Equipping an Electronics Lab
~
On the Cheap

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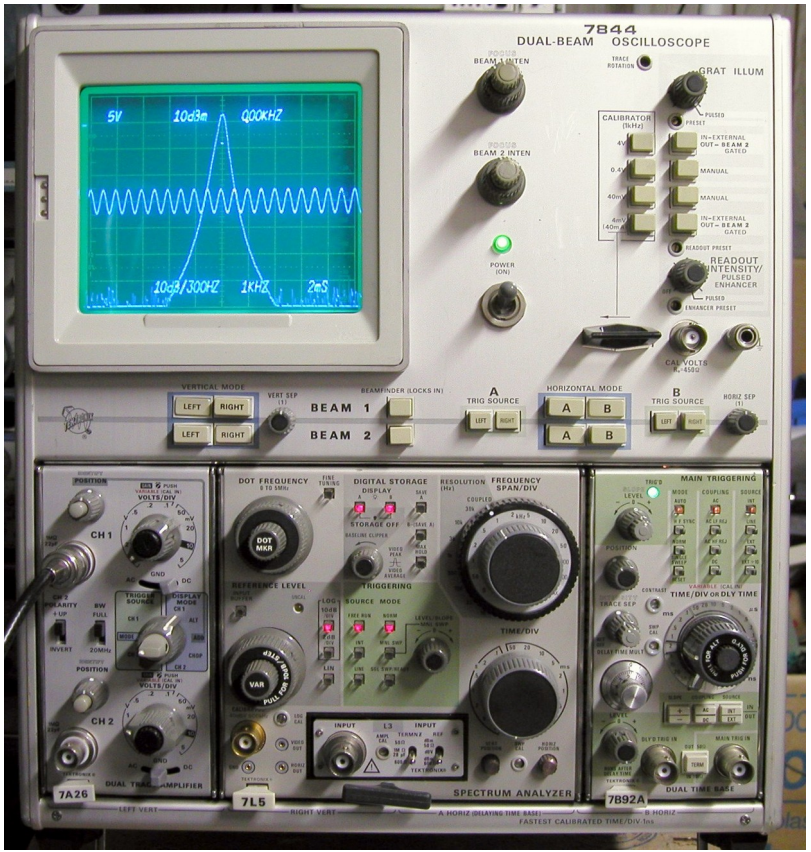
HV·Open
1 May 2019

Upcoming Events

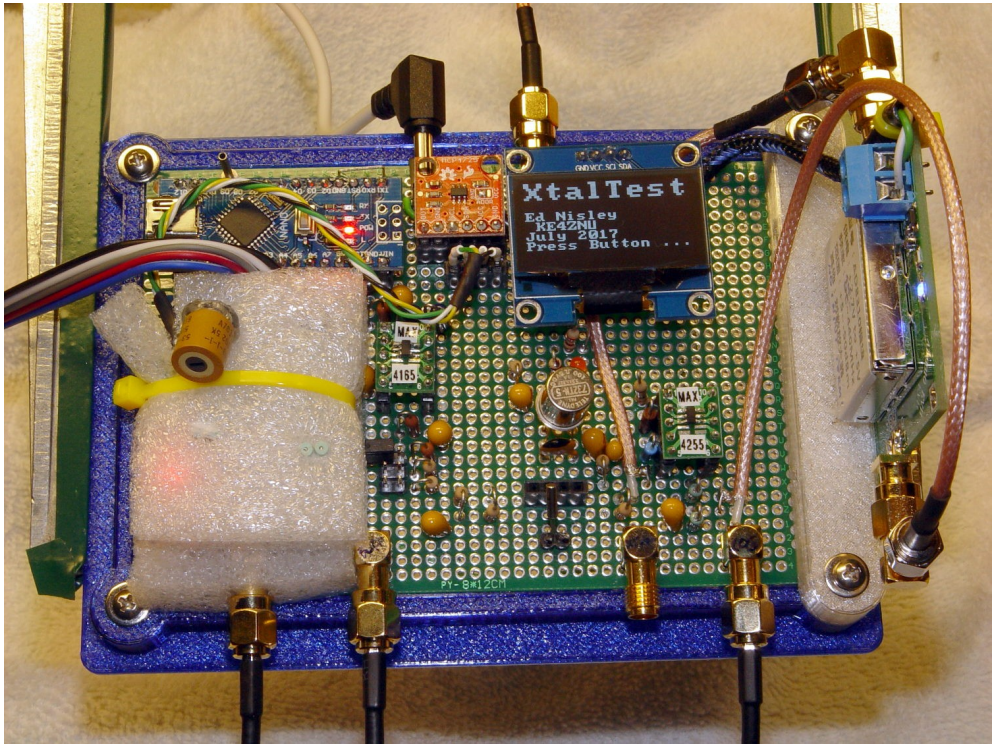
- Motivation
- Electronic Basics
  - Why are electrons negative?
- Essential Equipment
- Exotica
  - Why you don’t need it now
- Parts & Supplies



http://w140.com/tekwiki/wiki/7844

Golden Age of Electronic “Making”

- All The Hardware
  - Cheap & direct from China
  - If you’re not too fussy
- All the Software
  - In some language
  - Maybe *Software Libre*
- All The Information
  - Learning with no speed limit
  - Data sheets FTW!



https://softsolder.com/2017/06/20/lf-crystal-tester-dds-buffer-amp/

Debugging Rule #3

Quit thinking and *look*

http://debuggingrules.com/

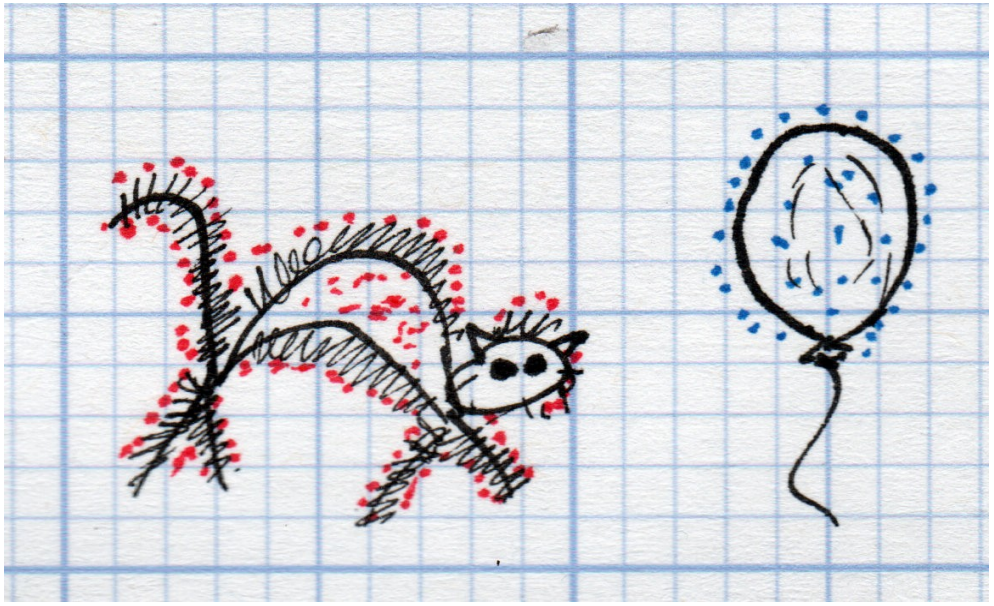
The Problem With Electronics

Nobody has “perfect voltage”

https://en.wikipedia.org/wiki/Absolute_pitch

In the Beginning: Charge

- Balloon
  - Rubber-like substances
- Cat
  - Fur-like substances
- Apply energy / friction
  - Rub!
- Charge?
  - Actually, charge **separation**



https://en.wikipedia.org/wiki/Electron#Discovery_of_effect_of_electric_force

Experimental Science

Triboelectric Series

- More Positive
  - Hair (+ + +)
  - Nylon
  - Glass = “*vitreous*”
  - Rabbit fur
  - **Cat fur**
  - Silk
  - Cotton (+)
- More Negative
  - Amber = ἤλεκτρον (-)
  - **Rubber balloon**
  - Resins = “*resinous*”
  - Sulfur
  - Rayon
  - Plastics
  - Teflon (- - -)

https://en.wikipedia.org/wiki/Triboelectric_effect#Triboelectric_series

Why Are Cats Positive?

For a reason that was not recorded,

[Ben Franklin] identified the term

positive with *vitreous* (“cat”) electricity
and
negative with *resinous* (“balloon”) electricity

https://en.wikipedia.org/wiki/Electric_charge

Electrical Fluid

[Franklin] also posited that
when matter contained

too little of the *fluid* it was negatively charged
and
when it had an excess it was positively charged

https://en.wikipedia.org/wiki/Electric_charge

Conventional Current Flow

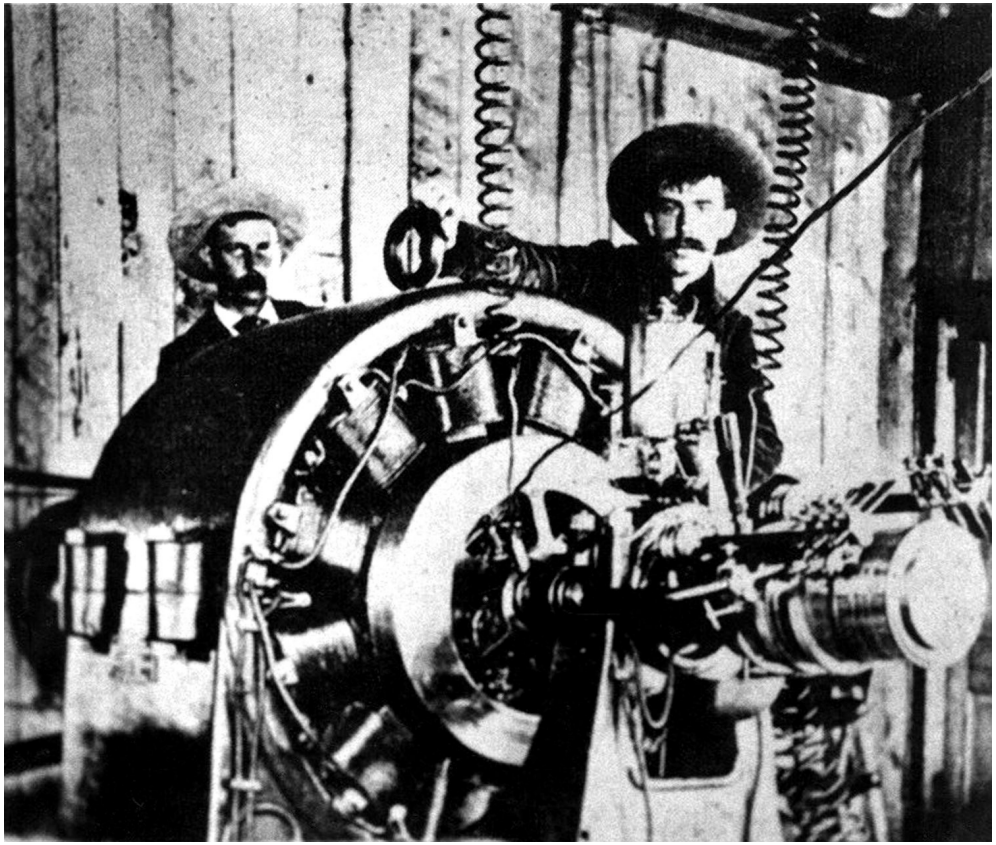
Electrical “fluid” flows from positive to negative

https://en.wikipedia.org/wiki/Electric_current#Current

Oooops …

Continuous Charge Separation

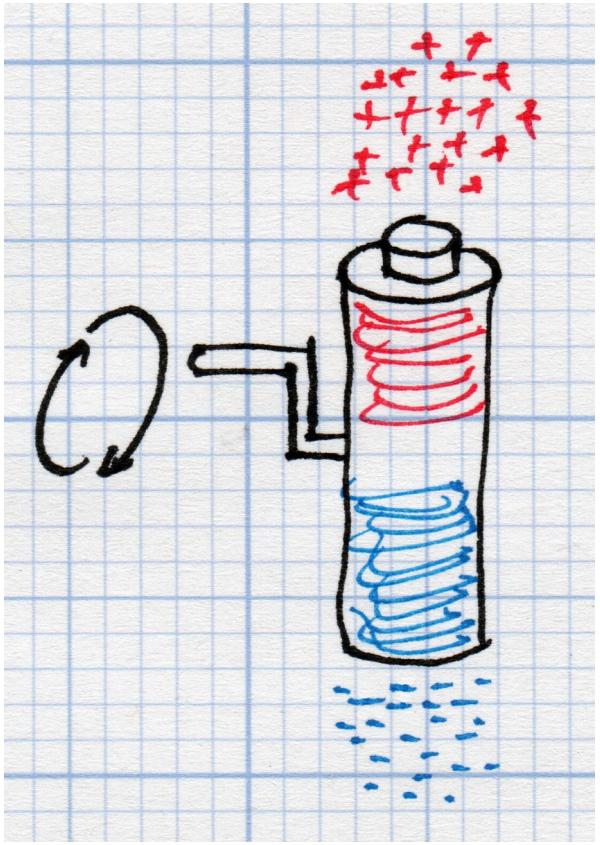
- Input = Energy
  - Mechanical
  - Chemical
  - Light / radiation
  - Electrical
- Output = Charge
  - Positive (fewer electrons)
  - Negative (more electrons)



https://en.wikipedia.org/wiki/Alternator

Power Supply

- Input ➔ Output Energy
  - Minus losses
  - Charge doesn’t increase forever
- Continuous operation
  - Until something runs out
  - … or the battery corrodes
- External circuit connections
  - Determines *everything else*



https://en.wikipedia.org/wiki/Power_supply

Bench Power Supply

- Adjustable voltage
  - 30 V = enough
- Adjustable current
  - 5 A = enough
  - 10 A >> enough
- UL listed? *Hah!*
  - Nothing on Amazon / eBay will be
- $50 to …

https://www.amazon.com/s?k=bench+power+supply

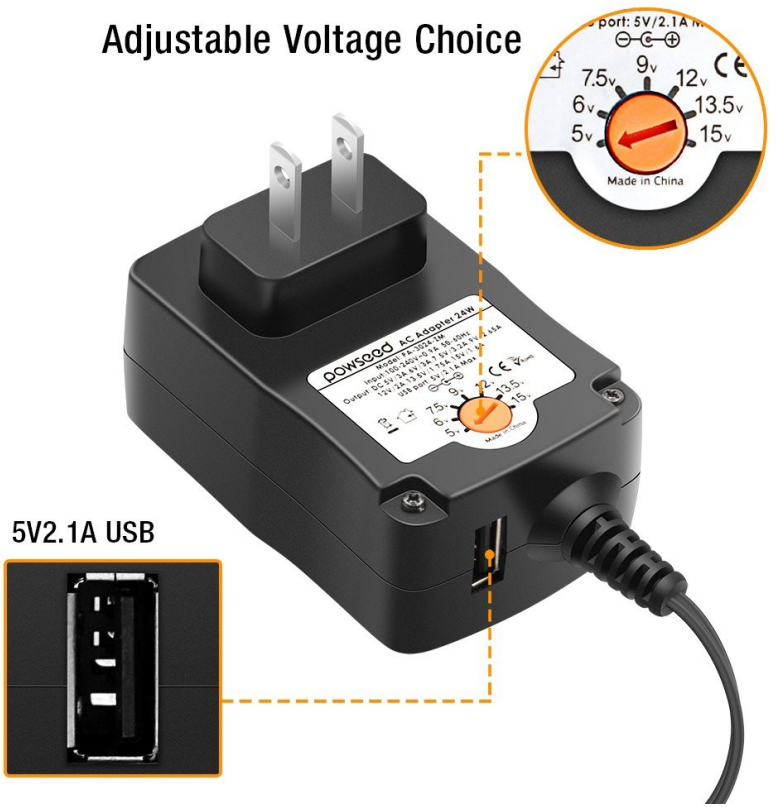
Tattoo Power Supply (!)

- Intended for *motors*
  - Terrible regulation
  - Plenty of noise
- Adjustable voltage
  - 1 V to 20 V (maybe)
- Current < 2 A (maybe)
- $20 w/ foot switch + plugs
  - $50 = full tattoo kit *with ink*!

https://www.amazon.com/s?k=tattoo+power+supply

Adjustable Wall Warts

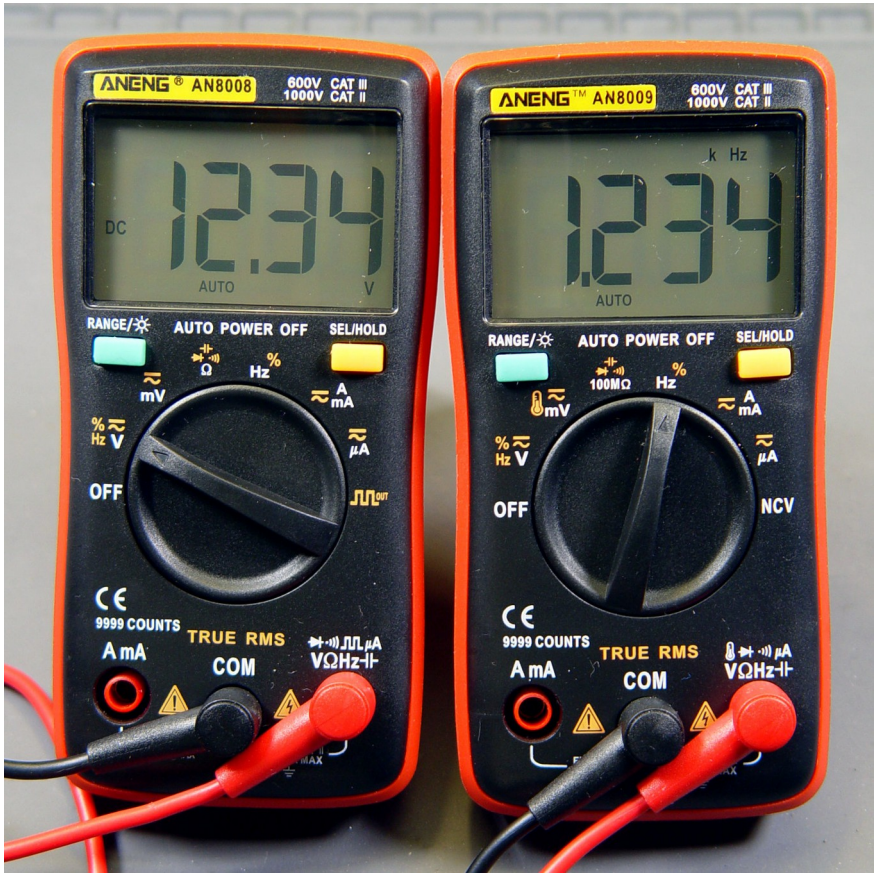
- Select-a-voltage
  - Maybe 5 V to 20 V
- Current < 1 or 2 A
  - Probably enough
- $10 to $20
- Some are UL listed!
- Amputate the DC plug



https://www.amazon.com/s?k=adjustable+ac+adapter

Essential Multimeter(s)

- Just buy one of these, OK?
  - ANENG AN8008
  - ANENG AN8009
- $25 (Amazon *or* eBay!)
  - Should include fancy probe kit
- **No high-energy sources**
  - Not 120 VAC power line
  - Use alligator clips, not probes



https://www.amazon.com/s?k=aneng+multimeter

No High-Energy Sources

- Regs exist for a reason
- Fake compliance labels
- Non-existent QC
- Simplest possible HW
  - No blast shields
  - No arc suppression
- Just. Don’t. Do. It.

https://softsolder.com/2019/01/04/multimeter-probe-cable-fail/

Fancy Multimeters

- Lab-grade gear
  - Real specs
  - Actual safety ratings
  - More digits = precision
  - USB + LAN connectivity
  - *More than you need now*
- $100 to absurdity
  - SDM3045X = $389

https://www.siglentamerica.com/digital-multimeters/sdm3045x-digital-multimeter/

Crap Multimeters

- Just. Don’t. Do. it.
  - Low accuracy
  - Low precision
- $5 to $10
  - FREE With Super Coupon!

https://www.harborfreight.com/7-function-digital-multimeter-63604.html

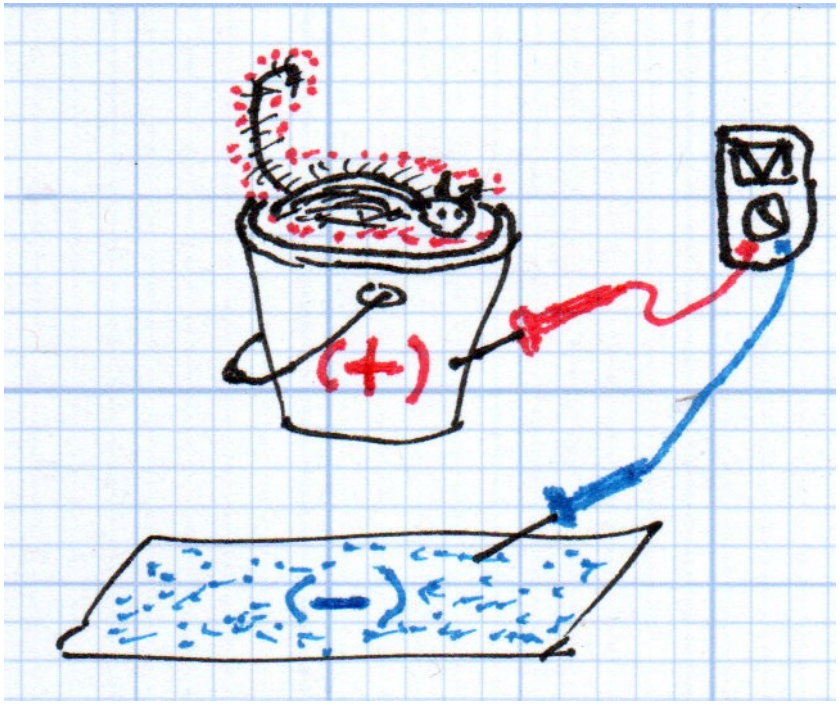
Do Not Buy Boat Anchors

- Incredible deals on (formerly) lab-grade instruments
  - Irreplaceable components
  - Unknown defects
- Avoid temptation, OK?

https://en.wikipedia.org/wiki/Boat_anchor_(metaphor)

Charge vs. Voltage

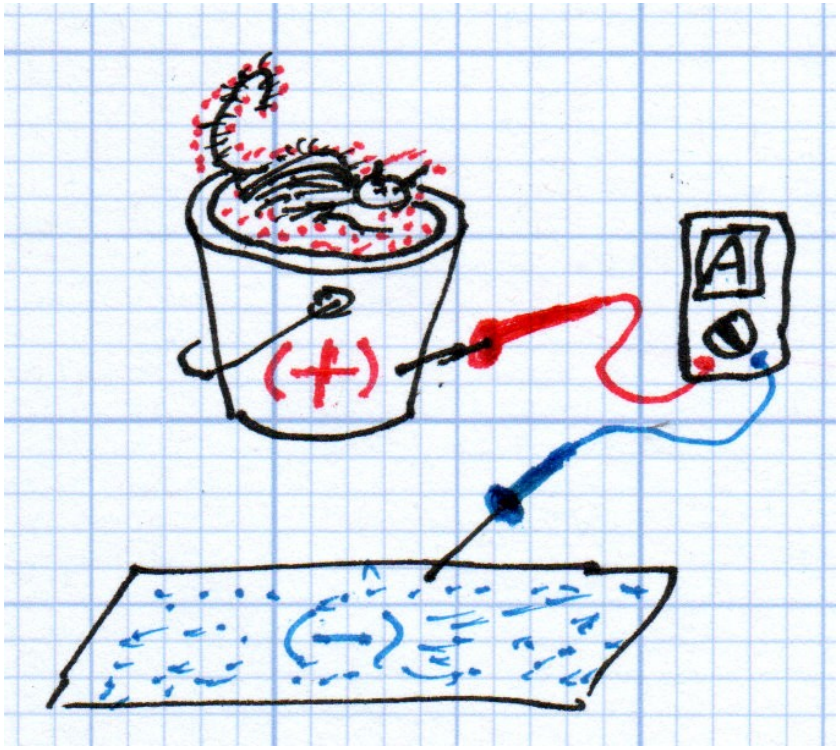
- Charge = Q = Coulomb
- Voltage = E = V = Volt
- V ∝ *relative* Q vs. reference
  - “Ground” = *unlimited* reference
- Multimeter set to V range
  - *No* current goes through meter
  - Polarity matters!



https://en.wikipedia.org/wiki/Voltage

Charge vs. Current

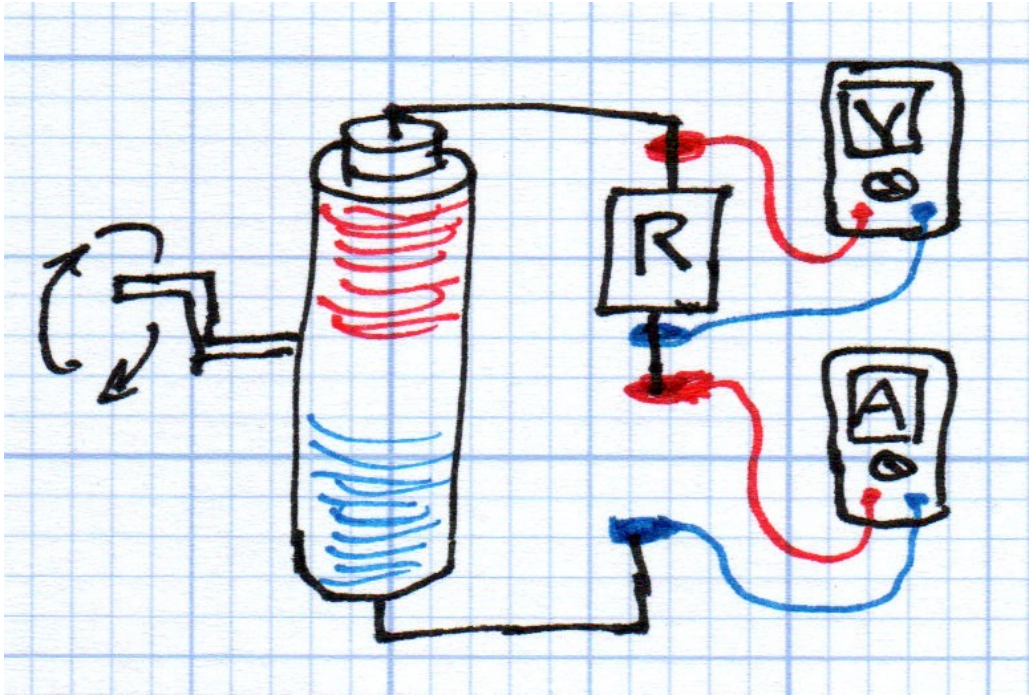
- Charge = Q = Coulomb
- Current = I (eye) = Ampere
- $I \propto \Delta Q / \Delta t$
  - Faster Q change = more I
- Multimeter set to A range
  - *All* current goes through meter
  - Polarity matters!



https://en.wikipedia.org/wiki/Electric_current

Voltage vs. Current vs. Resistance

- Resistance = Ω = Ohm
- “Ohm’s Law”
  - R = V / I
  - V = I × R
  - I = V / R
- Use alligator clips
- Polarity matters!



https://en.wikipedia.org/wiki/Electrical_resistance_and_conductance

Electronic Color Convention

- Red = positive = signal = “hot”
  - Also Yellow and maybe Green
- Black = common = “ground”
  - Also Blue and maybe Green

- *BLACK IS COMMON*
  - *Always!*

https://softsolder.com/2018/08/20/ebay-high-voltage-alligator-clip-test-leads/
https://en.wikipedia.org/wiki/Electronic_color_code

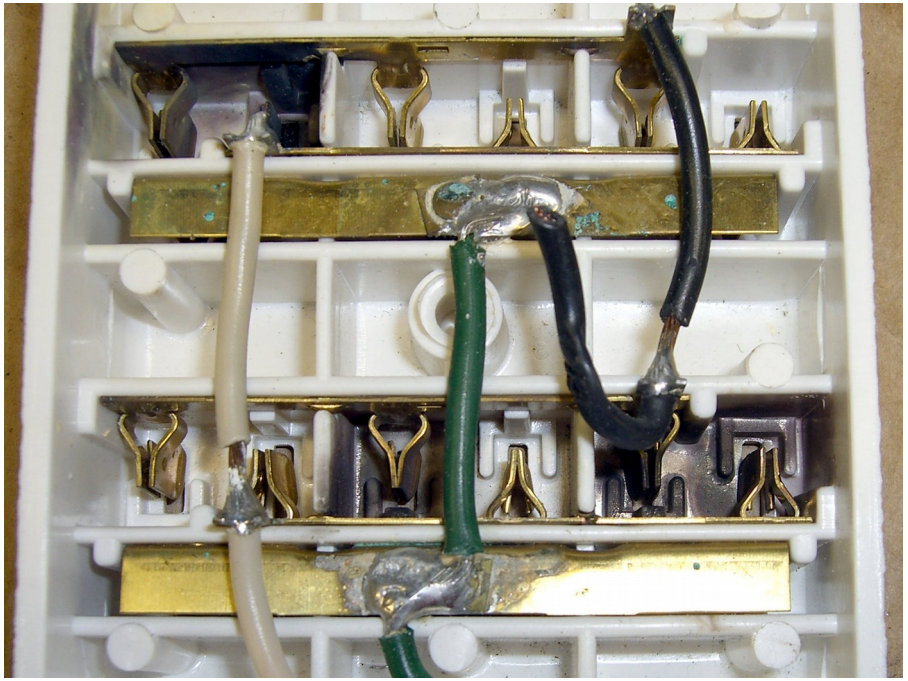
Multimeter Probes

- Red = signal
- Black = common
- Silicone insulation FTW

https://softsolder.com/2019/01/25/dmm-probes/

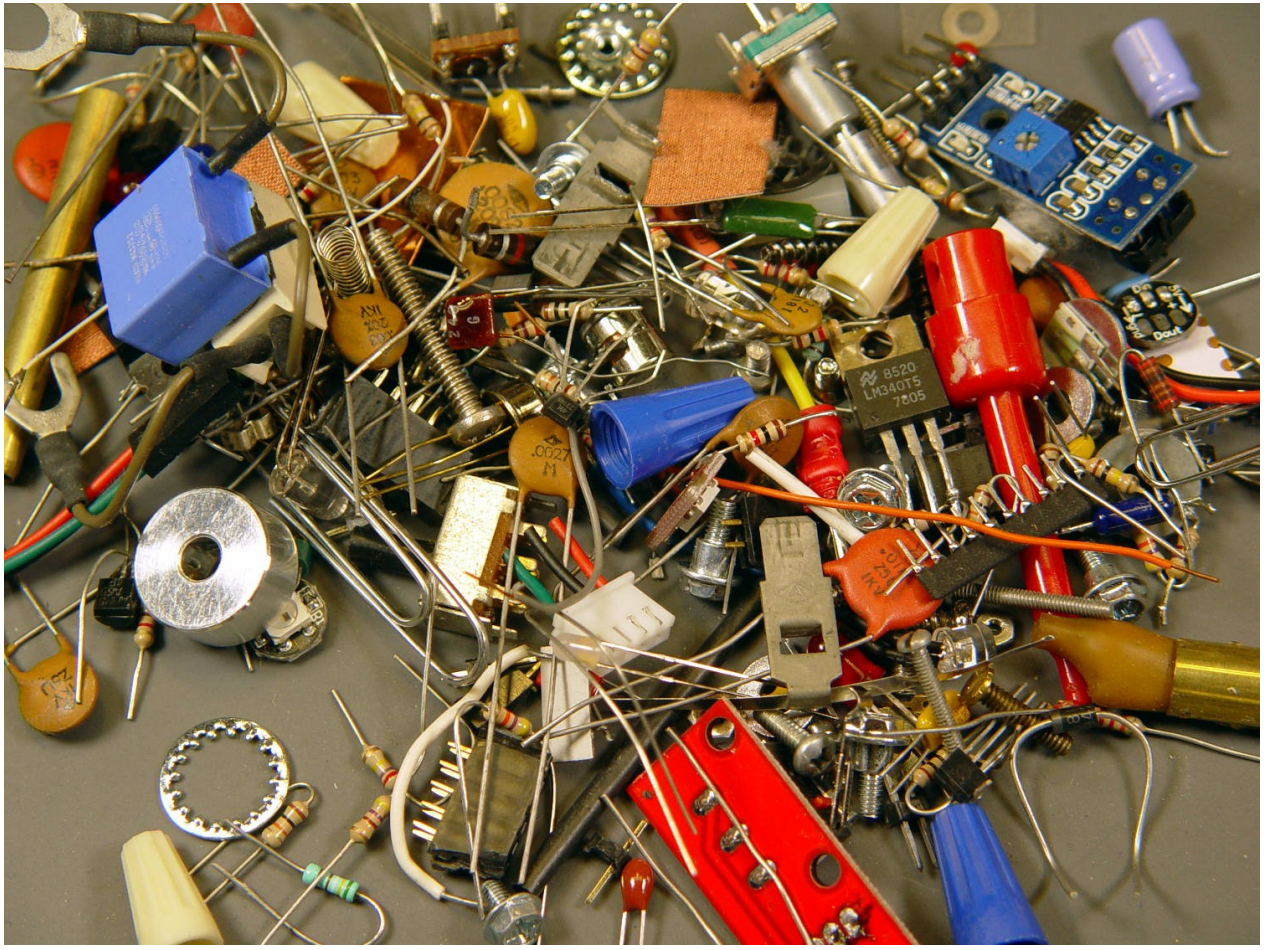
Electrical Color Convention

- Black = line = “hot”
  - Also Red and Blue
- White = neutral = “ground”
- Green = *safety* ground
  - Usually Green with Yellow stripe
- EU color code is different
- *BLACK IS HOT*
  - *What’s wrong with this picture?*



https://en.wikipedia.org/wiki/Electrical_wiring

Component Testing



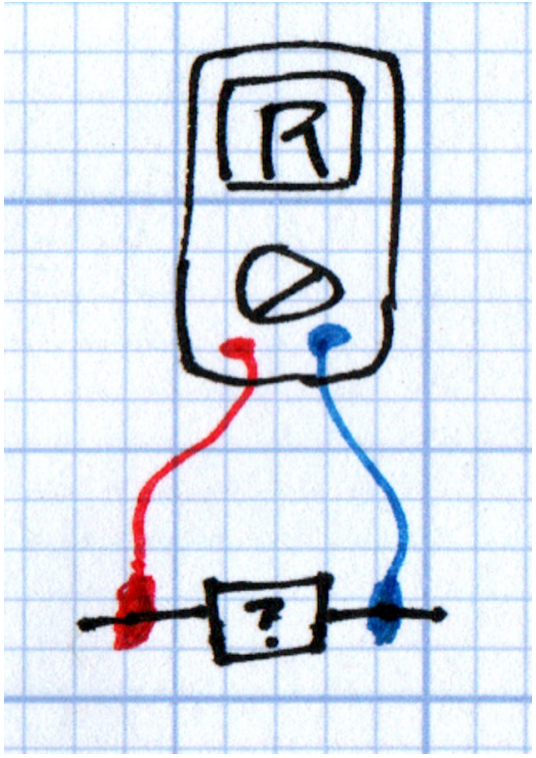
Component Testing

- Multimeters get you started
  - Resistance – Ω = ohm (kΩ MΩ GΩ TΩ)
  - Capacitance – F = farad (µF nF pF)
  - Diodes / LED – V = forward voltage
  - Alligator clips from probe kit!
- You will eventually need:
  - Transistor / MOSFET / JFET
  - Electrolytic capacitor ESR

https://softsolder.com/2018/07/31/cheap-flashlight-boost-converter-capacitor-fail/

Component Testing

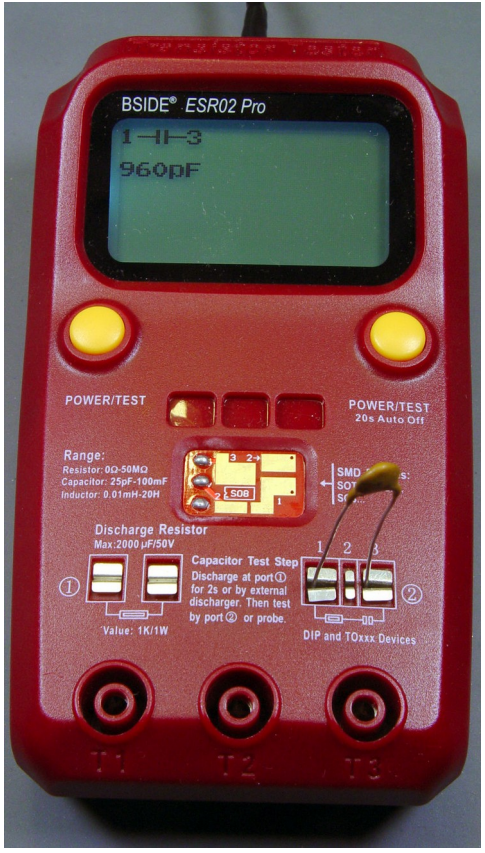
- Multimeter set to R / C / L / diode
  - Use alligator clips / SMD tweezers
  - Polarity matters for diodes / LEDs
- Only for two-terminal parts!
- *Always* measure before soldering
  - Mysterious color bands / codes
  - Laser etched marks
  - Trimmer caps / potentiometers



https://softsolder.com/2016/11/21/mica-trimmer-capacitors/

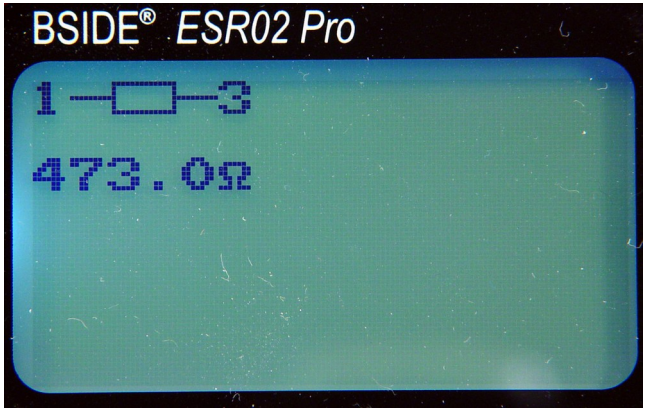
BSIDE ESR02 Tester

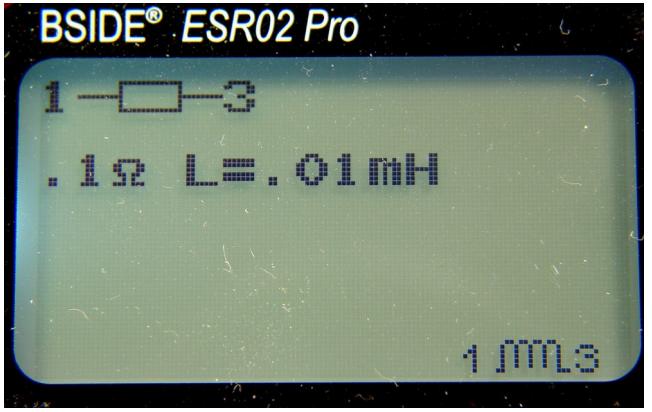
- Just buy this, OK?
  - Accurate enough for most purposes
- $25 to $35 (eBay vs. Amazon)
- Use alligator clips from probe kit
- Power from (*your*) 9 V wall wart
  - Eats 9 V batteries like candy
- Not for in-circuit testing

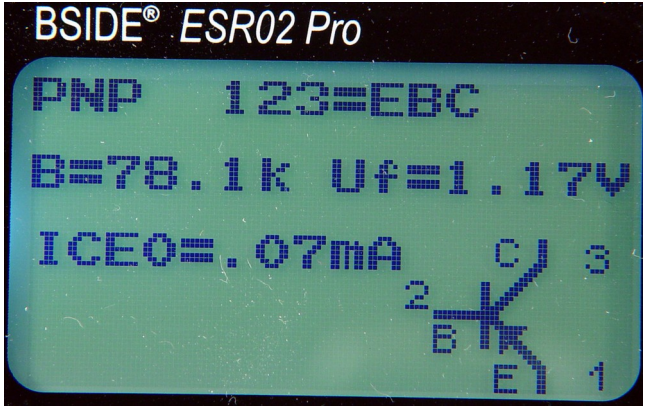


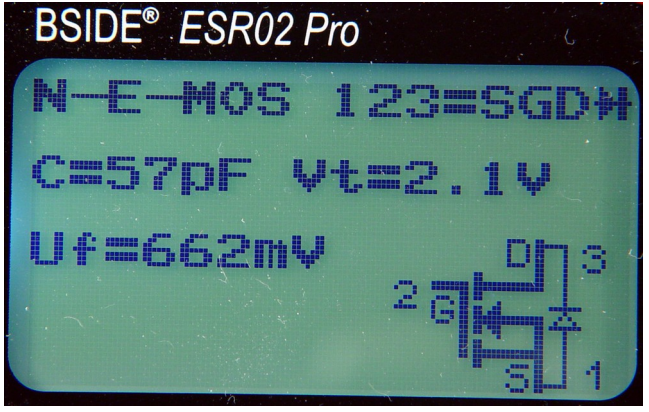
https://www.amazon.com/s?k=esr02+tester

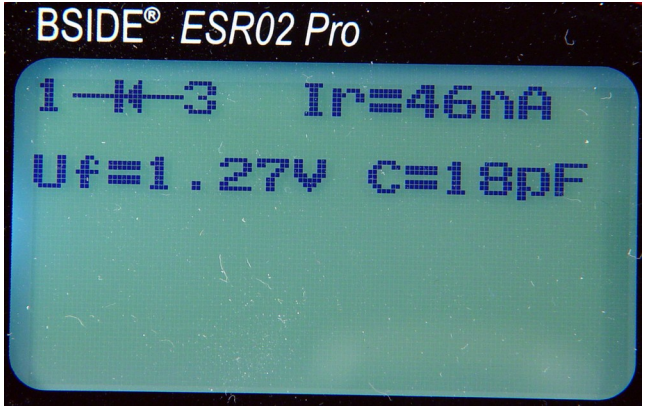
Measure. All. The. Things.







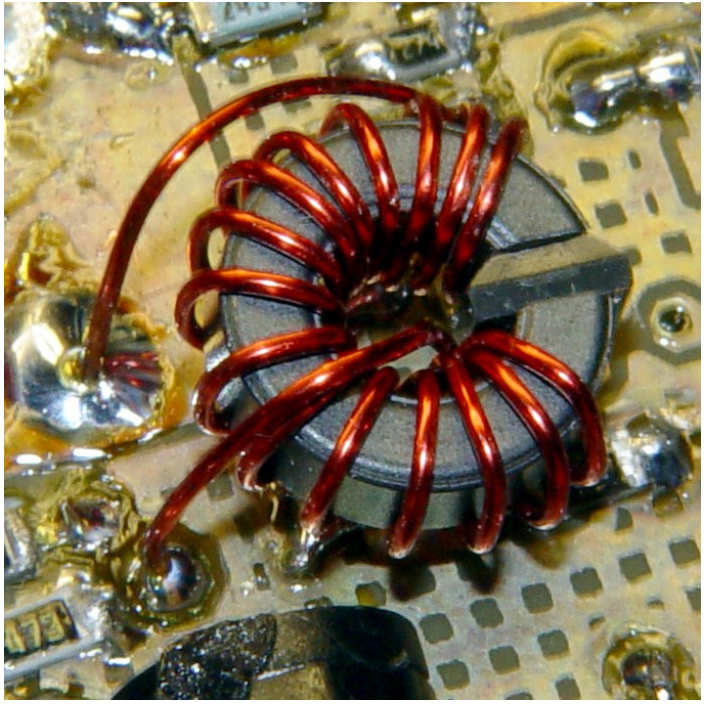




https://softsolder.com/2018/10/29/2n3904-and-2n3906-transistor-assortment-consistency-thereof/

Because Tolerance (?)

The Hall effect sensor … produces a bipolar output that depends on both the magnetic field's direction and intensity

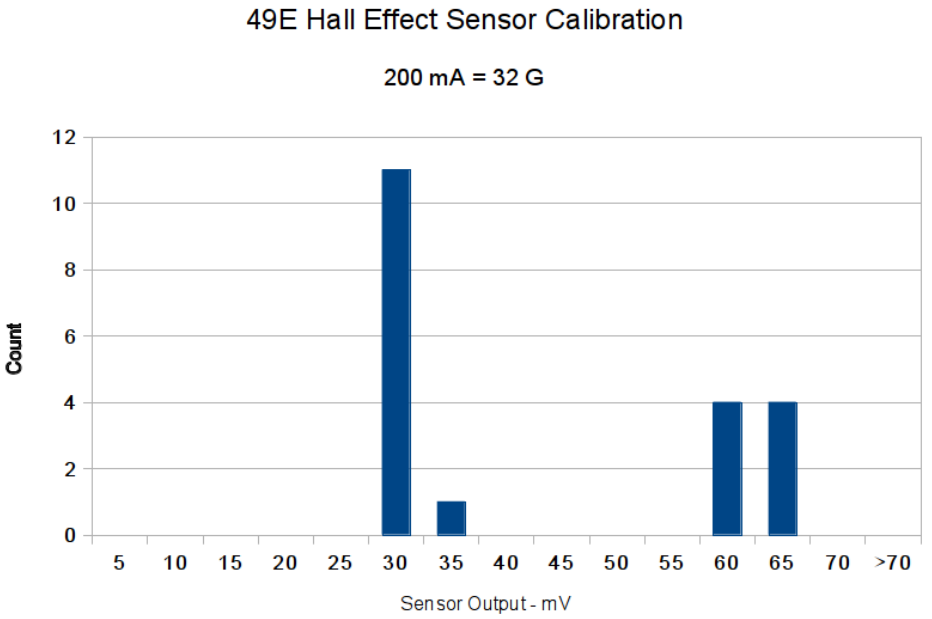


- Output voltage $\propto$ field?
  - Depends on ferrite mix
- Magnetic field $\propto$ current?

https://softsolder.com/2013/11/08/hall-effect-sensor-toroid-winding-direction/

Because QC Rejects

The nominal range …
runs neatly across the
gap in the middle



- What bell curve⁇
- Watch the gap
- This is not accidental

https://softsolder.com/2013/08/14/ebay-49e-hall-effect-sensors-parameter-spread/

Because Aging

[Eks] … discovered the grid bias on one of the tubes was totally wrong

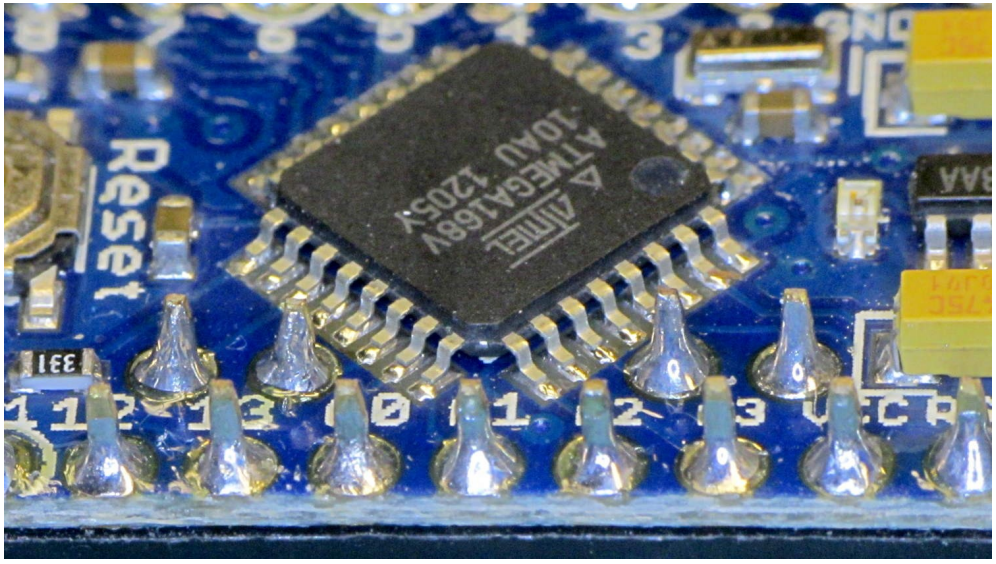
- What *is* this thing?
  - Pop quiz: what value?
- What's wrong with it?

https://softsolder.com/2009/12/14/debugging-tube-circuitry-open-resistor/

Because Production Oops

… the three [ADC] values came out around

215, 667, and 750

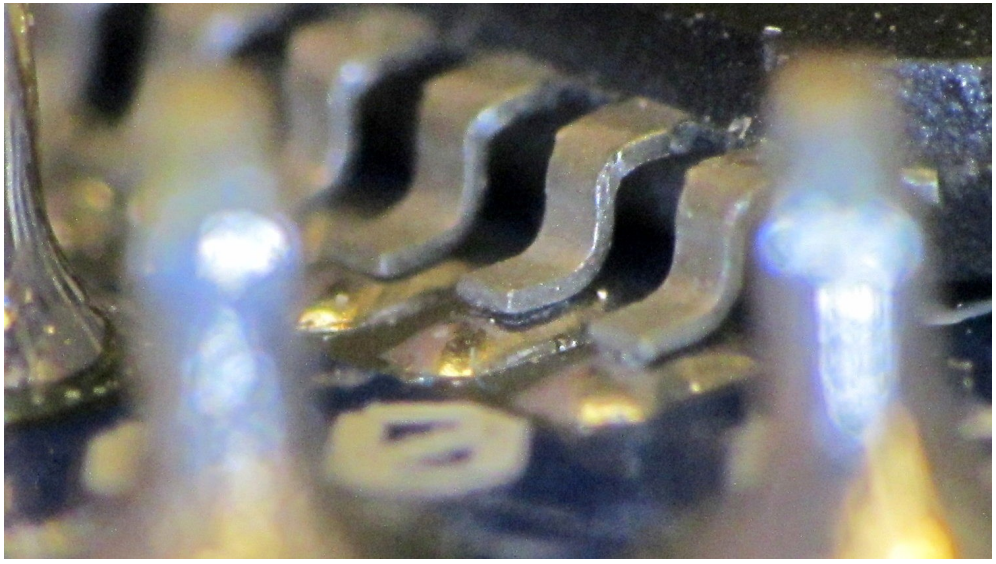


- What *is* this thing?
- What's wrong with it?

https://softsolder.com/2013/11/11/arduino-pro-mini-knockoff-solder-fail/

Because QC Escape

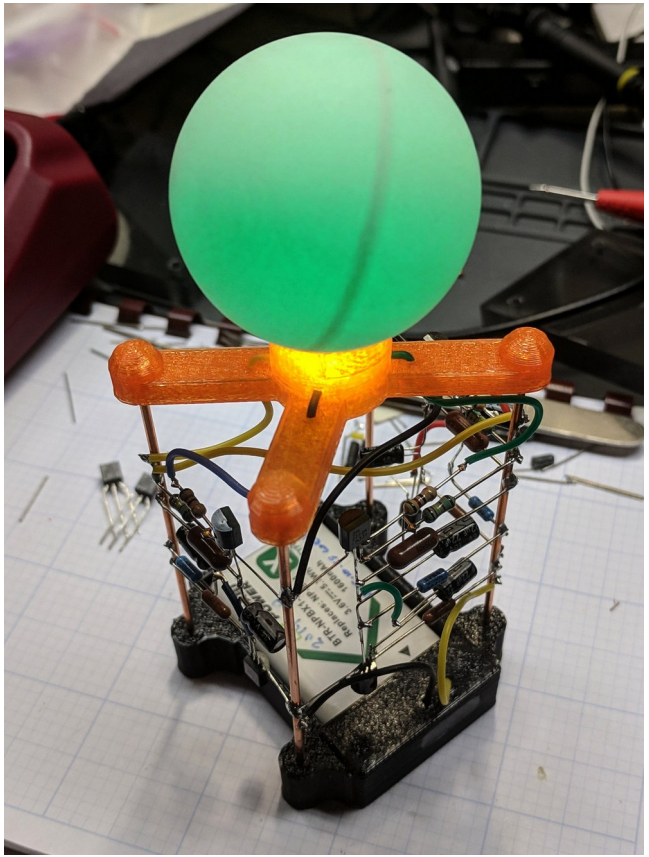
- Unsoldered pins!
  - Obvious, huh?
  - Some pins not visible
- Frequency dependent
  - Capacitance!



https://softsolder.com/2013/11/11/arduino-pro-mini-knockoff-solder-fail/

Building Things

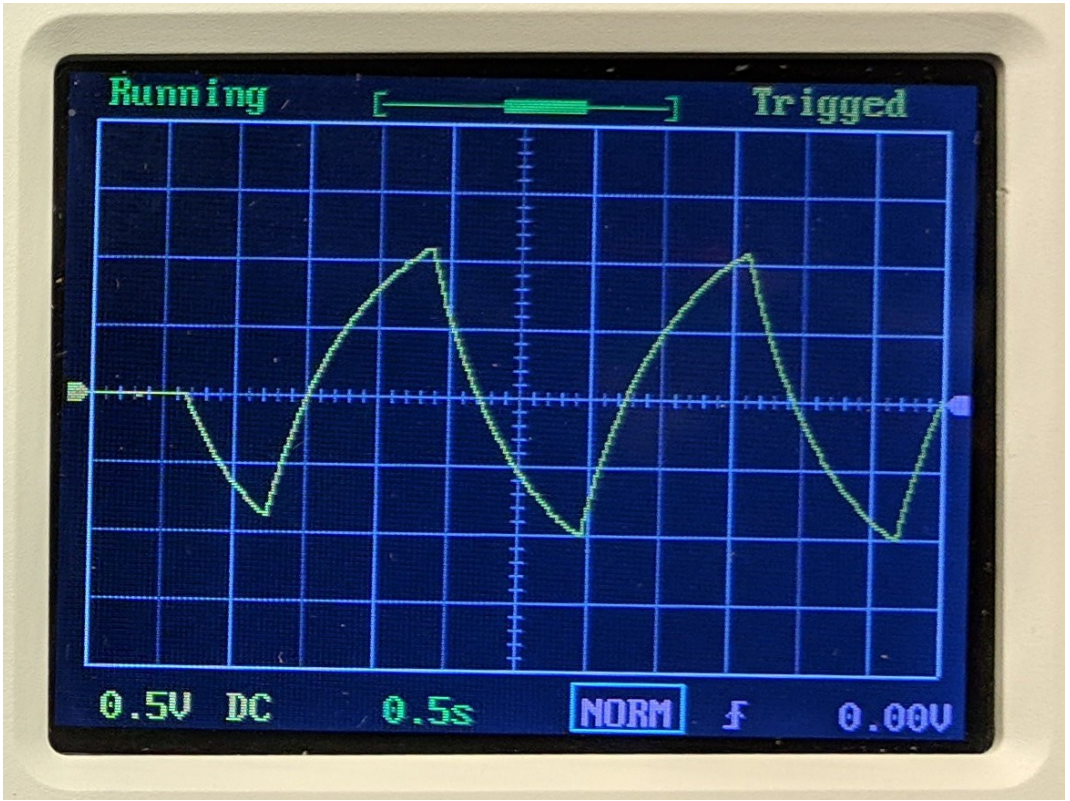
- Design theory
- Schematics
- Simulation
- Board holders / fixtures
- (Un)soldering irons & supplies
- Chassis / case / knobs
- And so forth and so on …



https://softsolder.com/2018/12/31/astable-multivibrator-rgb-led-circuitry-first-light/

Seeing Signals

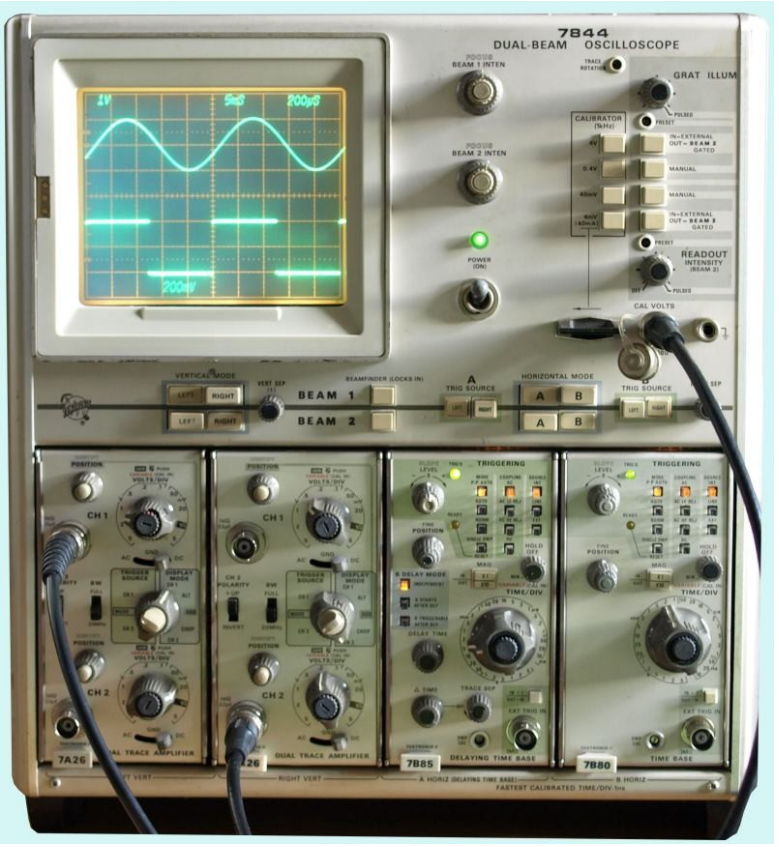
- Changes in time
  - Not simple waveforms
  - Meters = known shapes
- Amplitude = voltage
- Frequency = speed
- Waveform = shape
  - Periodic?
  - Episodic?



https://softsolder.com/2019/01/22/astable-multivibrator-dso150-vs-capacitor-voltage/

Oscilloscope

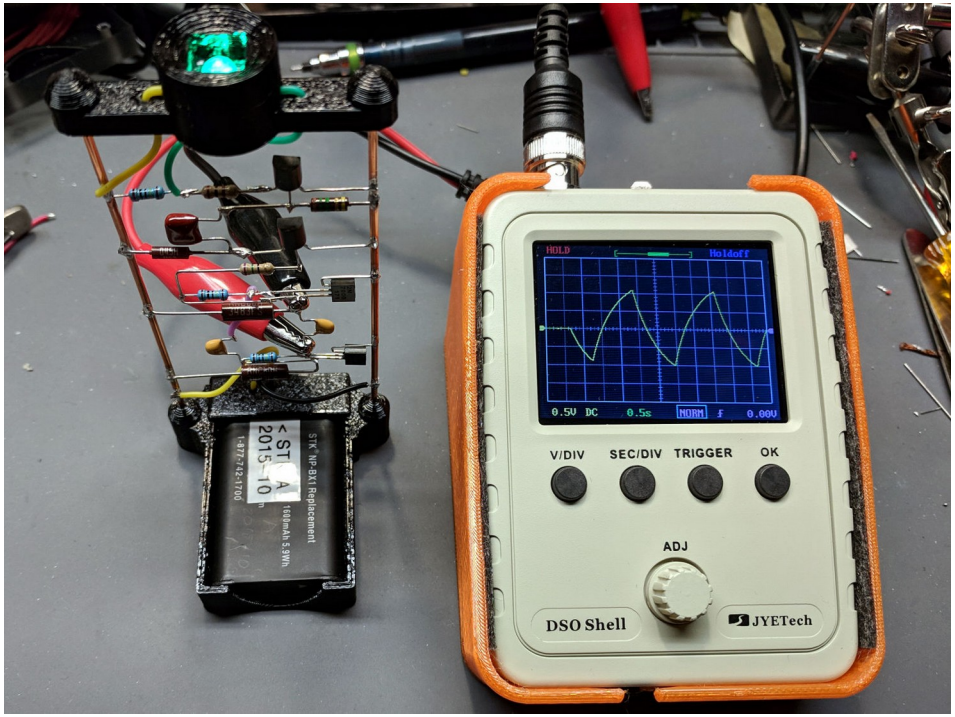
- Plot signal(s) vs. time
  - At least two channels
  - External trigger
- Golden Age of Cheap Scopes
  - Rigol / Siglent / *Big Names*
- RTFM?
  - Language barriers
  - Straight up ~~deception~~ omissions



https://en.wikipedia.org/wiki/Oscilloscope

JYETech DSO150 Oscilloscope

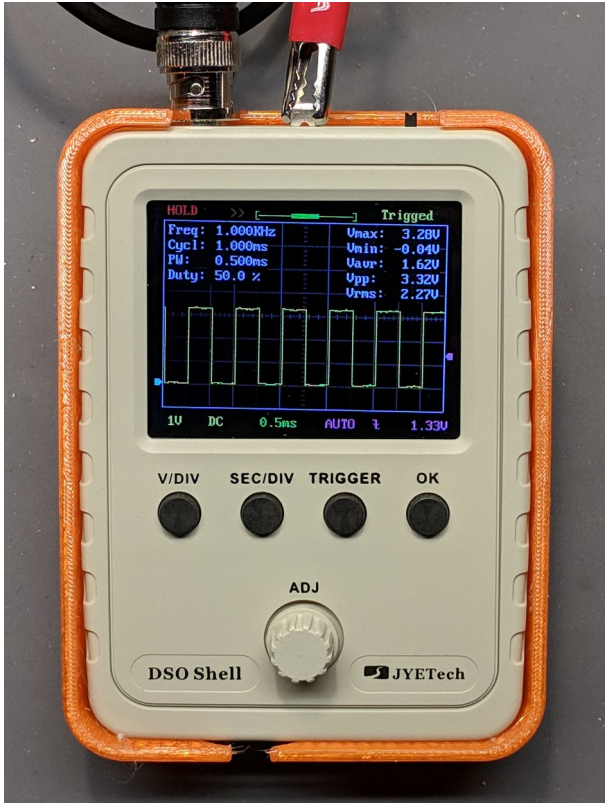
- Worst scope I'd use
  - Better than no scope at all
- OK for "audio" signals
  - 25 kHz usable bandwidth
- *Not* OK for "digital" work
  - Square edges >> bandwidth
- *It will lie to you*
  - You won't know it
  - This cannot end well



https://www.amazon.com/gp/product/B076HD5862

DSO150 Oscilloscope

- $32 *kit* (Amazon)
  - Nooelec = authorized source
- $26+ *assembled* (!) (eBay)
  - Chinese mass production FTW
- Needs 9 V external power supply
  - *Not* 6 × alkaline AA cells
- Counterfeits & knockoffs?



https://www.amazon.com/gp/product/B076HD5862

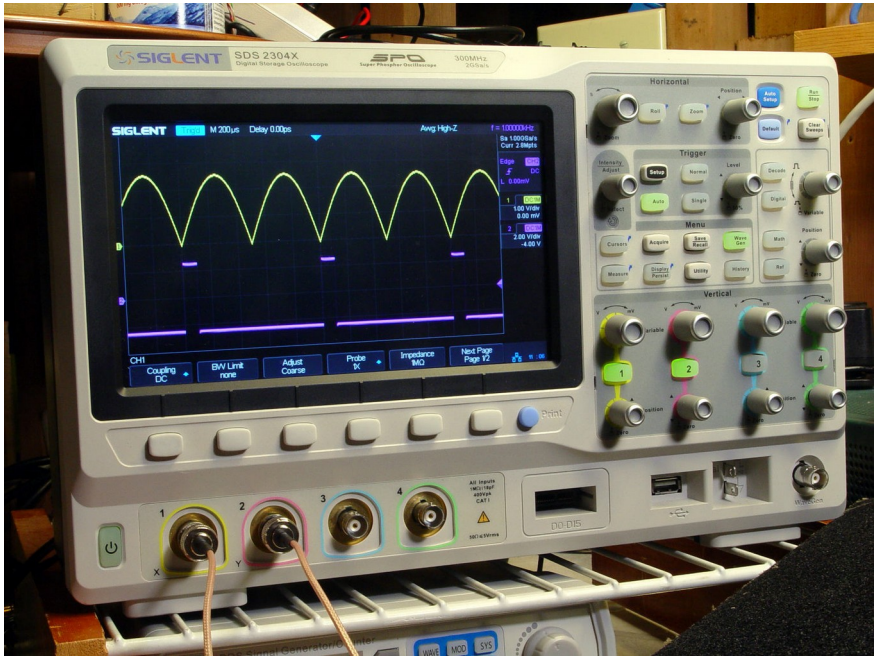
DSO150 Oscilloscope

- Customization + Improvement!
  - Thingiverse: 3D printed case
  - 18650 Li-Ion & boost regulator
  - USB battery charger
- It’s still the same scope
  - Single trace
  - Low bandwidth
  - No external trigger

https://www.amazon.com/gp/product/B076HD5862

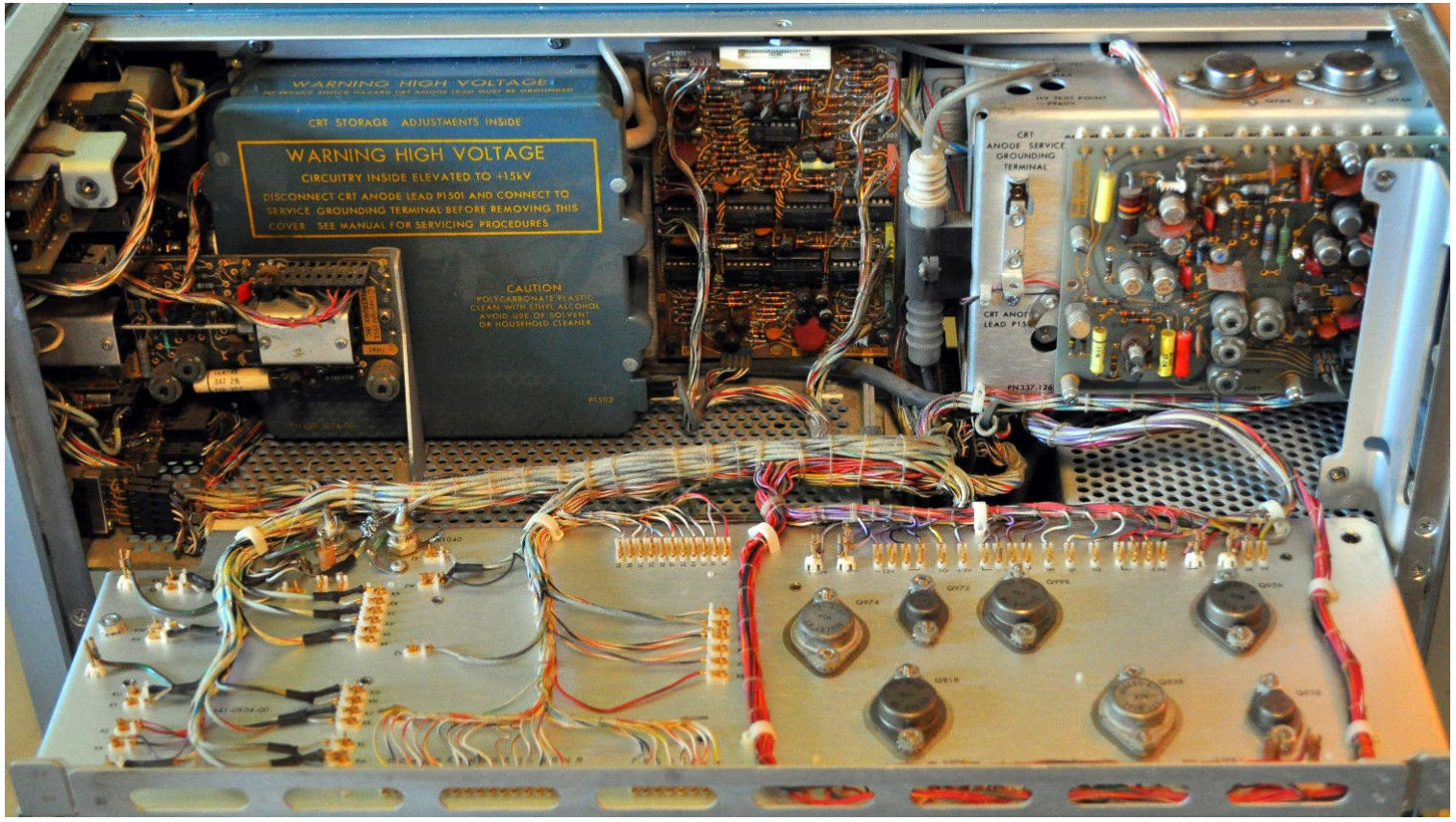
Bench Oscilloscope

- Any Rigol / Siglent scope
  - $200 to $500, modulo sales
  - Authorized distributors
  - Software bundles FTW
  - ≥100 MHz avoids stripped HW
  - Avoid DSO / LA options
- Buy / make panel cover!



https://softsolder.com/2019/03/18/rd-jds6600-signal-generator-warmup-time/

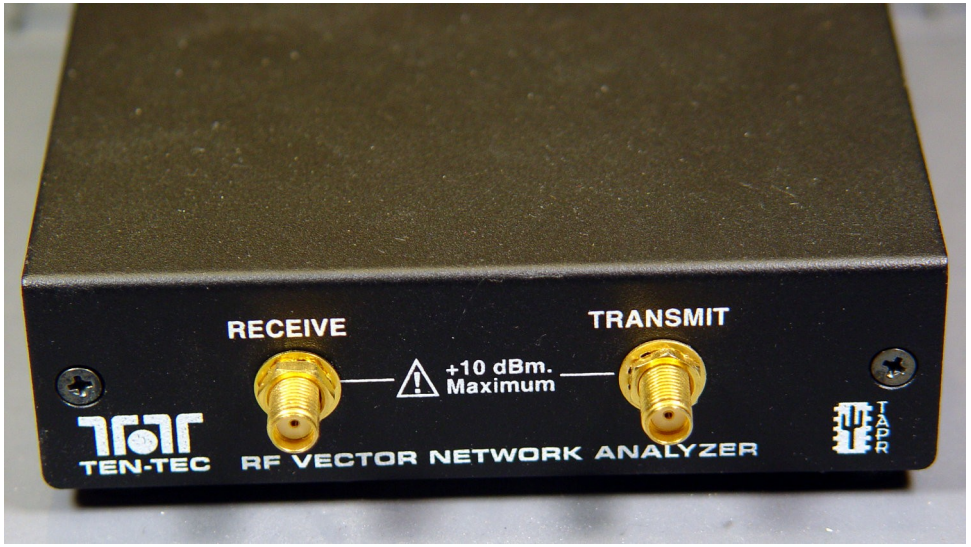
Do Not Buy Boat Anchors



http://w140.com/tekwiki/wiki/7514

USB Test Equipment

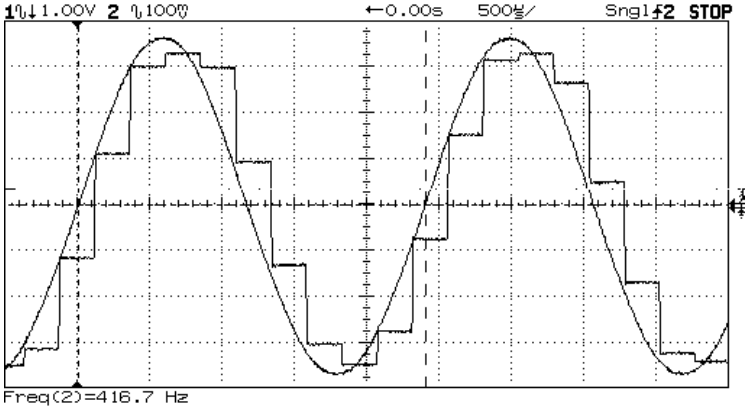
- It’s a black box
  - Company lifetime
  - Windows versions
  - Windows drivers
  - Proprietary source
  - Proprietary toolchain
- Just. Don’t. Do. It.
  - Unless it’s *really* cheap

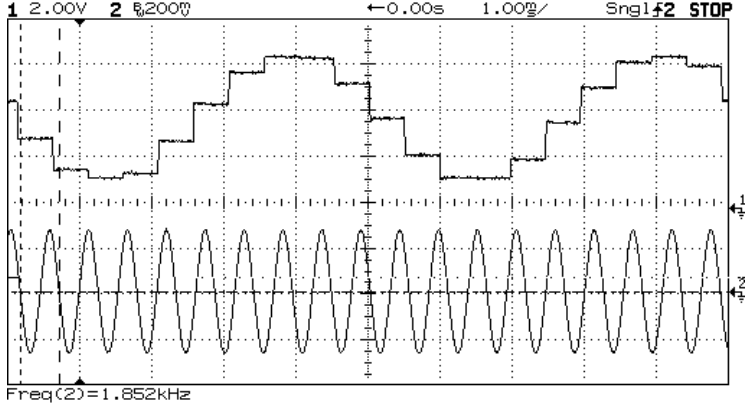


https://www.tapr.org/~n5eg/index_files/vna_library/current.htm

Stimulus-Response Testing

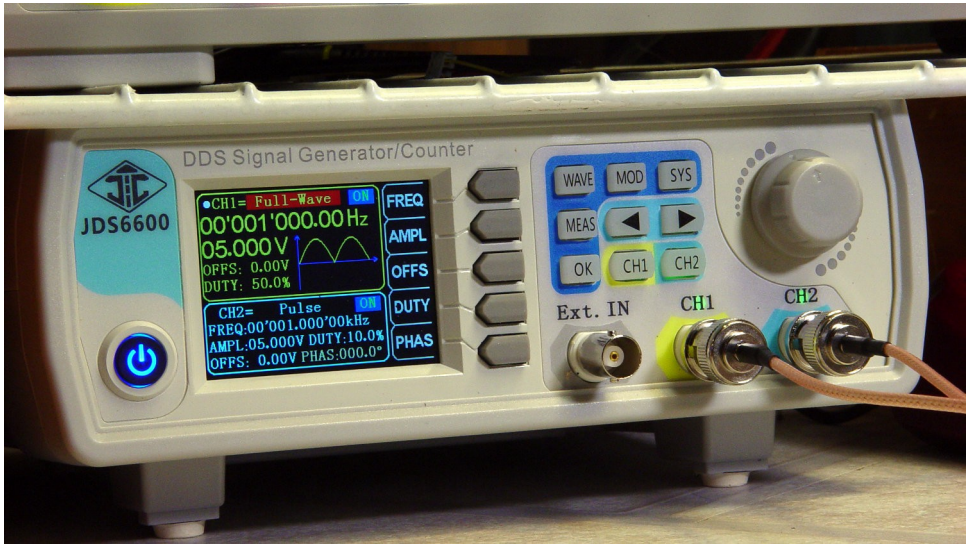
- Known input
  - Waveform
  - Frequency
- Your circuitry
  - Signal processing!
- Unknown output
  - *Anything* is possible
  - Expect the unexpected!





JDS6600 DDS Signal Generator

- Just buy this, OK?
  - RD Official Store
  - Counterfeits / knockoffs?
- 30 MHz = enough
  - Sine 15 / 30 / 40 / 50 / 60
  - Square ≤ 15 / 25 MHz
  - Other waveforms ≤ 6 MHz
- $60 to $90 (eBay / AliExpress)

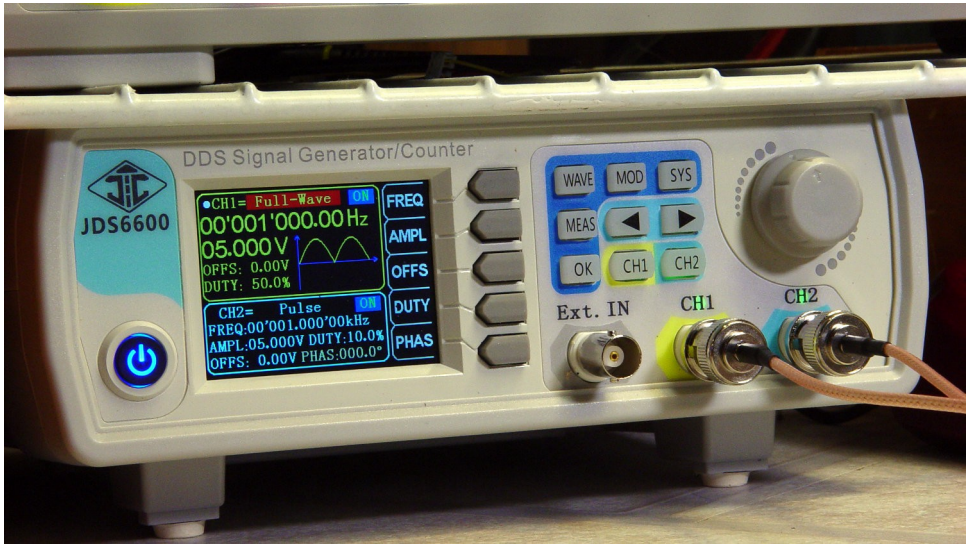


https://softsolder.com/2019/03/18/rd-jds6600-signal-generator-warmup-time/

JDS6600 Arbitrary Waveform Gen

The plan was to generate a sine wave RF carrier on channel 1 and modulate it with a baseband WSPR signal from channel 2.

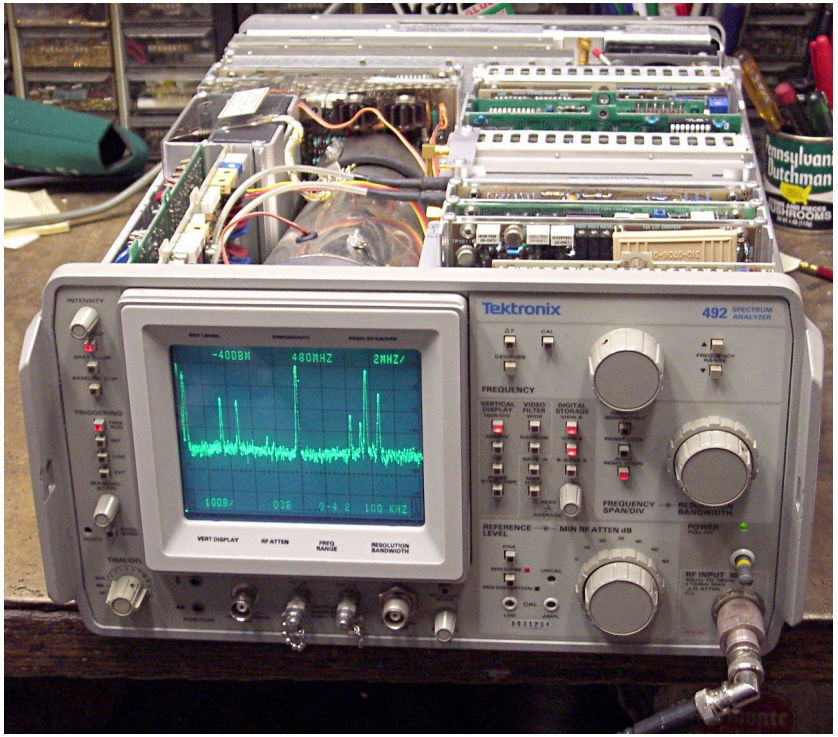
The output of CH1 could then be fed directly from the BNC connector on the front panel to an antenna for transmission.



http://www.arrl.org/files/file/QEX_Next_Issue/May-June2019/Steber.pdf

Exotica

- Spectrum Analyzer
- Logic Analyzer
- Logic Probe
- Frequency Counter
- Current Probe
- Semiconductor Curve Tracer
- You don’t need them (now)



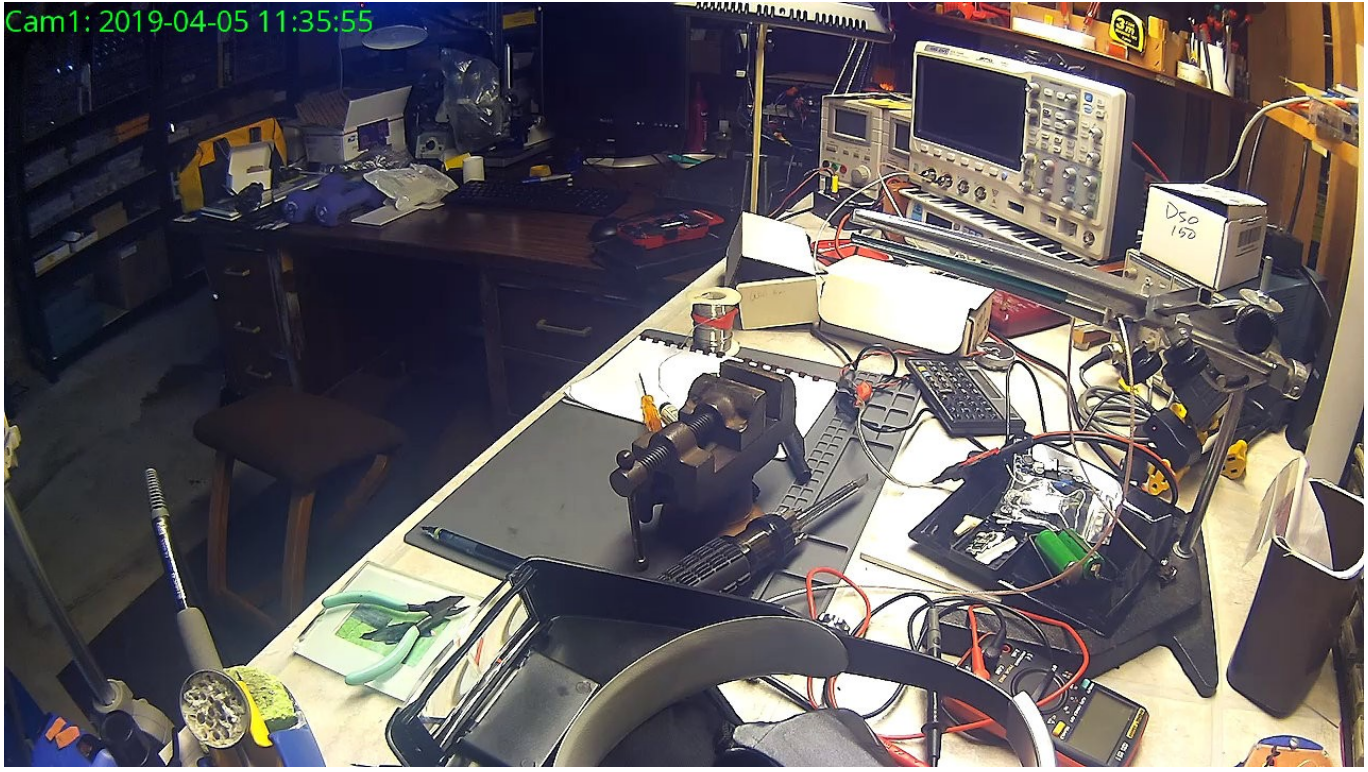
https://softsolder.com/2009/07/31/tektronix-492-spectrum-analyzer-backplane-pin-spacing/

Parts & Supplies

- Buy “kit” = “assortment”
- Pay +$2 for “US Stock”
  - But check delivery date!

https://softsolder.com/2018/10/29/2n3904-and-2n3906-transistor-assortment-consistency-thereof/

Parts & Supplies



https://softsolder.com/2019/04/09/wyze-v2-cameras-xiaomi-dafang-hacks-round-2/

Questions?

https://softsolder.com/

Ed Nisley

Say “NISS-lee”, although we're on the half-essed branch of the tree

Engineer (ex PE), Hardware & Firmware Tinker, Author

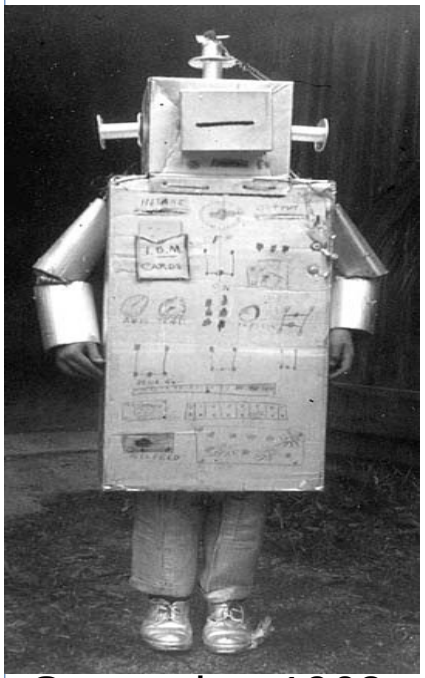
Blog The Smell of Molten Projects in the Morning - softsolder.com

Digital Machinist www.homeshopmachinist.net
Along the G-Code Way (2008 ...) - G-Code, math, 3D printing

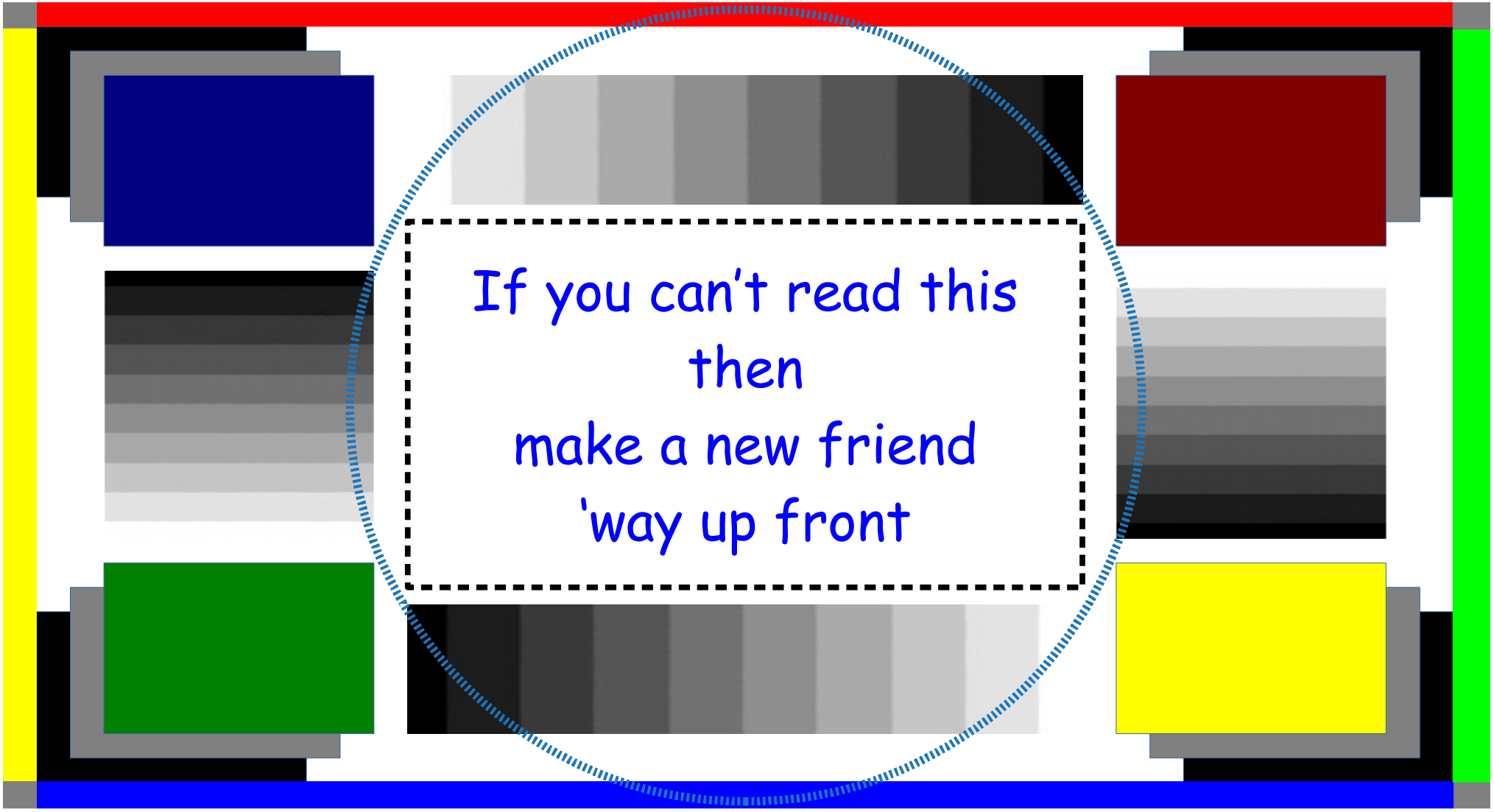
Circuit Cellar www.circuitcellar.com
Firmware Furnace (1988-1996) - Nasty, grubby hardware bashing
Above the Ground Plane (2001-2018) - Analog and RF stuff

Dr. Dobb’s Journal www.ddj.com
Embedded Space (2001-2006) - All things embedded
Nisley’s Notebook (2006-2007) - Hardware & software collisions

Book! The Embedded PC's ISA Bus: Firmware, Gadgets, Practical Tricks



September 1962


If you can't read this
then
make a new friend
'way up front