Getting Started in Electronic Design

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Stony Brook University
School *of* Marine and Atmospheric Sciences

Standard Disclaimers

Unless otherwise noted:

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- The presenter has no ownership interest in any commercial entity mentioned.

Special At-Sea 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 baubles, nor trinkets, nor 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.

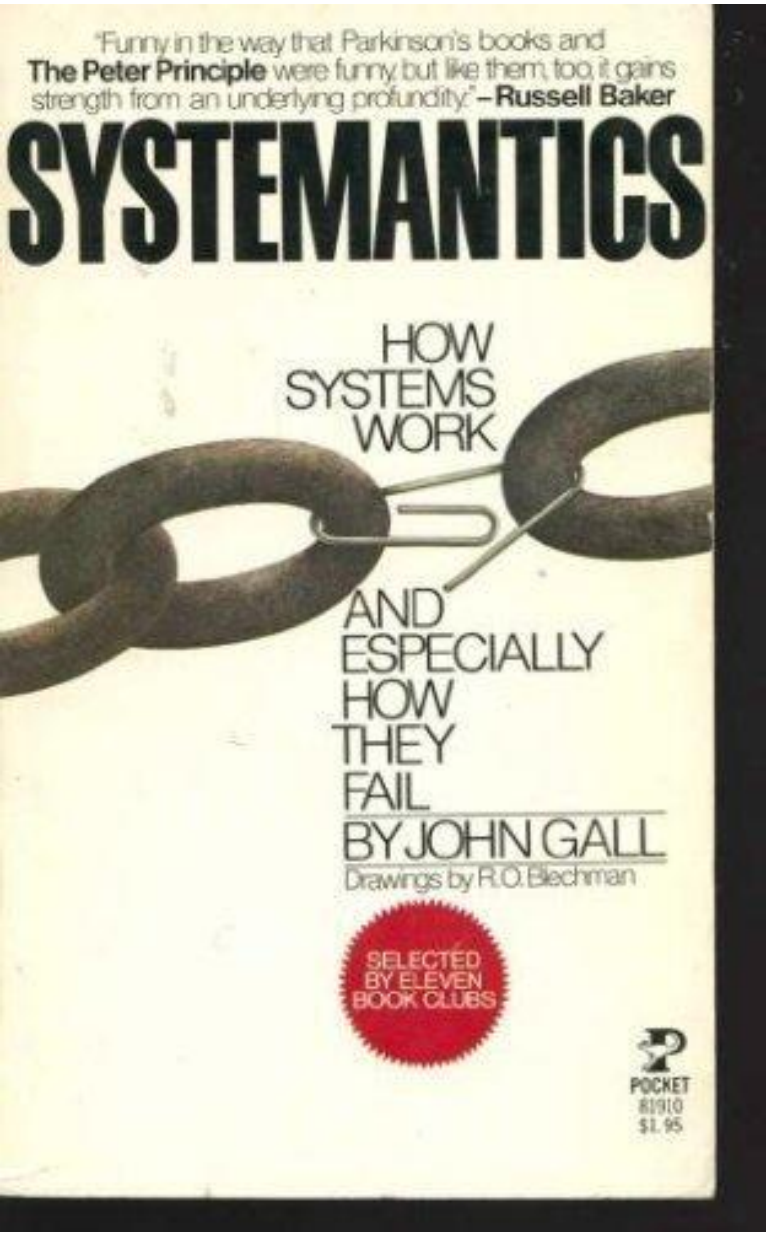
USE CAUTION with high voltage and high power.

CONSIDER redundant dumb limit controls and other fail safe features.

NOT for human safety applications.

5:00

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).

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

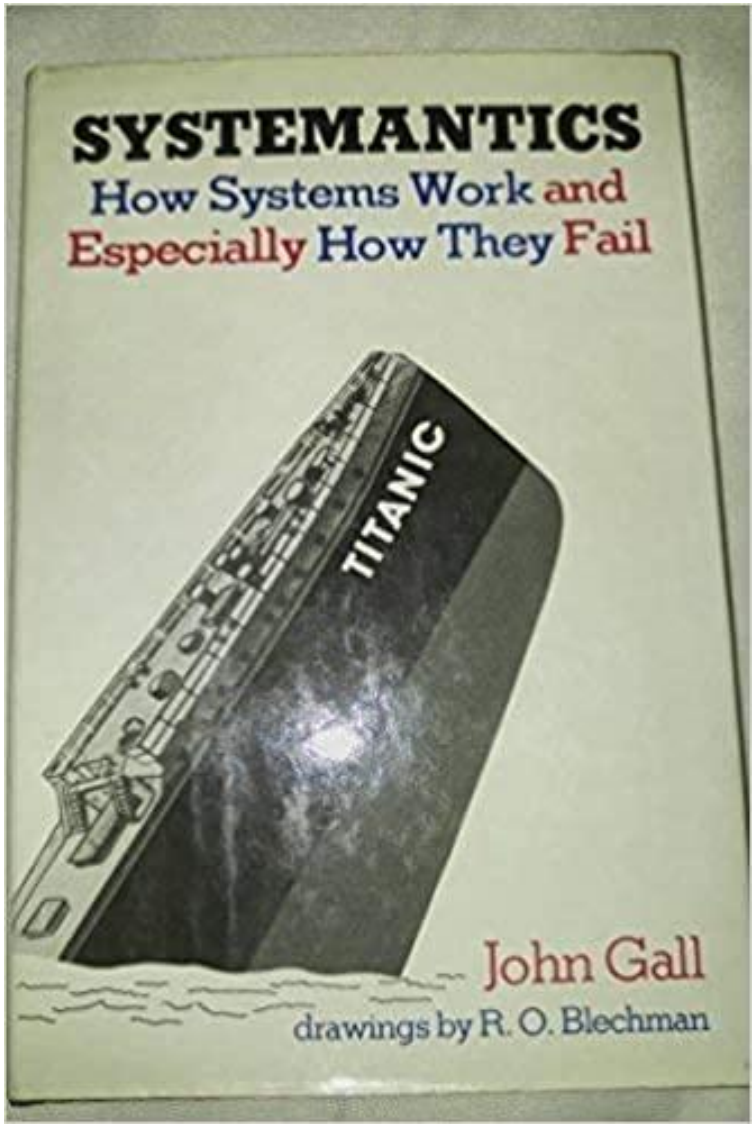
Electronic design is like code writing: design simple, robust, tested subsystems, then combine them to achieve a large and complex result.

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."

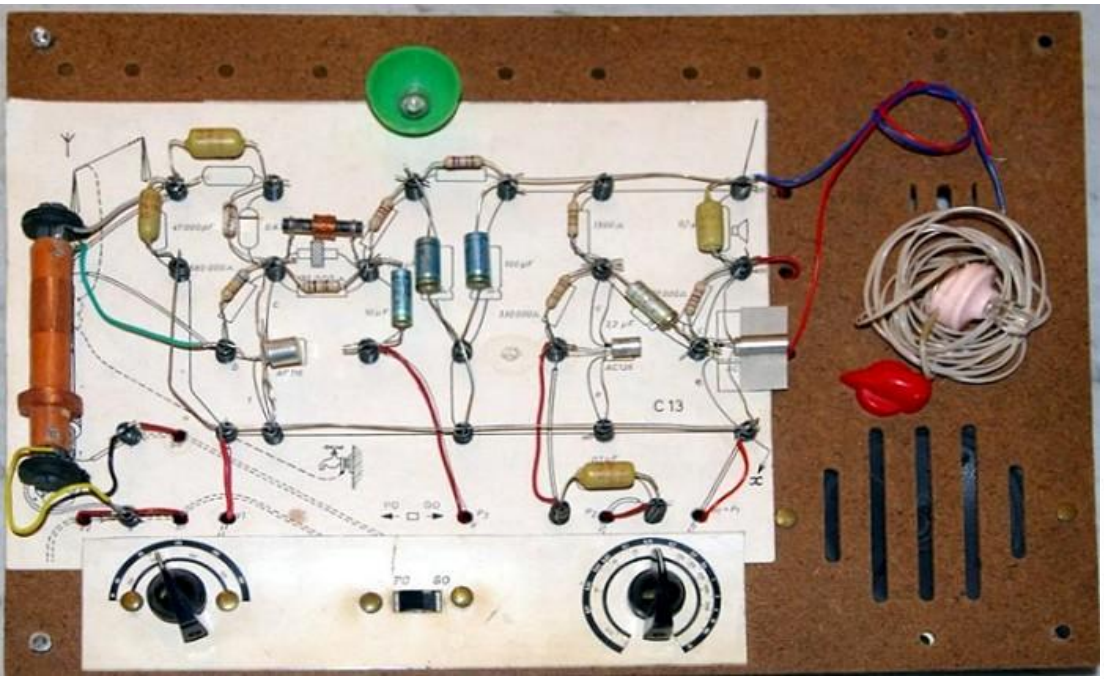


BEGIN BY DOING – my first kit

Phillips Electronics Engineer EE20 – circa 1966

20 projects including AM radio, audio amplifier, night light, etc.

Pictorial diagrams with open holes placed over pegboard, spring contacts fit through open holes, components fit between contacts.



BEGIN BY DOING – your first kit

Ultimate Arduino kit with ELEGOO Uno $65.99

(Also buy a real Arduino Uno just because)

Dozens of projects including servo, stepper motor, PIR motion detector, ultrasonic rangefinder, LCD and LED display, etc.

20:00

https://www.amazon.com/ELEGOO-Upgraded-Complete-Tutorial-Compatible/dp/B08C4SK6H3

“OK – I built them all – now what?”

“Nobody was born knowing how to do this stuff.” - me.

Recognize the simple subsystems and put them together in new ways.

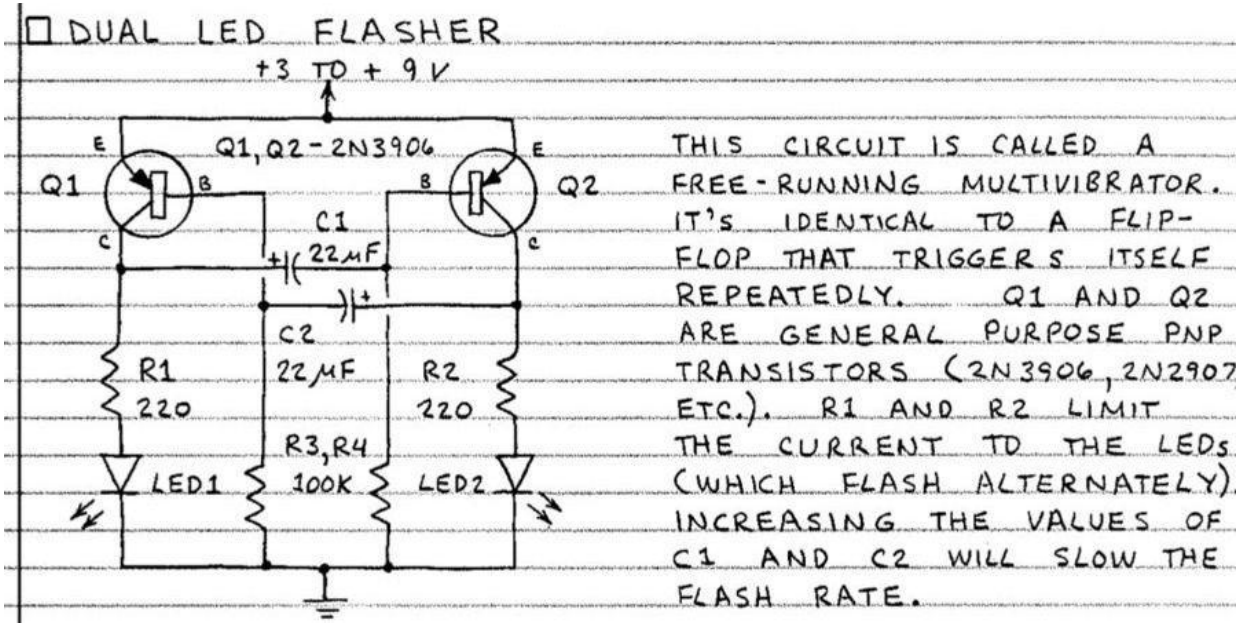
Add to your toolbox of simple systems.

Buy extra parts and m**ake your more useful creations permanent:** either with hand wired boards or commercial printed circuit boards.

Adding to your toolbox - Resources

Forrest W. Mims III

Author of 60 books, over 7.5 million copies sold.
Pre-microprocessor: focus on ICs and discrete component designs.
As responsible as anyone for my career.
Buy his books (widely available):
-Getting Started in Electronics
-Engineer's Notebook.
-Whatever else looks interesting.



25:00

Instructive Vendors

Lots of free information and tutorials
on how to use what they sell

Adafruit: www.adafruit.com

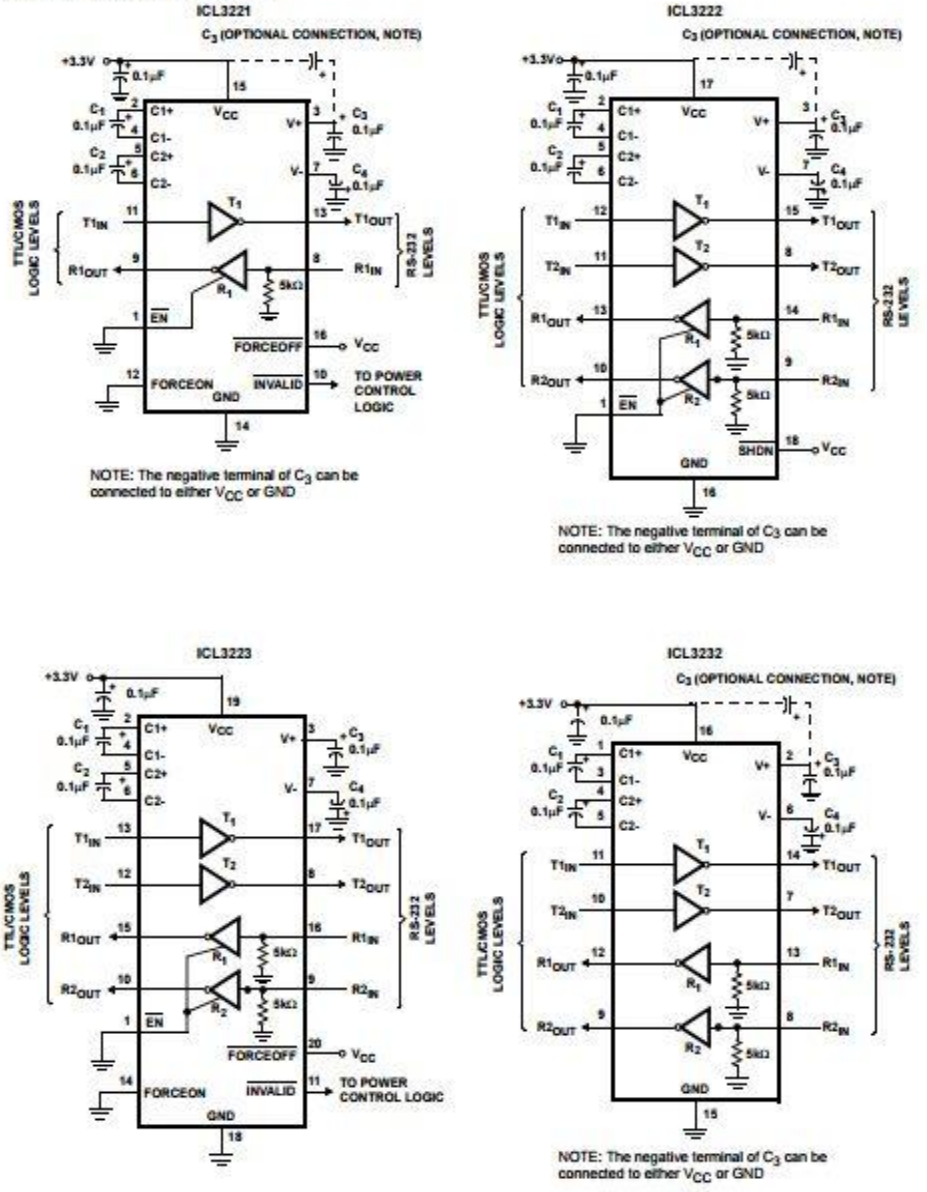
SparkFun: www.sparkfun.com

Make: www.makershed.com (also Make Magazine)

Jameco: www.Jameco.com
("Workshop" on their home page, also get on mailing list)

Instructables: www.instructables.com (just instruction)

Typical Operating Circuits



Don’t be afraid of datasheets

Good when you need to go deep.

Typical or test circuits often do just what you want!

SAVE A COPY
of the datasheet
of every active
component
in your design.

30:00

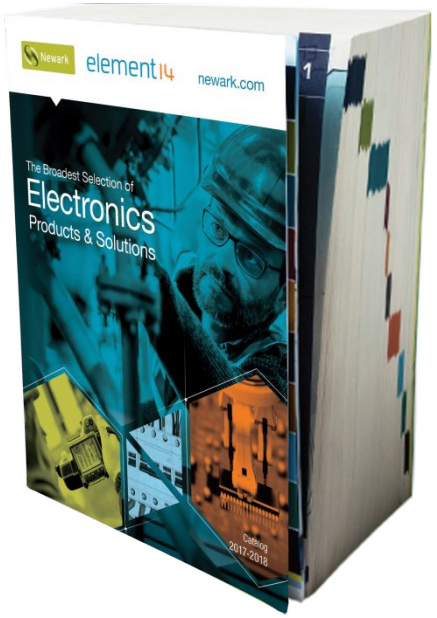
Component Vendors

Digi-Key: www.digikey.com

The 900 pound gorilla of suppliers: online stock status, same day shipping on orders received by 8pm central time, links to the datasheet of everything they sell.

Mouser: www.mouser.com

Good second source, quick ship, northeast US location.



Newark/Element 14: www.newark.com

Once famous for having everything presuming you were willing to pay higher than list price, now just famous for having everything. Still publishes a paper catalog large enough to use as a weapon.

Canal Street NYC – how I miss it!

35:00

http://www.nytimes.com/2001/07/22/nyregion/the-tinkerer-s-last-stand-sold-for-pennies-on-the-streets-of-williamsburg.html?_r=0

Speciality and Surplus Vendors

Marlin P Jones - http://www.mpja.com/
(Bench power supplies)

Herbach and Rademan - http://www.herbach.com/

Electronic Goldmine - http://www.goldmine-elec-products.com/

Aretronics: https://aretronics.com/

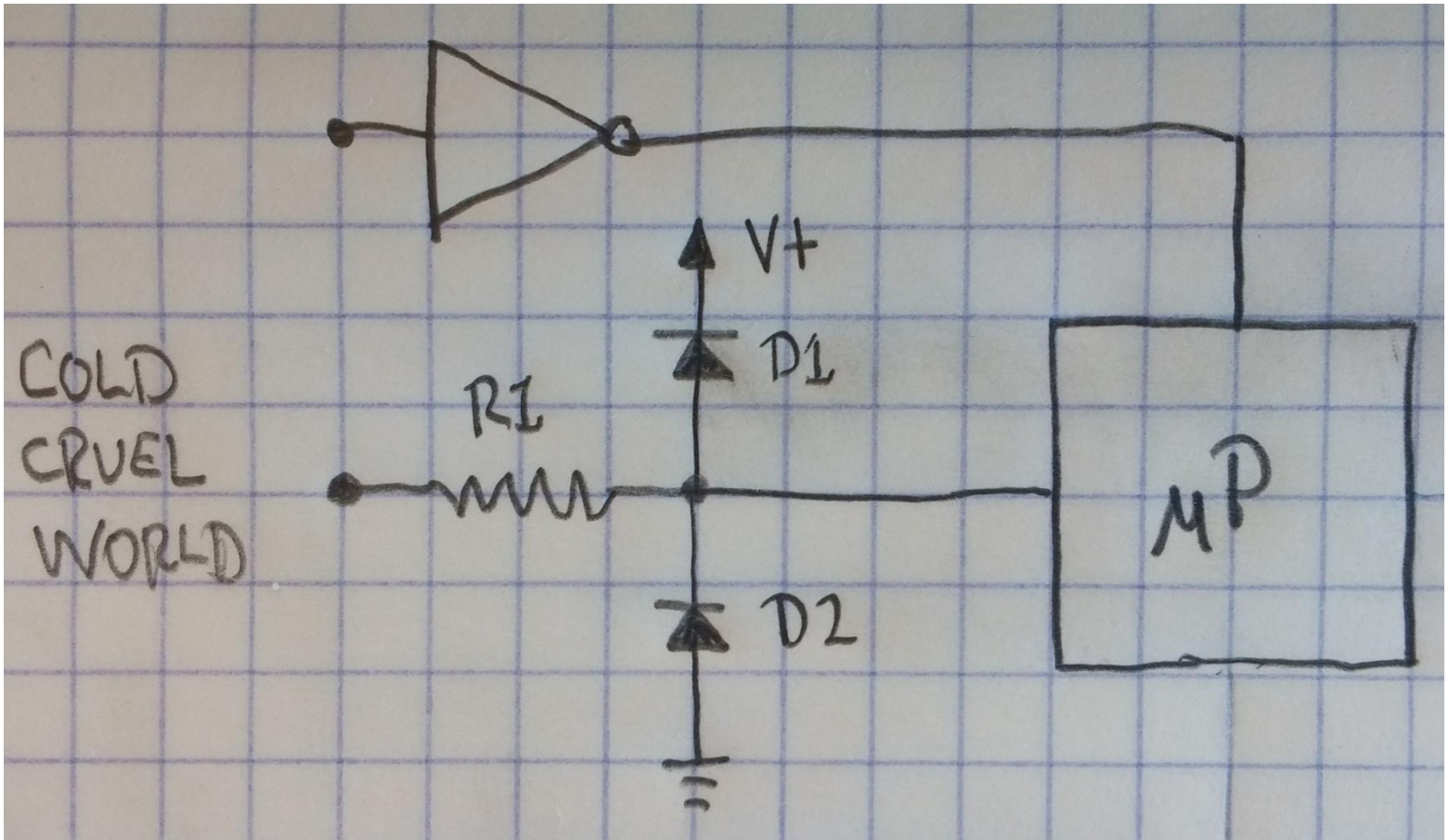
More vendors at: http://amasci.com/surplus/surpls.html

Design and Document

Build your own recipe book of useful circuits that work.

DIGITAL INPUT CIRCUIT PROTECTION

Upper: use 1/6 of a 4049 series inverting buffer in a socket – way cheaper than a new processor!
Lower: D1, D2 = 1N4148, R1 = 1K. Diodes clamp input to within 0.6V of V+ and ground, resistor limits current.



40:00

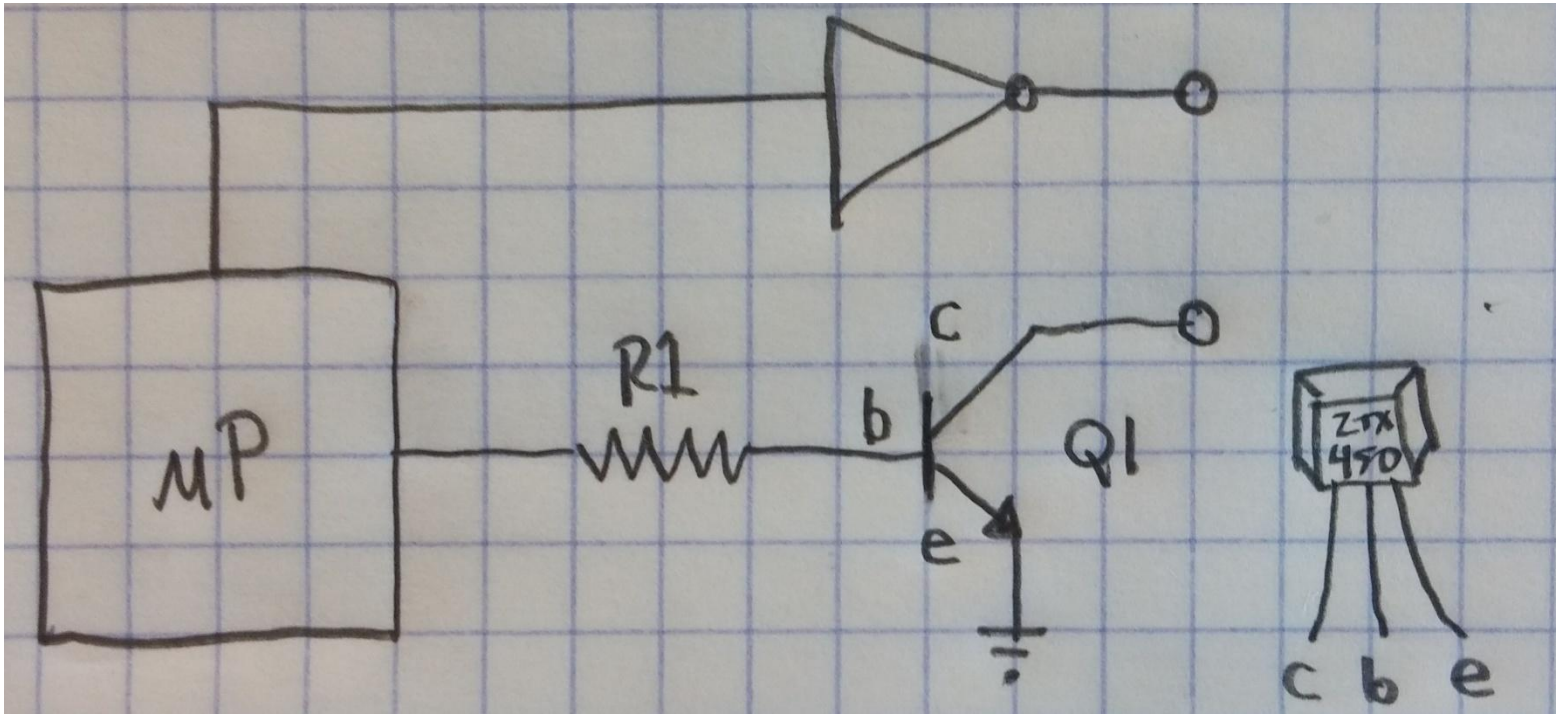
DIGITAL OUTPUT CIRCUIT PROTECTION

Upper: use 1/6 of a 4049 series inverting buffer in a socket – way cheaper than a new processor!

Lower: Q1 = Zetex ZTX450 NPN transistor, R1 = 49.9K.

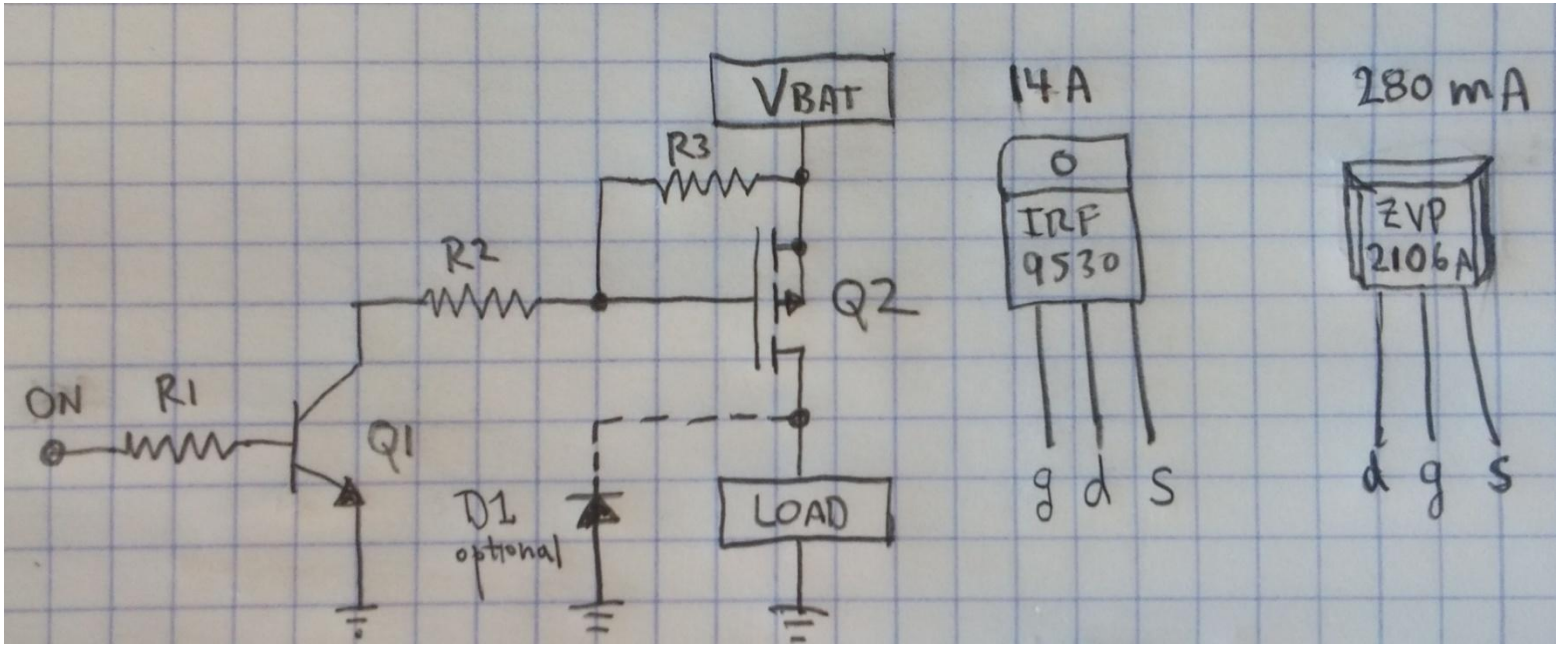
Note 1: This is what you call an “open collector” output.

Note 2: ZTX550 is PNP version of ZTX450.



P CHANNEL POWER OUTPUT

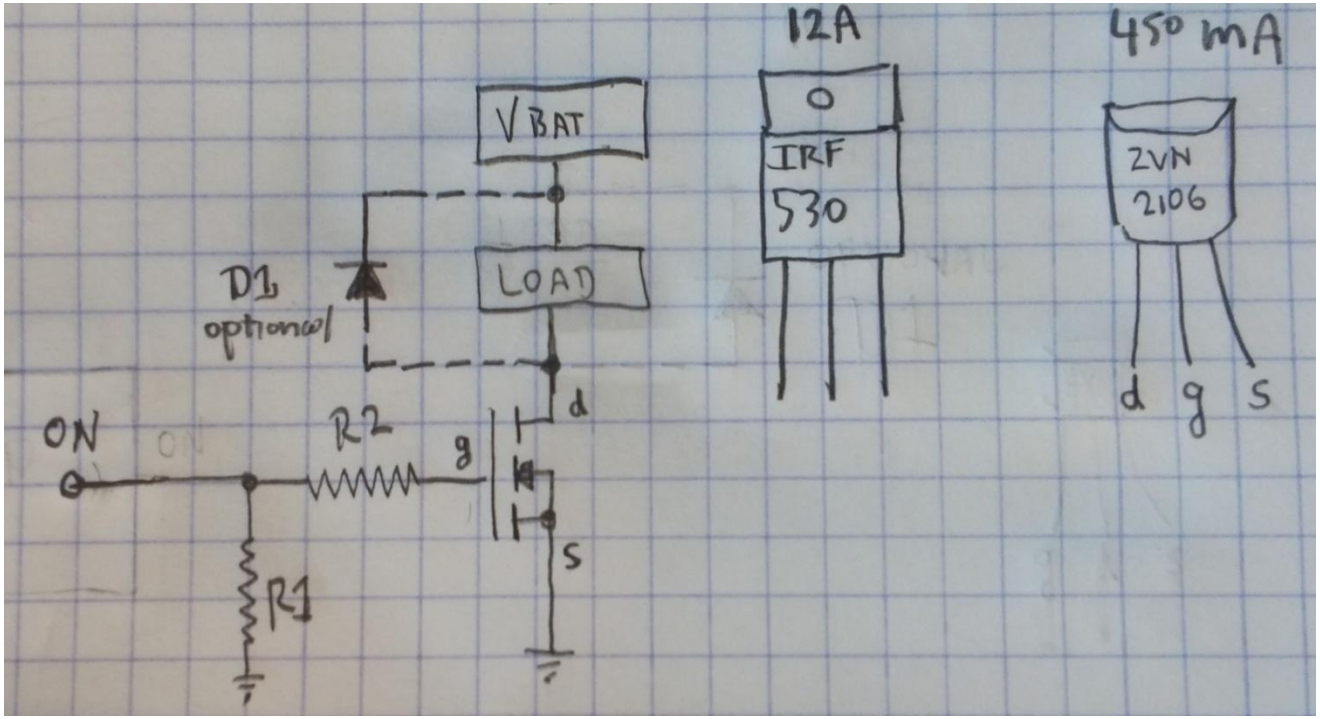
Q1 = Zetex ZTX450, Q2 = Zetex ZVP2106a (current up to 200 mA) or International Rectifier IRF9530 (current up to 10A), R1 and R2 = 49.9K, R3 = 1M. D1 = 1N4003 diode, optional for inductive loads.

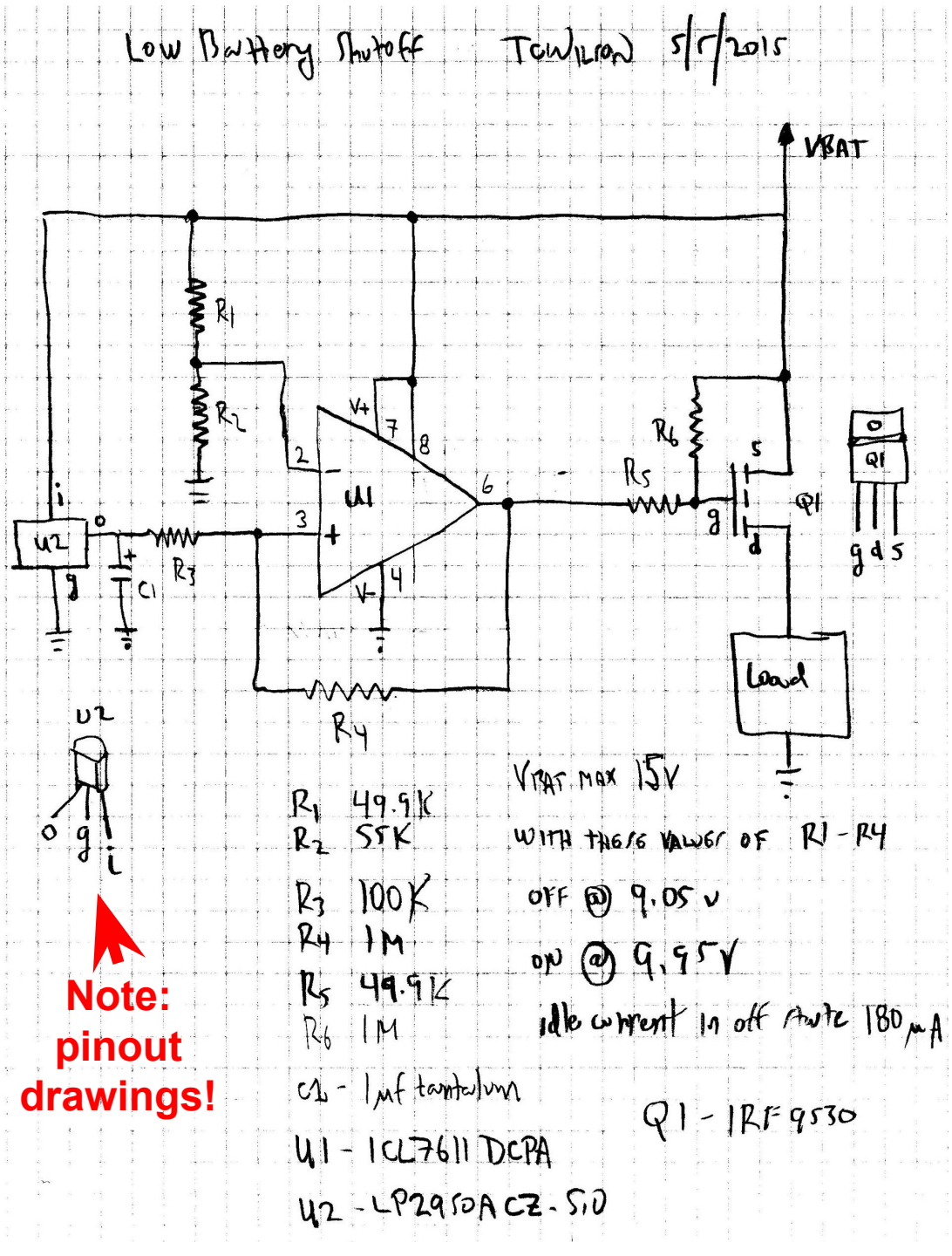


45:00

N CHANNEL POWER OUTPUT

Q1 = Zetex ZVN2106 (current up to 300 mA) or
International Rectifier IRF530 (current up to 10A), R1 = 1M, R2 = 49.9K.
D1 = 1N4003 diode, optional for inductive loads.





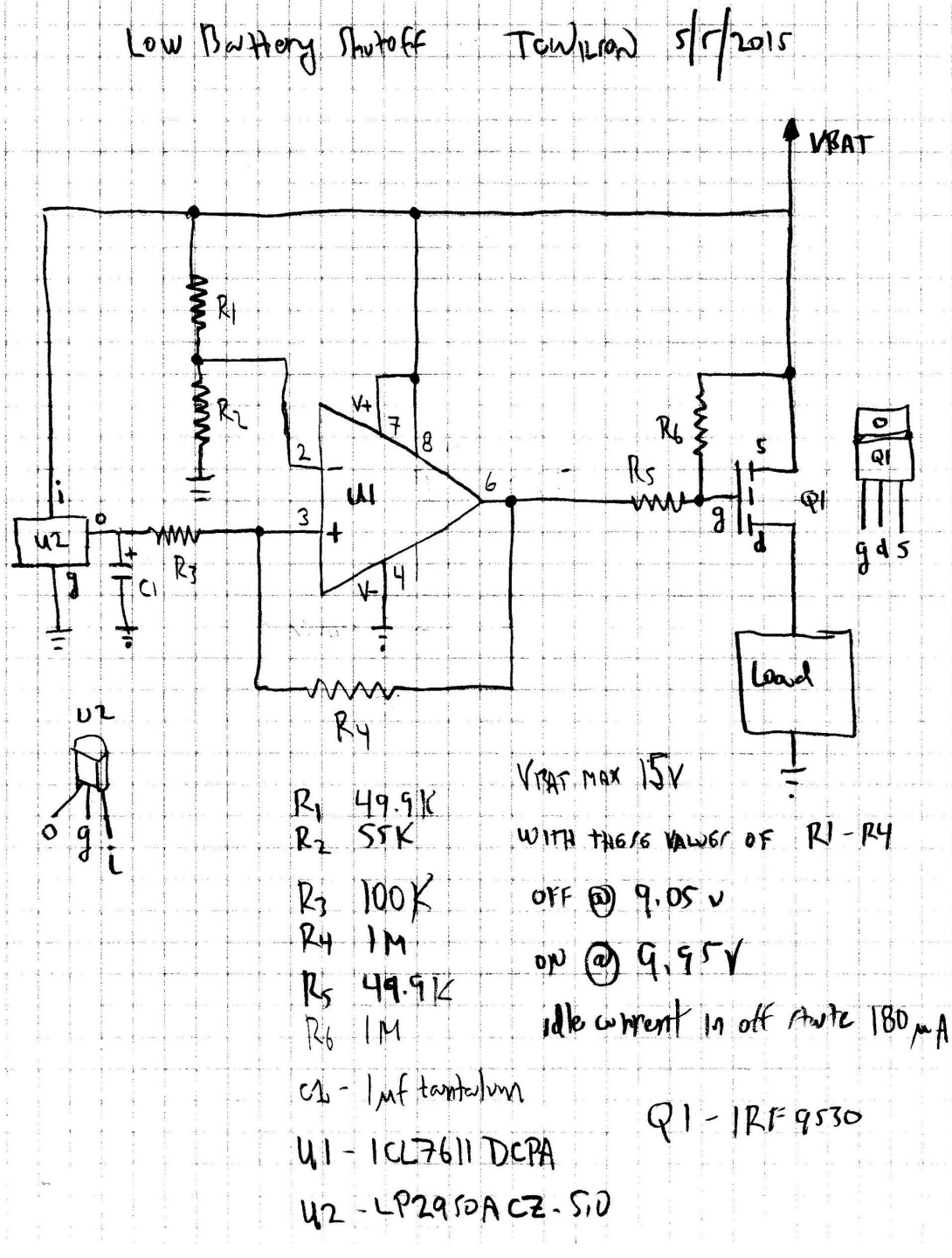
Put it All Together

LOW BATTERY SHUTOFF CIRCUIT

Theory of operation and circuit notes.
T.C. Wilson – 5 May 2015.

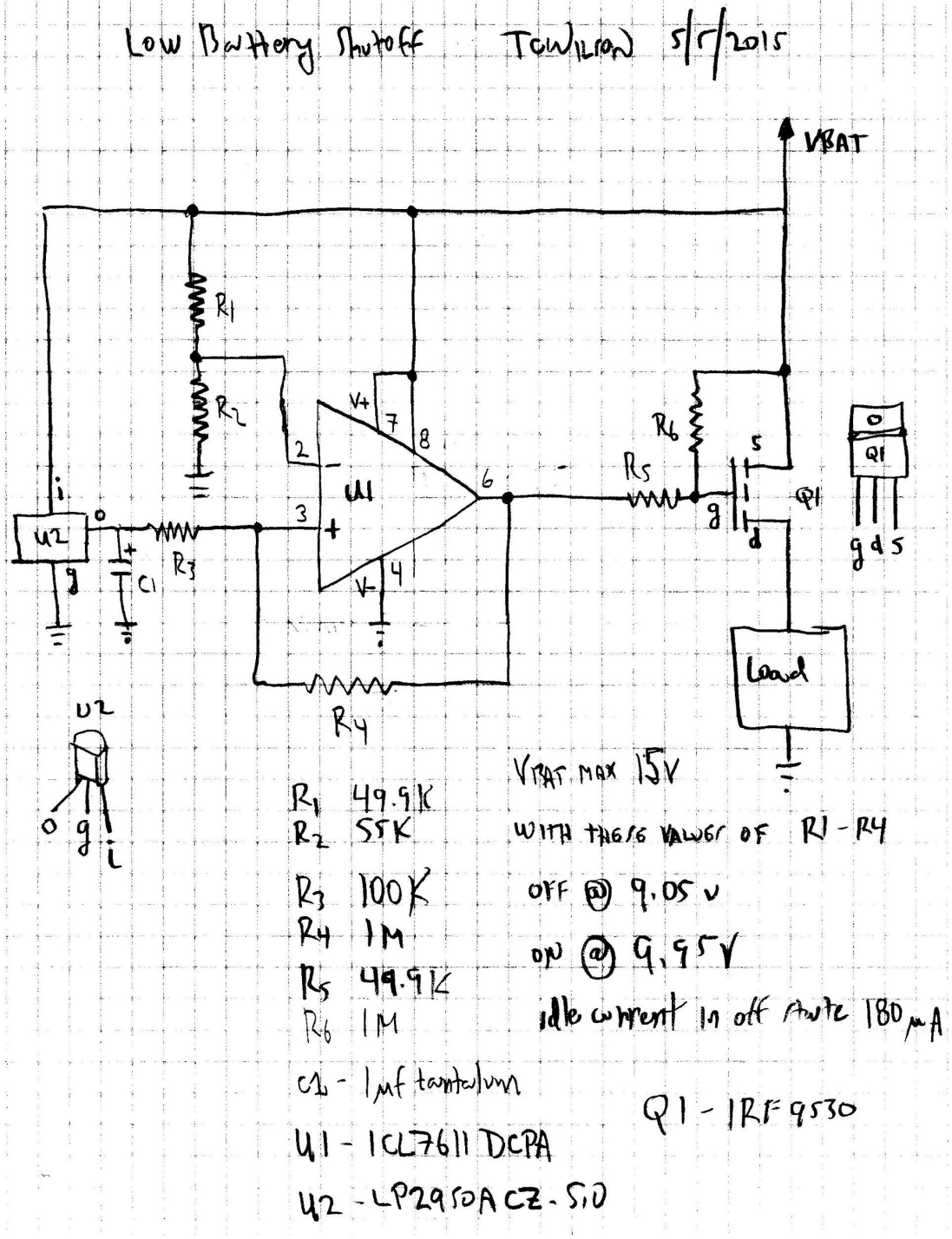
1. Regulator U2 provides a reference voltage of 5.0 volts. C1 provides stabilization. Another reference such as a zener and resistor could be used but the LP2950 is small, has low idle current, and I had a drawer full of them.

50:00



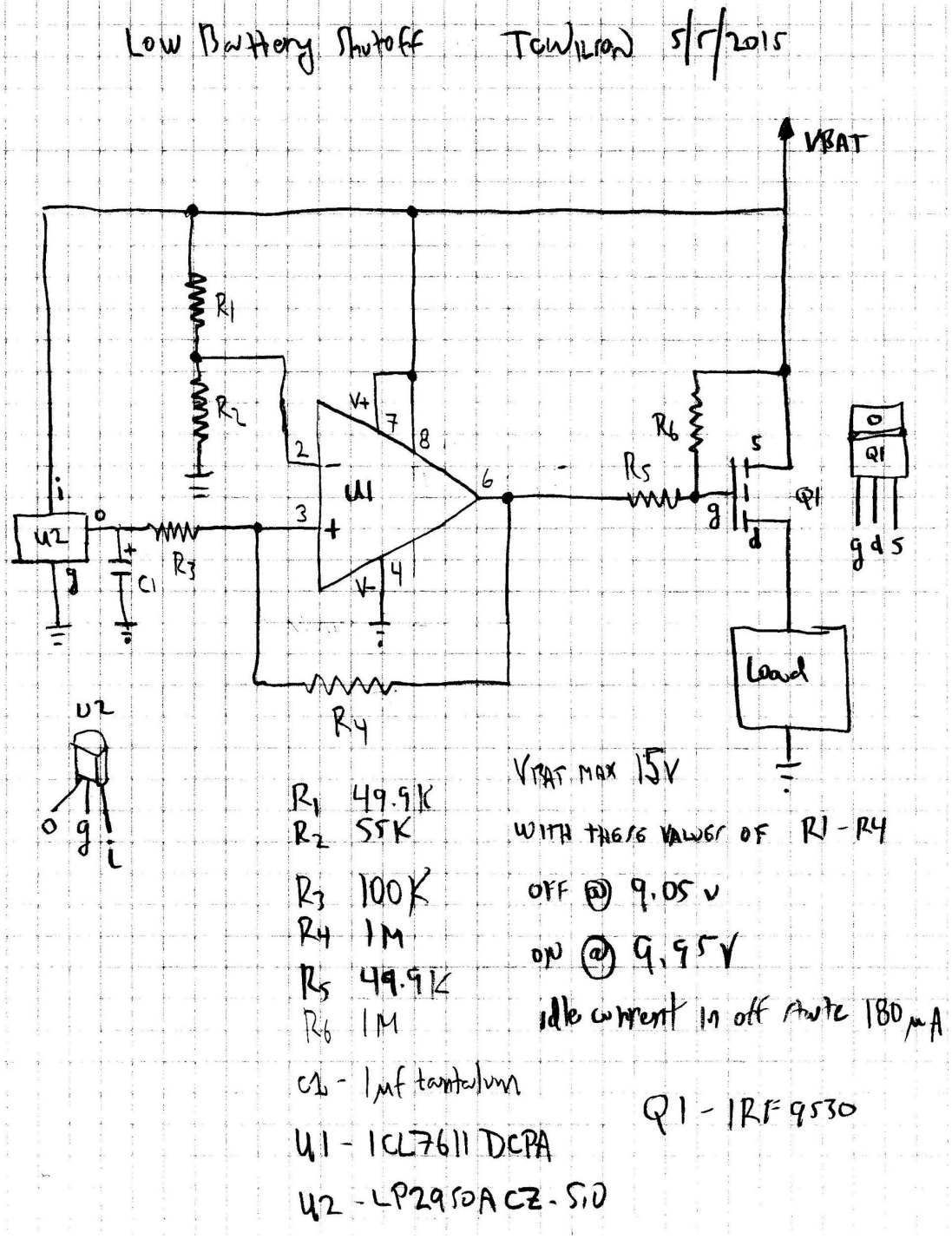
2. U1 is a CMOS low power op amp that can drive output to the supply rails (important in this application). R1 and R2 form a voltage divider defining the setpoint for the shutoff. When pin 2 voltage is less then pin 3 voltage output pin 6 is driven low and turns on power MOSFET Q1 through R5. R6 provides additional pullup to turn off Q1.

U1 pin 8 sets idle current iQ (higher iQ=higher bandwidth). Since bandwidth is not important in this application pin 8 is tied to V+ for minimum idle current of 10 uA. Overall idle current of the circuit in shutdown is 190 uA, if you care to reduce this you could probably set R1 + R2 = 1 Mohm instead of 100 Kohm.

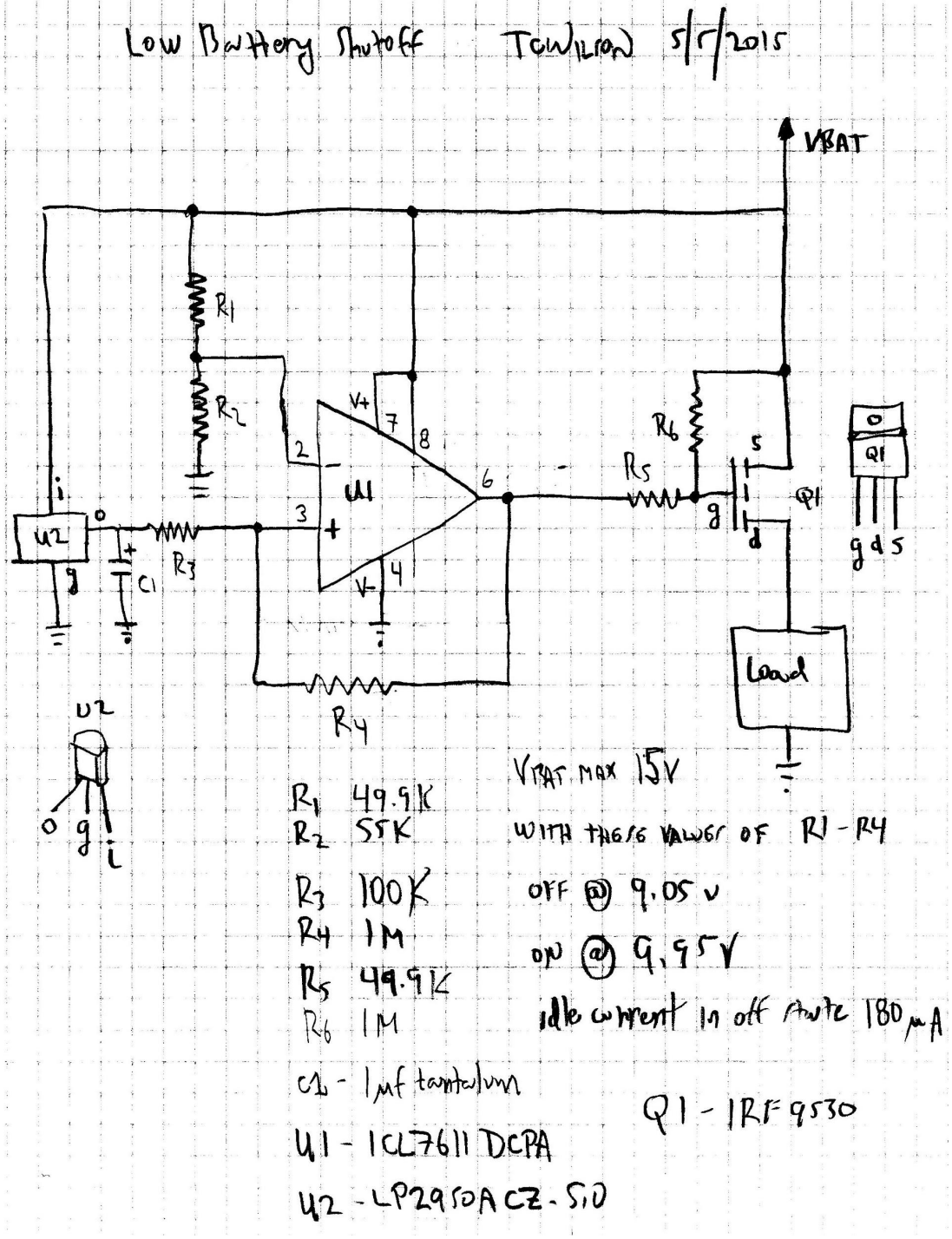


U1 limits the upper voltage range of the circuit to 15 volts (absolute maximum rating for the ICL7611 is +/-8V for V+ to V-). Another op amp with greater voltage range might be used but it will need to be able to provide rail to rail output – and be sure to check the definition of pin 8 as the iQ set pin is not a standard on most op-amps

55:00

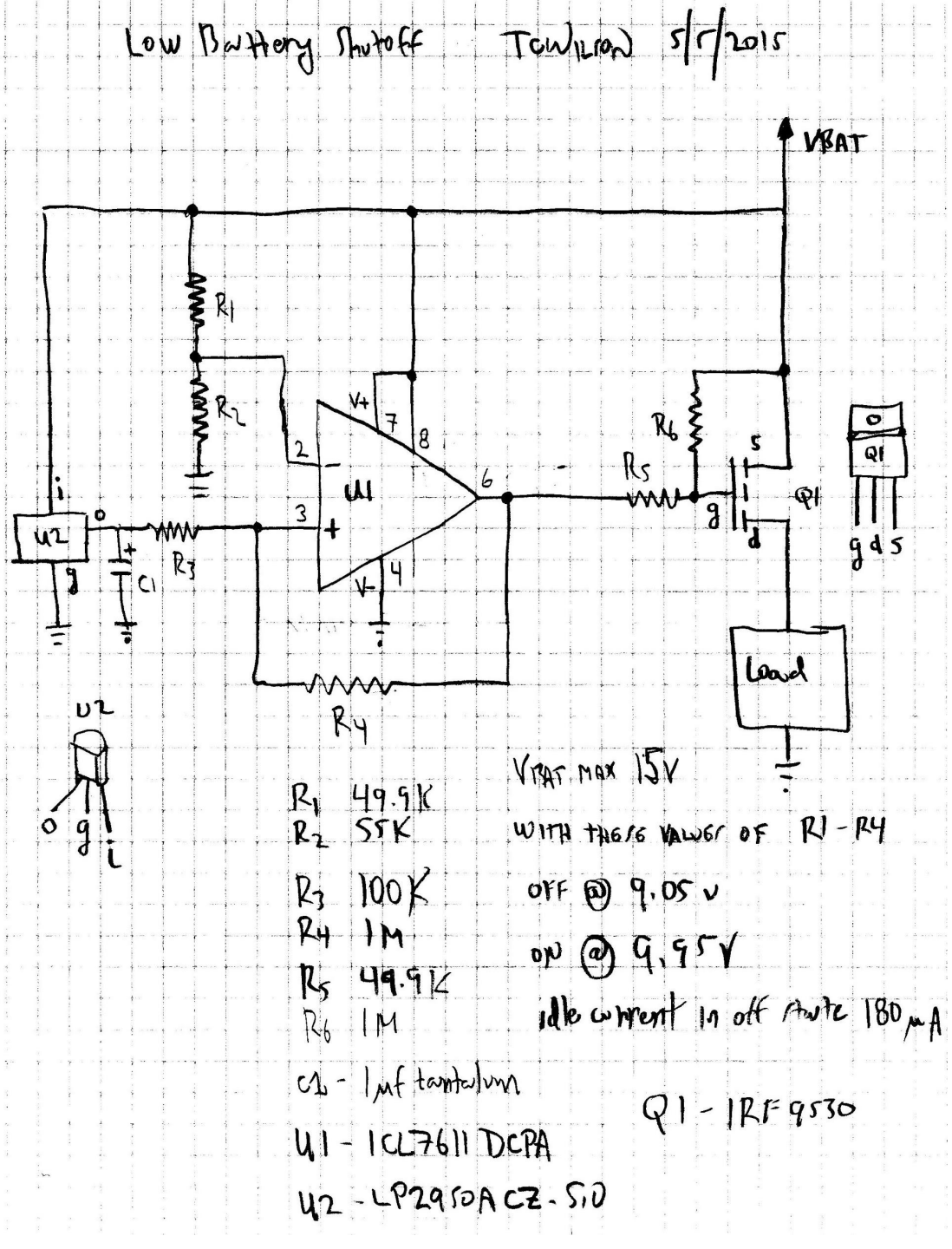


3. R4 provides positive feedback = hysteresis to the circuit. When the circuit turns power on (voltage at pin 2 becomes higher than pin 3) pin 6 swings low and drives pin 3 even lower through R4, reinforcing the voltage difference between pins 2 and 3. Similarly, when the circuit turns power off (voltage at pin 2 becomes lower than pin 3) pin 6 swings high and drives pin 3 even higher through R4, again reinforcing the voltage difference between pins 2 and 3.



4. Because of the required hysteresis, determining the startup and shutdown points is a recursive process. Select R1 + R2 = about 100 Kohm, with the ratio selected so that voltage at pin 2 is 5 volts at a value of VBat midway between the desired shutdown and restart voltages. R4 should remain at 1 Mohm. The greater the value for R3 the larger the hysteresis.

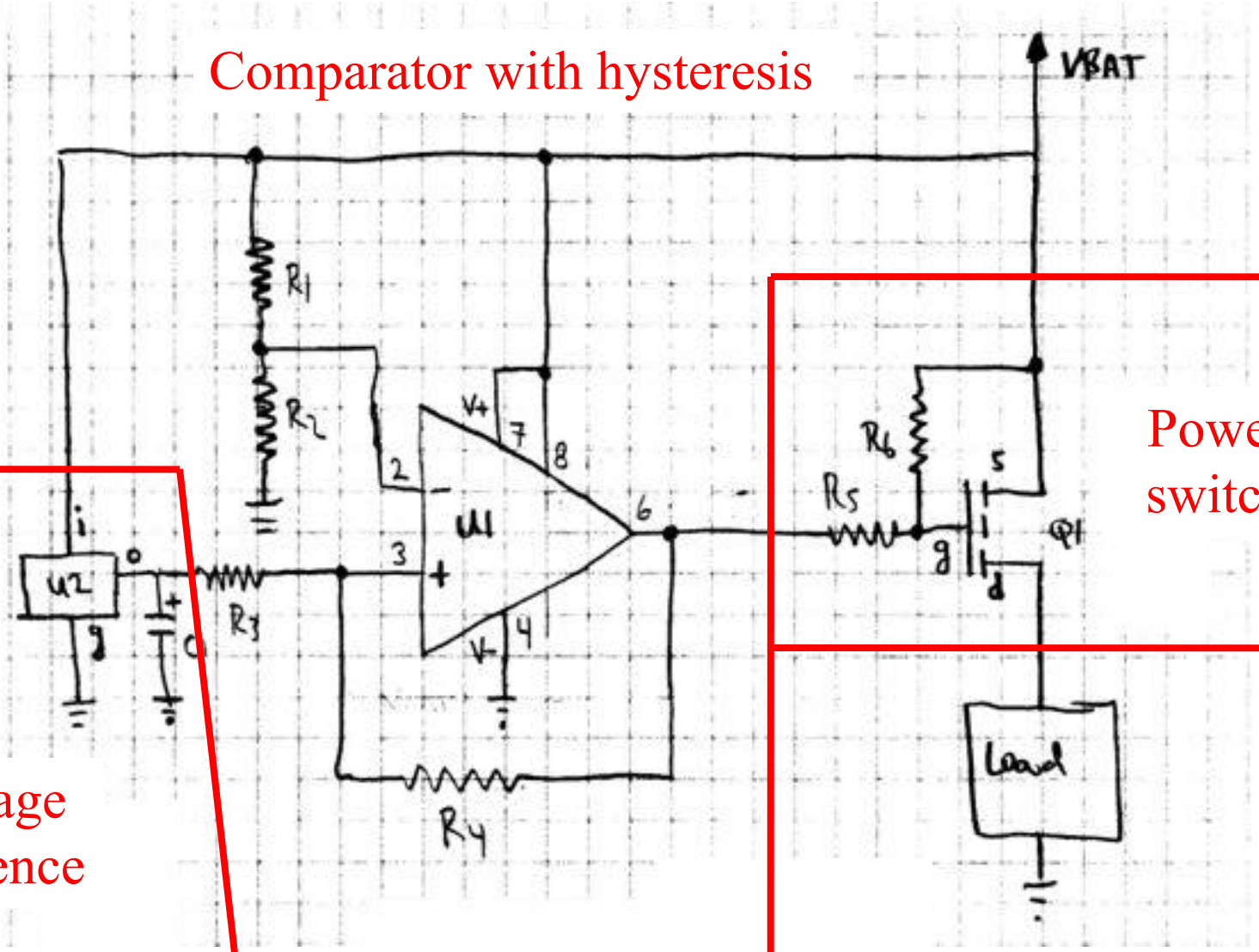
1:00



At values of R1=49.9Kohm, R2=55Kohm, R3=100Kohm, and R4=1Mohm the falling shutdown voltage is approximately 9.05V and the rising restart voltage is 9.95V. Hysteresis should be large enough to prevent power from cycling on and off as the load is applied.

To determine a new setpoint – pick some reasonable values for R1, R2, and R3, put a load on the circuit, measure the shutdown and restart voltages, and tweak the values for the resistors until you get the specifications you need.

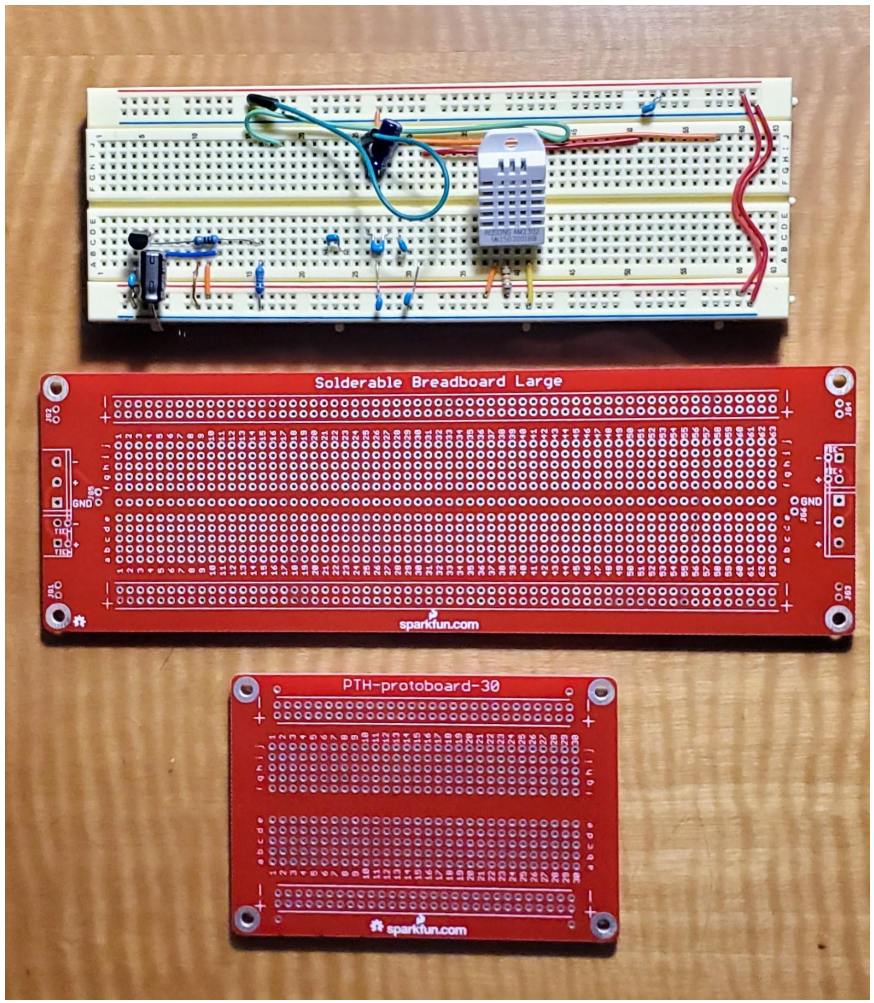
DO YOU SEE THE SUBSYSTEMS?



1:05

MAKING IT PERMANENT - HAND WIRED

Do not disrespect hand wiring.
It's not a prototype, it's a one-off!



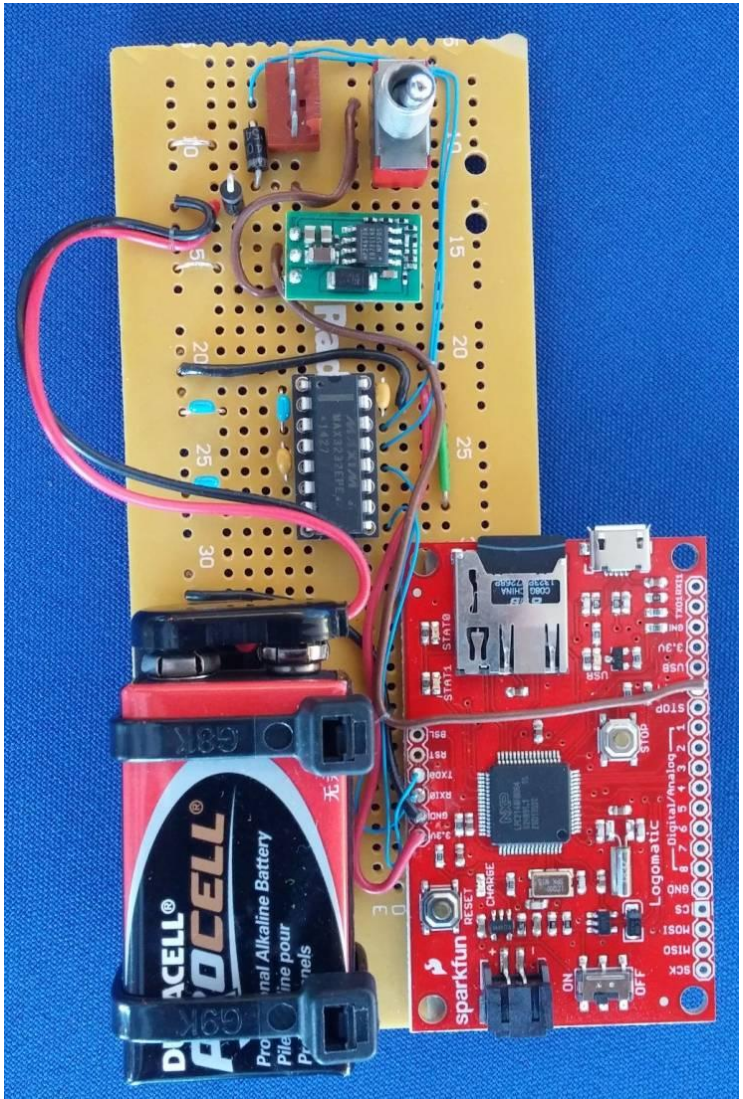
DEBUG the design
on a plug in protoboard

then

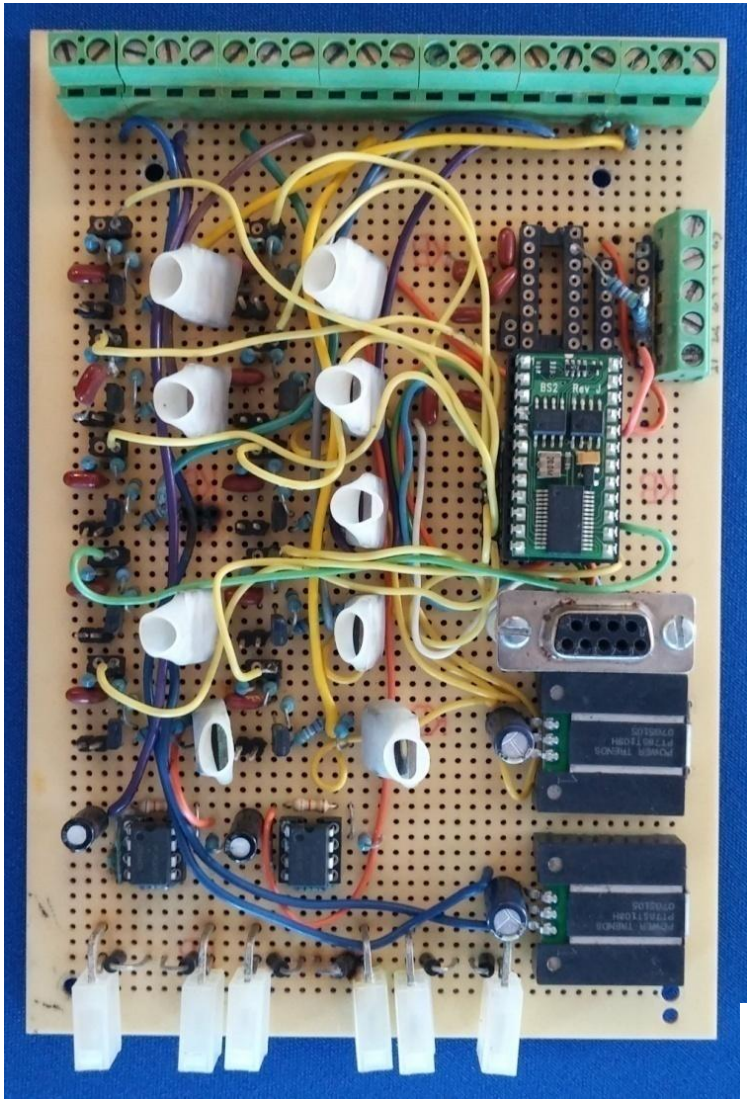
COPY
onto a solderable
breadboard

MAKING IT PERMANENT - HAND WIRED

GPS logger



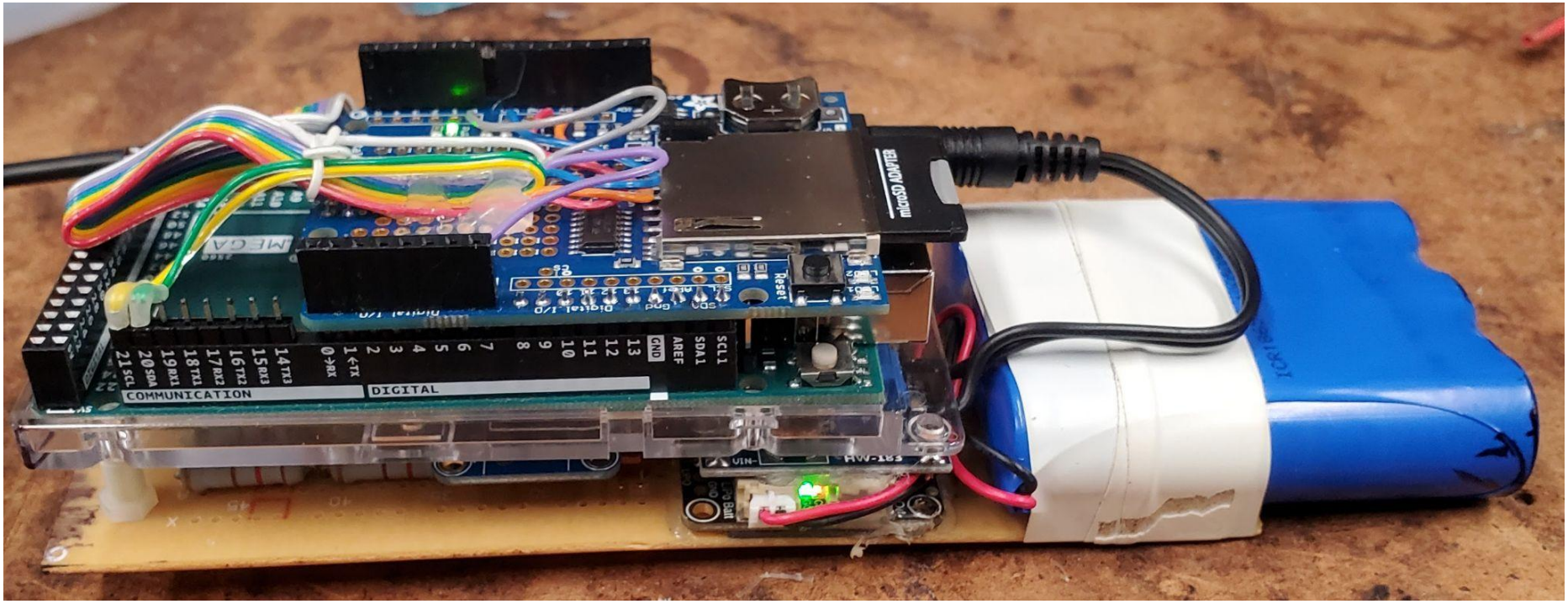
Met buoy power control



1:10

MAKING IT PERMANENT - HAND WIRED

Thermoelectric Generator Logger



Measures voltage and current through internal resistive load, relative humidity & temperature inside pressure case, and battery voltage. Recharges 10 AH lithium polymer battery pack through USB or DC jack.

MAKING IT PERMANENT - COMMERCIAL PCB

Beware of "free PCB design" software offered by a PCB vendor - usually traps you with that vendor

KiCAD: www.KiCAD.org
Cross platform, open source PCB design and layout software.
Design around free drill sizes.
Output "Gerber" files, email to board maker with credit card.

"Designing Your Own PC Board", RVTEC 2020:
https://www.unols.org/sites/default/files/202010rvt_ap17.pdf
YouTube recording:
https://www.youtube.com/live/N3lHpPac66c?si=-jMMrDbgrKE8be8I&t=7190

Getting Your Board Produced:
Advanced Circuits - http://www.4pcb.com/
Best prices for small runs of bare boards – 2 layers, $33 each, min qty 4.
https://www.4pcb.com/pcb-prototype-2-4-layer-boards-specials.html

For populated boards try www.Circuithub.com
Expensive - first board $2,000, additional boards $10 each.

In a Week or So...

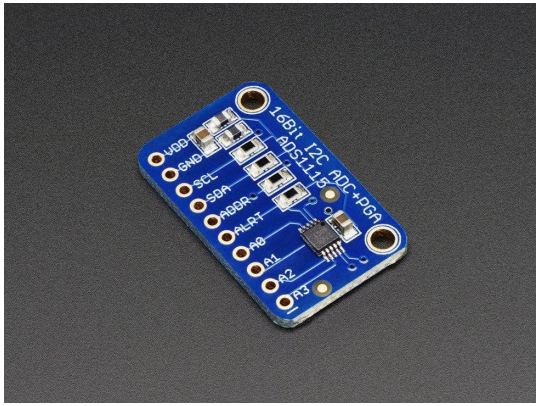
Free popcorn in every order!

Arduino Mega Field Logger Board

NOTE:
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" or the chip of interest on sites like sparkfun.com, adafruit.com, and even Amazon.com can return many useful boards:



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

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

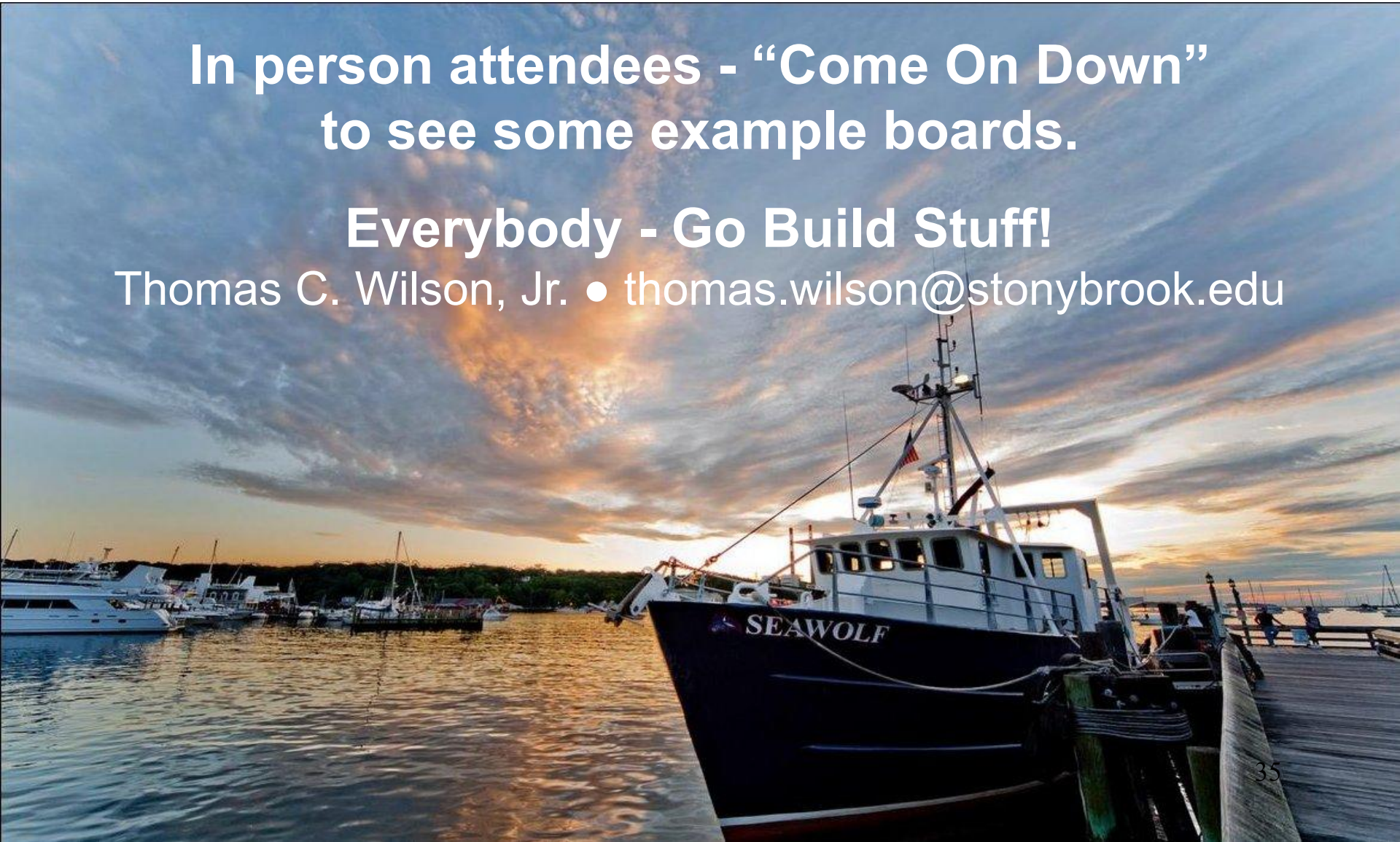

Chris Crosby


Miles Litzmann


Lucas Merlo

and of course my shipmates at RVTEC.

Thank you! Questions?



In person attendees - “Come On Down”
to see some example boards.

Everybody - Go Build Stuff!

Thomas C. Wilson, Jr. ● thomas.wilson@stonybrook.edu