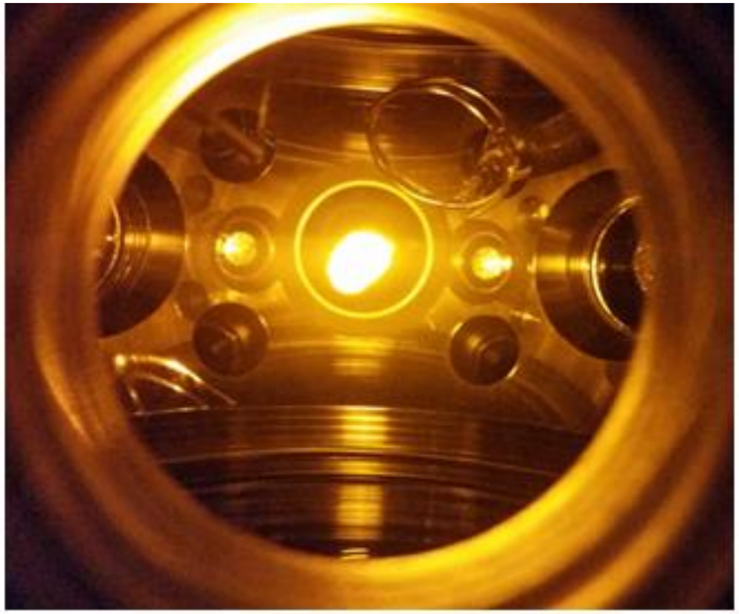
Magnetic Field Stabilization in a BEC



Cameron Cinnamon

REU Project

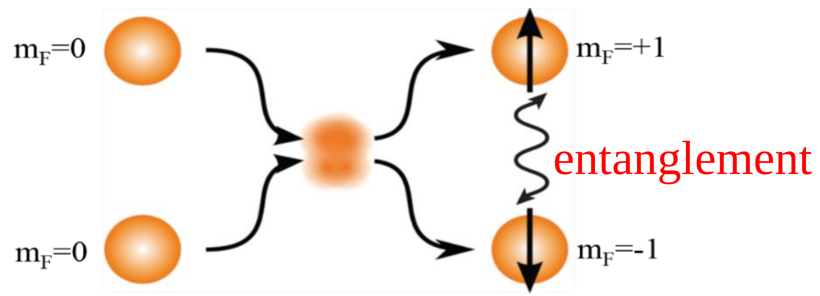
Advisor: Arne Schwettmann

Graduate Student: Shan Zhong

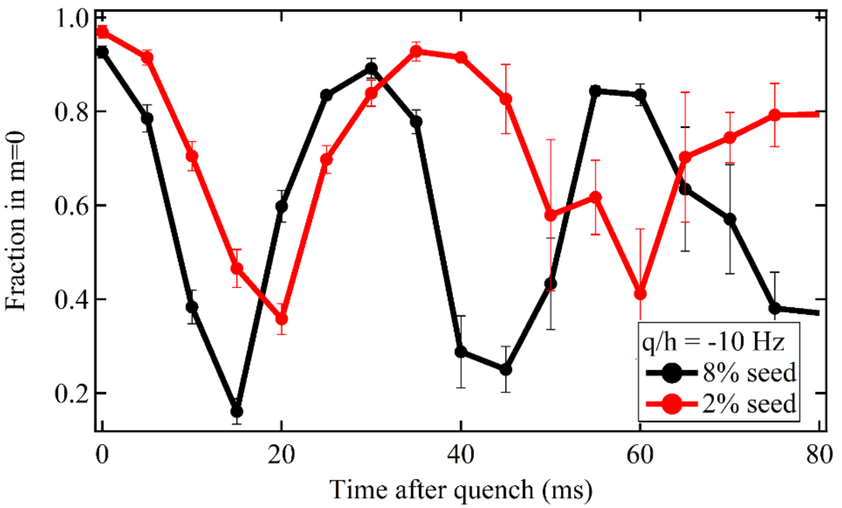
Department of Physics and Astronomy, University of Oklahoma

Introduction

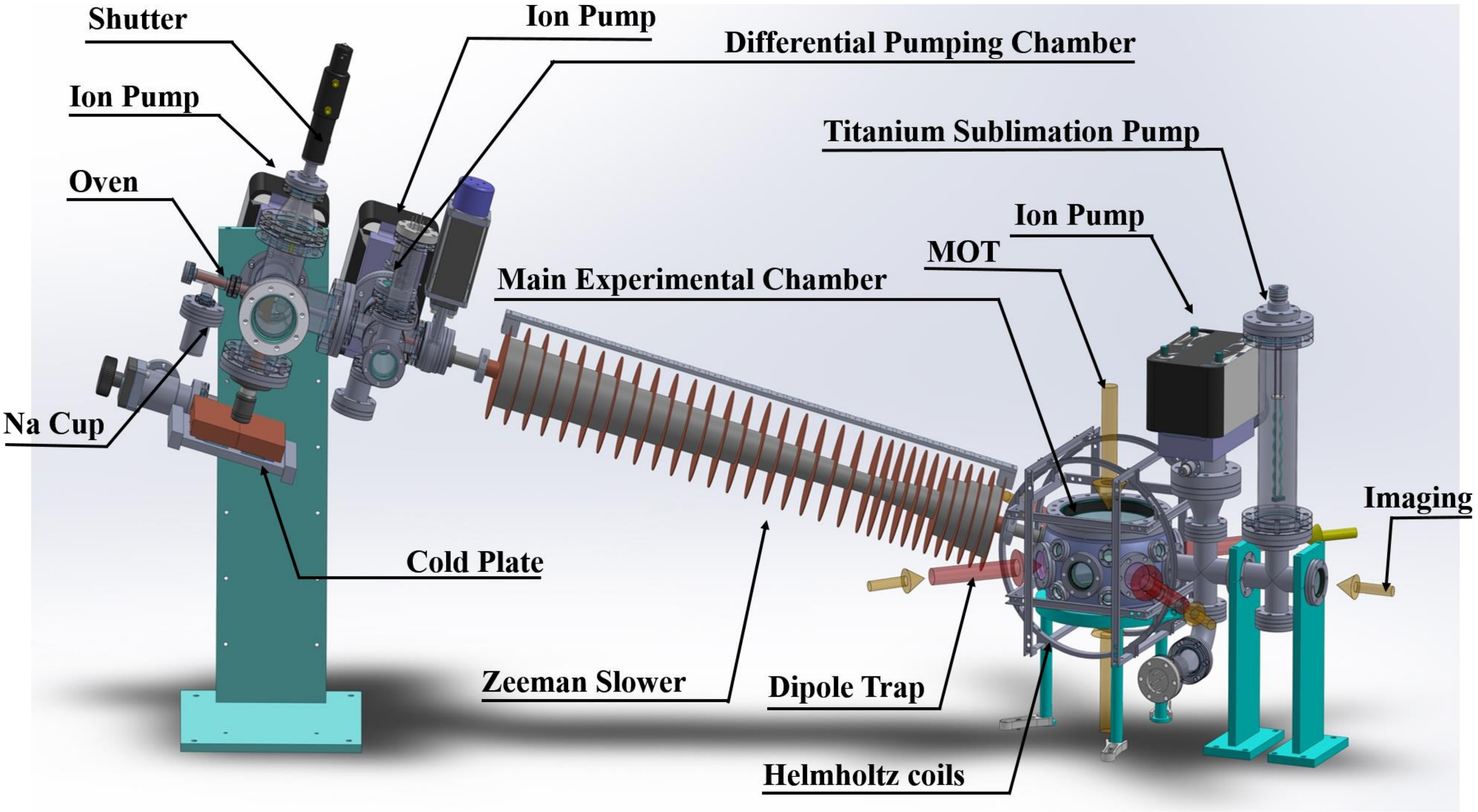
- Ultra cold sodium gas
- Laser cooling and trapping
- T≈100 nK BEC is formed
- Spin exchange collisions create **entanglement**
- Entanglement allows us to use the atoms as sensors
- These collisions are very sensitive to magnetic fields.
- My project was to stabilize B-Field to reduce these error bars.



$$|m_F=0\rangle + |m_F=0\rangle \rightarrow |m_F=+1\rangle + |m_F=-1\rangle$$

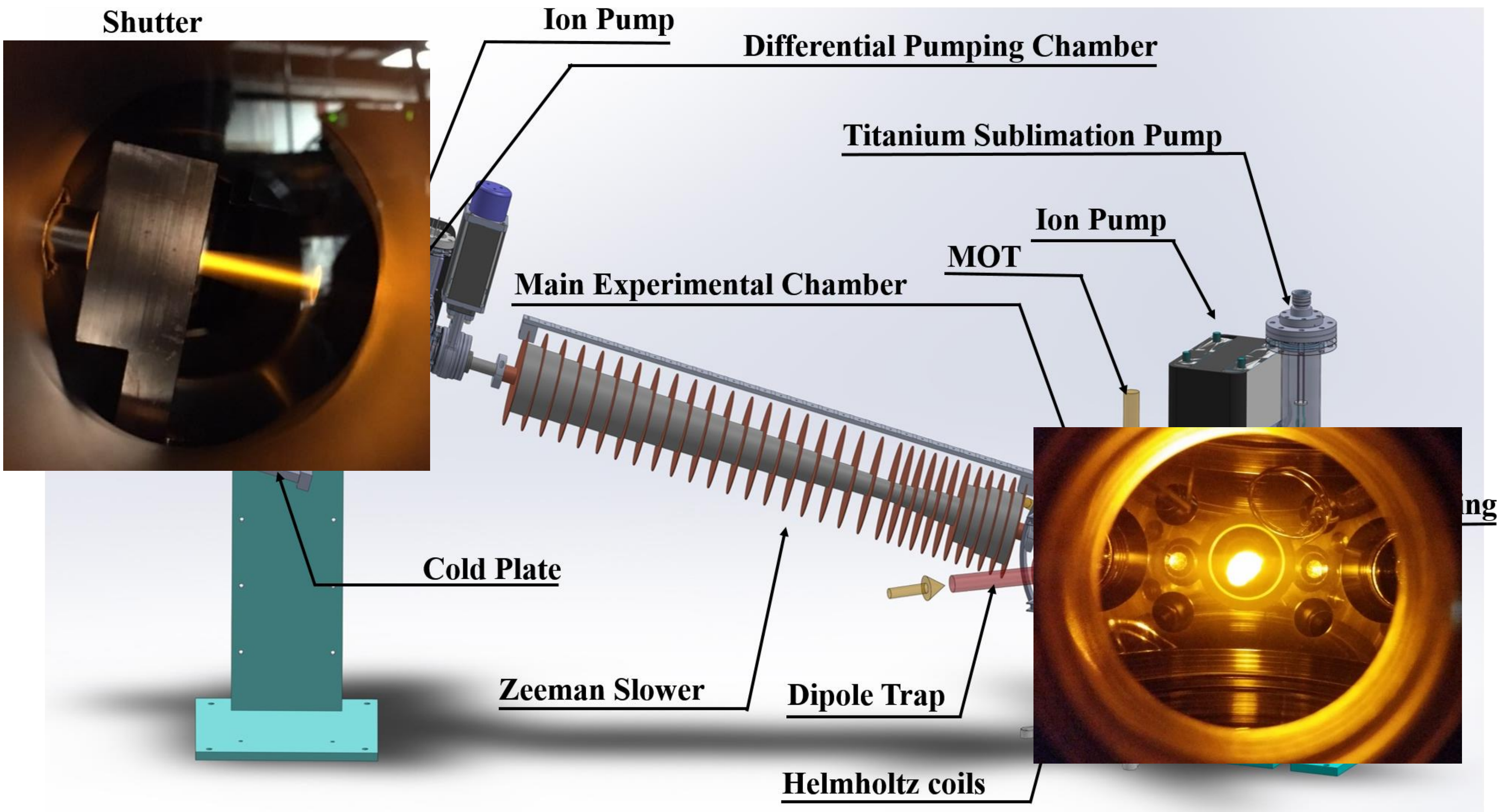


Spinor BEC Setup



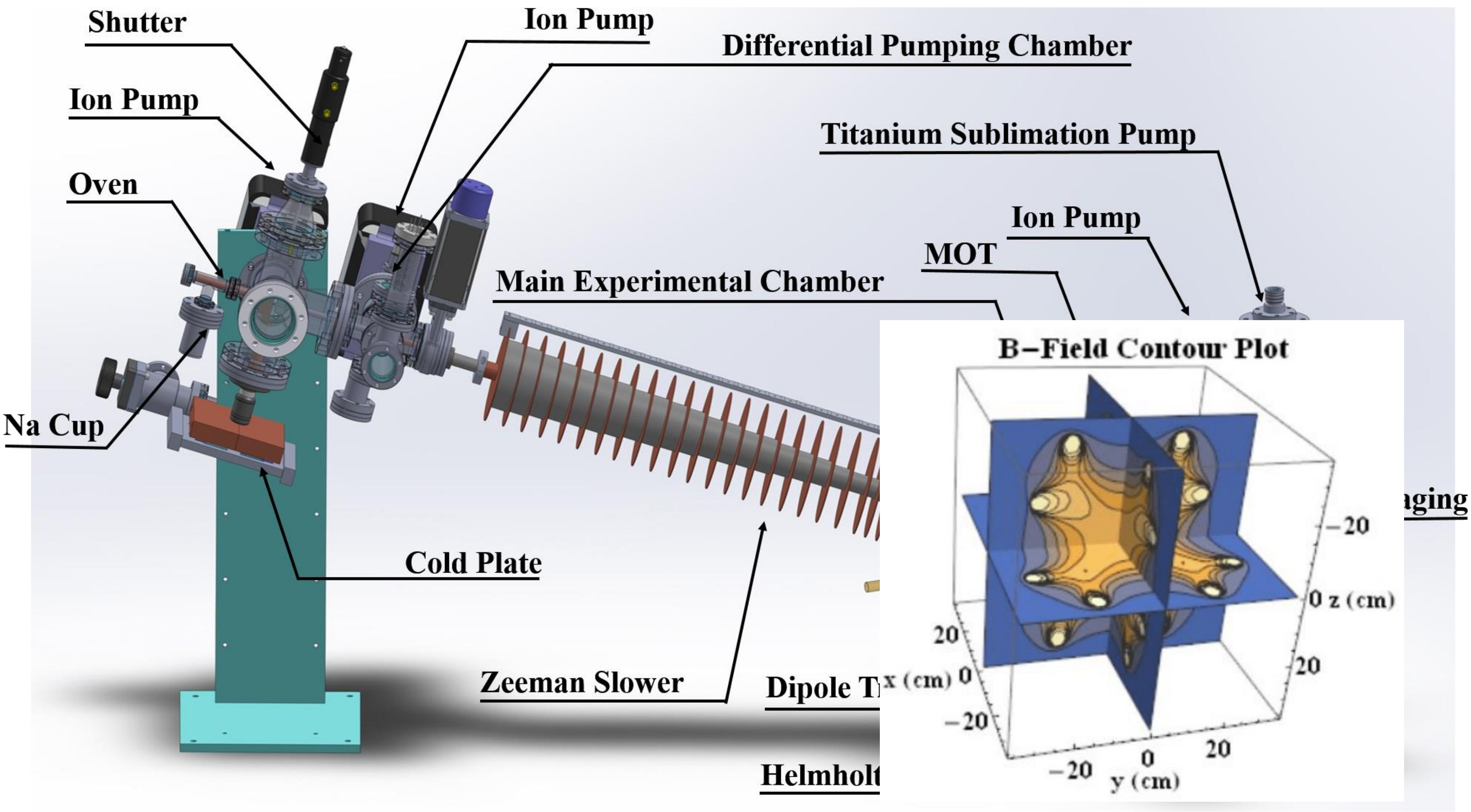
- Hot atomic gas is created in an oven, slowed in the Zeeman slower tube, and then trapped and cooled in the main chamber.

Spinor BEC Setup



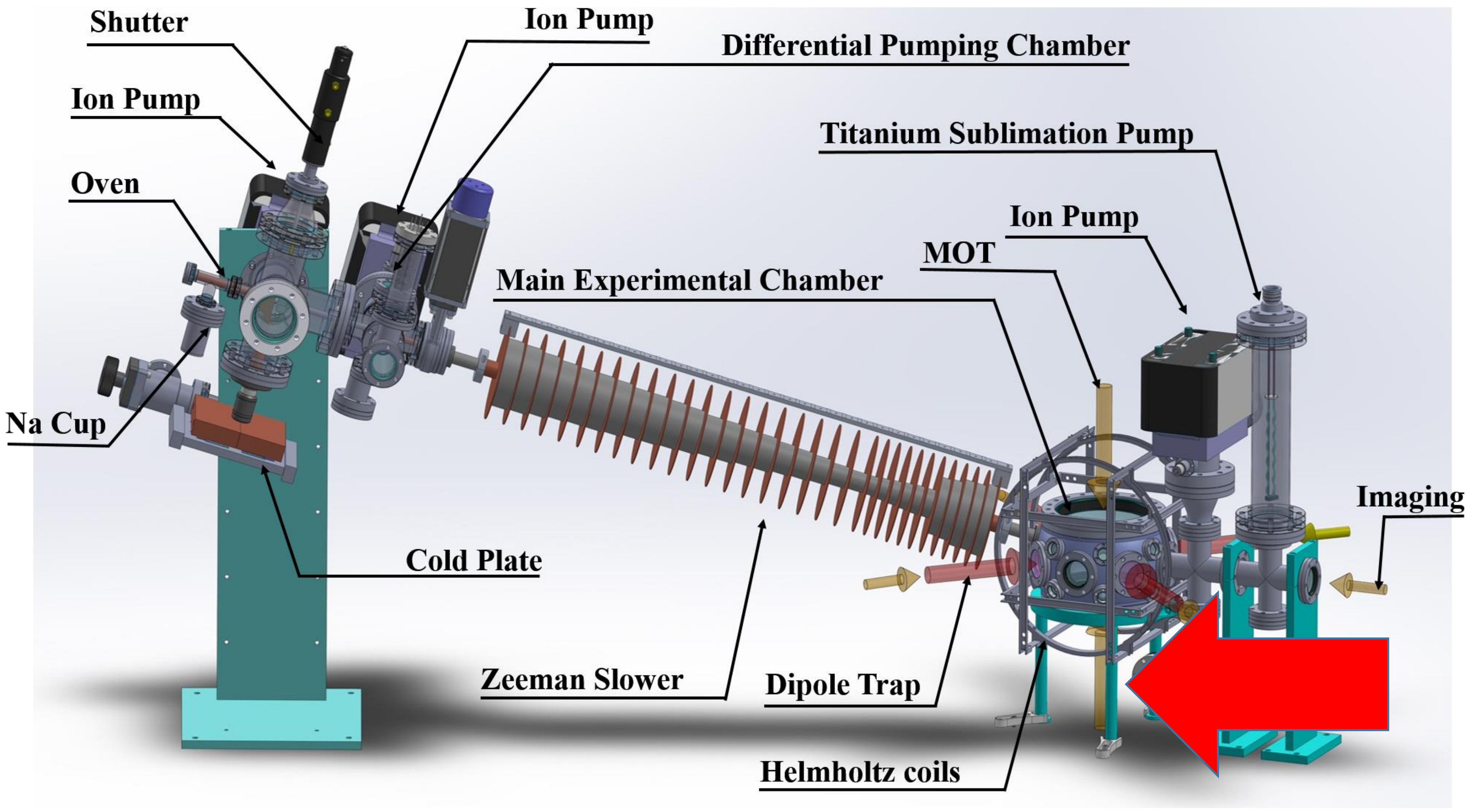
- Hot atomic gas is created in an oven, slowed in the Zeeman slower tube, and then trapped and cooled in the main chamber.

Spinor BEC Setup



- Hot atomic gas is created in an oven, slowed in the Zeeman slower tube, and then trapped and cooled in the main chamber.

Spinor BEC Setup

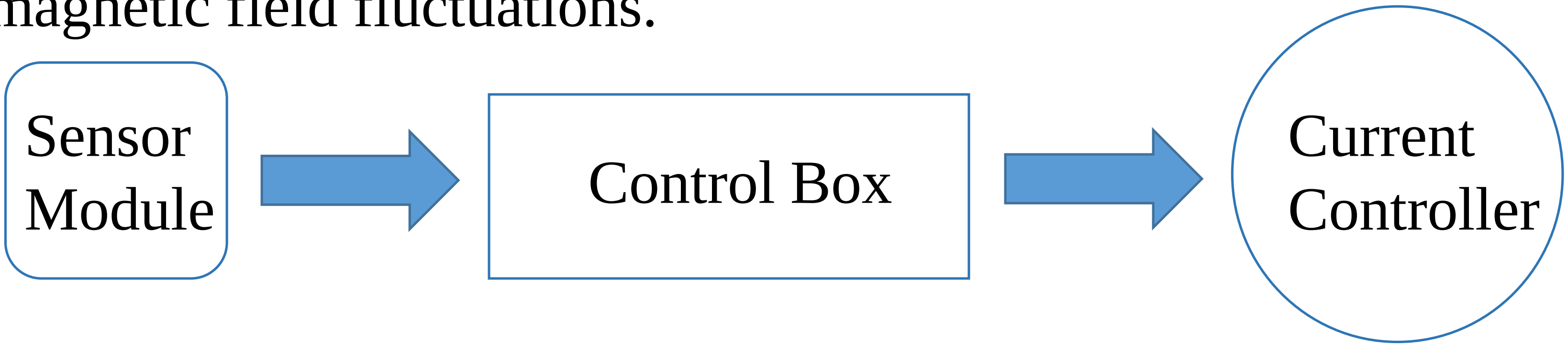


- Hot atomic gas is created in an oven, slowed in the Zeeman slower tube, and then trapped and cooled in the main chamber.

Magnetic Field Stabilization

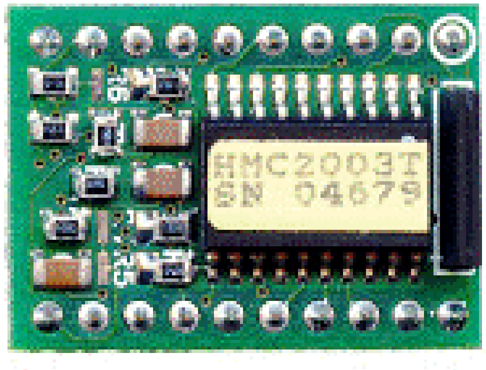
-AMO

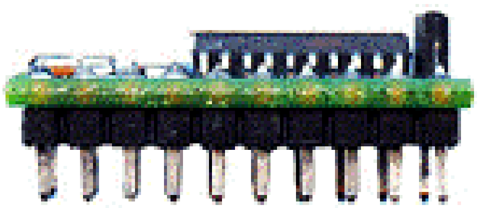
- Compensate for external B-Field fluctuations: opening drawers, moving chairs, moving elevator, etc.
- My project was to finish the implementation of a B-Field sensor.
- The sensor detects μGauss fluctuations in the magnetic field surrounding the vacuum chamber.
- This information is sent to the current controller for the Helmholtz coils.
- The current controller adjusts current through the coils to minimize magnetic field fluctuations.



Honeywell HMC2003

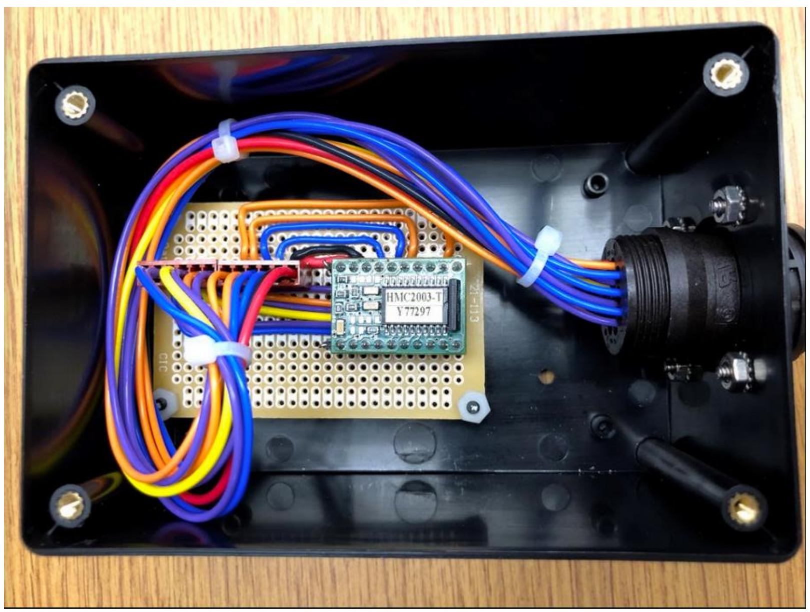
- Sensitivity of 40 μGauss
- Output of 1 Volt/Gauss
- Output of 0.5 – 4.5 Volts
- Field range of ±2 Gauss
- Offset capability of ±4 Gauss
- 3 axis sensing and feedback
- Powered by 15VDC
- Magnetization set/reset capable

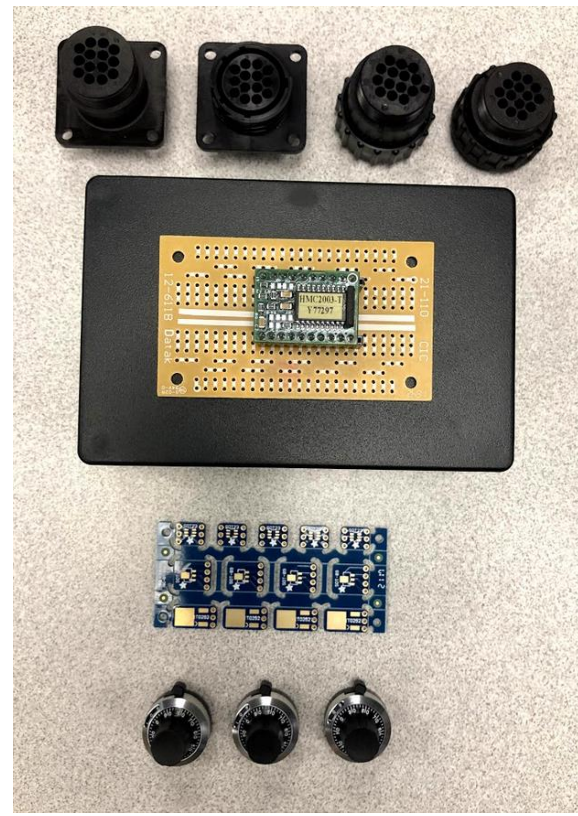




Sensor Module

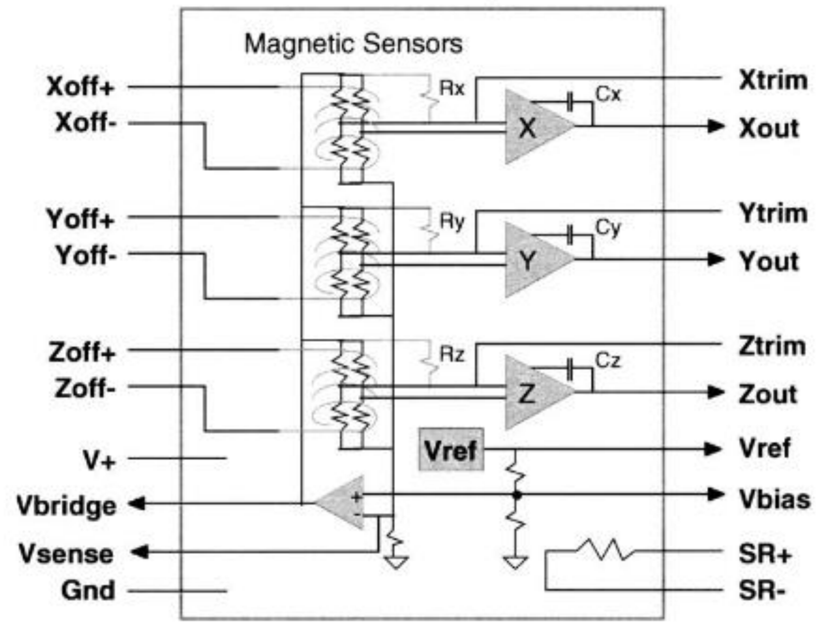
- Designed to be semi-portable
- Modular and accessible design
- Wiring solution of cable connector
- Plastic box to minimize eddy currents





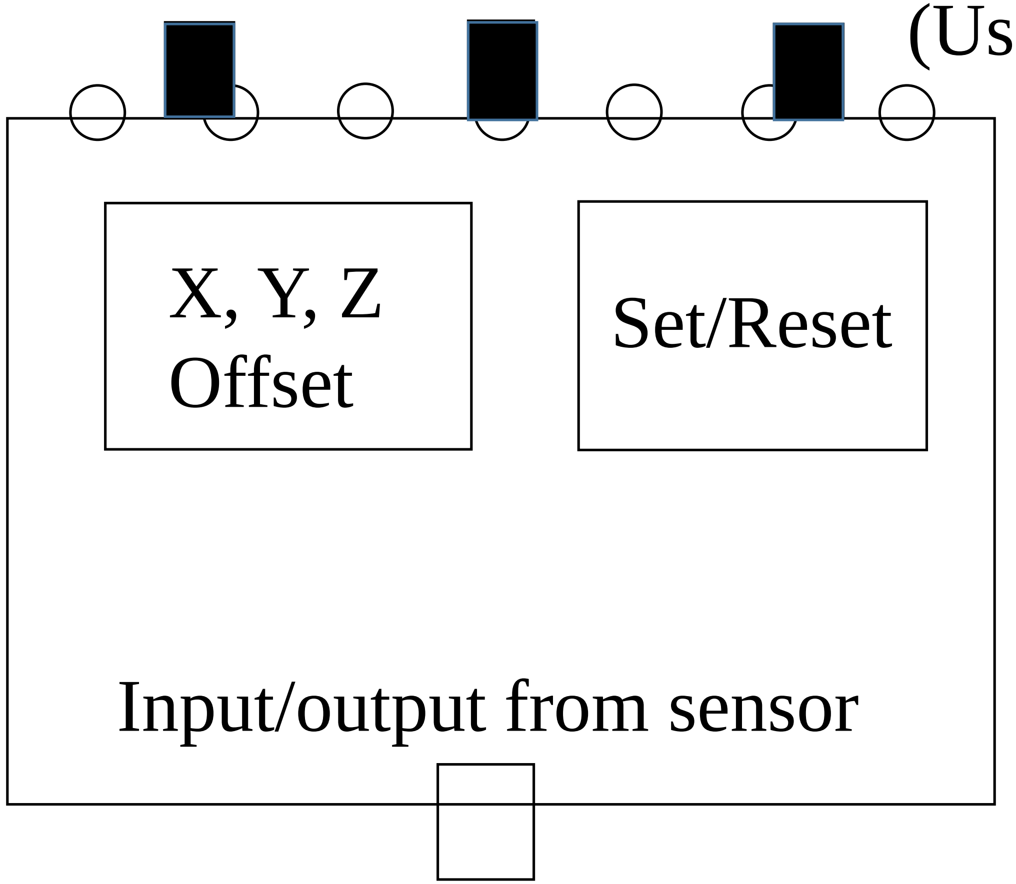
Sensor Details

- Offset straps allow us to shift zero point of sensor
- Set/Reset straps demagnetize the sensor
- Power input of 15 V
- Outputs X, Y, Z voltage



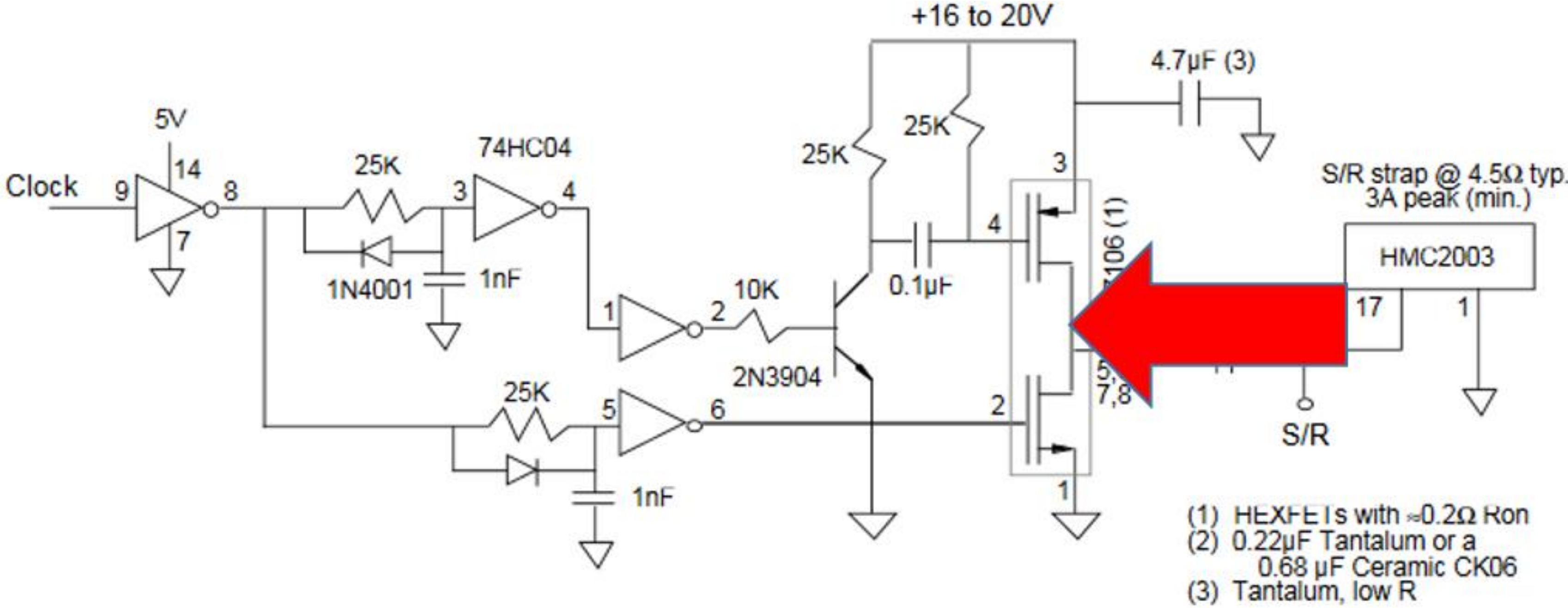
Control Box

- Set/Reset triggered by a 5 Volt pulse when needed
- X, Y, Z offset controlled by user



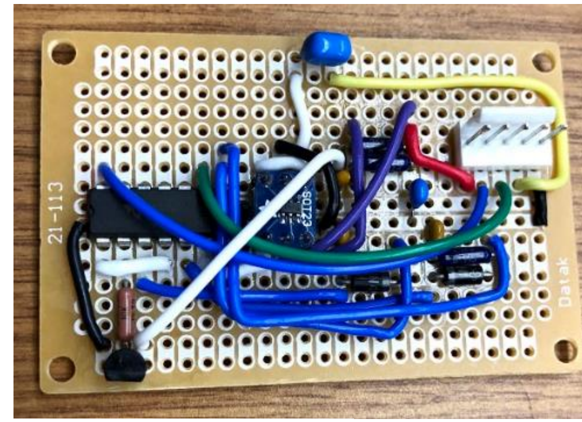
Magnetization Reset Circuit

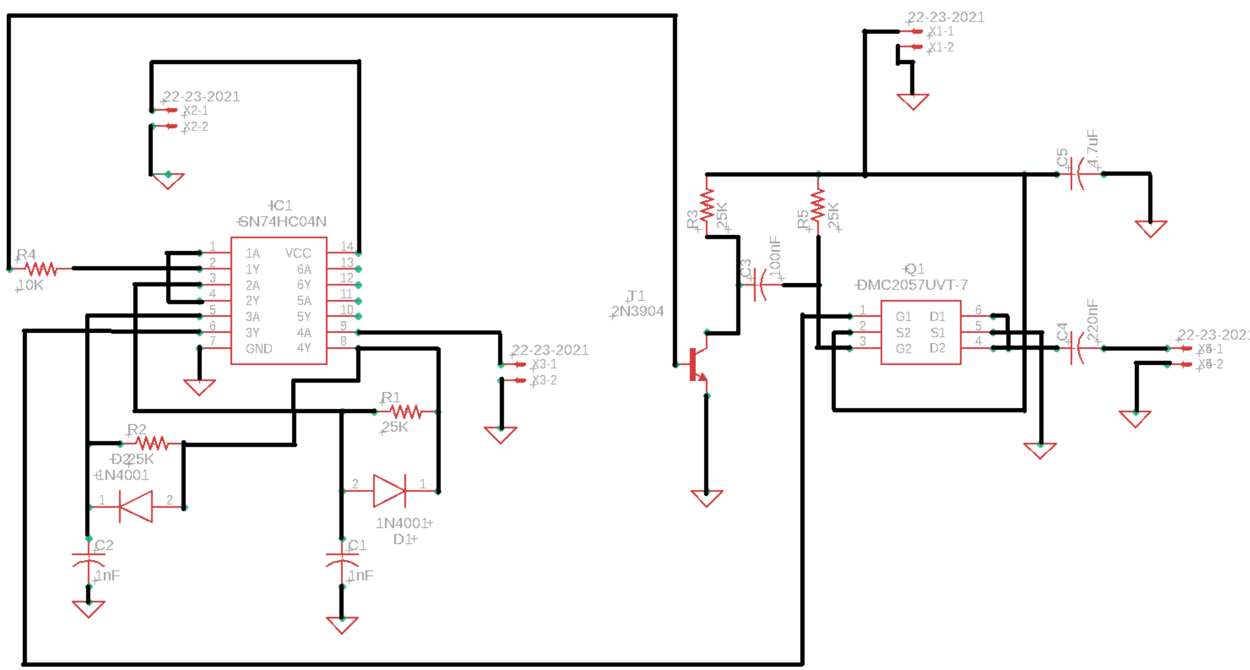
- Recommended by Honeywell
- Takes 5 Volt digital input
- Outputs a short, high current pulse (3 Amps) to reset sensor
- Transistor needed to generate high current
- Needed modification



Reset Circuit 2.0

- Replaced HEXFET with a MOSFET
- Tested on breadboard then built
- Connector allows for easy attach/detachment

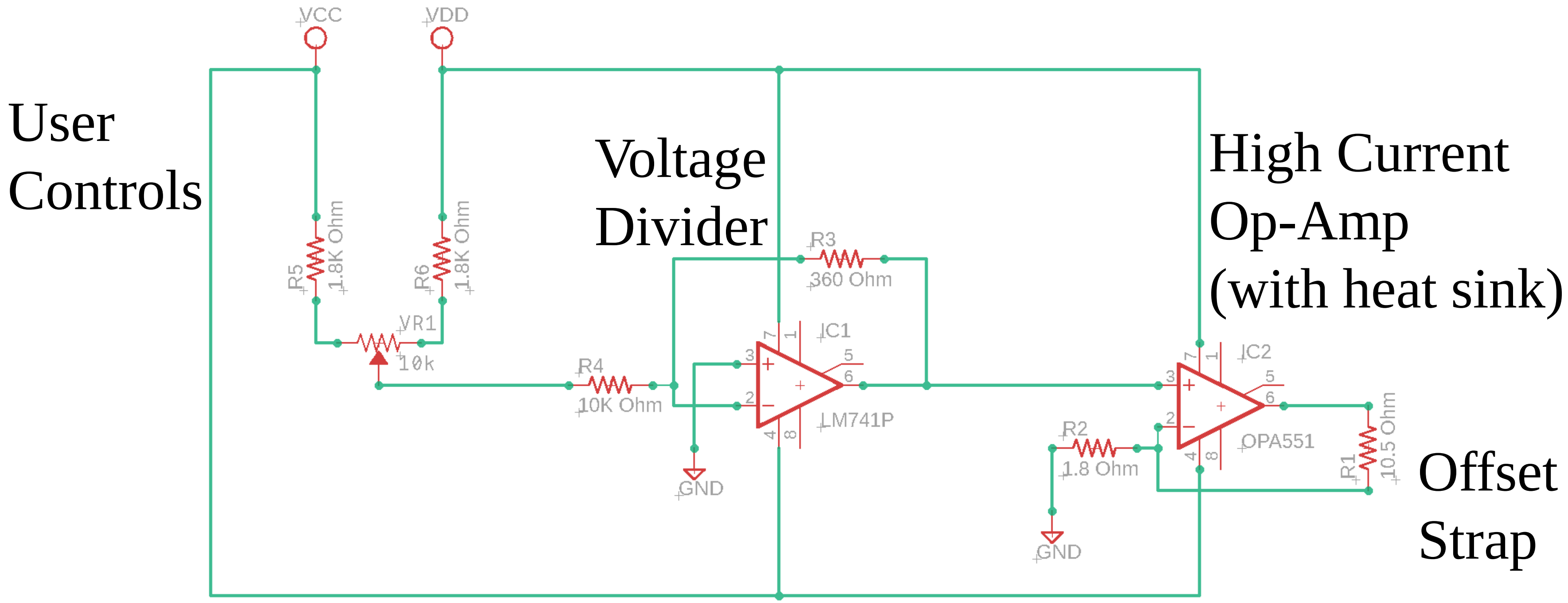




Field Offset Circuit

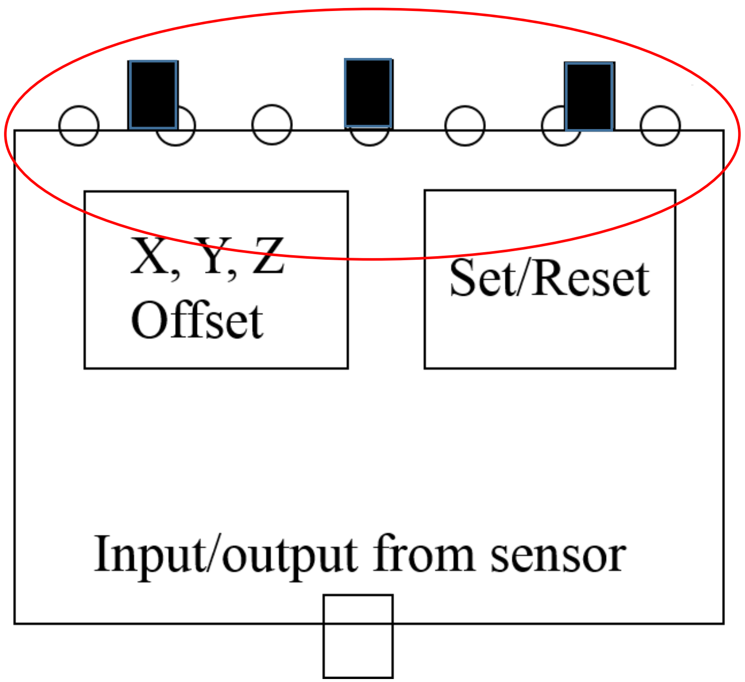
OU-AMO

- Studied designs from former Capstone student
- Chose to design my own
- Constant current source that is adjustable to ±200 mA
- Low current op-amp divides voltage
- High current op-amp controls offsetting voltage



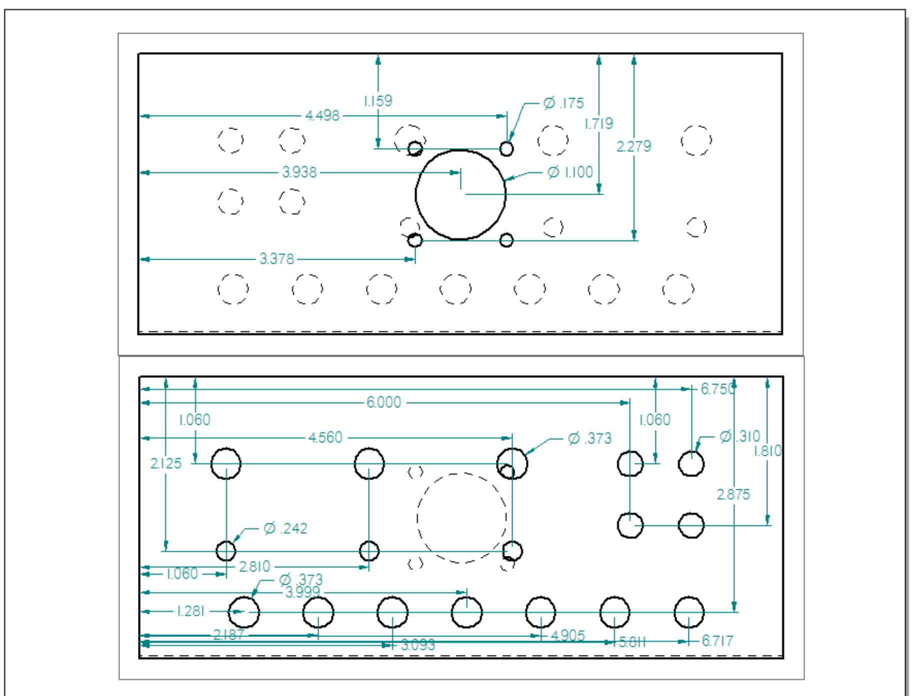
Front Panel Requirements

- Potentiometers for field offset in X, Y, Z
- Switches for optional LabVIEW offset control
- 7 BNC connections
- 4 banana-jack power connections
- Sensor Module 14 pin cable connection



Control Box Design & Build

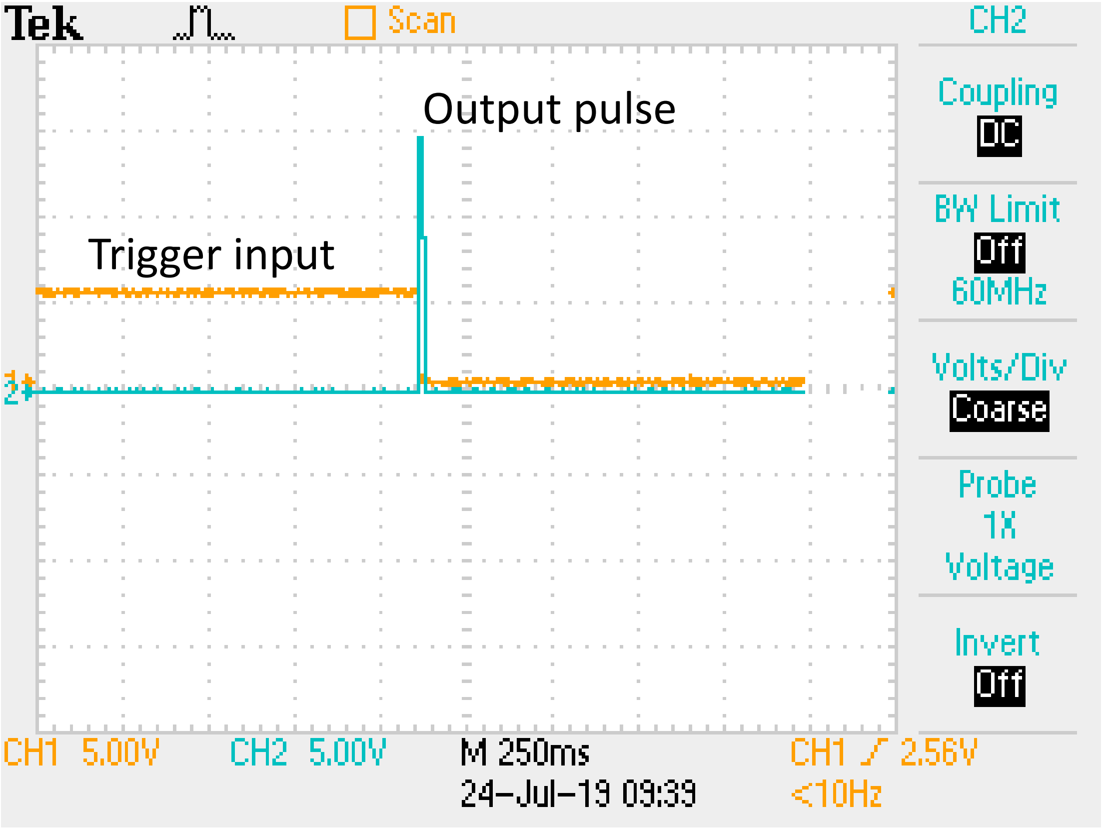
- Designed the front panel in Solid Edge CAD
- Drilled holes with mill in shop



Final Assembly

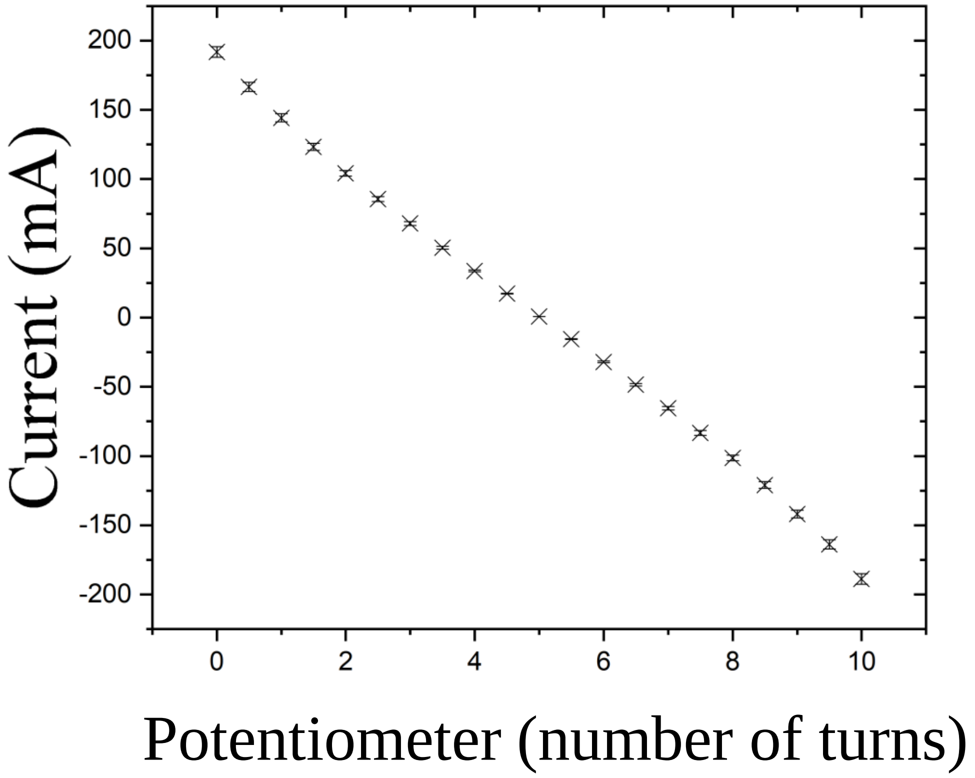
Testing Set/Reset

- 5 V clock input
- Tested with a 5 Ohm resistor in place of S/R strap
- 3 A output pulse
- Adjustable output



Testing Offset

- Shows full ±190 mA output
- Potentiometer used for test
- Measured current deflection on multimeter



Conclusion

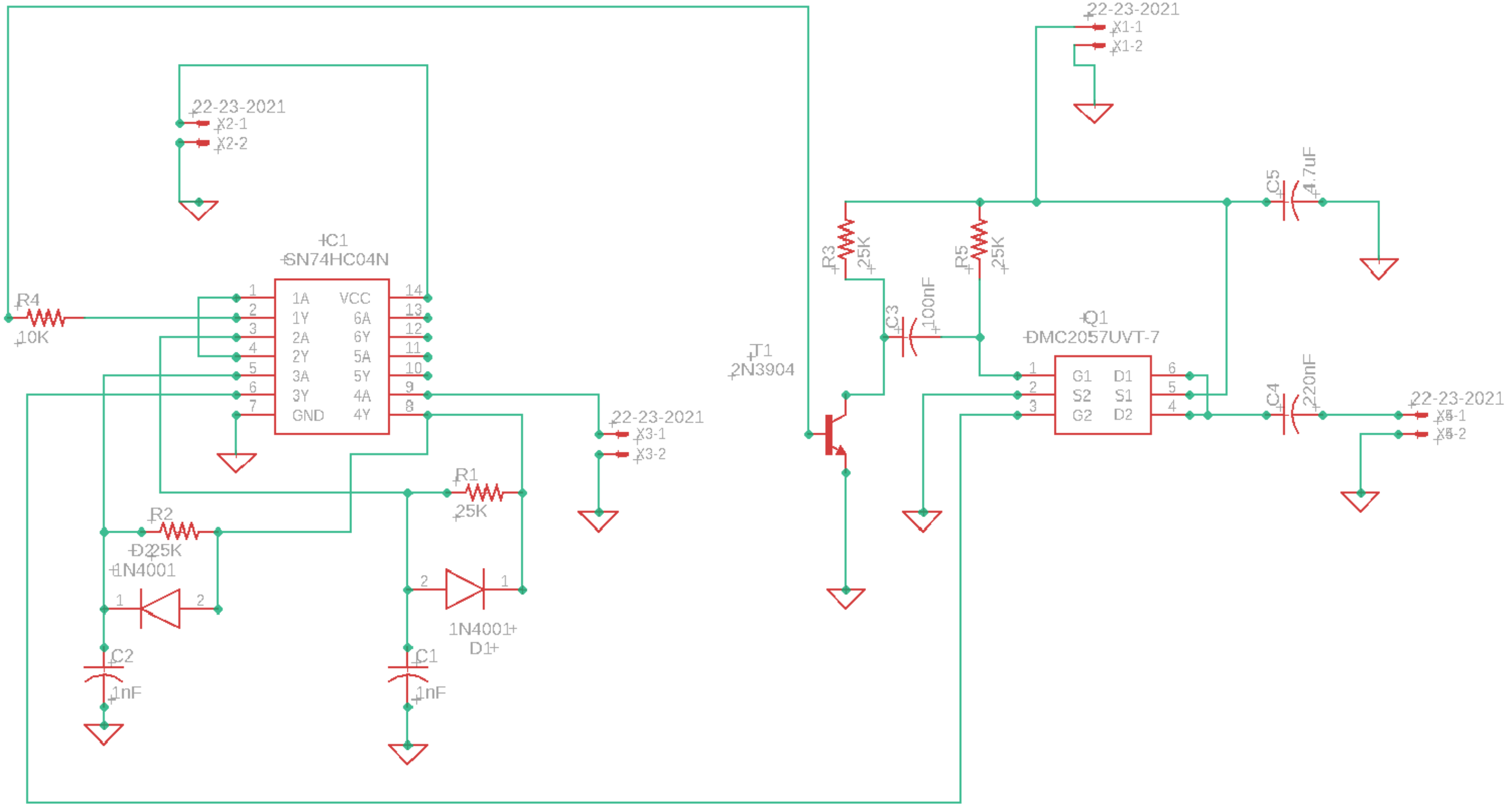
- The BEC experiments rely on a precise magnetic field.
- To reduce B-Field noise, I’ve designed and implemented a sensor for use in BEC experiments.
- Built and tested the control box and its components
- Gained knowledge and experience in circuit design, testing, troubleshooting, repair as well as drafting and machining

HMC2003

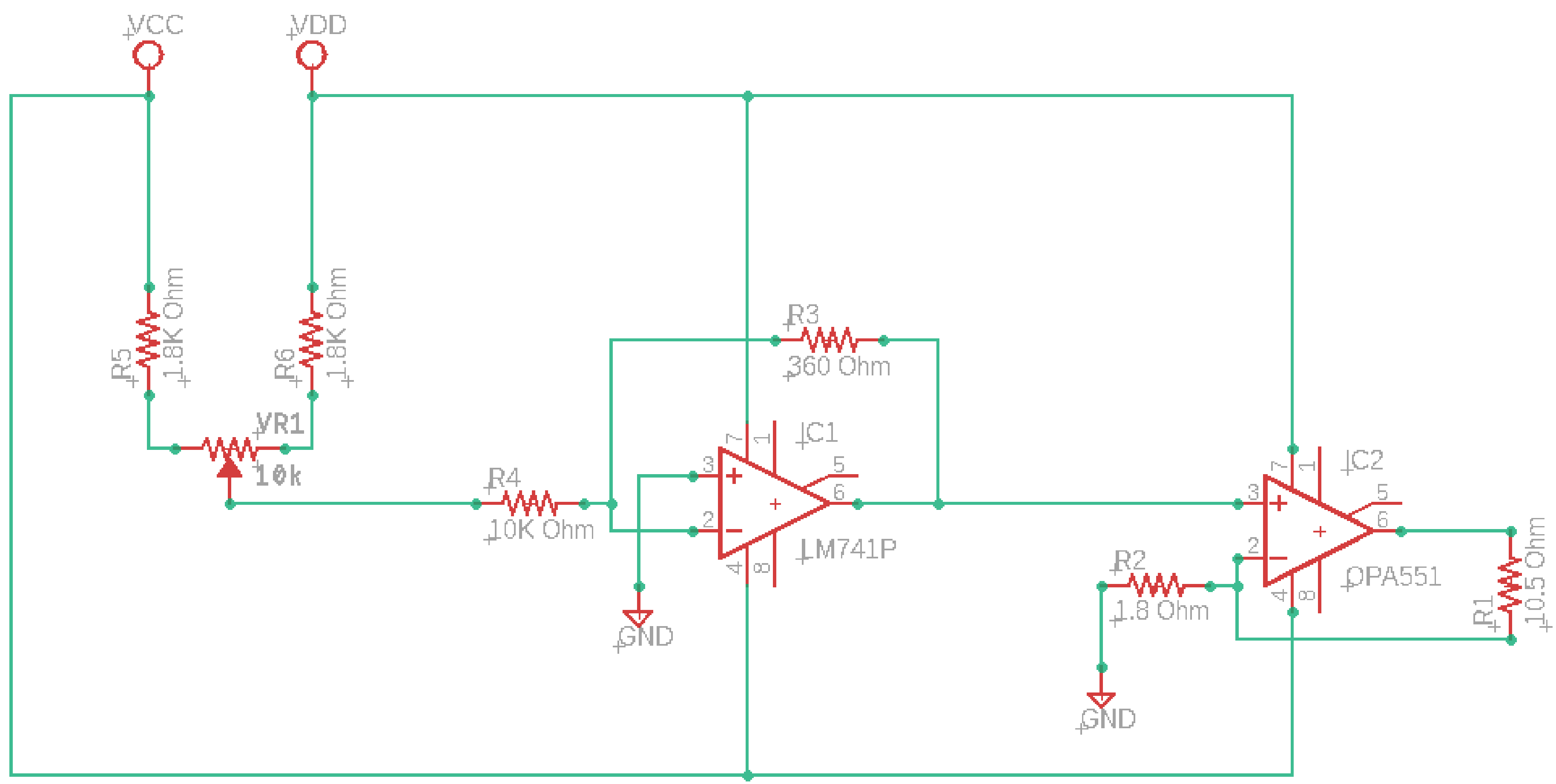
SPECIFICATIONS

Characteristics	Conditions	Min	Typ	Max	Units
Magnetic Field					
Sensitivity		0.98	1	1.02	V/gauss
Null Field Output		2.3	2.5	2.7	V
Resolution			40		μgauss
Field Range	Maximum Magnetic Flux Density	-2		2	gauss
Output Voltage	Each Magnetometer Axis Output	0.5		4.5	
Bandwidth			1		kHz
Errors					
Linearity Error	±1 gauss Applied Field Sweep ±2 gauss Applied Field Sweep		0.5 1	2 2	%FS
Hysteresis Error	3 Sweeps across ±2 gauss		0.05	0.1	%FS
Repeatability Error	3 Sweeps across ±2 gauss		0.05	0.1	%FS
Power Supply Effect	PS Varied from 6 to 15V With ±1 gauss Applied Field Sweep			0.1	%FS
Offset Strap					
Resistance				10.5	ohms
Sensitivity		46.5	47.5	48.5	mA/gauss
Current				200	mA
Set/Reset Strap					
Resistance			4.5	6	ohms
Current	2 us pulse, 1% duty cycle	3.0	3.2	5	amps
Tempcos					
Field Sensitivity			-600		ppm/°C
Null Field	Set/Reset Not Used Set/Reset Used		±400 ±100		ppm/°C
Environments					
Temperature	Operating Storage	-40 -55	- -	+85 +125	°C °C
Shock			100		g
Vibration			2.2		g rms
Electrical					
Supply Voltage(3)		6		15	VDC
Supply Current				20	mA

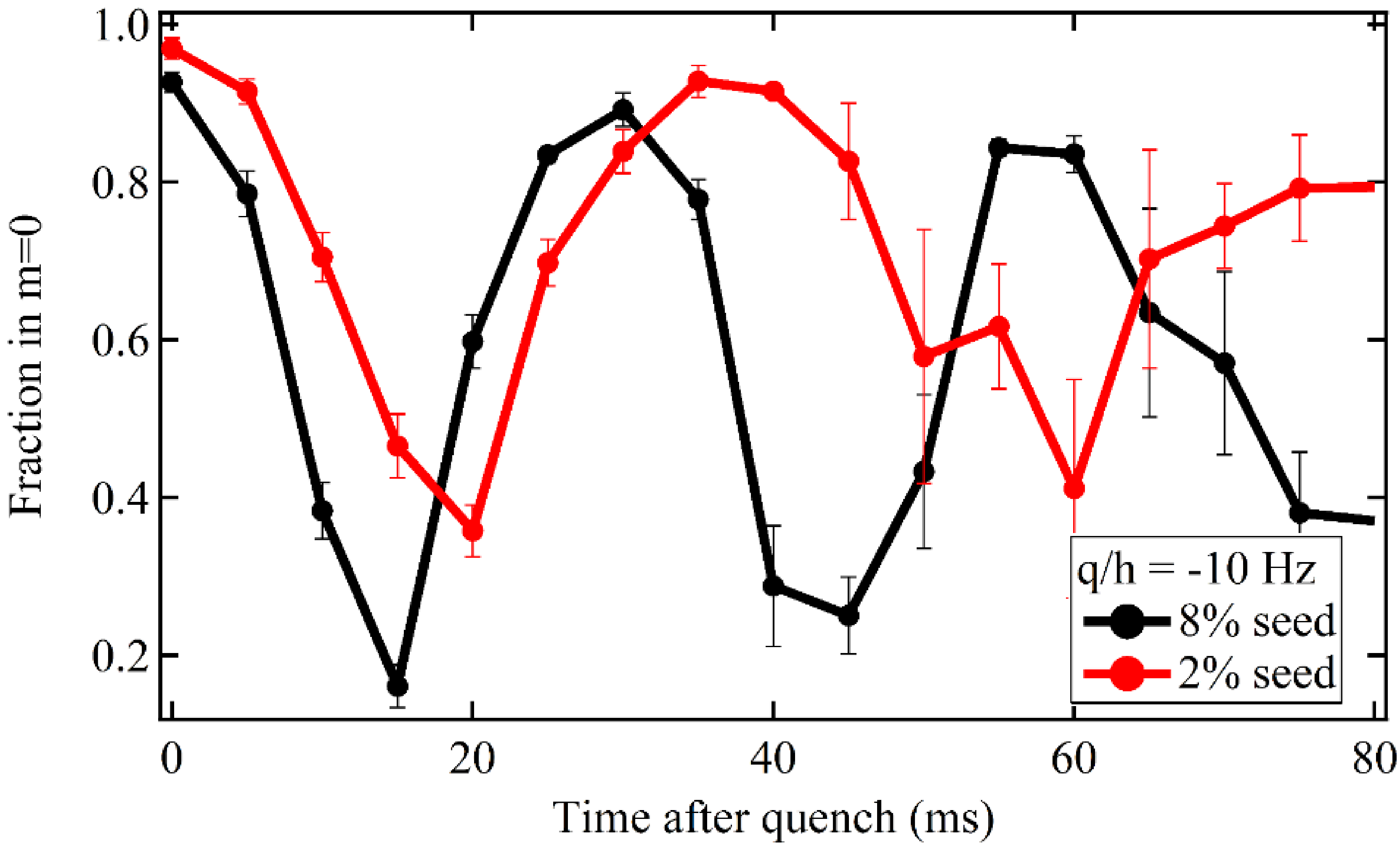
(1) Unless otherwise stated, test conditions are as follows: Power Supply = 12VDC, Ambient Temp = 25°C, Set/Reset switching is active



22-23-2021
X2-1
X2-2
IC1
SN74HC04N
1A
1Y
2A
2Y
3A
3Y
GND
VCC
6A
6Y
5A
5Y
4A
4Y
R4
10K
R1
25K
R2
25K
D2
1N4001
D1
1N4001
C2
1nF
C1
1nF
X3-1
X3-2
T1
2N3904
R3
25K
R5
25K
C3
100nF
Q1
DMC2057UVT-7
G1
S2
G2
D1
S1
D2
C5
4.7uF
C4
220nF
X1-1
X1-2


VCC
VDD
R5
1.8K Ohm
R6
1.8K Ohm
VR1
10k
R4
10K Ohm
R3
360 Ohm
IC1
LM741P
GND
R2
1.8 Ohm
IC2
OPA551
R1
10.5 Ohm
GND

OU-AMO



Fraction in m=0
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
Time after quench (ms)
q/h = -10 Hz
8% seed
2% seed