Building Ultra-Low Noise Control Systems for Scanning Tunneling Microscopy

Rogelio Baucells, Keely Paul, Denis Le, Kersten Galeta , Guangxin Ni, PhD

Department of Physics, National High Magnetic Field Laboratory, Florida State University

Introduction:

A Scanning Tunneling Microscope (STM) is a non-optical microscope that works by scanning a very sharp probe tip over the surface of a sample locally with 0.1nm lateral resolution and 0.01nm depth resolution. STM is widely used for fundamental research to obtain atomic-scale images of conductive surfaces. It provides a three-dimensional profile of the surface information, allowing characterization of surface morphology, topological surface states, phase transitions, and the local density of states at an atomic level. The process of STM involves bringing a sharp, wire tip–mounted on a piezoelectric scanner–within a few angstroms of the conductive sample and applying a small bias voltage–measured by a transimpedance amplifier– across the gap. This tunneling current is fed into a feedback loop "which controls the voltage applied to the Z-axis electrode of the piezo scanner and acts to maintain a constant tunneling current, and therefore a constant tip-sample distance (23 et al., 2015)." To generate a topographic image of the sample at atomic resolution, the anatomically sharp tip controls the flow of the tunneling current to only pass through the closest atom on the tip to the sample surface and a raster scan is performed by scanning the tip across the sample using the X and Y axes and measuring the Z-axis voltage as a function of scan position. From this, if we uncover high-order topological phases in a superconductor, we can apply the generated hinge Majorana modes to fault-tolerant quantum computing which could enable testing more sophisticated protected circuits in small-scale quantum devices.

Methods:

- Constructed 3 power supplies with the following specifications: (Figure 2-5)
- Box 1: (+/- 250V)
  - 2 x U400Y20F (1/4 A) (250V)
  - 2 x VRB200GTIOR (1/2 A) (250V)
- Box 2: (+/- 16V)
  - 2 x VRB1GG500F (1/2A) (250V)
- Box 3: (+/- 16V)
  - 1 x VA5MT600F (1A) (250V)
  - 2 x VRB9G300F (1 A) (250V)
- Constructed a INA110 amplifier
  - 18V, and can be amplified by 50
  - Pin 3 was crossed with pin 11 in order to amplify the voltage by 500 (Figure 1)
- Constructed a digital-to-analog converter/ a analog-to-digital converter (DAC/ADC)

Results:

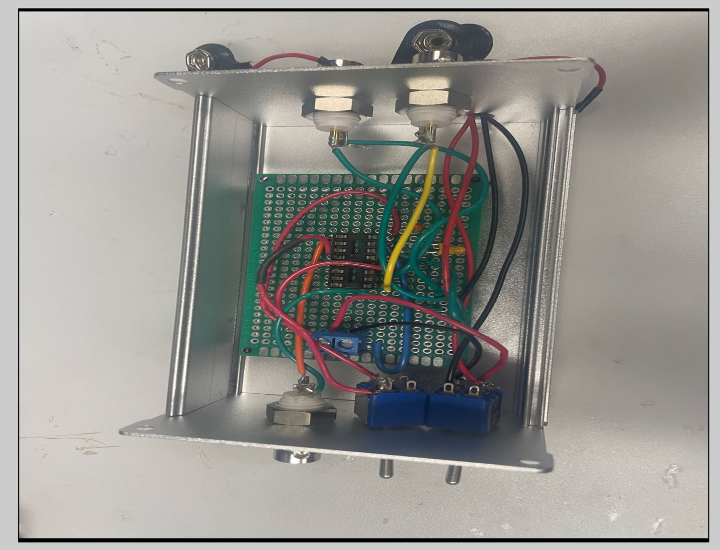
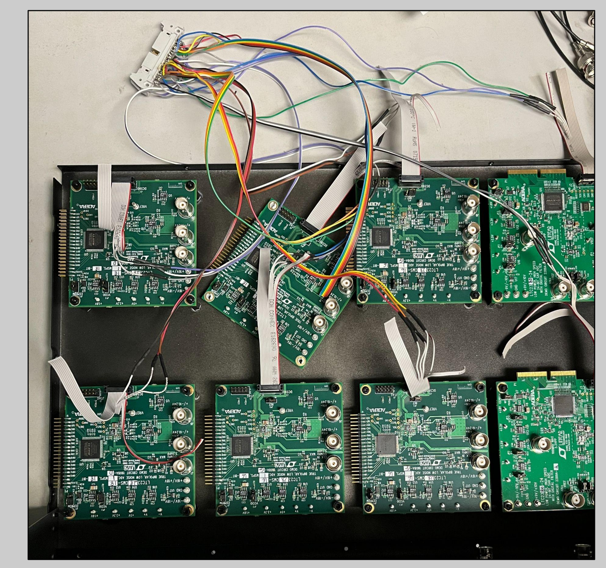


Figure 1: INA110 Amplifier



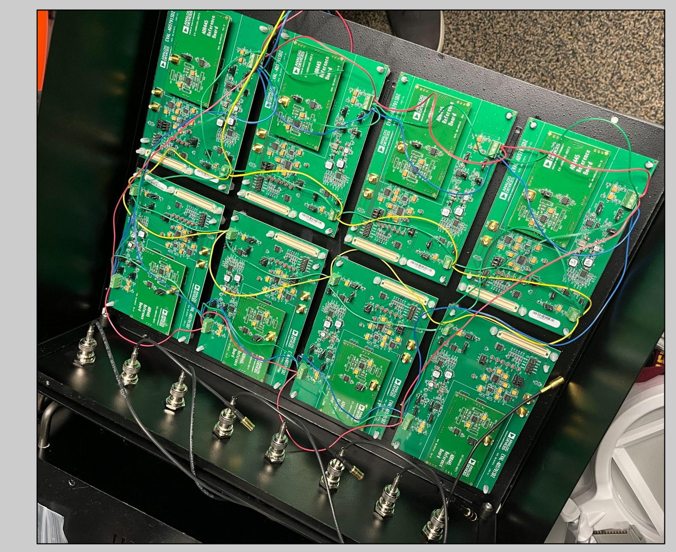


Figure 2 & 3: DAC/ADC Converter

Figure 4: Power Supplies

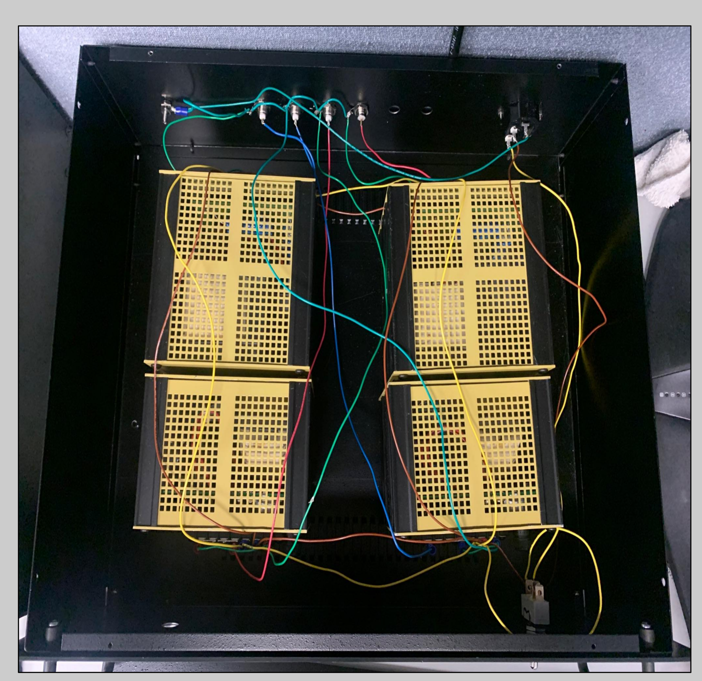


Figure 5: Box 1

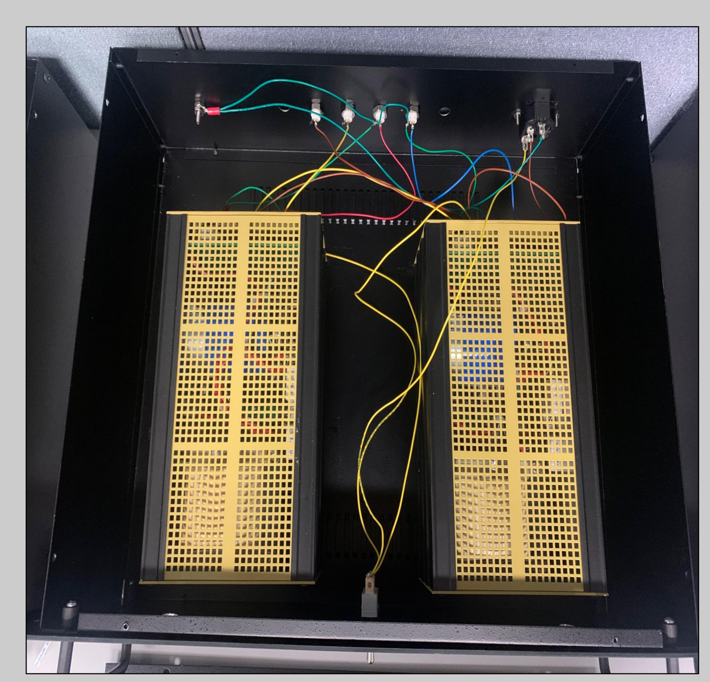


Figure 6: Box 2

Figure 7: Box 3

- Figure 1: This figure shows the wiring for the INA110. In order for it to be amplified pin 3 and pin 11 are connected to either sides of the switch.
- Figure 2-3: These figures display the DAC/ADC converter. One converts a digital signal into an analog signal, and the other one vice versa.
- Figure 4: This shows the general look of the power boxes, with 2 of them having switches (Box 1 & 2) while the other (Box 3) will be connected to Box 2
- Figure 5-7: This shows the inside of each power supply and how the wires were connected to give a stable, noise-reducing, connection to the instrument
  - Box 1 is unregulated giving an output of +/- 250V while Box 2 and 3 are regulated to give an output of +/- 16V

Conclusion:

- Once these parts for the STM microscope were completed, they were tested and were working successfully with little interference.
- The Power Supplies are able to supply a stable flow of current with little noise
- The INA110 Amplifier was successful in amplifying the signal making it sufficient to operate the STM microscope for a long period of time.
  - It can amplify the voltage by 500 or to keep it at 18 volts.
- The Amplifier experiences low noise and will minimize the vibrations allowing for a clearer and more precise image.
- The STM microscope requires a Digital current in order to be operated, and then it sends information back to the computer in a more complete and precise manner via Analog currents.
- The AC/DC convertor will transform the Alternating current to Digital current, allowing for the flow of electricity to be stable and usable with this instrument
- The only components missing to fully assemble the STM microscope is the Isolator.
- The isolator will stabilize the instrument as it uses ultra-low frequency that cause vibrations which interfere with the imaging.
- Once this is completed, it will be tested and if successful, will be assembled together to form the STM microscope.

References:

- Chen, C. J. (1993). *Introduction to scanning tunneling microscopy*. Oxford University Press.
- 23, T. S. on O., Phạm Minh Đức on October 26, 26, T. S. on O., 24, S. S. on J., 5, Y. L. on J., 1, N. G. on J., Phạm Minh Đức on April 22, Phạm Minh Đức on April 1, 3, T. C. on A., Phạm Minh Đức on April 5, 5, D. B. on A., 25, V. B. on M., 25, D. B. on M., 26, V. B. on M., 13, V. B. on A., 18, V. B. on A., 18, J. A. on A., 2, V. B. on J., Phạm Minh Đức on March 19, ... 16, H. on A. (2015, October 21). *Home-built STM*. Dan Berard. Retrieved March 10, 2022, from https://dberard.com/home-built-stm/