

High Current Amplifier for Helmholtz Coil with Capacitive Compensation

EE Senior Design

Briner, B., Uhl, A., Degollado, E., Ibarra, D., Molina, A., Duran, E.

Executive Summary

This project focuses on the design and simulation of a **high-current, wide-bandwidth amplifier** capable of driving a **Helmholtz coil** for magnetic-field generation and characterization applications.

Texas Instruments sponsored the effort with interest in observing how their power electronics components behave under high-frequency, high-current, and high-thermal-stress environments.

The primary objective was to produce a system capable of sourcing and sinking significant current while **maintaining waveform integrity** and **controllability** across a wide operational frequency range.

Background

- The client of our sponsor requires intense testing of a magnetic angle device that will be used in a product. Errors in this device can lead to fatalities.
- The development of precise magnetic fields is important for the validation of magnetic sensing devices within safety applications. As these devices are installed into systems with electromagnetic interference, there is a need for controlled testing systems to reproduce a range of magnetic field conditions with accuracy and predictability.
- This motivates the design for a high bandwidth, high current Helmholtz amplifier to reliably generate a uniform magnetic field and to cancel out stray magnetic interference.

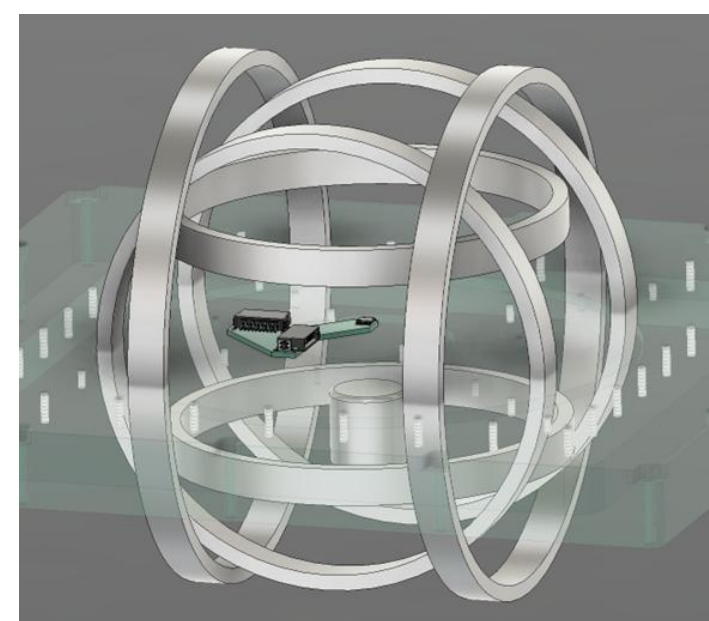


Figure 1. Helmholtz coil model

- A key aspect for this design is the use of capacitive compensation where equal valued capacitors are placed in series and parallel of the coil to cancel out inductive effects.

Experimental Setup

- To verify the proper function of the amplifier, we simulated its frequency response in LTSpice over 6 decades, from 10 Hz to 1 MHz.
- The inner diameter dimensions of the coil were simulated at an inductance of $80.63\mu\text{H}$ with an input sinusoid of 1.39V and supply voltage of 18V.
- Formulas using Accel Instruments documentation were used to calculate value of the series and parallel capacitor value to leave a DC resistance and resonant load.

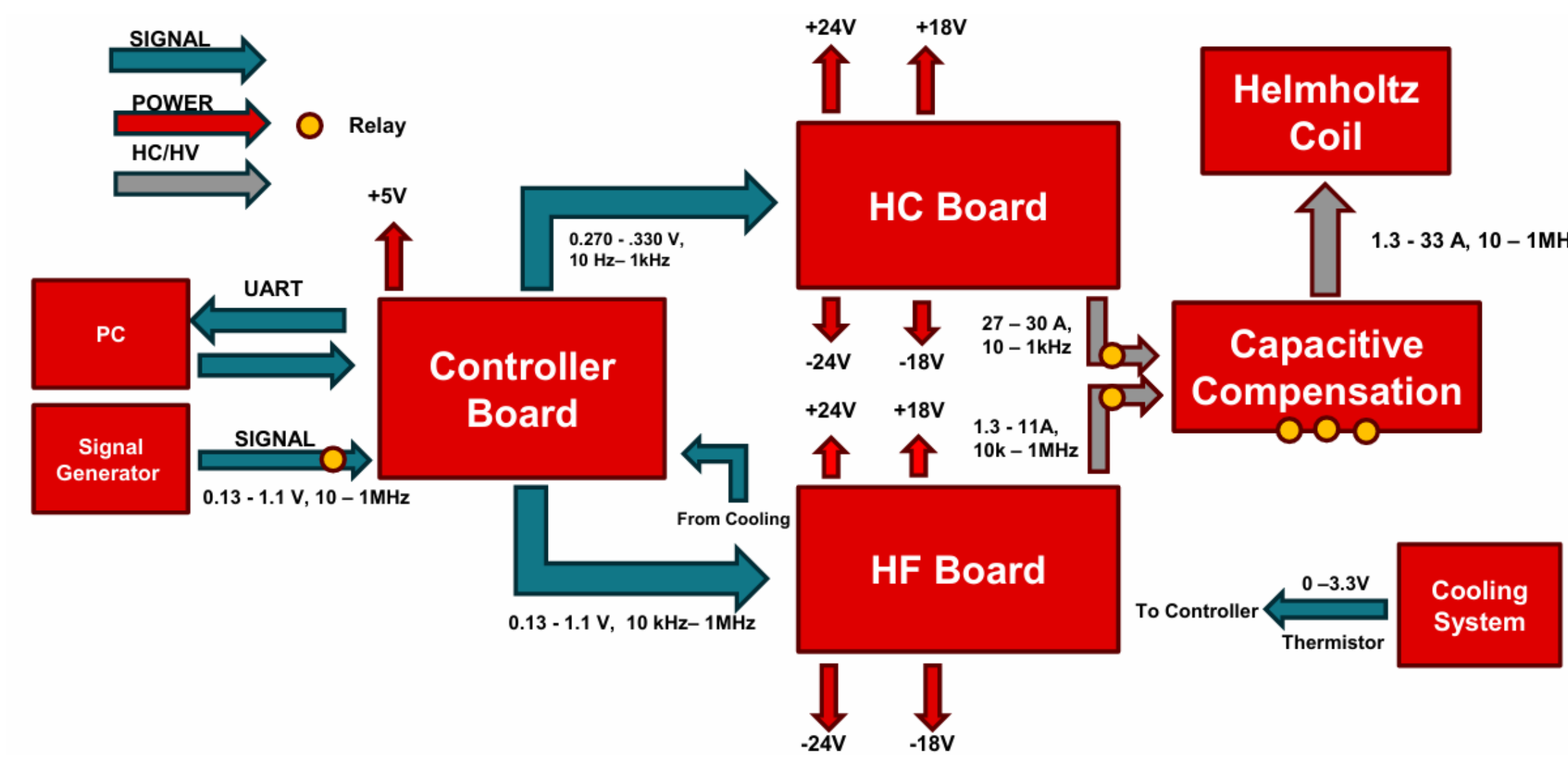


Figure 2. Block diagram

Experimental Test Plan

- Hardware Verification:** Before applying high power, the physical integrity of the PCB and thermal systems must be validated.
 - Continuity Test:** Point-to-point impedance checks across PCB to validate traces and identify possible shorts.
 - System Integration:** Solder components for both boards and install tunnel heatsink to ensure proper heat dissipation.
- Initial Electrical Characterization:** Testing with a controlled dummy load.
 - Sinusoid input via function generator outputting $\pm 1.39\text{V}$ with rail power supplies of $\pm 18\text{V}$ via Chroma power supply.
 - Validate proper current draw using 10Ohm power resistor without inductive back-EMF.
- Inductive Load & Field Simulation:** Transition from resistive to reactive load to mimic Helmholtz electrical characteristics
 - Change load to power inductor to match DC resistance and inductance of actual coil.
 - Monitor output wave-form to ensure the driver maintains stability and current accuracy.
- SOA Validation:** Monitoring temperature using temperature probes to monitor components in real-time. Confirm that the system operates within **Safe Operating Area** under full load to prevent thermal runaway or device breakdown.

Experimental Results

Table 1. Helmholtz Amplifier Data Points and Results

Frequency (Hz)	Board	$V_{\text{out}} (\pm\text{V})$	$I_{\text{out}} (\pm\text{A})$
10	HC-LF	0.17	33.36
100	HC-LF	1.41	27.80
1k	HC-LF	14.2	27.8
10k	LC-HF	57.2	11.3
100k	LC-HF	288.7	5.7
1M	LC-HF	608	1.2

Conclusions

- Design Methodology:** Through precise circuit design based on Class-AB amplifier architecture, control theory, and simulation, a Helmholtz driver has been developed. The system follows the principle of $V \propto f \propto I^{-1}$ allowing it to accurately drive a Helmholtz coil based on a desired applied signal.
- Project Outcomes & Impact:** The project successfully met the sponsor's goals of testing devices under varying frequencies, currents, and electromagnetic fields to simulate diverse operating environments. Our design resulted in a safe, user-friendly device that accelerates the testing process, optimizes labor, and significantly reduces overall testing time for our sponsors.

References

- C. Ledbetter, "TI_UTArlington_EE_SeniorDesign_Fall25," Internal PPT, Texas Instruments, Inc., 2025. (Not publicly available)
- Accel Instruments, 2024, "High Frequency Magnetic Field Generator," <https://www.accelinstruments.com/Applications/WaveformAmp/Magnetic-Field-Generator.html>, accessed Mar. 28, 2026.
- De Melo, R. G., and Santos, D., 2019, "Howland Current Source Applied to Magnetic Field Generation in a Tri-Axial Helmholtz Coil," *IEEE Access*, Vol 7 pp. 125649-125661.

Acknowledgements: We would like to thank Christopher Ledbetter for his guidance and support throughout the duration of this project.