Do-It-Yourself Crystal Diodes

Mt. Beacon Amateur Radio Club
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Coming Attractions

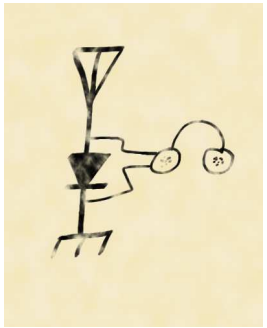
Radio Rocks
EZ Curve Tracer
AM Radio Circuit Model
Minerals: Diodes & Thingies
Rust Never Sleeps
Why Diodes Matter

In The Beginning

- Before integrated circuits...
- Before transistors...
- Before vacuum tubes...
- Before *electronics*...
- ... there were radios!
  - Modern crystal radio by VE6AB

The Simplest Possible Radio

- Antenna
- Ground
- Earphone
- Detector
  - AM demodulator (huh?)
  - A rock on a hard place
  - Crystal diode!
- Tuning? *Bah!*

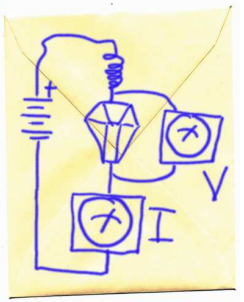


Mineral Samples

- Who knew?
  - Nobody!
  - Conflicting stories
- Try all combinations
  - Most don't work
  - How can you tell?
- Instrumentation
  - Numbers = science!

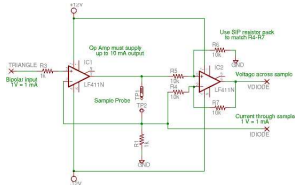
The Big Idea

- Jam current (I) in
  - How much?
  - Polarity?
- Measure volts (V) across
  - Range?
- Plot results: curves!
  - It can be done manually
  - *Much* more fun automatically
  - Oscilloscope screen shots

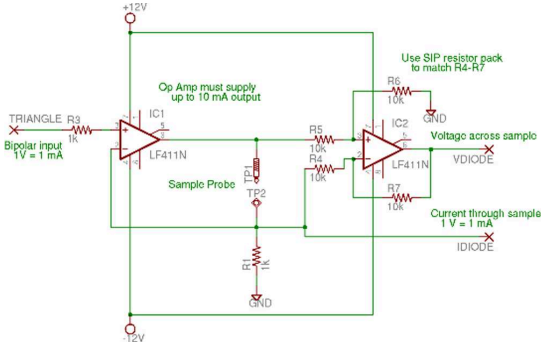


The Little Details

- Triangle wave input
  - 200 Hz, 8 V peak
  - Voltage to Current
  - Oscilloscope X axis
- Measure V at sample
  - Differential to single
  - Oscilloscope Y axis
- ±10 mA and ±10 V
  - Makes itsy sparks…



Enlarged to Show Texture

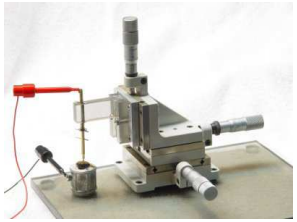


Cat's Whisker Probe

- Mineral in metal pot
- Pin-point probe
  - Steel? Bronze? Carbon?
- 3-axis ball+slide mount
- Springy contact thing
- Patience?
- Patience…
- Patience!

He Who Dies With The Most Stuff...

- 3-axis linear positioner
  - 0.001” resolution
  - 0.5” accessible cube
  - Zero backlash
- Black-belt dweebdom
  - But if you have one…



Probe and Sample Holder

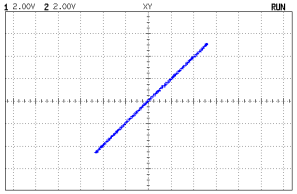
- Telescoping brass tubes
- Tapered clock pins
- Springy thing
- Friction-fit probe tips
  - Steel, bronze, carbon…
- Low frequency means clip leads work fine

Sample Holder

- EMT fitting “cup”
  - Al foil padding
- Wood’s Metal
  - Solid contact
  - Melts at 160° F
  - But: **Pb**+**Cd**+Bi+Sn
  - Field’s Metal = 144° F
  - Cerrosafe = 165° F
- See that hole?

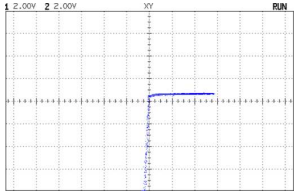
Calibration – 1 kΩ Resistor

- 1 V in = 1 mA out
  - Slope = resistance
- Set Scope Axes
  - X = current (2 mA/div)
  - Y = voltage (2 V/div)
- Linear!
  - Whew…
- Tweak DC offset = 0



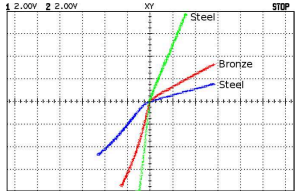
Calibration – 1N914

- Jellybean Si diode
- V_{fwd} = 0.5 V
  - Pretty close
- I_{rev} = zilch
  - Limited by diff amp’s input resistance
- A *nearly* ideal diode



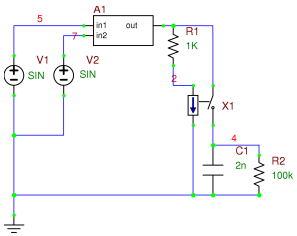
Iron Pyrite

- Green trace
  - Nearly a resistor
- Red trace
  - Almost a diode
- Blue trace
  - Better & worse
- Same lump!
- Does probe really matter?



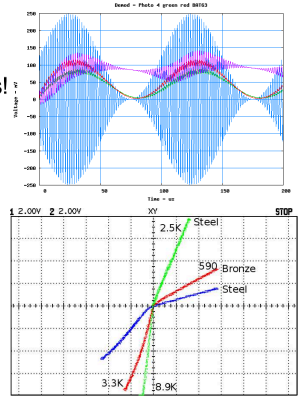
Spice Model of AM Radio

- V1*V2 = AM radio signal
- C1 & R2 ≈ earphone
  - High impedance…
- Switch X1 = diode!
  - “Voltage controlled”
  - Perhaps a lousy switch
- Resistance(s) from plots
  - R = ΔV /Δ I = slope
  - Eyeball approximations



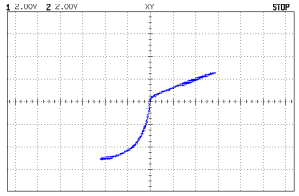
AM Demodulation

- Low voltage RF
  - Remember: before tubes!
- Crystal diodes are OK
  - Green ≈ 3.6 / 1 (rev/fwd)
  - Red ≈ 5.6 / 1
- Modern diodes are NG
  - Purple = Schottky ≈ ∞ / 1
  - V_{fwd} much too high
- Bad diodes are good!



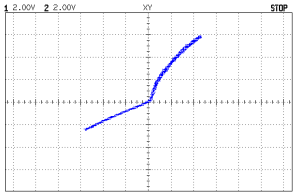
Iron Pyrite

- Huh?
  - Sorta Zener-ish
- Mostly OK diode
  - For low I & V, anyway
  - That’s good enough!



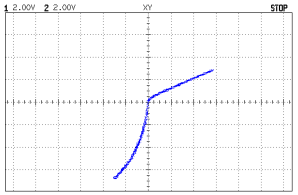
Galena (?)

- Backwards polarity
  - Whatever that means
- Very low V_{fwd}
- Bronze probe
  - So what?
- Best of many spots
  - Who knew?
  - Maybe it's just lead?



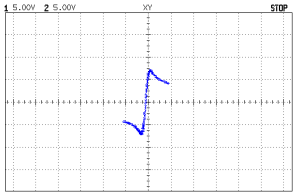
Chalcopyrite

- Say kal'•keh•pie'•right
- Looks diode-ish
  - If you squint
- Moderate V_{fwd}
- Pretty good, actually
- But wait...



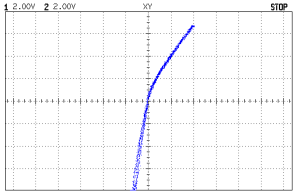
Chalcopyrite

- It's a Diac!
  - Bilateral trigger diode
- It's a resistor!
  - Very high resistance
  - For *very* low current
- It's a *negative* resistor!!!
  - Current ↑ with Voltage ↓
- Note scale change
  - 5 V and 5 mA / div

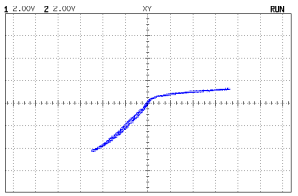


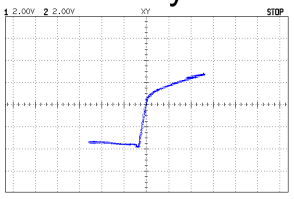
Galvanized Steel

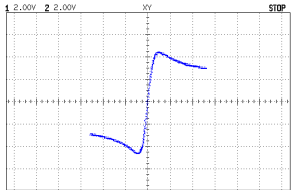
- Propane torch
  - Little black spots…
  - Do this outdoors!
- Iron-tin-zinc alloy
  - Cadmium? *Ick!*
- Looks like high R
  - And not a diode
- But wait…

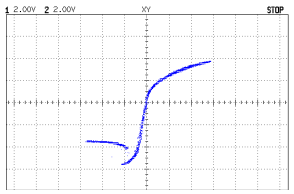


Galvanized Steel Bestiary







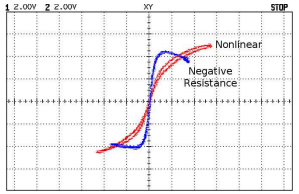


Rust Never Sleeps

- Ordinary steel bolt
- Salt + towel + copper
  - Cu + Fe = 650 mV
  - At *only* 1 mA
  - Slow and steady
- AA cell
  - 1500 mV & 10 mA
  - 4 hours later…

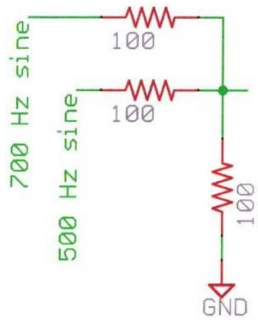
Steel Corrosion

- Nonlinear
- Symmetric
  - Sorta, kinda
- Negative resistance
  - Oscillator!
- No Battery Needed
  - Self-biasing "circuit"
  - DC bias + small AC

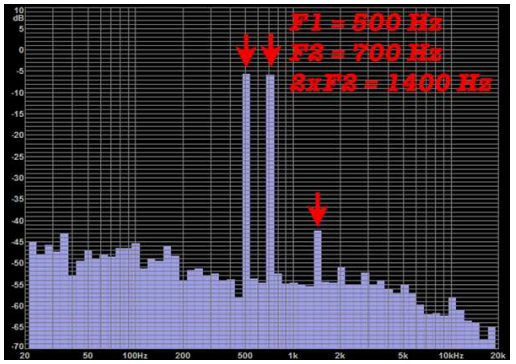


Linear Mixing Circuit

- Only "resistors"
- Easy equations
  - Ohm's Law, etc
- Sum of amplitudes
  - No surprises

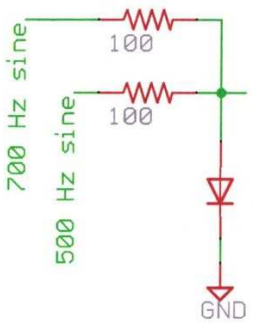


Linear Mixing Results

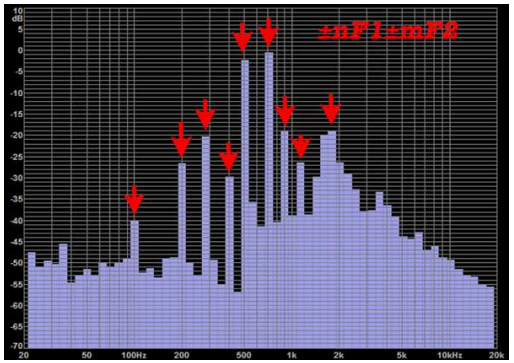


Nonlinear Mixing Circuit

- Usually a diode, but …
  - *Any* nonlinearity will do
- Equations? Hah!
  - No analytic equations
  - Simulation values?
- Harmonic frequencies
  - $\pm nF_1 \pm mF_2$
- Surprises!



Nonlinear Mixing Results



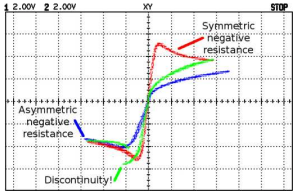
RF meets The Rusty Bolt

- Mountaintop radio
  - *Many* transmitters
  - High RF field intensity
  - *Sensitive* receivers
  - Galvanized towers
  - Acid rain
- Corrosion happens
- Intermodulation!
  - $\pm nF_1 \pm mF_2 \pm pF_3 \pm \ldots$

Mt Beacon NY - Photo by WB2UWU

DIY Diodes

- They're everywhere
- They're cheap
  - OK, not that positioner
- They're easy, sorta
- You'll learn…
  - … about diodes
  - … about electronics
  - … about patience



References

My column in Circuit Cellar magazine: www.circuitcellar.com
October 2006 has gritty details, has file of scripts, pictures, other stuff
February & April 2003 describe nonlinear frequency mixing

Semiconductor curve tracer using PC sound card: George Steber, WB9LVI
Circuit Cellar, Jan 2004
ARRL QEX, July 2006: www.arrl.org/qex/2006/07/qx7steber.pdf

Good overview of crystal-set parameters: www.oldradioworld.de/gollum/analysis.htm

Zinc negative resistance oscillators: http://home.earthlink.net/~lenyr/zincosc.htm

Galvanic Series table: www.ocean.udel.edu/seagrant/publications/corrosion.html

Wood's metal, springs, phosphor bronze sheet, tools from MicroMark: http://micromark.com

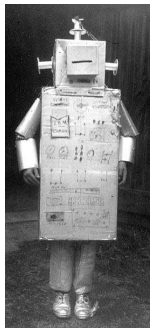
Taper pins and small parts from TimeSavers: www.timesavers.com

Capturing oscilloscope traces with Kermit: www.columbia.edu/kermit/index.html

Converting HPGL to bitmaps with hp2xx utility: www.gnu.org/software/hp2xx

Who Am I?

- Ed Nisley - KE4ZNU
  - Say "NISS-lee", even though my ancestors were half-essed
  - Engineer, author, tinker, family guy
  - Circuit Cellar: Above the Ground Plane - www.circuitcellar.com
    - Analog & RF stuff
  - Digital Machinist: Along the G-Code Way - www.homeshopmachinist.net
    - CNC machining & programming



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