Thesis Outline

Title: The development of a novel capacitive impedance-based water conductivity sensor

* Intro
  + Why framework
    - Salt in water
    - Runoff
  + Currently existing conductivity sensors
    - Standard 3 probe resistance measurements
      * AC
      * DC
      * Pulsed DC
    - Inductive
    - Others
  + Cons of currently existing sensors
    - Standard sensor is prone to corrosion and fouling
      * Corrosion resistant versions use platinum, increasing cost
    - Inductive sensor is not great at low conductivities and is power hungry
  + Needs
    - No direct contact of metal with water
    - Sensitivity across whole conductivity range from DI water to mine runoff
    - Cheap as hell
    - Small
    - Low power consumption
    - Fabrication using techniques easily available to hobbyists
    - Easy to calibrate
    - Does not require complex circuitry to drive and read
* Description of project goals
  + Develop sensor
  + Characterize sensor
  + Develop approach to making sensor practical
  + If possible, integrate sensor into sensing system
* Design
  + Parallel-plate capacitor
    - Thin polymer insulation over both plates
    - Water is between plates
  + Conductivity of water influences capacitance
  + Capacitor is driven on one leg with HF AC
    - Sensor is a open-circuit at DC
    - AC also helps avoid polarization of dielectric and ions in water
  + Vpp or Vmax is read from other leg of capacitor
* Implementation method
  + Magnet wire
    - Cheap and widely available
    - Standardized and very uniform dimensions
    - Pre-coated with insulator
    - Easy to manipulate, solder, and form
    - Fairly robust
  + Acrylic plastic frame
    - Cheap, widely available, robust, and laser cut-able
    - Is an insulator
    - Doesn’t hydrate very much over time
    - Transparent
      * Easy to check for biofouling, corrosion, leaks, cracks, etc.
  + Tsunami Board
    - Is an Arduino-style microcontroller joined with a DDS chip and DAC
    - Can both produce AC drive waveform and read from the sensor all on one board
    - Relatively inexpensive ($60 USD)
    - Open source; all files, code, schematics and design drawings are on Github
    - PCB gerber files are freely available
    - Also, it’s all I had in my desk….
    - Cons: It’s kinda shitty
      * Frequency dependent amplitude
      * Grounding issues/ USB problems
      * No enclosure
      * It’s really horrible at making repeatable, accurate, and jitter-free measurements
* Testing/Experimental methods
  + Jar testing (using scope and sig gen)
    - To find out:
      * Does it work at all? (Yes)
      * Do measurements drift? (No)
      * What’s an ideal frequency
      * Do different salts make a difference? (No)
    - Method
  + Barrel testing
    - To find out:
      * Is the sensor subject to interference (No)
        + From metal
        + External RF/mag fields
        + People
        + Vibration
        + From its own feed cables
        + Boundaries of containers/water
        + Further robustness testing
    - Method
  + Beaker testing
    - Purpose:
      * Characterize response of sensor
      * Draw calibration curves and functions
      * Compare to commercial device
      * Test code
    - Method
      * Magnesium chloride
      * 3.5 L beaker
      * Conventional sensor as control
  + Impedance analyzer testing
    - Purpose:
      * Can we assign real component values to the SPICE model?
    - Method
      * Lots of profanity and percussive maintenance performed on a 30-year old machine exhumed from the basement of an occult anarchist
* Data/Characterization
  + Lots of tables, graphs, pictures, numbers, etc.
    - Graphs
    - Tables
    - Pictures
  + Schematic
  + SPICE Model
  + Data from Dan’s machine
* Discussion and conclusion
  + Discussion of sensor behavior
    - Acts as tank circuit
  + Discussion of response curve properties
    - Super nonlinear :/
    - U shape – ambiguity ☹
    - Attempts to model the curve
      * Split curve
      * Symmetric sigmoidal
    - Discussion of effect of frequency on response
  + Discussion of measurement strategies
    - Double curve consensus
      * Attempts
        + Cal curves using sequential measurements
        + Cal curves using concurrent measurements
      * Problems
        + Curves are too similar
        + Tsunami chokes under the pressure
    - Phase
      * Should be phase inversion at trough
      * Tsunami board can’t effectively measure phase above 10khz, and not unambiguously
    - Single curve
      * Use probing frequency sufficiently low so that trough is at 0
      * Problems: Sensitivity will be poor at high conductivities
* Future Work
  + Purpose built excitation and measurement circuits
    - Sig gen with output magnitude feedback
    - Precision instrumentation rectifier
  + Cal curve formulas defined using REAL software
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  + Joe
  + Andy
  + Bobby
  + Simo :P
  + Lenny
  + Joe the Janitor
  + Random folks at the IEEE conference in Torino
  + Random folks at Hackaday
* Appendix
  + MOAR Photographs
  + Raw data spreadsheets