# Low Cost, Open Source Instrument Design

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This research was supported by the Jamie Cassels Undergraduate Research Awards, University of Victoria

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## Background

Research teams rely on scientific instruments to measure, process, manipulate, and observe the world. Instruments, even simple ones, are typically expensive, and purchased using grant funding in a time consuming process.

**SMART Lab needed a suite of material testing and processing instruments, but found them cost prohibitive.**

*IMCE's damping analyzer for measuring elastic moduli and damping of new materials [1].*
***Price: $73,000***

*Pulse magnetizer [2] for neodymium magnet manufacturing.*
***Price: $5,000-10,000***


*Emstat potentiostat [3] for corrosion and other electro-chemical experiments.*
***Price: $1,500***

## Instruments in Academia

While papers are often published on an aspect of an instrument (e.g. computer modeling of a pulse magnetizer circuit, or the mathematical modeling of resonating bars for RFDA), rarely are comprehensive, accessible guides produced for the researcher to duplicate.

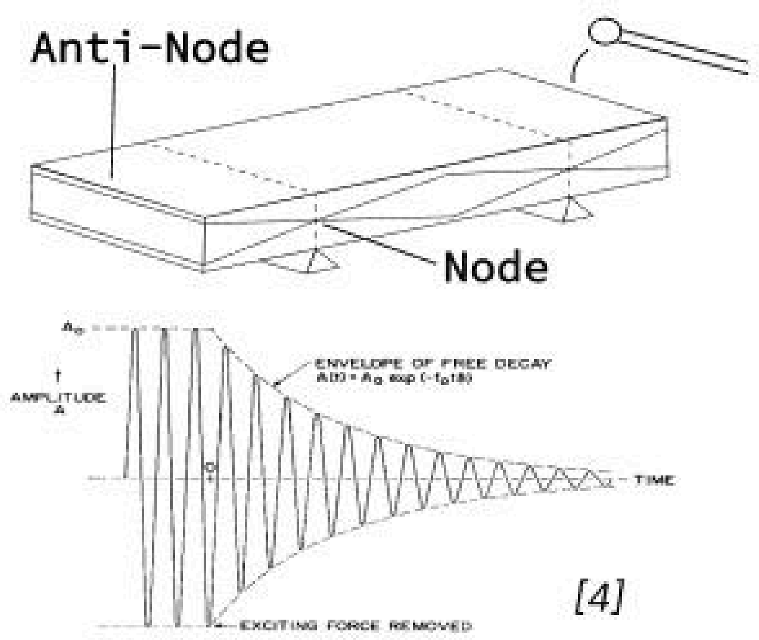
***Goal: Develop cost effective instruments that are fully documented so they may be used for research purposes.***

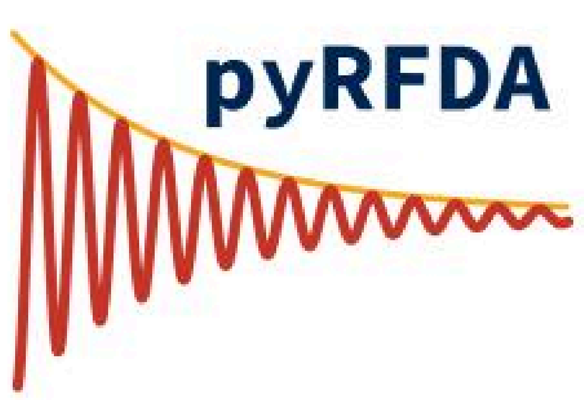
## Resonant Frequency Damping Analysis

When experimenting with new alloys of metal, it is desirable to know the elastic modulus (stiffness, roughly speaking) and damping coefficient (how quickly vibrations are dissipated by internal friction).

*Striking a bar or rod of known dimensions causes it to resonant at a frequency which is directly related to the elastic moduli of the material from which it is made.*

*The amplitude of these vibrations decays exponentially, at a rate given by the damping coefficient δ.*



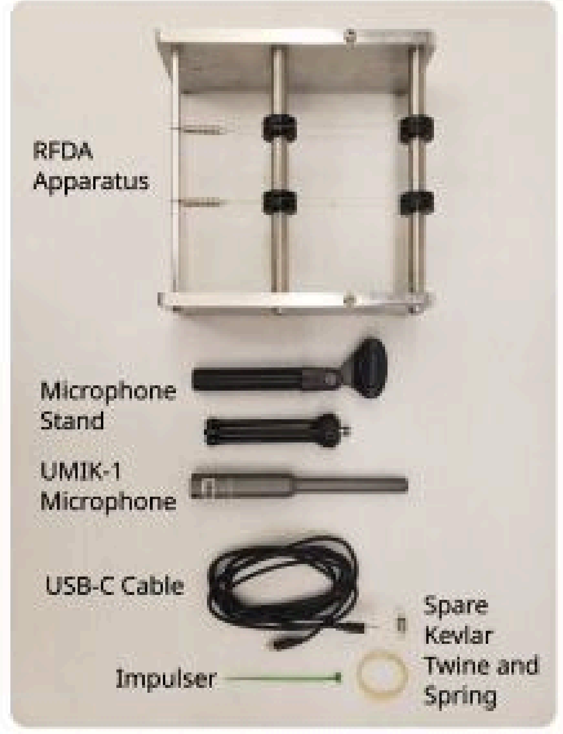




Commercial instruments for holding/ striking samples and analyzing the resulting vibrations are costly.

To remedy this, *pyRFDA* was written as an intuitive interface and analysis program to record audio of resonating bars and automatically compute material properties.

Complete project and documentation available for free on GitHub under permissive MIT license.

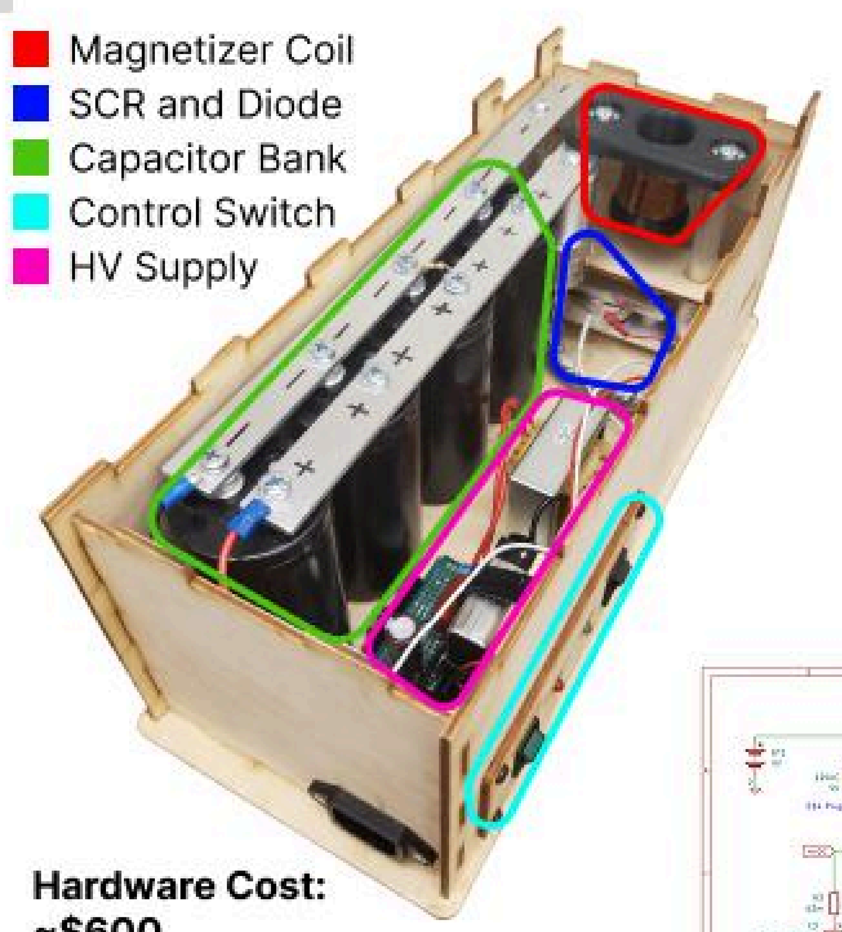
***Hardware Cost: ~$250***




## Pulse Magnetizer for NdFeB Recycling

Neodymium (Nd) magnets are vital for modern brushless motors powering emerging EV technologies. Research into Nd recovery and recycling requires testing the magnetic strength of the recovered Nd.

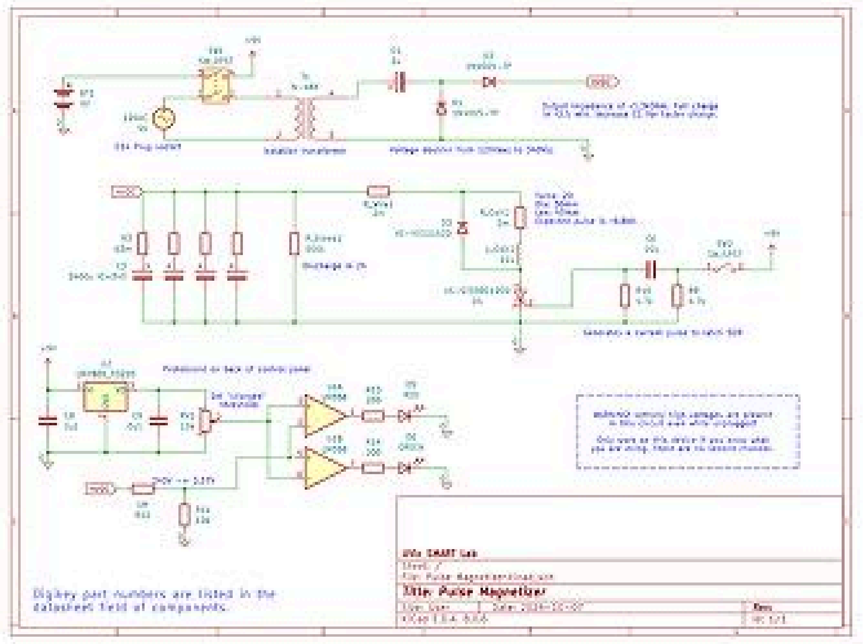
Initially non-magnetic, NdFeB magnets are exposed to an extremely strong magnetic field (>2T), which imposes permanent magnetic properties.




**Hardware Cost: ~$600**

A low cost bench-top pulse magnetizer was designed based on Yuriy Skvortsov's SCR circuit [5].

Voltage doubled mains charges a 340V, 2400uF capacitor bank. A high current SCR switches ~7kA of current to produce a 3.5T field.

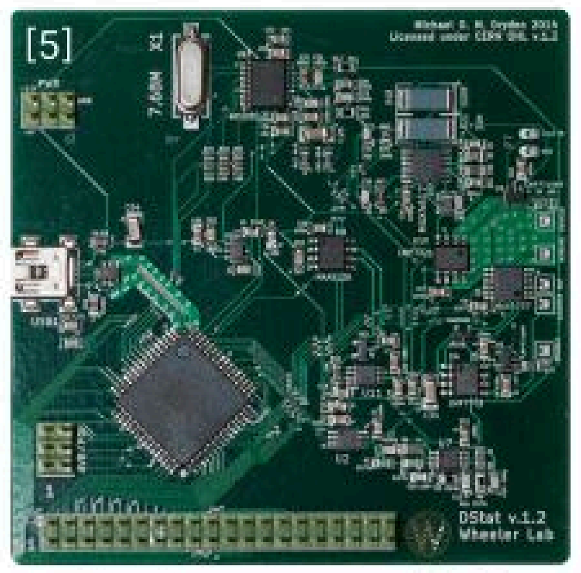
The magnetizer was tested by heating commercial 20×5mm NdFeB disk magnets above their Curie point to remove all inherent magnetism. Exposure to the full 3.5T field restored magnet to ~98% of original strength.

Schematic, BOM, CAD, and coil design spreadsheet available under permissive MIT license on GitHub.

## DStat Potentiostat

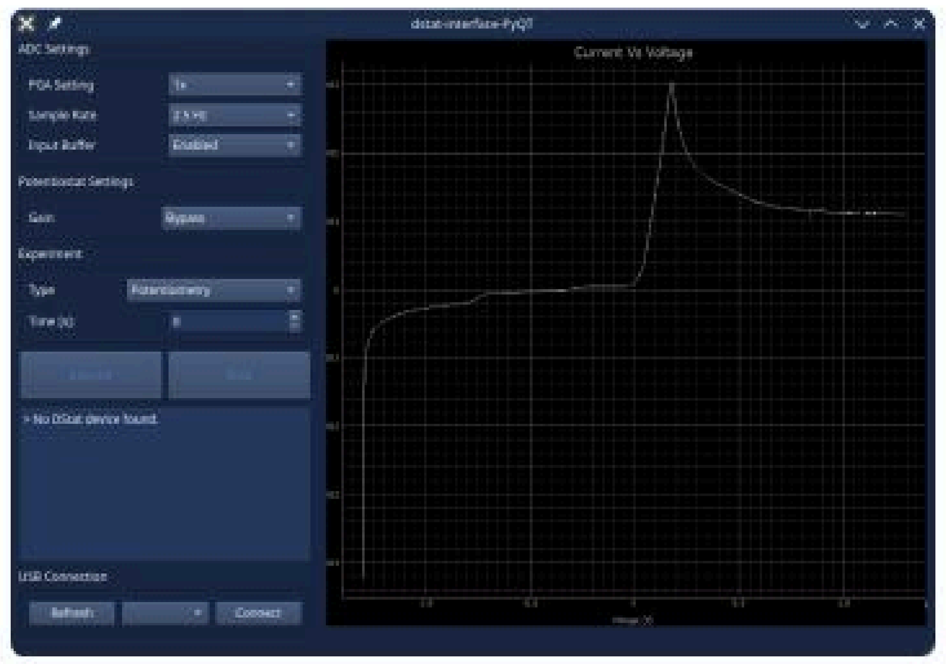
A device called a potentiostat is frequently used in electrochemistry. Of particular interest to SMART is linear sweep voltammetry (LSV) for measuring corrosion behaviour of new alloys developed for medical use.

Fortunately, *Wheeler Microfluidics Lab* from UoT designed an open source potentiostat "DStat" [5] which was recreated by SMART Lab.




***Hardware cost: ~$200***

Published in 2015, the supporting Python 2.7 interface is now unsupported and in need of a refresh. SMART Lab created a modern Python 3, PyQT interface from the ground up. Available on GitHub under GPLv3.



This kind of revamping is only possible due open nature of DStat's hardware and software, and would be infeasible with commercial instruments.

### References

[1] [1] "Advanced material testing instrument - RFDA professional," RFDA Professional, https://imce.eu/rfda-professional/ (accessed Mar. 9, 2025).

[2] "Capacitive magnetizer," www.alibaba.com, https://www.alibaba.com/product-detail/CAPACITIVE-MAGNETIZER-MZM-2010K1S-P-for_1601184153279.html?spm=a2700.galleryofferlist.normal_offer.d_title.41b113a0UNrzzz (accessed Mar. 9, 2025).

[3] "Palmsens EMSTAT3+ blue potentiostat," PalmSens Emstat3+ Blue Potentiostat, https://www.basinc.com/products/PALM-ES3+BLUE (accessed Mar. 9, 2025).

[4] IMCE, Integrated Material Control Engineering N.V. IMCE, Slingerweg , Belgium, (accessed May 1, 2024)

[5] Y. Skvortsov, "Pulse (re)magnetizer for neodymium magnets," Medium, https://medium.com/@yuriy.skvortsov/pulse-re-magnetizer-for-neodymium-magnets-e5c42aefbf78 (accessed Mar. 9, 2025).

[6] Dryden MDM, Wheeler AR (2015) DStat: A Versatile, Open-Source Potentiostat for Electroanalysis and Integration. PLoS ONE 10(10): e0140349. https://doi.org/10.1371/journal.pone.0140349 (accessed Mar. 9, 2025)