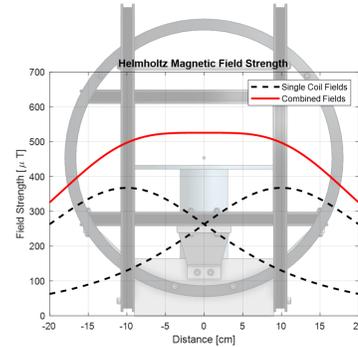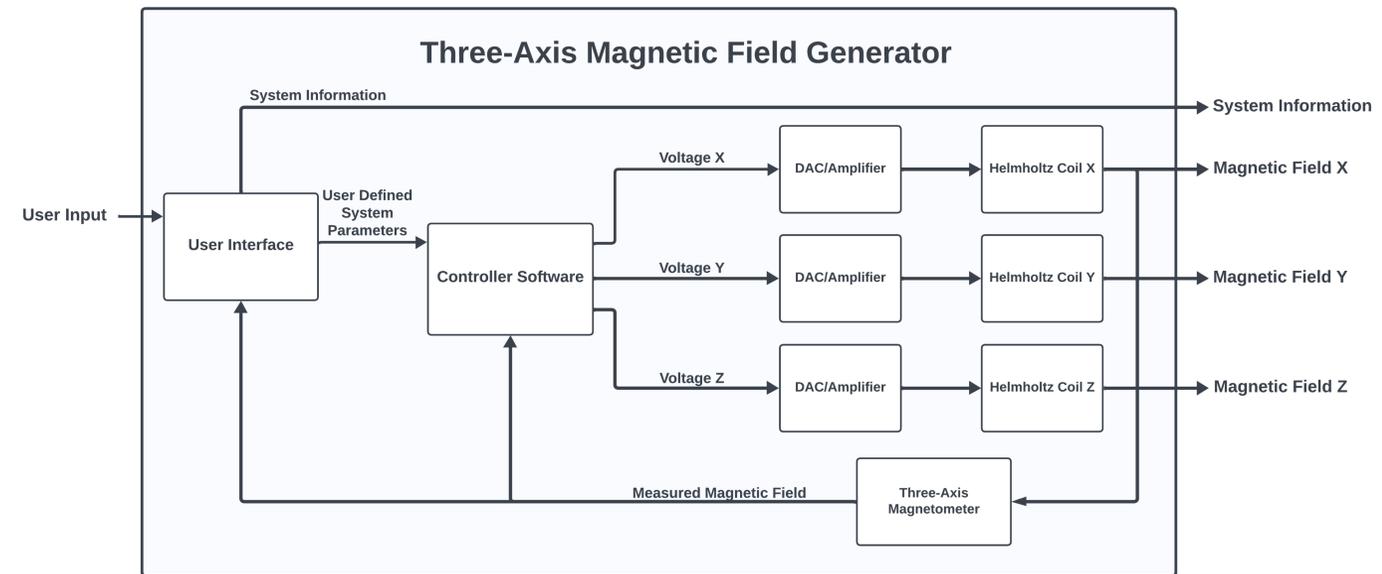# Three-Axis Magnetic Field Generator

Project

The Three-Axis Magnetic Field Generator allows users to explore electromagnetism by creating stable magnetic fields in three independent directions. The goals of this project are:

- *Educational Demonstration:* The generator provides users with instant visual feedback on how their input affects the magnetic fields, enhancing their intuitive understanding of electromagnetic laws.

- *Instrument Calibration:* The calibration of scientific devices such as magnetometers require precise, controlled magnetic fields. This generator creates these fields to facilitate this calibration.

- *Device Testing/Verification*: Devices such as pacemakers, cochlear implants, and other Actively Implanted Medical Devices (AIMDs) require testing to characterize their resiliency to magnetic fields. The generator creates magnetic fields strong enough to test these medical devices.
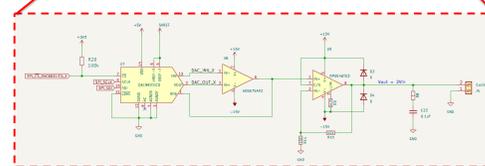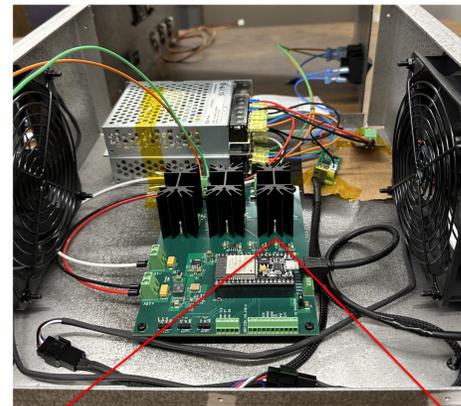

Helmholtz Magnetic Field Strength

Methods

Using a magnetometer paired with control software, the generator drives three pairs of wound copper coils (Helmholtz coils) to create stable magnetic fields following user input.

- *Helmholtz Coil Design*: Using equations that relate currents to magnetic fields, an excel sheet was used to design the coil dimensions and windings.

- *Physical Construction*: Using the CAD software Onshape, the system was modelled for fabrication.

- *Power Amplifier Circuitry:* The ESP32 microprocessor provides signals to the power amplifier circuits, which supply the currents required to produce +/- 500 µT magnetic fields.

- *Controller Software:* The control system (see *System*) computes desired magnetic field outputs based on magnetometer data.

- *User Interface:* A 2-inch LCD provides the user with visual feedback while three potentiometers and a rotary encoder allow the user to adjust the magnetic fields.

System

Three-Axis Magnetic Field Generator

Conclusions

- *Magnetic Field Strength:* The generator successfully produces a magnetic field with amplitude 500 µT.

- *Magnetic Field Stability*: The generator provides a stable and controlled magnetic field via software control.

- *Magnetic Field Volume:* The generated magnetic field is near constant in a volume of 4x4x4 inches.

Helmholtz Coil Geometry

Value	Symbol	Value	Units
Coil radius	a	20	cm
Coil turns	N	63	unitless
Total coil length	L	79.17	m

Wire Characteristics

Value	Symbol	Value	Units
Wire gauge	AWG	20	unitless
Diameter	d	0.8118	mm
Wire resistance	R	2.79	Ω

Magnetic Field and Resolution

Value	Symbol	Value	Units
Max Voltage	V_{max}	10	V
DAC Resolution	b	16	bit
Voltage Resolution	ΔV	305.18	µV/b
Maximum Current	I_{max}	1.80	A
Current Resolution	ΔI	54.79	µA/b
Maximum B Field	B_{max}	508.51	µT
B Field Resolution	ΔB	15.52	nT/b

Impedance of Both Coils

Value	Symbol	Value	Units
Series inductance	L	3.97	mH
Mutual inductance	M	0.39	mH
Total inductance	L_{total}	8.72	mH

3dB Cutoff

Value	Symbol	Value	Units
3dB Cutoff	f_c	101.68	Hz

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User Guide: