

Inexpensive Scanning Tunneling Microscope for Academic Research

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1. Introduction

- Scanning Tunneling Microscope (STM) is an instrument used to obtain images of the surface of a material at atomic resolution.

2. Requirements

- Resonant frequency of the mechanical system should be $< 1\text{Hz}$.
- Voltage amplifiers to produce $\pm 15\text{ V}$ to produce a resolution of $\sim 0.01\text{ nm}$ in the Z direction.
- Noise figure should be $< 3\text{ nV}/\sqrt{\text{Hz}}$ for the amplifier.

3. Problem Statement

- Cost of industrial STM can cost up to \$500,000, making it financially inaccessible.
- Construct a STM with commercially available components and a limited budget to be used for future research of nanoelectronics and Northern Arizona University.

4. Challenges

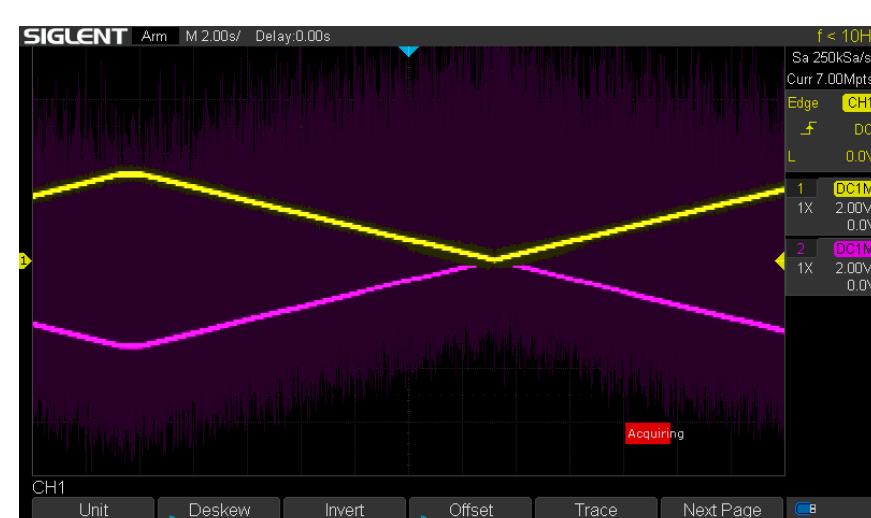


Figure 1. + and - x signal from the piezo driver circuit

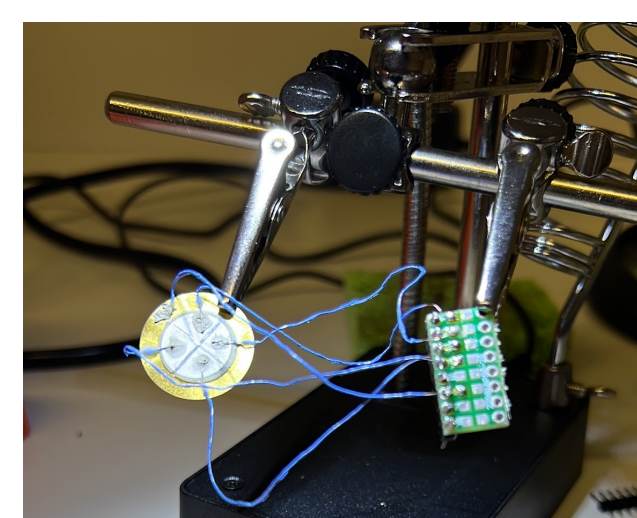


Figure 2. Piezo disk connected to a breakout board, using silver paste to solder contacts.

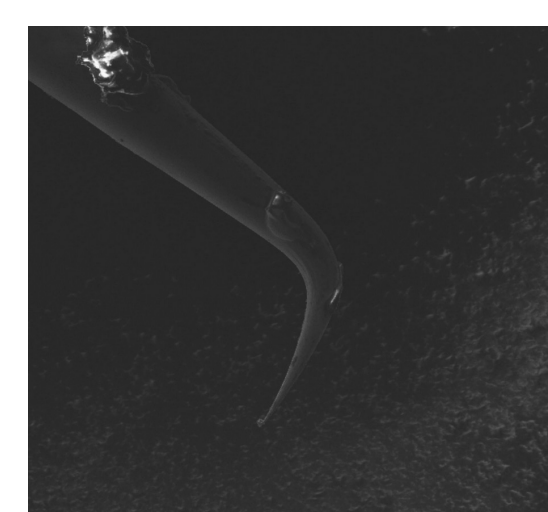


Figure 3. SEM image of one of the tungsten scanning tips that got bent in the etching process

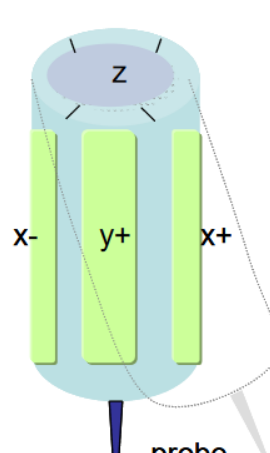


Figure 4. Tube scanner: requires large voltages to achieve the same displacement as a disk scanner

5. Solution Statement

➤ Methods

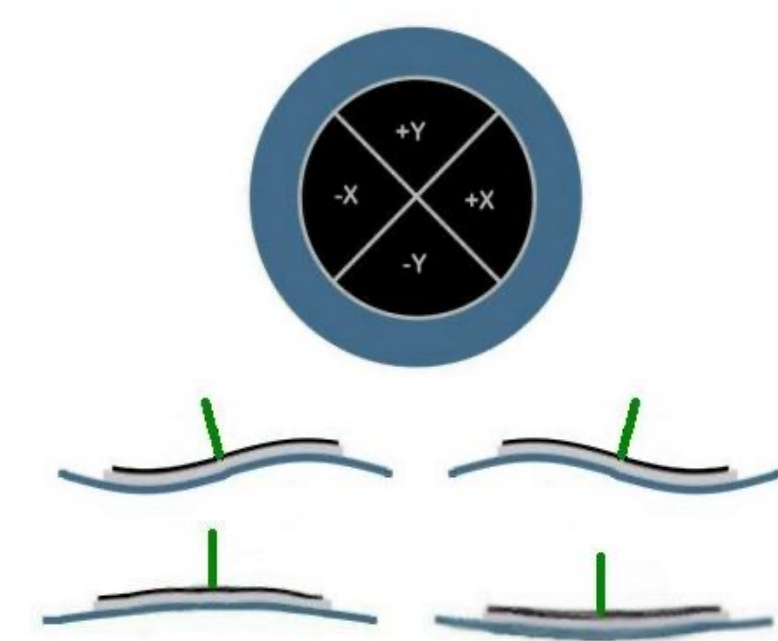


Figure 5. Piezo disk showing how quadrants should be divided, and their movement.

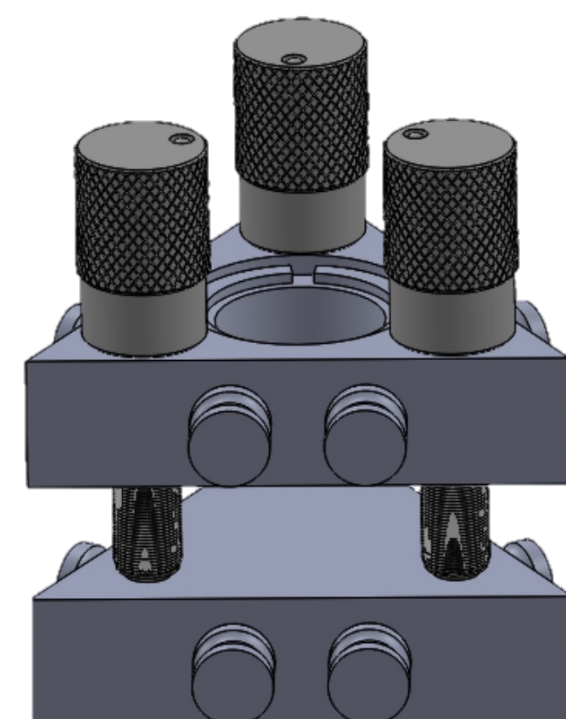


Figure 6. CAD model of the final design of the mechanical structure

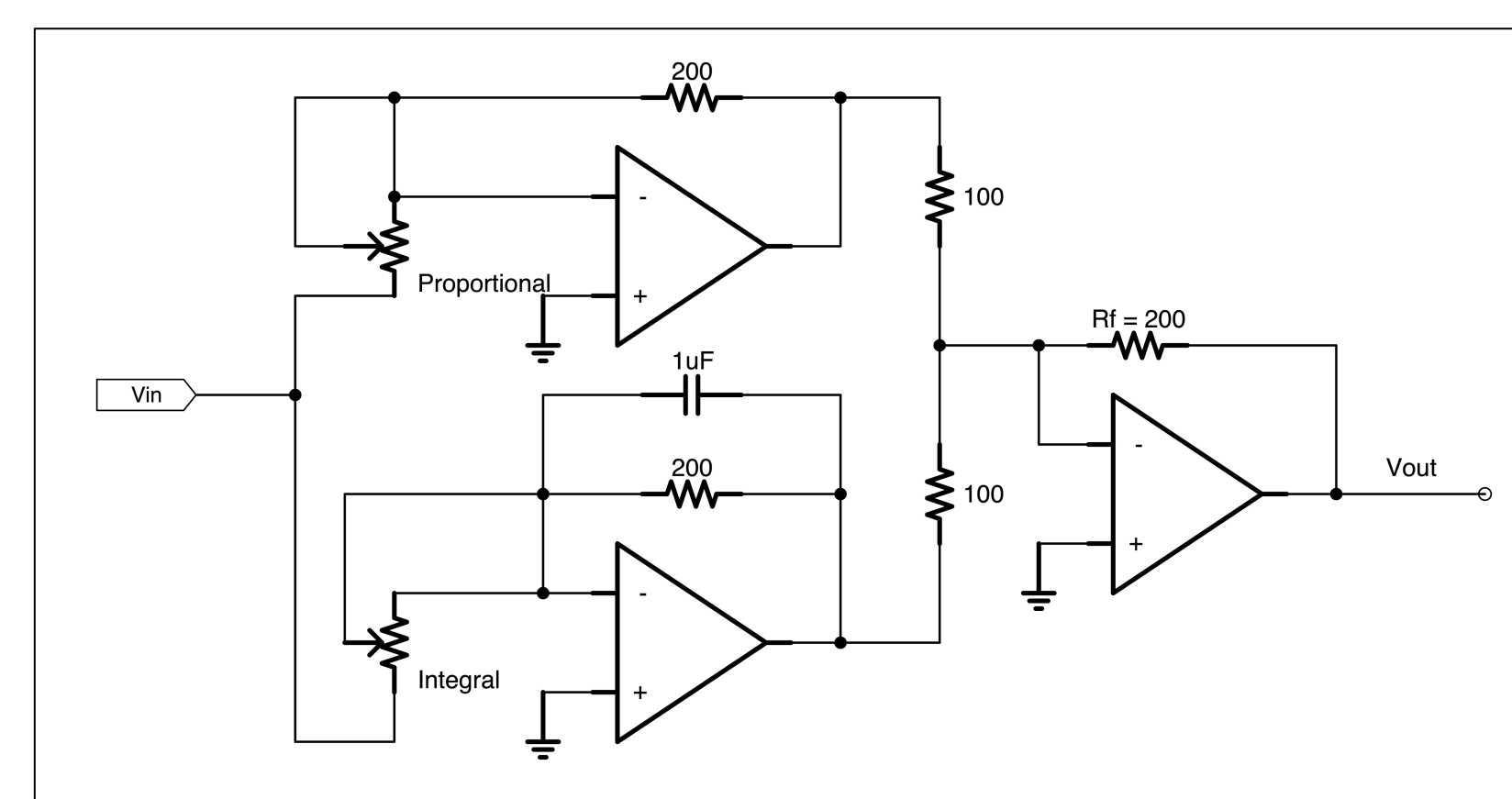


Figure 7. Schematic of the analog PI controller.

➤ Prototype

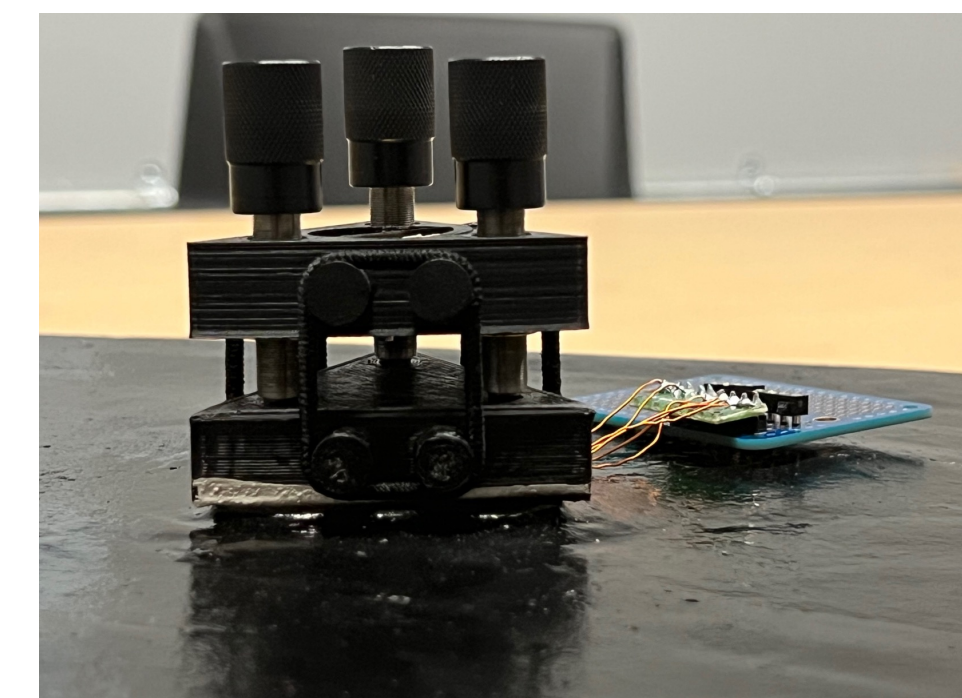


Figure 8. Final prototype of the mechanical structure, with piezo disk integrated.

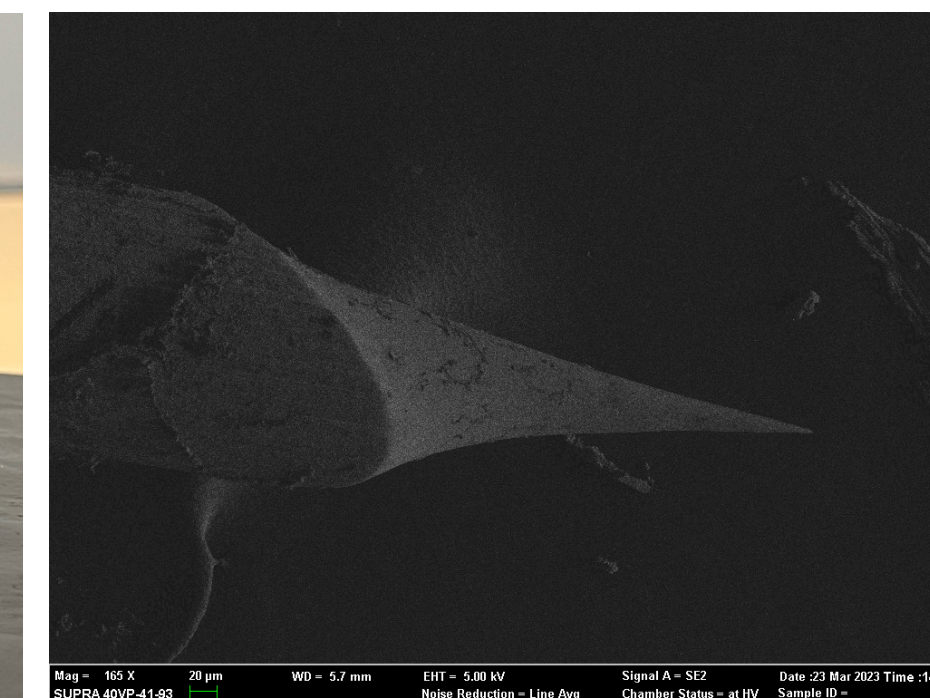


Figure 9. SEM image of tungsten tip.



Figure 10. Final version of piezo disk with tip placement.

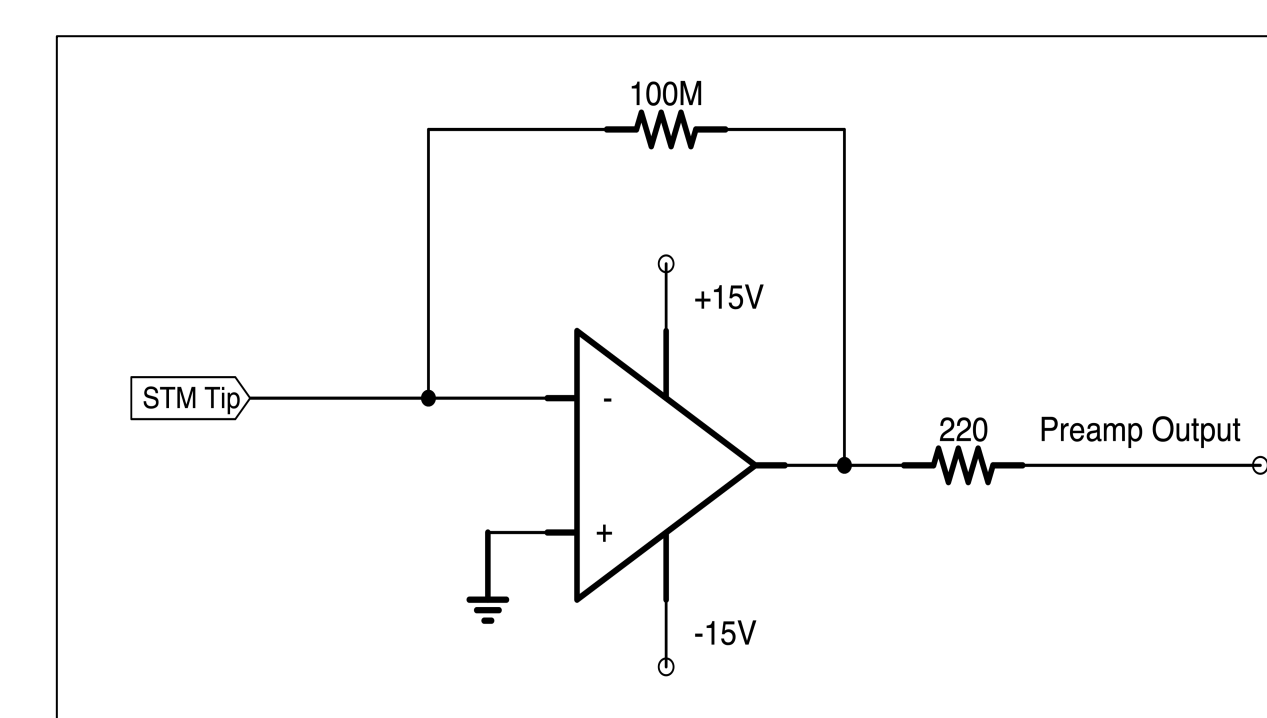


Figure 11. Schematic of the preamplifier.

6. Architecture

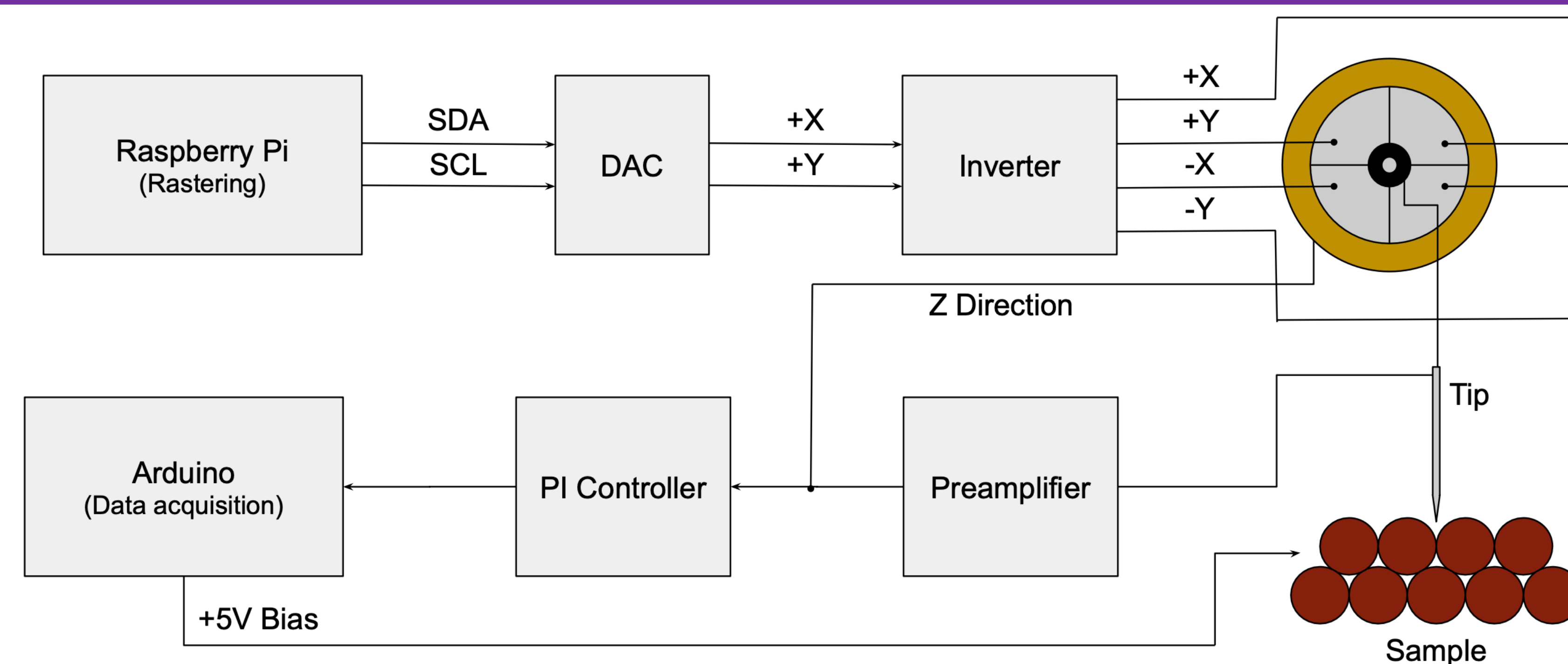


Figure 12. Block diagram showing how all submodules perform together once integrated.

12. References

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- [2] J. Tersoff and N. D. Lang, "1. Theory of Scanning Tunneling Microscopy," in *Methods in Experimental Physics*, vol. 27, Elsevier, 1993, pp. 1-29. doi: 10.1016/S0076-695X(08)60006X.
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7. Testing

- Each sub-module was tested first separately, then once again during the assembly of the integrated system.

8. Results

- The team was able to successfully collect raw data from the STM which can be processed into a photo at a later date.

9. Conclusion

- Built with a budget of \$500 for academic use.
- Will remain in the Complex Systems Laboratory at NAU for research on nano-electronics or related fields.

10. Future work

- Investigation into using the system for nano-device fabrication and research
- Further improvements to the mechanical structure by improving the vibrational isolation

11. Acknowledgements

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