

Getting Started in Electronic Design

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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 RVTEC “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.

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

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.

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.

GALL' S LAW (part 2)

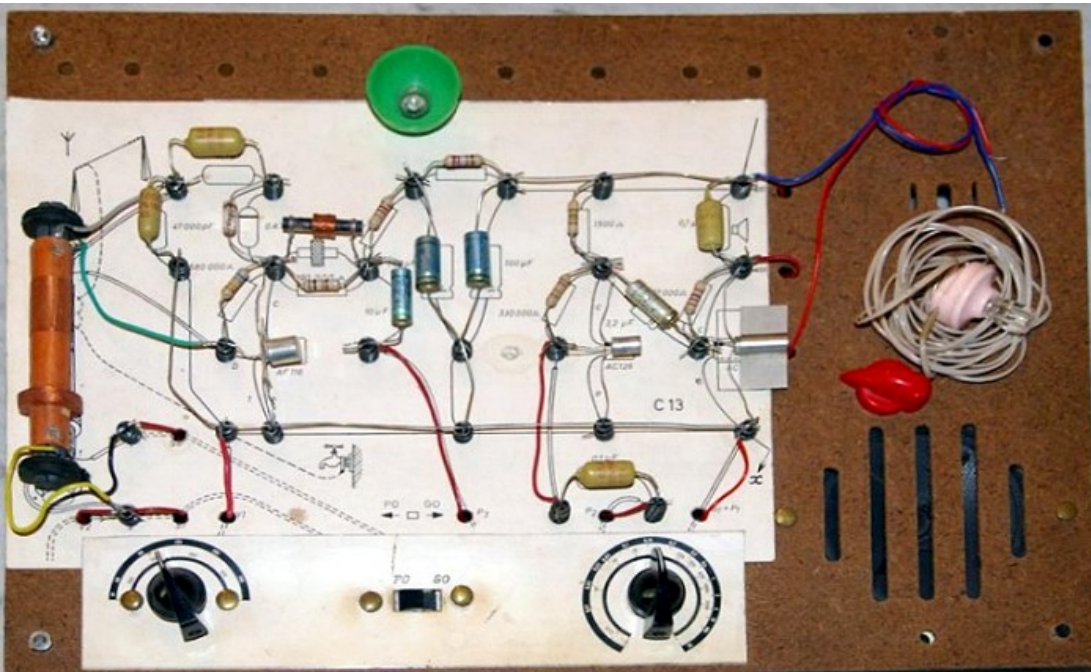
“A complex system designed from scratch never works and cannot be patched up to make it work. You have to start over, beginning with a working simple system.”

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.

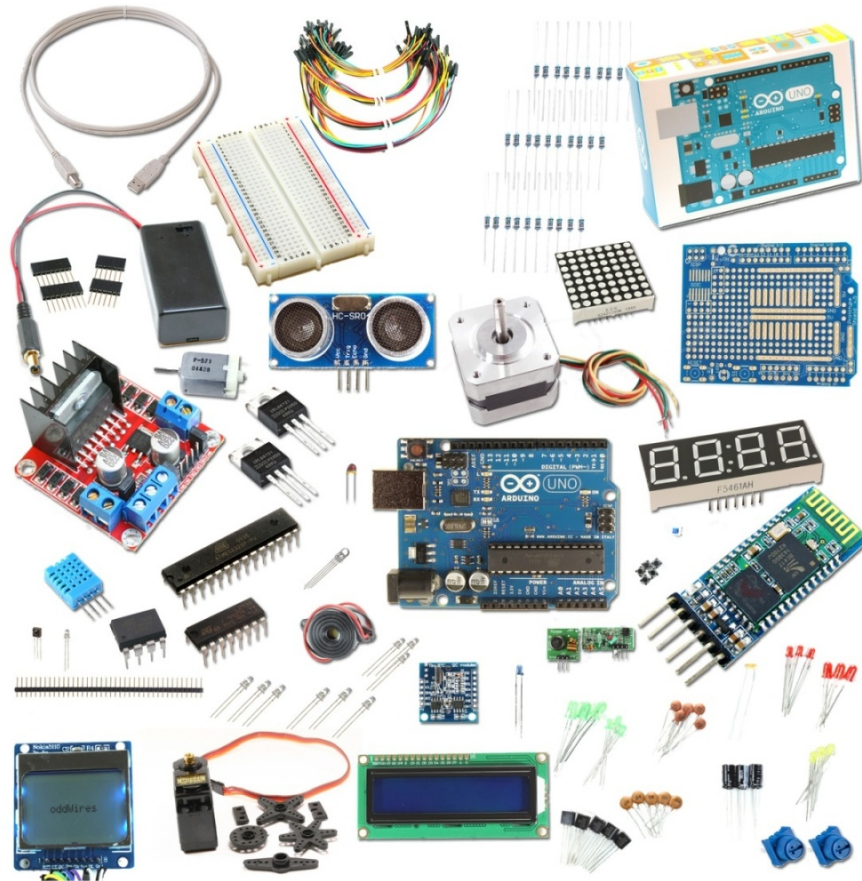


BEGIN BY DOING – your first kit

Oddwires ultimate kit with Arduino Uno and carrying case

\$139.95 (I'd buy one for every tech in the fleet)

61 projects including servos, stepper motors, Bluetooth, ultrasonic rangefinder, LED and LCD displays, etc.



20:00

OK – I built them all – now what?

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

Add to your toolbox of simple systems.

Buy extra parts and make your more useful creations permanent: either with hand wired boards, homemade printed circuit 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.

Focus on ICs and discrete component designs.

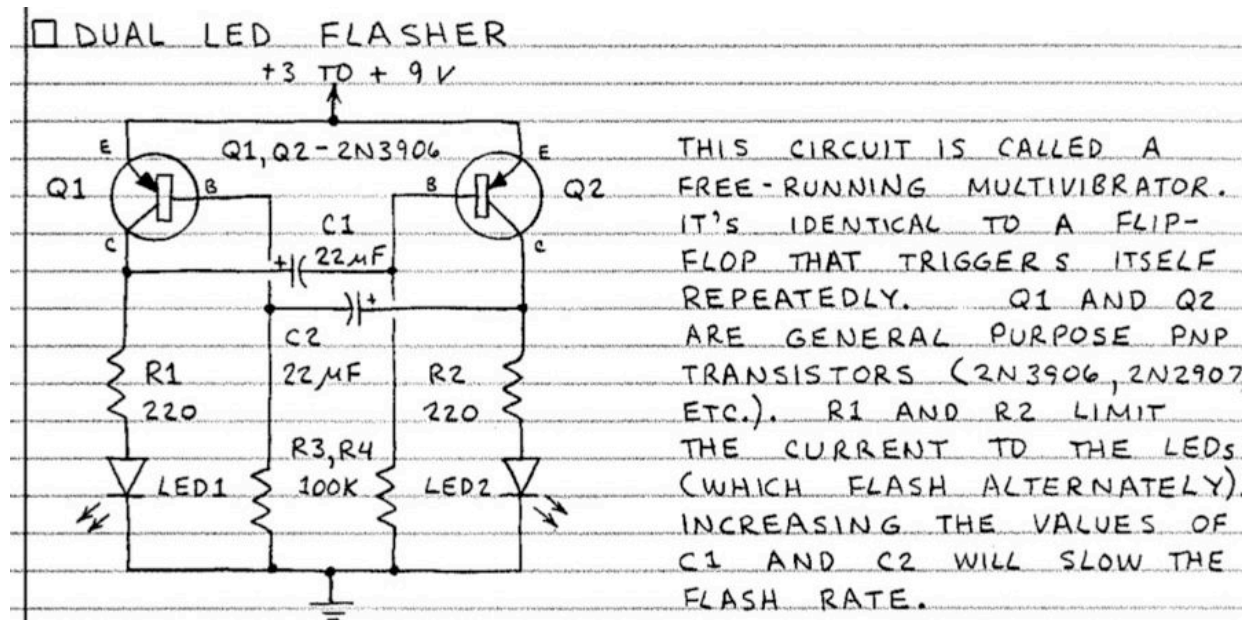
As responsible as anyone for my career.

Buy his books (widely available):

- Getting Started in Electronics

- Engineer's Notebook.

- Whatever else looks interesting.



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)

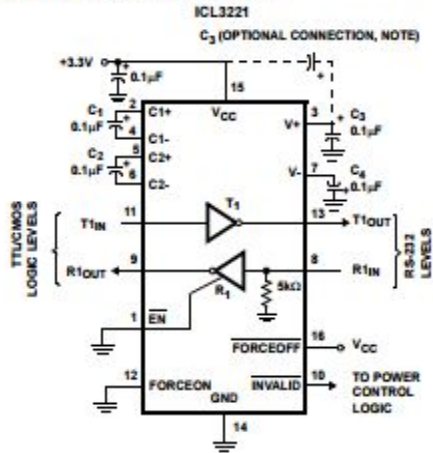
Jameco: www.Jameco.com

(“Workshop” on their home page, also get on mailing list)

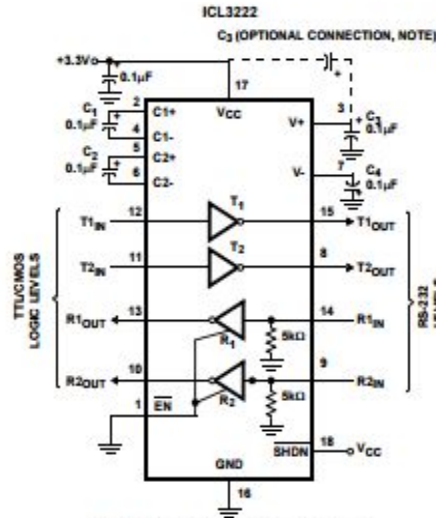
Oddwires: www.oddwires.com (see Arduino project ideas)

Instructables: www.instructables.com (just instruction)

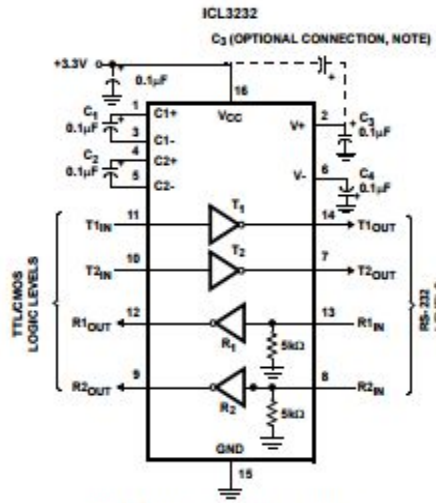
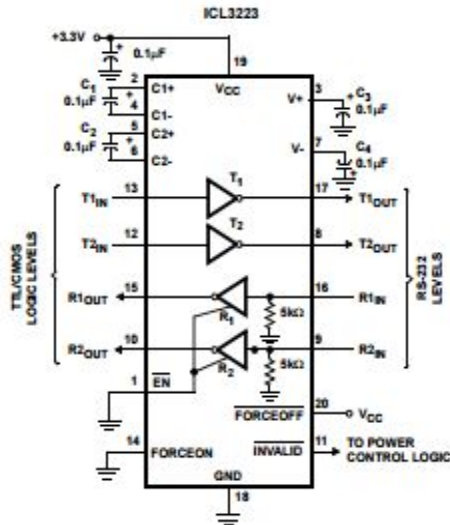
Typical Operating Circuits



NOTE: The negative terminal of C₃ can be connected to either V_{CC} or GND



NOTE: The negative terminal of C₃ can be connected to either V_{CC} or GND



NOTE: The negative terminal of C₃ can be connected to either V_{CC} or GND

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.

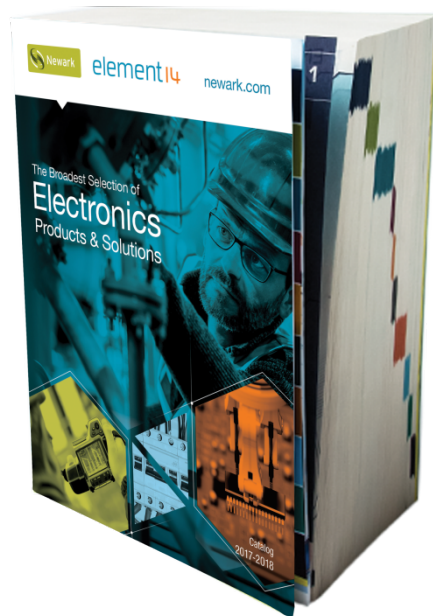
Component Vendors

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.

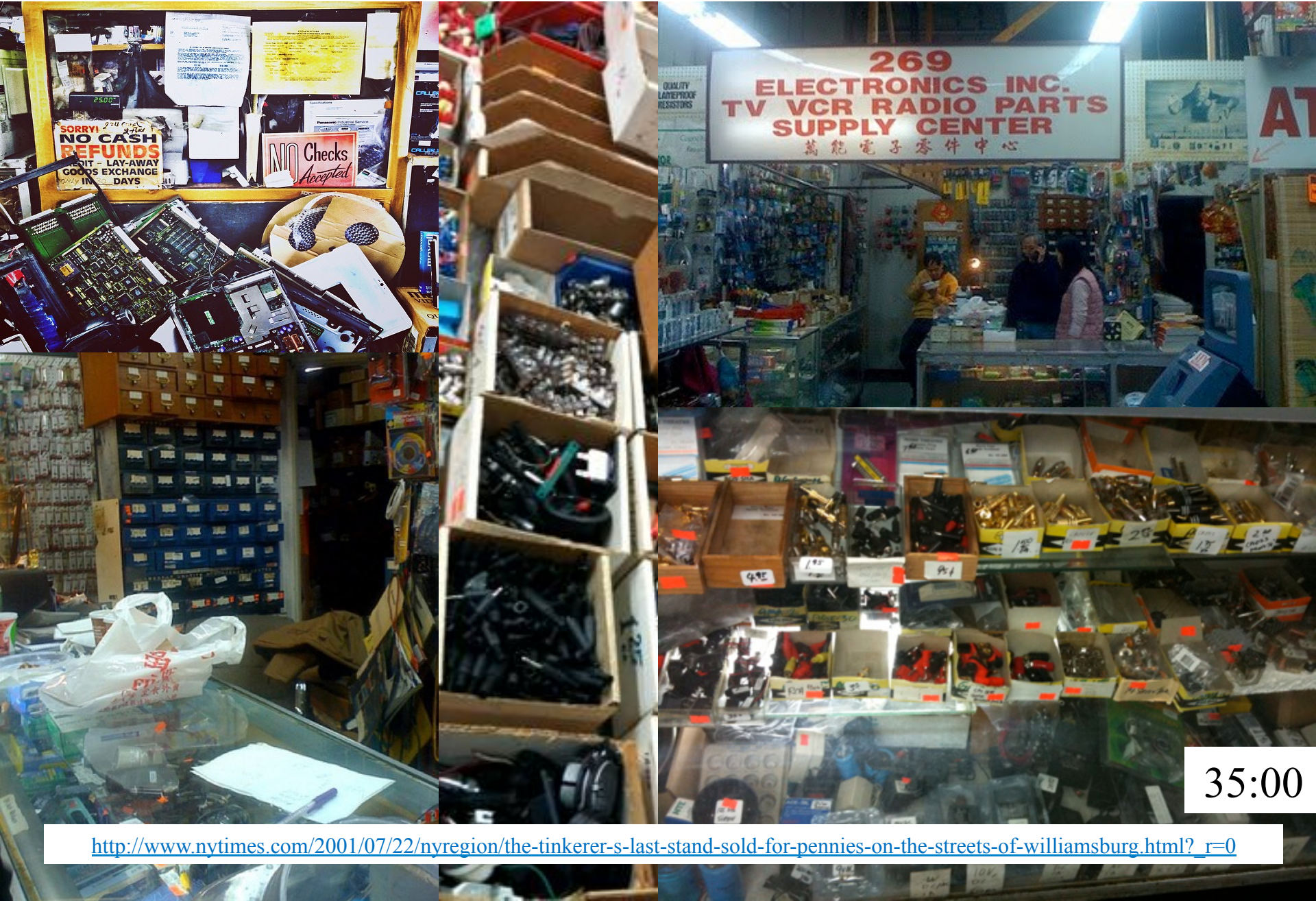
Mouser: www.mouser.com

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/>

C and H Surplus - <http://candhsurplus.com/>

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

All Electronics - <http://www.allelectronics.com/>

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

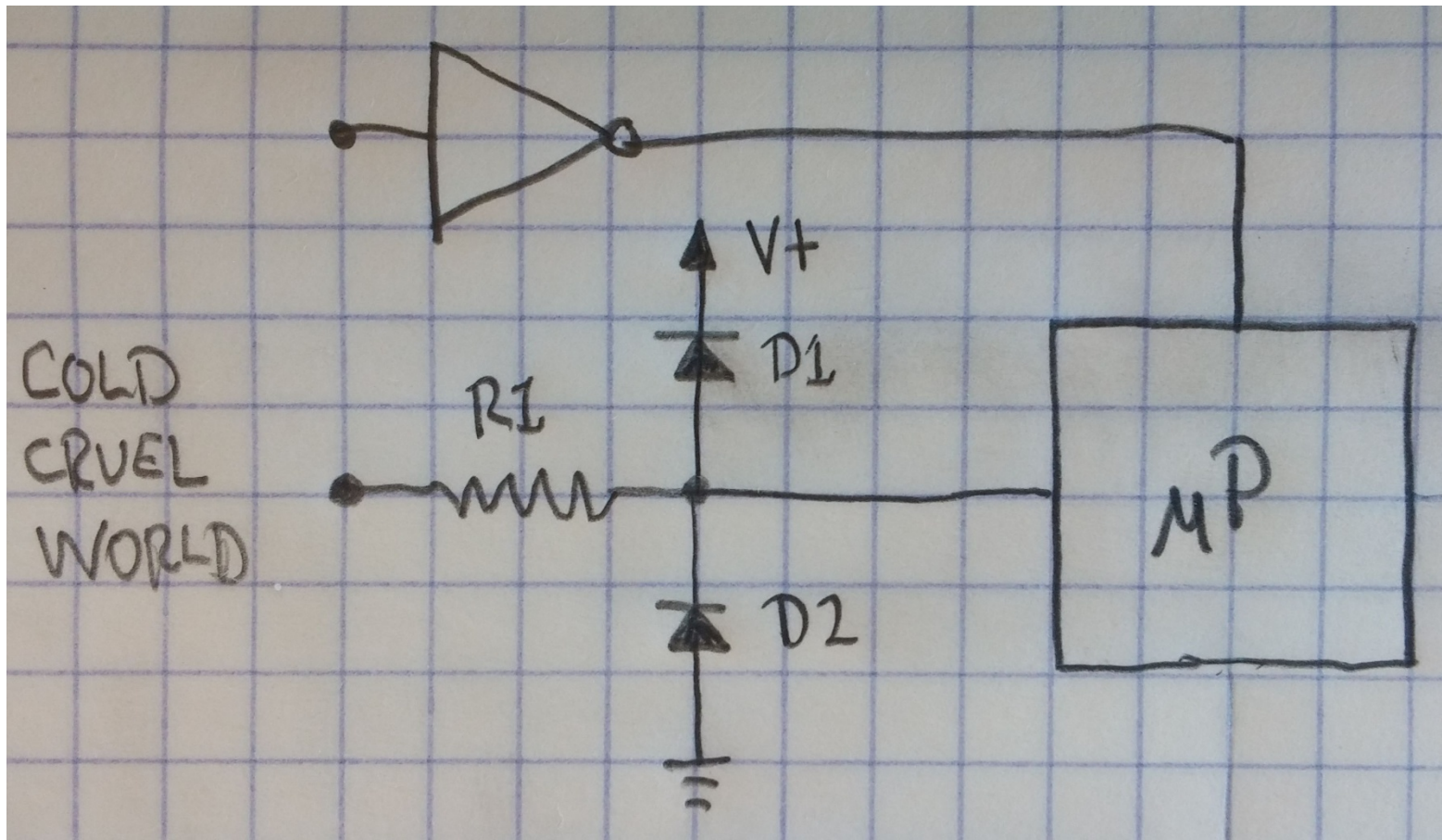
Design and Document

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.



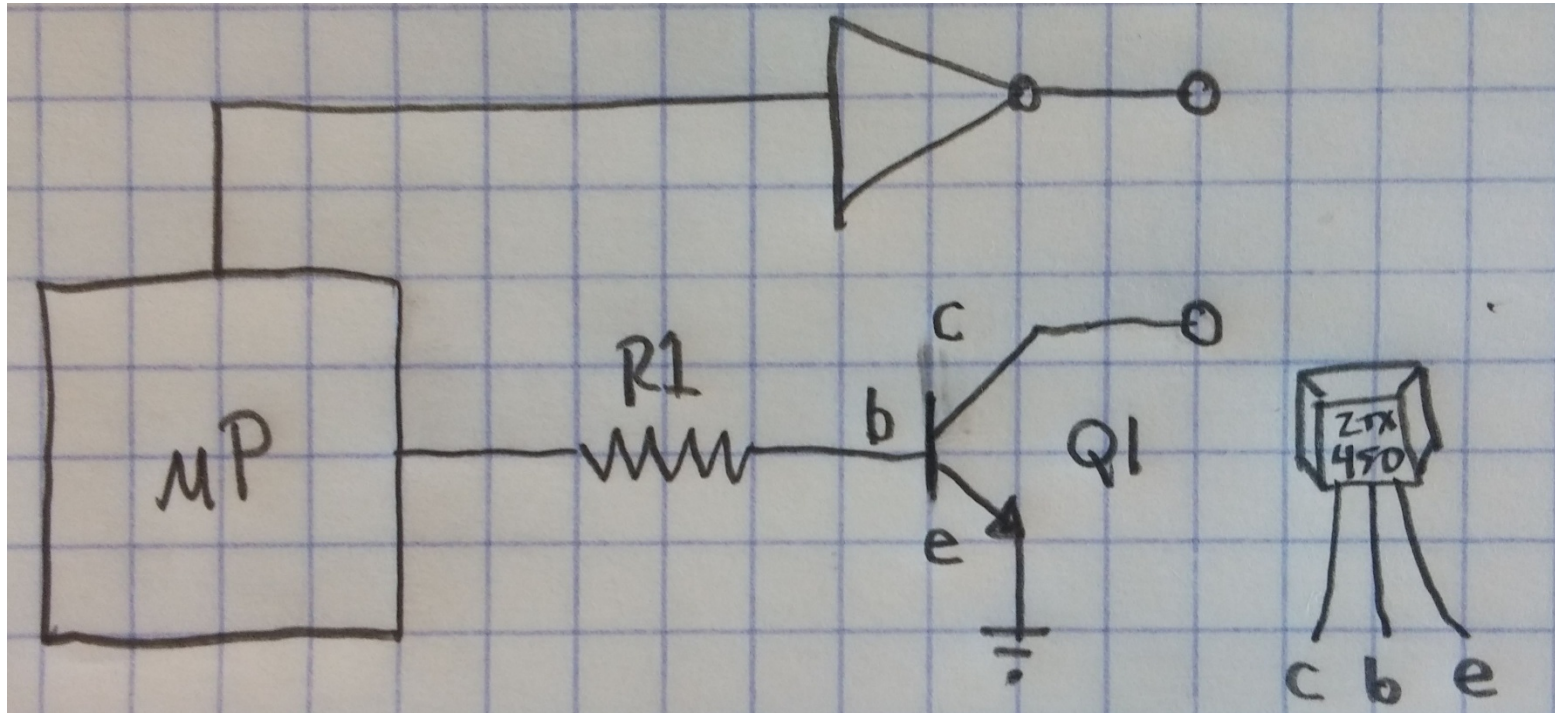
DIGITAL OUTPUT CIRCUIT PROTECTION

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.

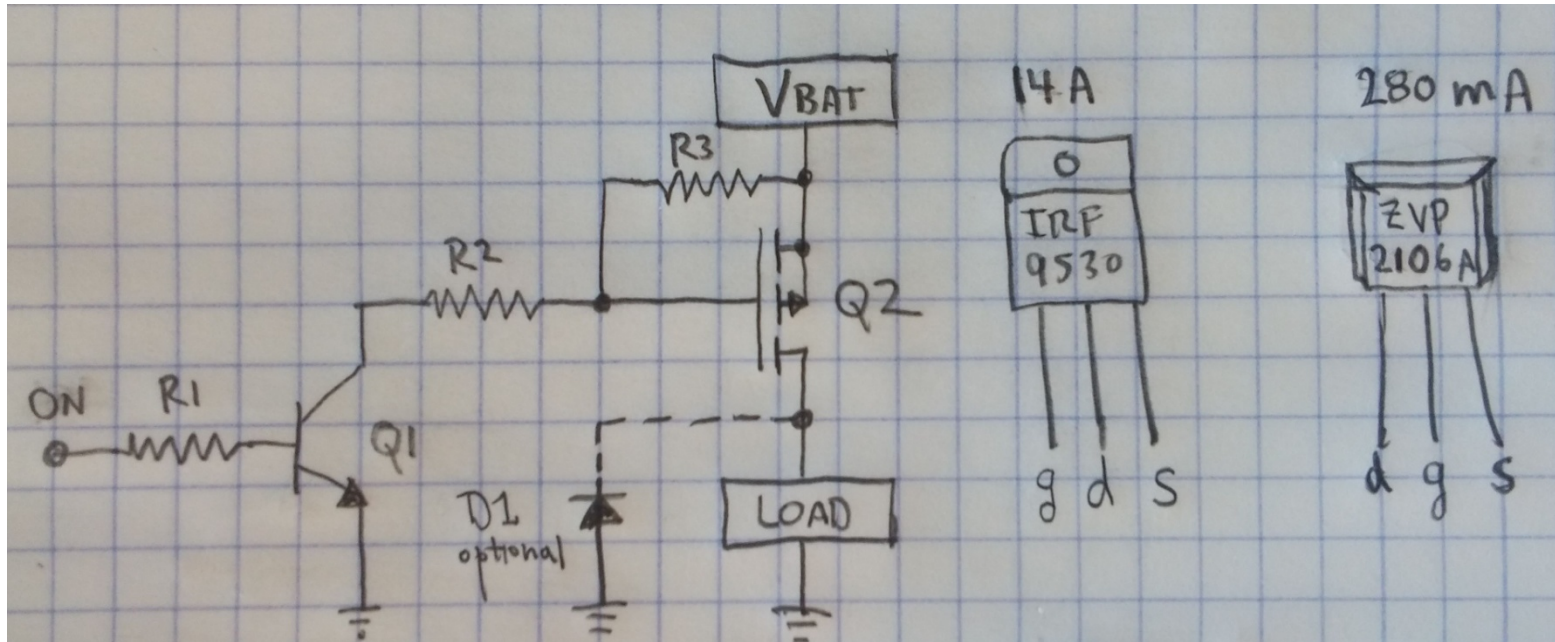
Note 1: This is what you call an “open collector” output.

Note 2: ZTX550 is PNP version of ZTX450.



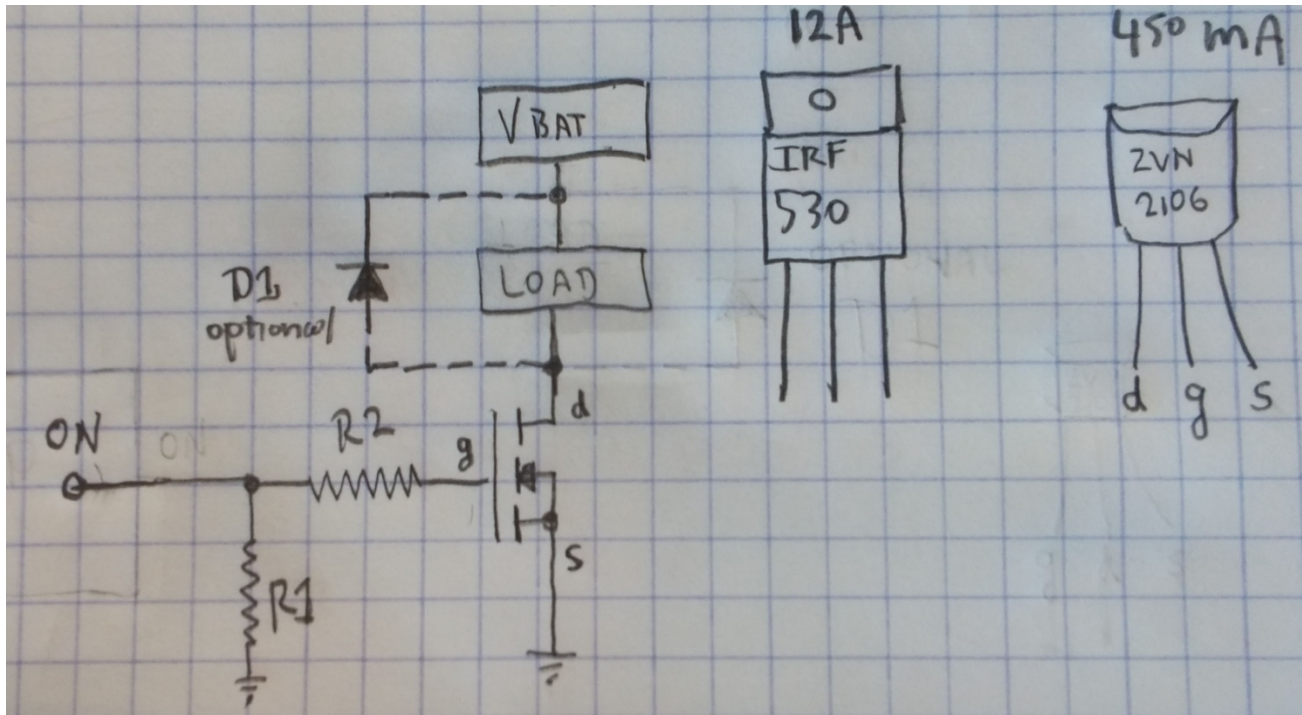
P CHANNEL POWER OUTPUT

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.



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.

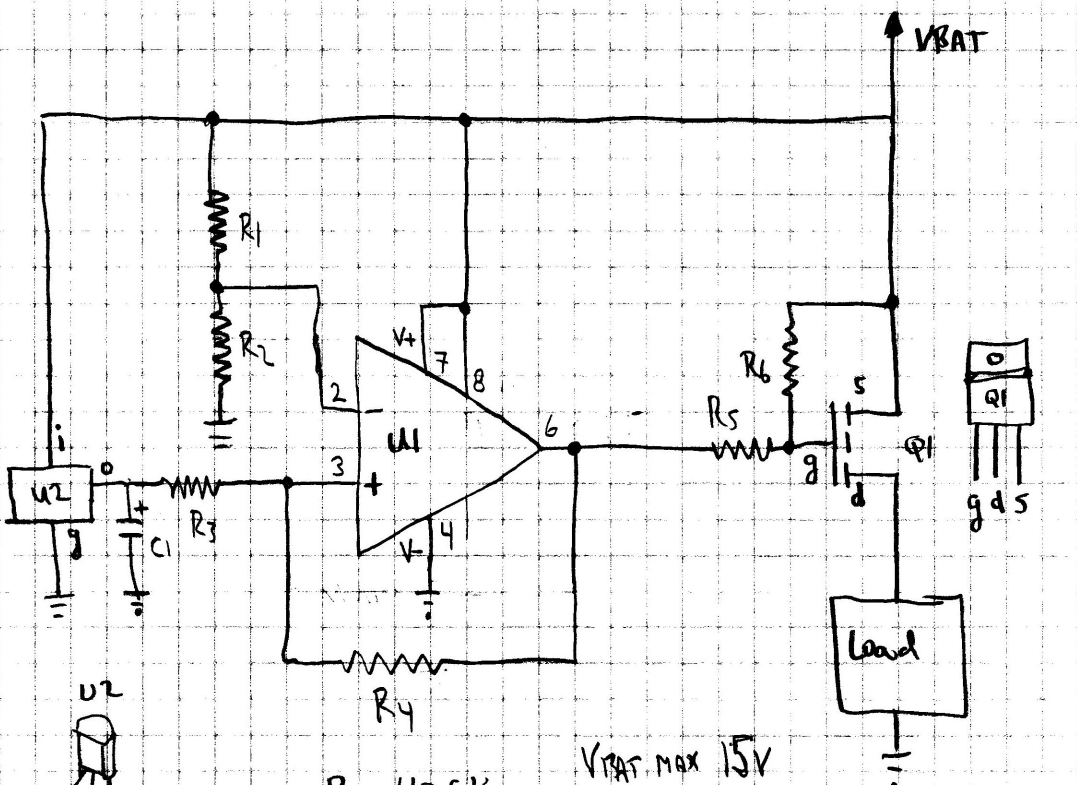


Put it All Together

LOW BATTERY SHUTOFF CIRCUIT

Theory of operation and circuit notes.

T.C. Wilson – 5 May 2015.



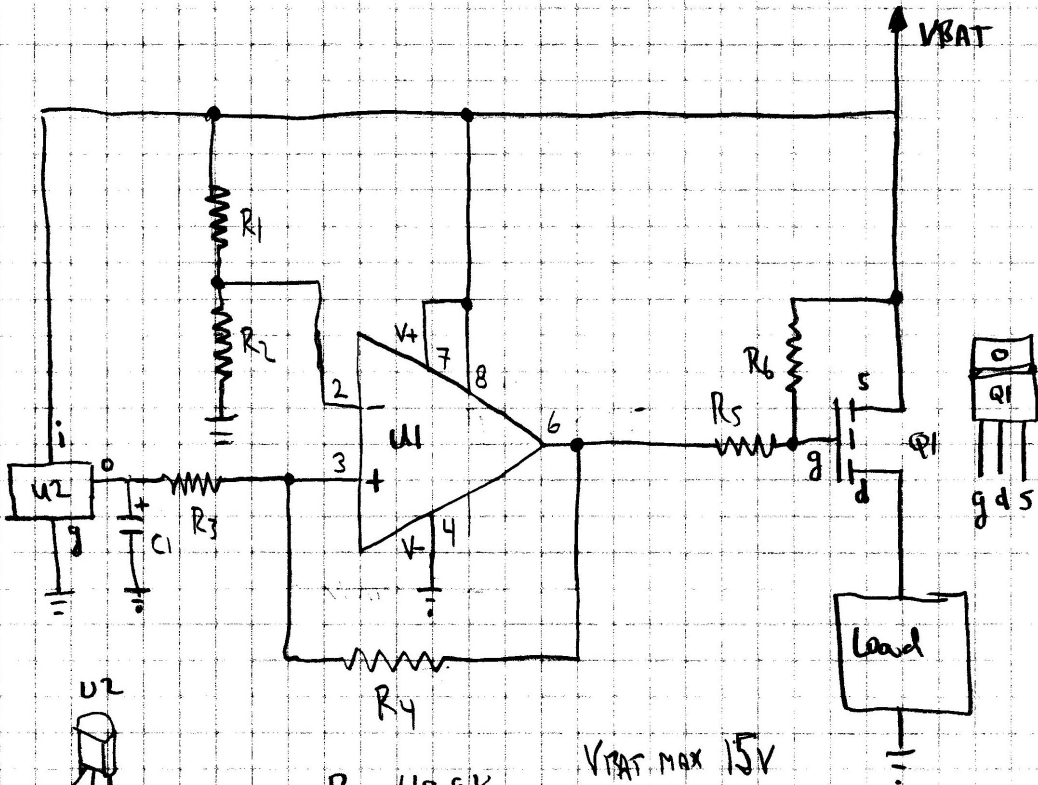
U2
↑
**Note:
pinout
drawings!**

- R₁ 49.9K
 - R₂ 57K
 - R₃ 100K
 - R₄ 1M
 - R₅ 49.9K
 - R₆ 1M
 - C₁ - 1µf tantalum
 - U₁ - ICL7611 DCRA
 - U₂ - LP2950A CZ-5.0
- V_{BAT} MAX 15V
 WITH THESE VALUES OF R₁-R₄
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off mode 180µA
- Q₁ - IRF9530

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 have a drawer full of them.

Low Battery Shutoff TOW/LEON 5/1/2015

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 than 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.



- R1 49.9K
- R2 55K
- R3 100K
- R4 1M
- R5 49.9K
- R6 1M

VBAT MAX 15V
 WITH THESE VALUES OF R1-R4
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off state 180µA

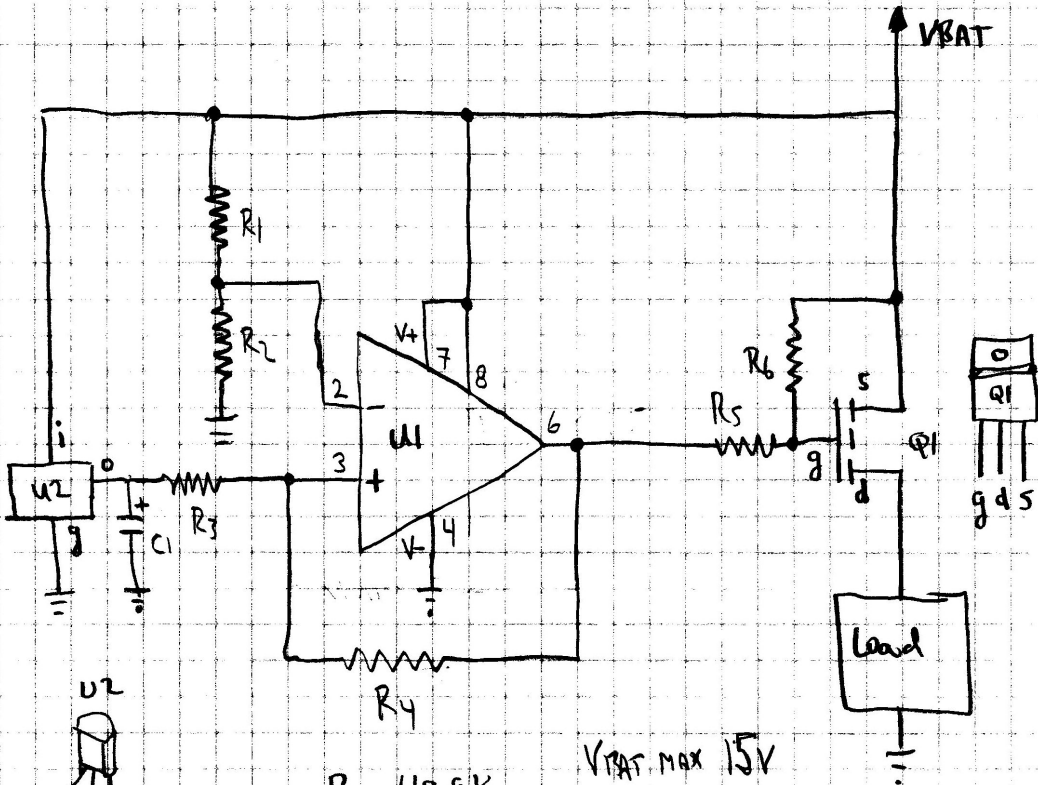
- C1 - 1µf tantalum
- U1 - ICL7611 DCRA
- U2 - LP2950ACZ-5.0

Q1 - IRF9530

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

Low Battery Shutoff TOW/LEON 5/1/2015

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



- R1 49.9K
- R2 55K
- R3 100K
- R4 1M
- R5 49.9K
- R6 1M

VBAT MAX 15V
 WITH THESE VALUES OF R1-R4
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off state 180µA

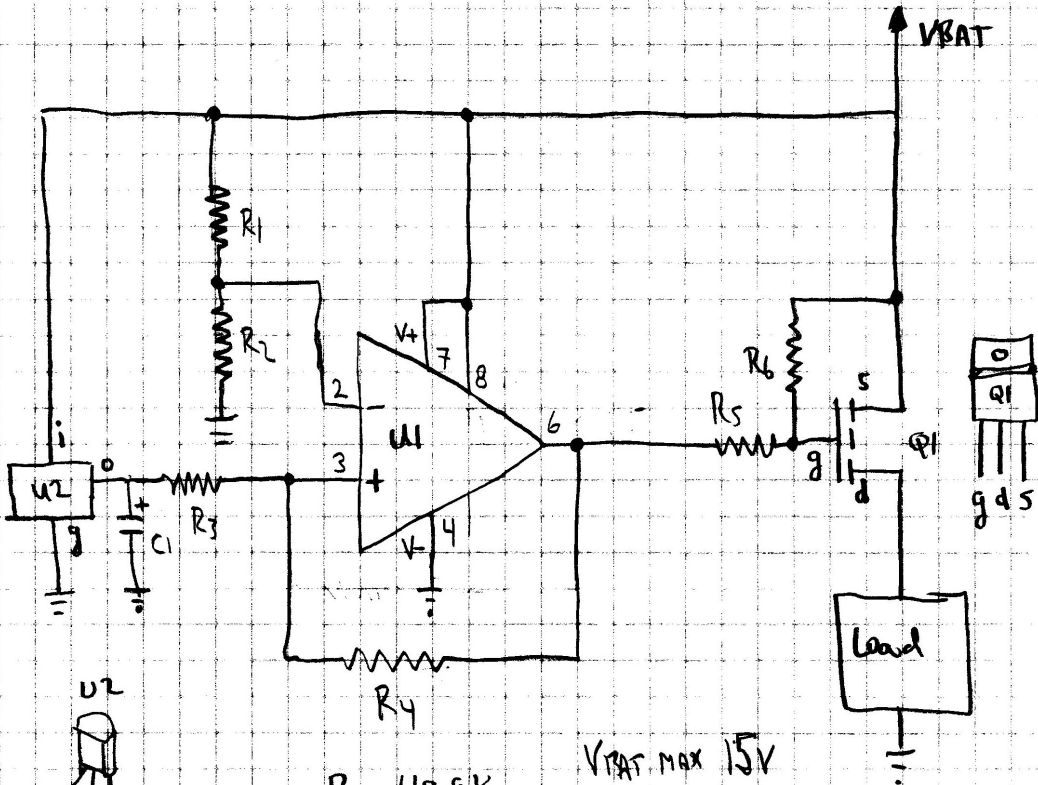
C1 - 1µf tantalum

U1 - ICL7611 DCRA

U2 - LP2950 ACZ-S10

Q1 - IRF9530

Low Battery Shutoff TOW/LEON 5/1/2015



- R1 49.9K
- R2 55K
- R3 100K
- R4 1M
- R5 49.9K
- R6 1M

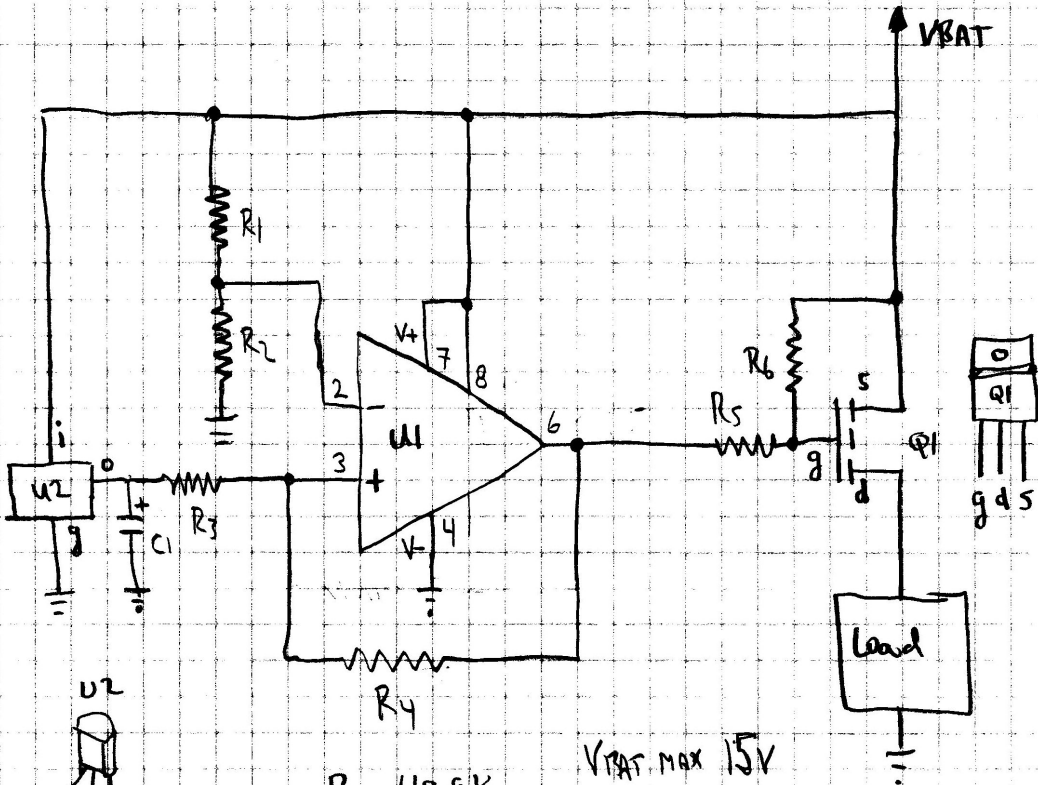
VBAT MAX 15V
 WITH THESE VALUES OF R1-R4
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off state 180µA

- C1 - 1µf tantalum
- U1 - ICL7611 DCRA
- U2 - LP2950ACZ-5.0

Q1 - IRF9530

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.

Low Battery Shutoff Towilson 5/1/2015



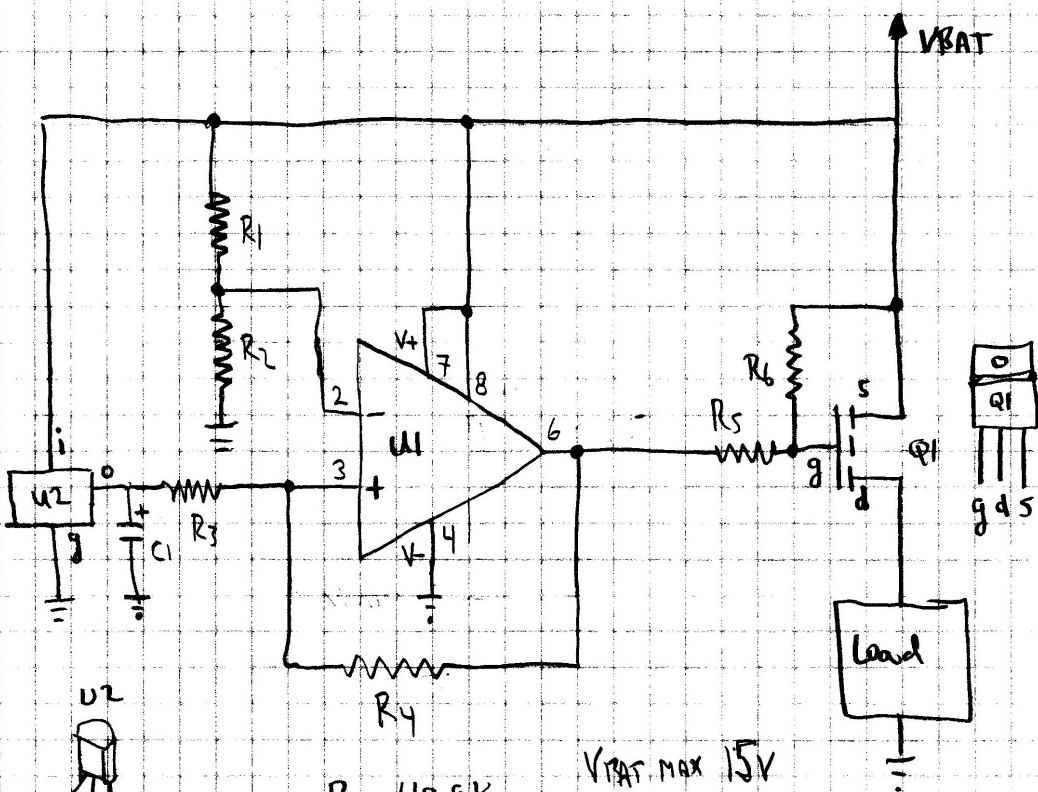
- R1 49.9K
- R2 55K
- R3 100K
- R4 1M
- R5 49.9K
- R6 1M

V_{BAT} MAX 15V
 WITH THESE VALUES OF R1 - R4
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off state 180µA

- C1 - 1µf tantalum
- U1 - ICL7611 DCRA
- U2 - LP2950ACZ-5.0
- Q1 - IRF9530

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.

Low Battery Shutoff TOWILRON 5/1/2015



- R₁ 49.9K
- R₂ 55K
- R₃ 100K
- R₄ 1M
- R₅ 49.9K
- R₆ 1M

V_{BAT} MAX 15V
 WITH THESE VALUES OF R₁-R₄
 OFF @ 9.05V
 ON @ 9.95V
 idle current in off state 180µA

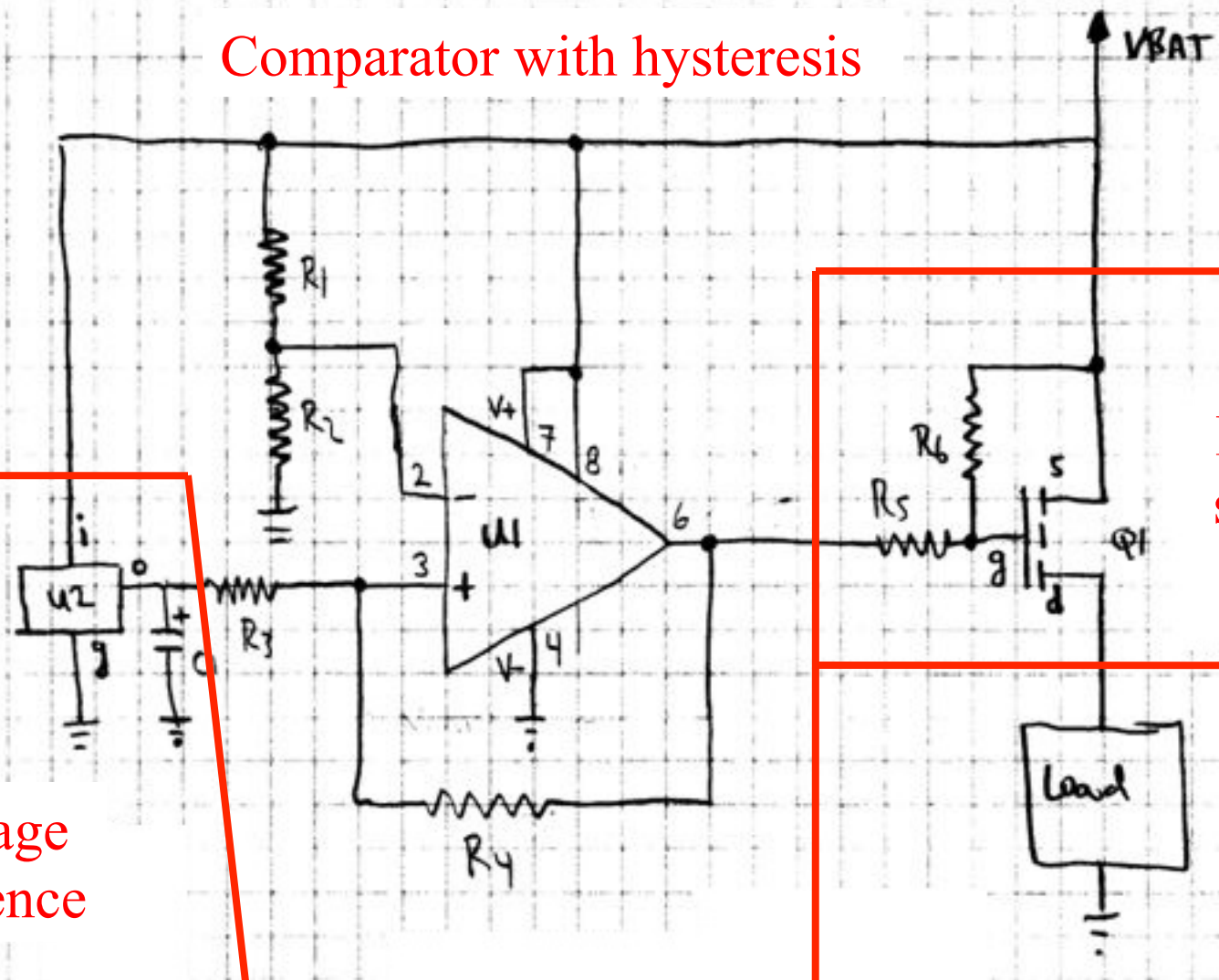
- C₁ - 1µf tantalum
- U₁ - ICL7611 DCRA
- U₂ - LP2950ACZ-5.0
- Q₁ - IRL9530

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?

Comparator with hysteresis



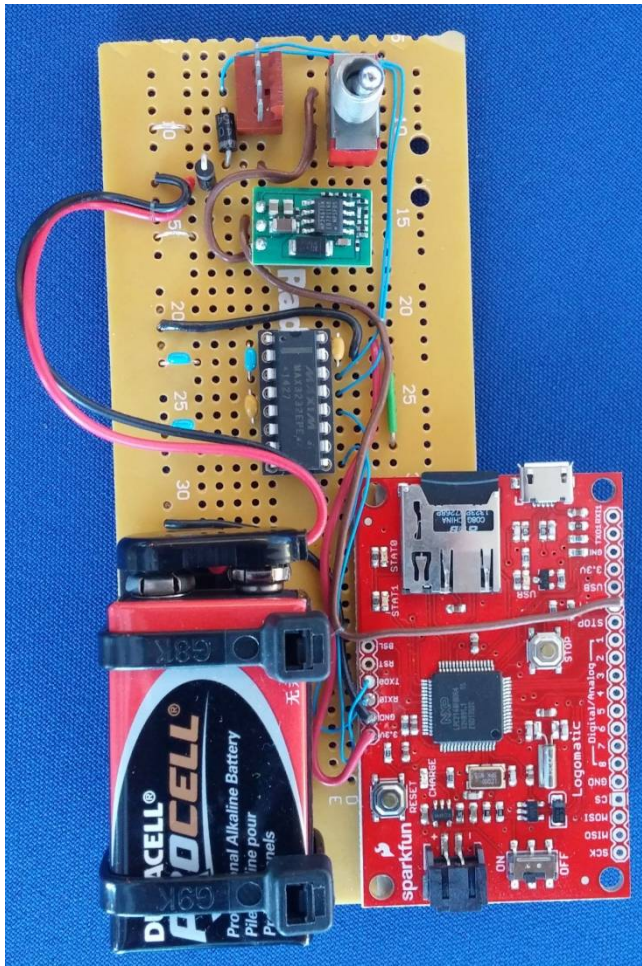
Voltage reference

Power switch

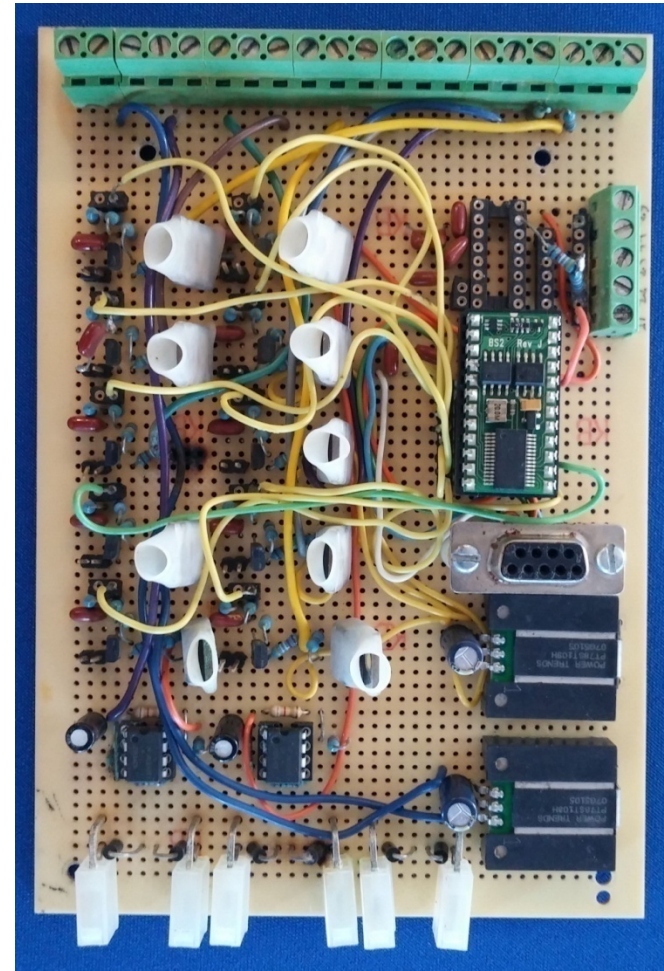
MAKING IT PERMANENT - HAND WIRED

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

GPS logger



Met buoy power control



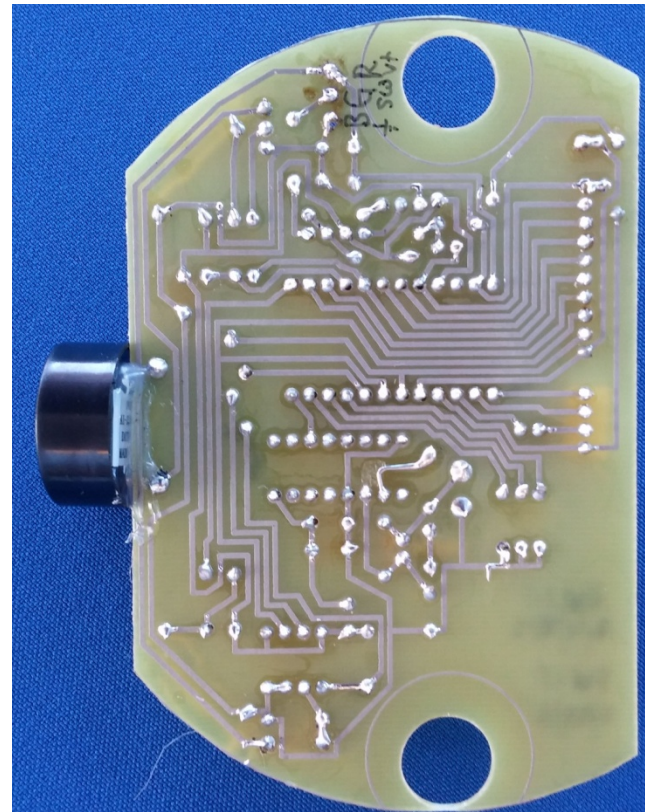
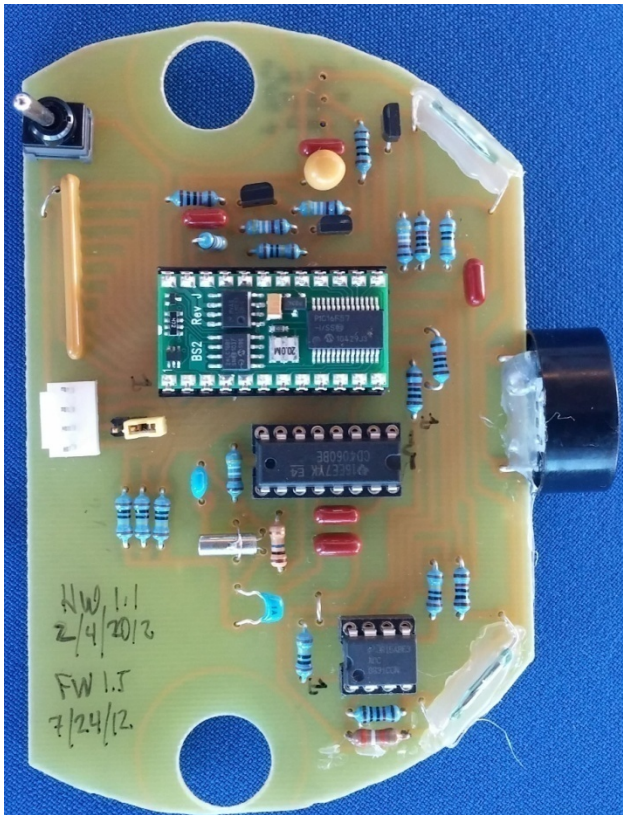
MAKING IT PERMANENT - DESKTOP PCB

“Desktop PCB Fabrication” – RVTEC 2004

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

Only change – Mental Automation is mostly out of business, “not recommended for new design(ers)”. Try KiCAD <http://kicad-pcb.org/>

Challenger deep sea pump replacement timer board



MAKING IT PERMANENT - COMMERCIAL PCB

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

Design around free drill sizes.

Output “Gerber” files, email to board maker with credit card.

Advanced Circuits - <http://www.4pcb.com/>

Best prices for small runs – 2 layers, \$33 each, min qty 4.

Alberta Printed Circuits – <http://www.apcircuits.com/>

Best prices for medium runs (10+ pieces)



SHOW AND TELL

- 1. Engineers Notebook – 1980 (first printing).**
- 2. Engineer's Notebook II – 1982 (first printing).**
- 3. Getting Started in Electronics.**
- 4. Make Ultimate Arduino Microcontroller Kit.**

Three PC boards – all TCW designs.

- 1. Hand wired board – GPS logger.**
- 2. Hand wired board – Met buoy power control.**
- 3. Desktop PC board – Challenger deep sea pump timer.**
- 4. Commercial PC board – GPS/Argos drifter.**

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



Alex Sneddon

and of course my shipmates at RVTEC.

QUESTIONS? I AM NOT AFRAID.



THANKS FOR LISTENING!



AFTERWARDS - GO BUILD STUFF!