

Testing the Fundamental Symmetries Between Matter and Antimatter

UM-CERN REU Final Presentation | Supervisor: Dr. Timothy Friesen

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EP/UAD | ALPHA

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August 16, 2018



- (1928) Paul Dirac theorizes existence of the positron

Dirac Equation

$$i\hbar\gamma^\mu\partial_\mu\psi - mc\psi = 0$$

$$E = \pm mc^2$$



Antihydrogen Laser PHysics Apparatus

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- (1928) Paul Dirac theorizes existence of the positron
- All elementary particles have antiparticles
 - ▶ Charge conjugation
- All atoms can have antiatoms (p,n,e⁻ | $\bar{p}\bar{n}e^+$)
- There should be matter-antimatter symmetry in the universe
- CPT Theorem and the Standard Model
 - ▶ Matter-antimatter asymmetry problem

Dirac Equation

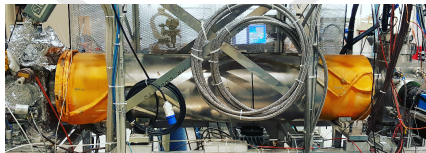
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Antihydrogen Laser PHysics Apparatus

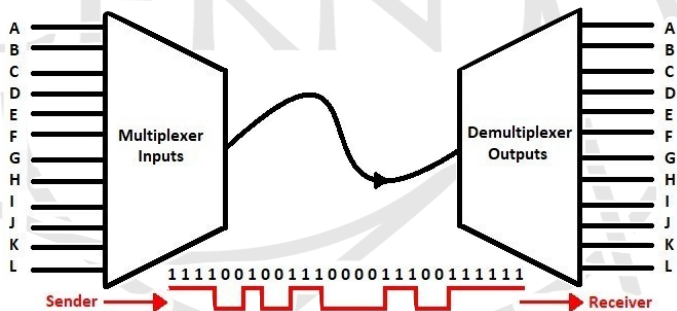
- Designed to build and trap cold antihydrogen
- Make precise spectroscopic comparison of H and $\bar{\text{H}}$
 - ▶ Ground state hyperfine splitting
- Determine inertial/gravitational mass
- Currently building the all new ALPHAg apparatus



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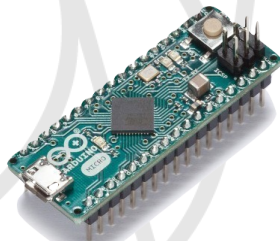
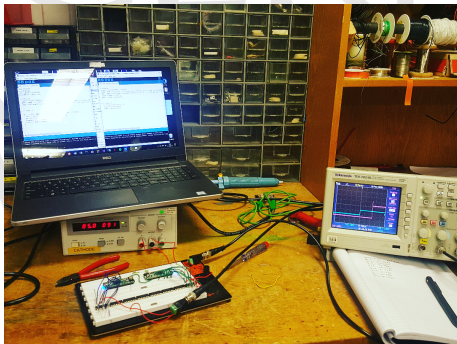
My Project: Serial Multiplexer

- Improve upon an existing piece of equipment (Serial Multiplexer)
 - ▶ Reduces the number of fiber cables between equipment
 - ▶ Helps to create a buffer between noisy equipment and the apparatus



My Project: Attacking the Problem

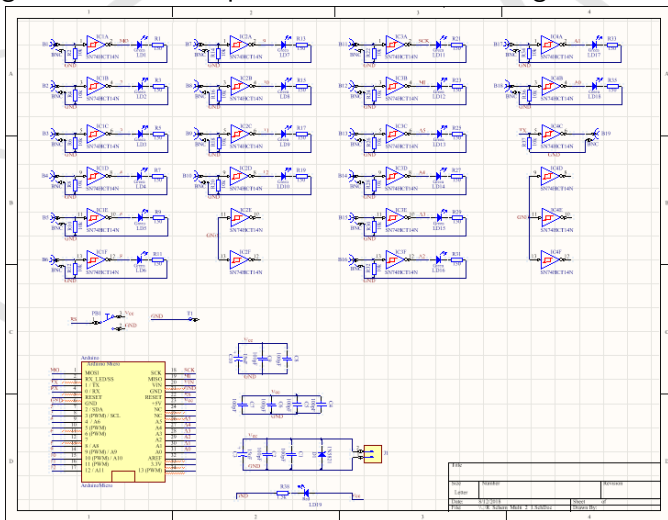
- Built around the Arduino Microcontroller
- Tested the limitations of the Arduino to maximize outputs and minimize transmission time
- Coding to manipulate port registers



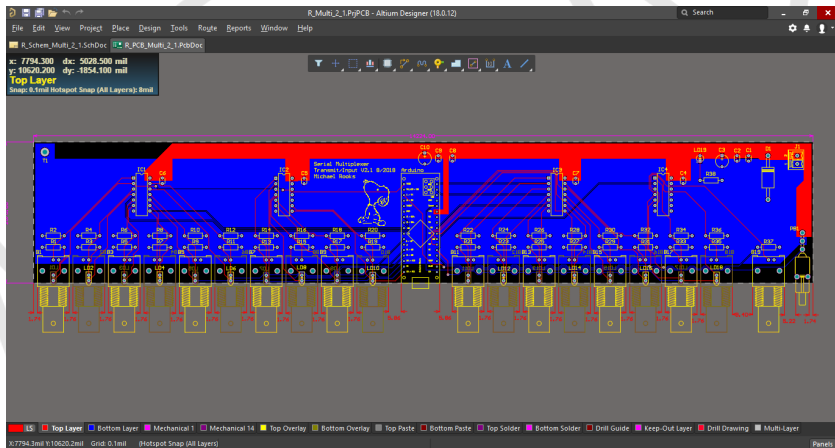
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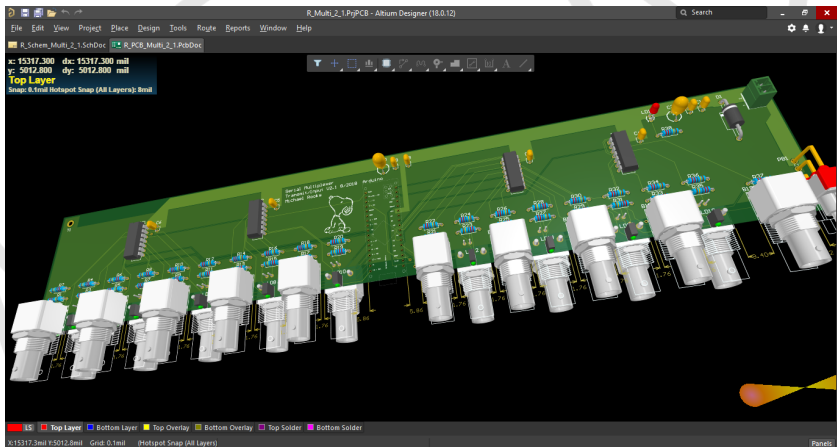
- Design the circuit and printed circuit board using Altium Designer



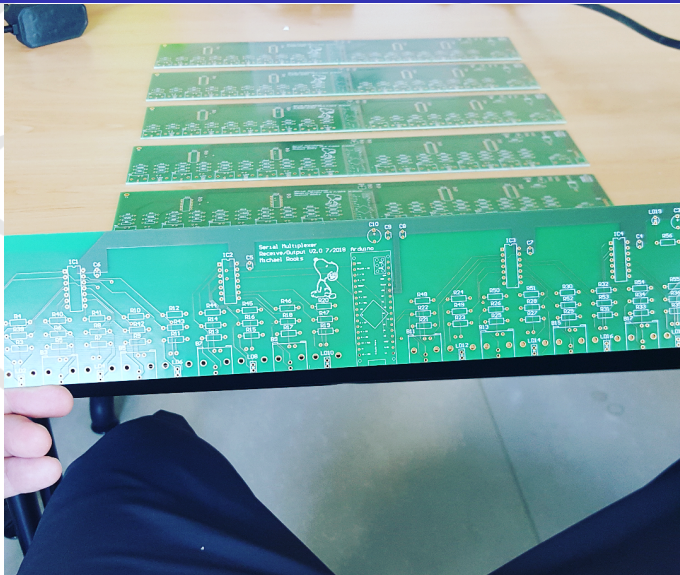
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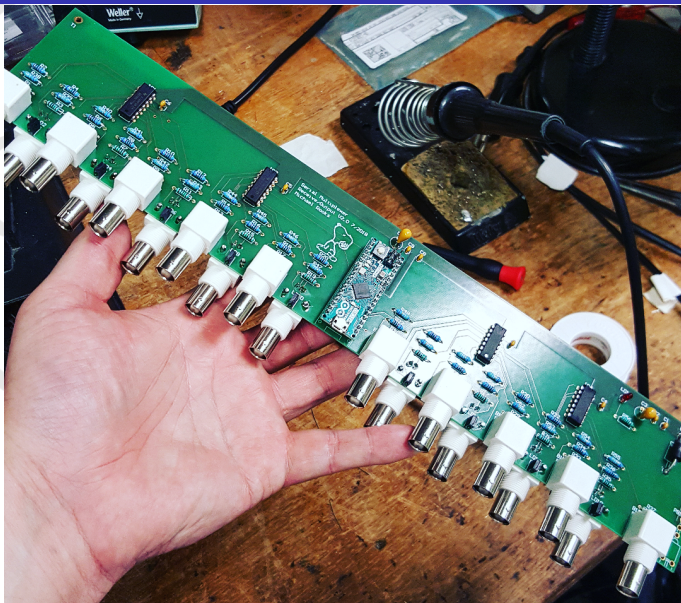
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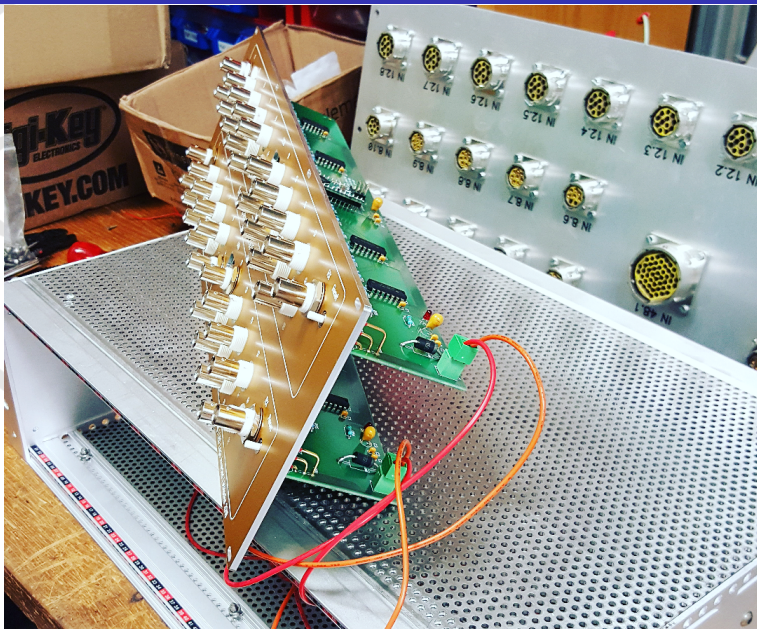
My Project: Attacking the Problem



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My Project: Attacking the Problem



My Project: Results

- Improvements I made:

- ▶ Each board now has 18 i/o's respectively, previously 8
- ▶ Each box holds 2 boards, previously 1
- ▶ Made opening for USB port for easily upgrading firmware and software
- ▶ Fixed a reset problem found in previous version



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Final Thoughts

- Met some really great down to Earth physicists
- Look forward to hearing about the results from the ALPHAg experiment this fall
- Why did I come here? What did I find?



Experimental
Physics

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Special Thanks

- Thanks to the National Science Foundation for funding the Research Experiences for Undergraduates
- Thanks to the University of Michigan for hosting this summer REU
- Thanks to Myron, Steve, Junjie and Jennifer for making my day.

Thanks Tim for being a super awesome boss!

