**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.

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.

Diagram:

```
DUAL LED FLASHER
+3 TO +9V

Q1, Q2 - 2N3904
C1 = 22uF
R1 = 220
R2 = 220
R3, R4 = 100k
LED1
LED2

THIS CIRCUIT IS CALLED A FREE-RUNNING MULTIVIBRATOR.
IT'S IDENTICAL TO A FLIP-FLOP THAT TRIGGERS ITSELF
REPEATEDLY. Q1 AND Q2 ARE GENERAL PURPOSE PNP
TRANSISTORS (2N3904, 2N2907 ETC.). R1 AND R2 LIMIT
THE CURRENT TO THE LEDS (WHICH FLASH ALTERNATELY)
INCREASING THE VALUES OF C1 AND C2 WILL SLOW THE
FLASH RATE.
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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)
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
Speciality and Surplus Vendors

(Bench power supplies)

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

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


All Electronics - http://www.allelectronices.com/

More vendors at: http://amasci.com/surplus/surplus/surpls.html
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.
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.
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.
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 \( R_1 + R_2 = \) about 100 Kohm, with the ratio selected so that voltage at pin 2 is 5 volts at a value of \( V_{\text{Bat}} \) midway between the desired shutdown and restart voltages. \( R_4 \) should remain at 1 Mohm. The greater the value for \( R_3 \) the larger the hysteresis.
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)

GPS/Argos drifter
SHOW AND TELL

2. Engineer’ s Notebook II – 1982 (first printing).

Three PC boards – all TCW designs.
2. Hand wired board – Met buoy power control.
3. Desktop PC board – Challenger deep sea pump timer.
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!

Let’s All Go To The Lobby
To Get Ourselves A Treat!

AFTERWARDS - GO BUILD STUFF!