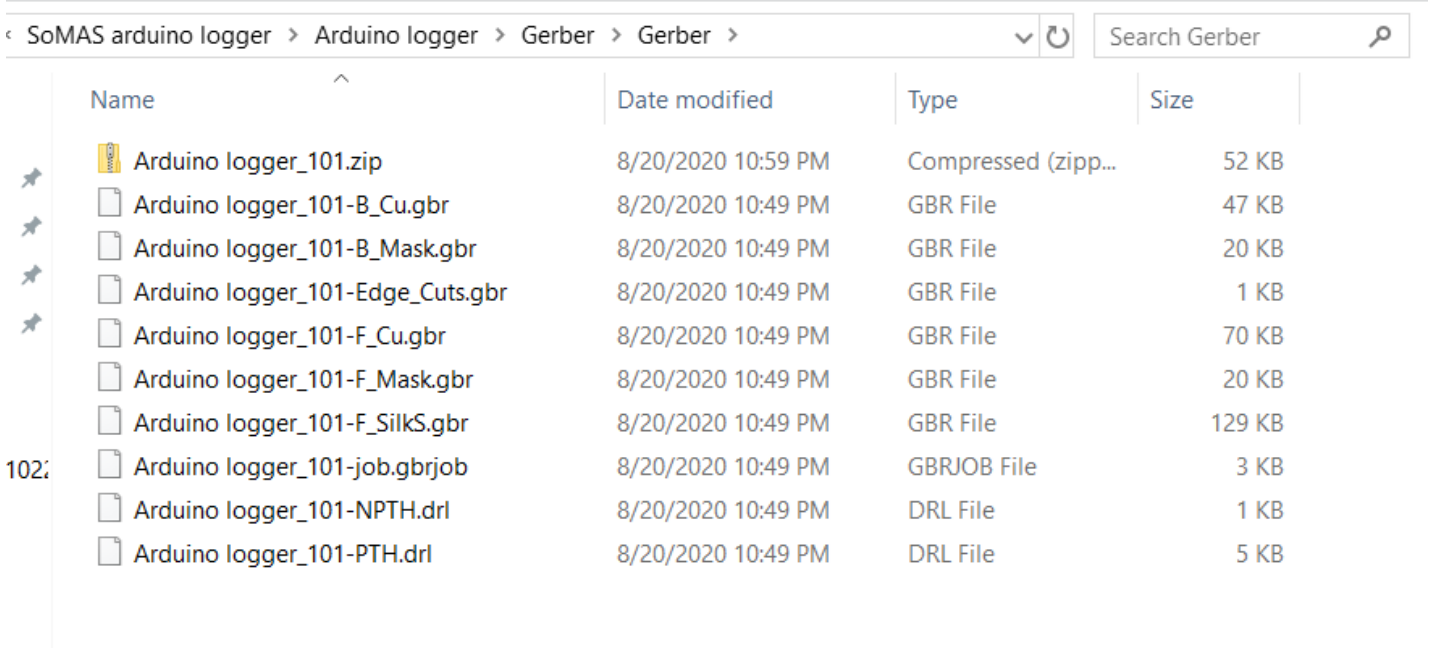
Export Manufacturing Files

Warning - do NOT select "extended X2 format."



25:00

Manufacturing Files List



*.gbr = Gerber photoplot format:
B_Cu = back copper, F_Cu = front copper,
Edge-cuts = board edges, B_mask = back solder mask, F_mask = front solder mask,
F_SilkS = front silkscreen, B_SilkS = back silkscreen.

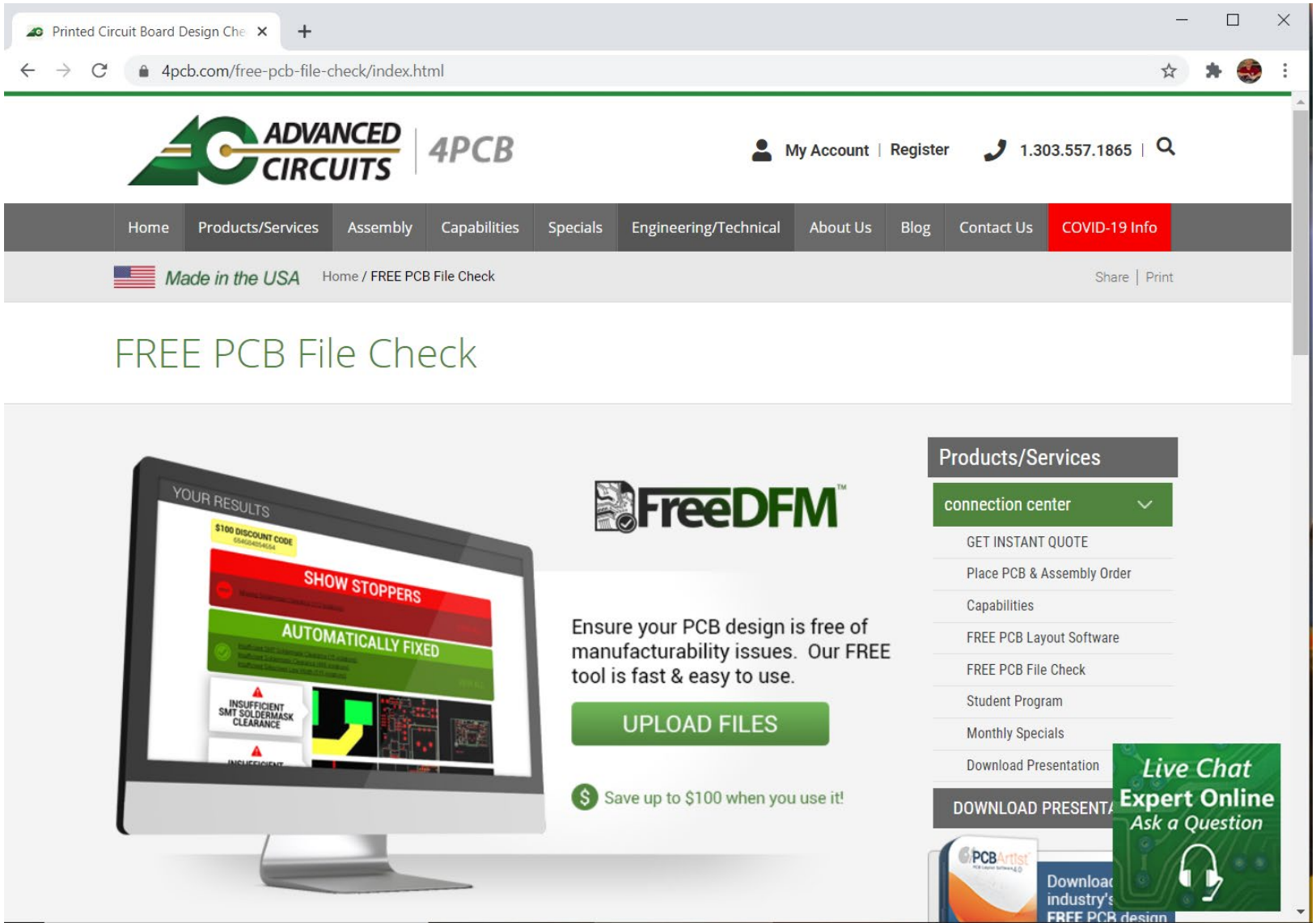
*.drl = Excelon drill file:
NPTH = non-plated through holes, PTH - plated through holes

*.gbrjob = job file, not sure what this does.

ZIP IT ALL TOGETHER!

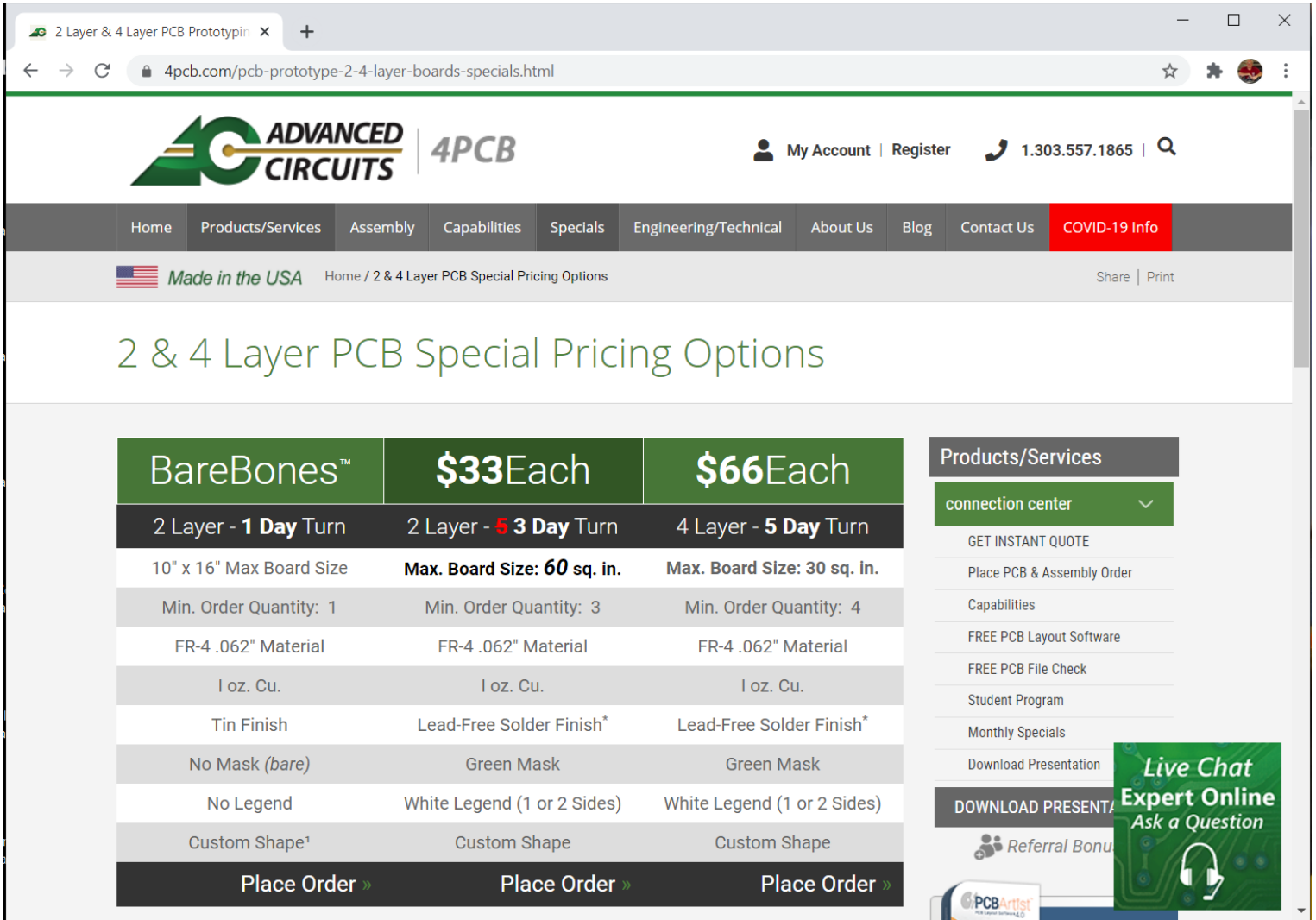
Design Rules Check @ 4pcb.com

Upload zip file for free DFM - report usually back in <2 hours.



Manufacturing @ 4pcb.com

After your design passes Free DFM, upload and place order.
$33 special is usually cheaper until you get quantity >20.



In a Week or So...

Free popcorn in every order!

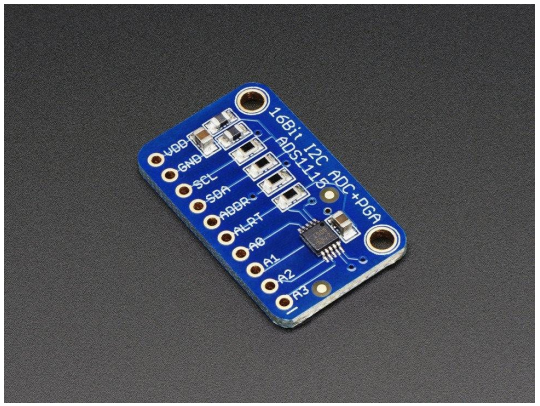
Assemble

Remember “mostly” through hole?

Surface mount component plus SMC/DIP adapter board.

To use surface mount components on through hole boards, search for “SMC to DIP adapter boards”

Searching “breakout boards” on sites like sparkfun.com or adafruit.com returns many useful devices



ADS1115 - 4 channel, 16 bit a/d with programmable gain amplifier

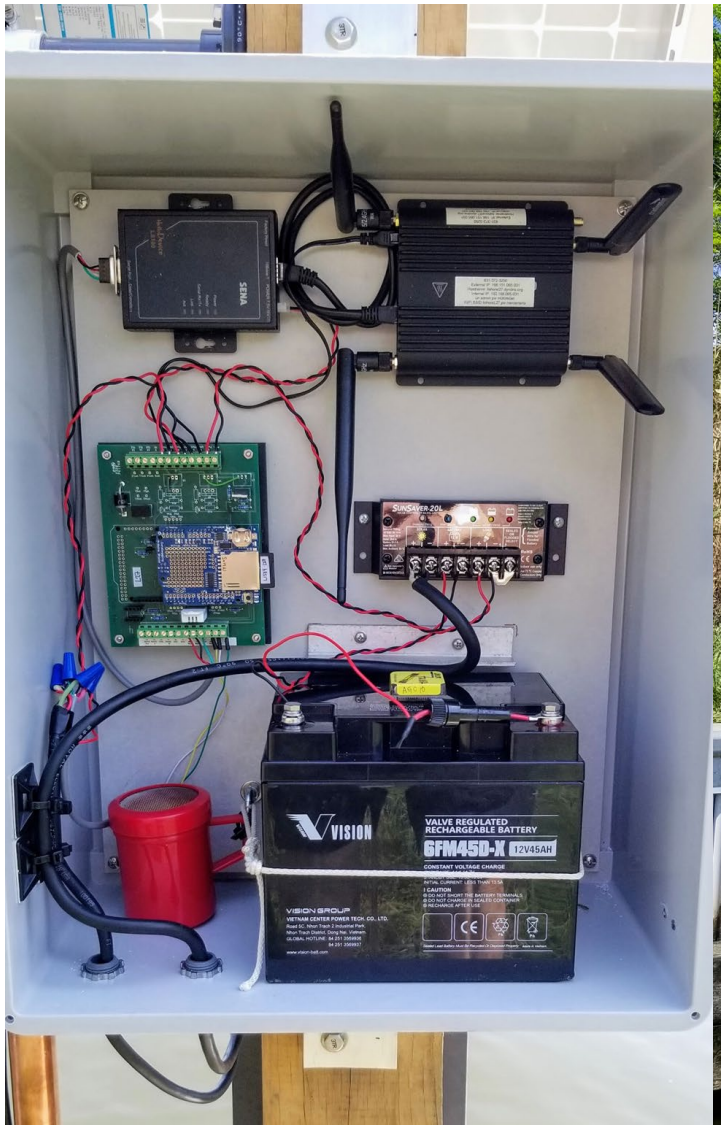
30:00

Program and Test

L to R: 4G router, serial to IP converter, datalogger, RS485 pressure sensor.

Deploy!

Summer 2020: two tide stations, two salinity stations, one multiparameter floating platform.
Telemeters processed data, but 8GB flash allows local storage of every instrument scan (probably for the life of the station) for reprocessing or troubleshooting - has already proven useful.
Expect to upgrade six existing data stations in the next six months.

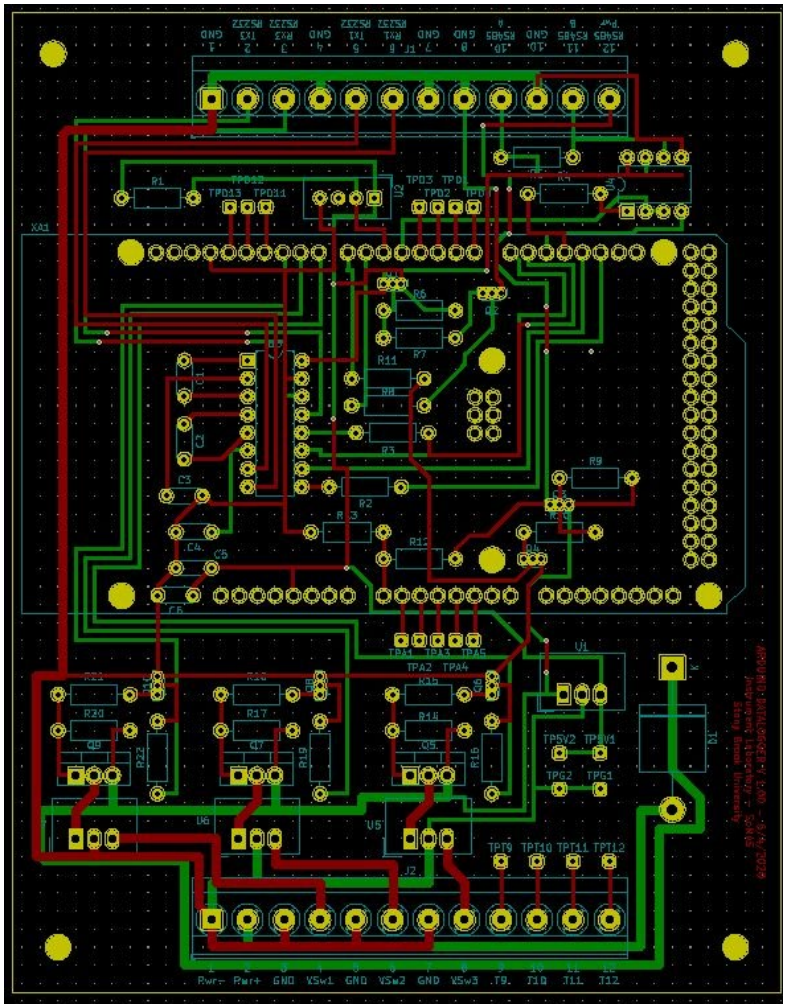


Version 1.00 worked - but there's always a punch list

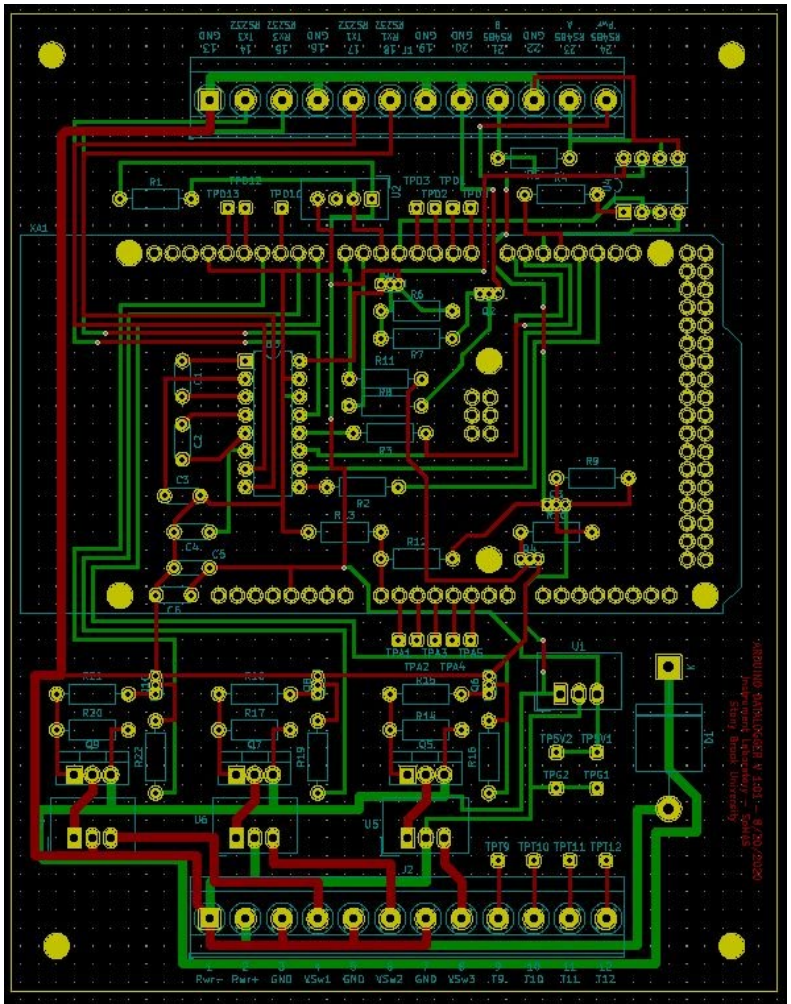
Version 1.01 - Removed orphan via and trace to nowhere, moved one digital line to fix hardware conflict, renumbered terminal strip #2 to 13-24 instead of duplicated 1-12.

Next version 1.1 - more accurate Real Time Clock add 4-channel 16-bit A/D with PGA.

Version 1.00



Version 1.01



ACKNOWLEDGEMENTS

To Forrest W. Mims III - for simple systems that work.

To my parents, who always found a few dollars to invest at Halley Electronics, Radio Shack, and Pagoda Hardware - and to the longsuffering employees of Halley Electronics, Radio Shack, and Pagoda Hardware.

To teachers, mentors, students, and colleagues including
Henry Harrison, David Lucyk, Bob Slavonik,



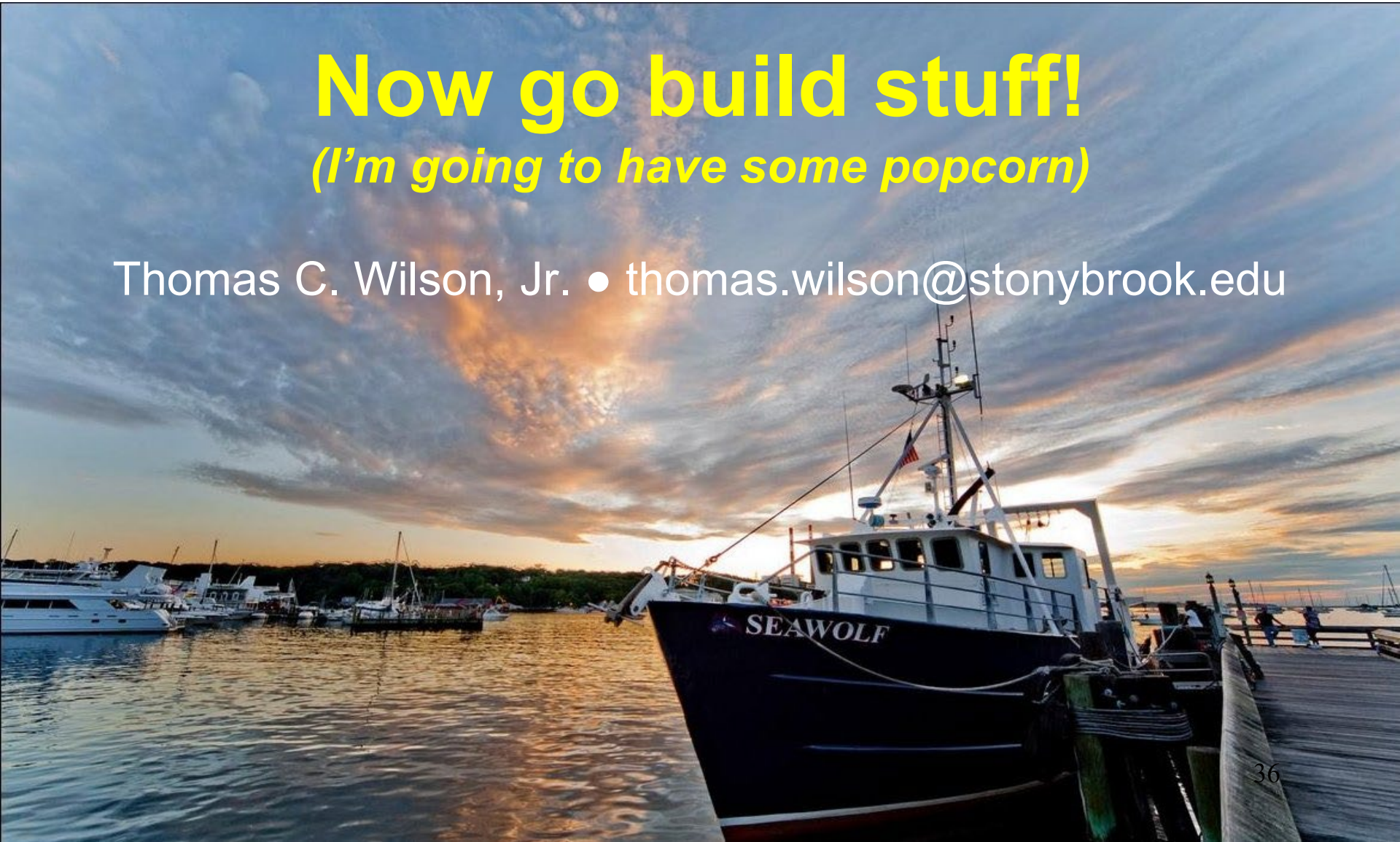


Trevor Young Greg Smith Alex Sneddon Chris Crosby Miles Litzmann

and of course my shipmates at RVTEC.

QUESTIONS? I AM NOT AFRAID.

Thank you!



Now go build stuff!

(I'm going to have some popcorn)

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