

Abstract: To dynamically compensate phase fluctuations in optical fiber path, we have employed an optical phase-locking loop that uses a piezoelectric fiber stretcher. We have designed a linear high voltage amplifier for driving the stretcher. The amplifier converts a 0 - 5V control signal into a 0 - 150V output capable of driving a 2- μ F capacitive load.

Introduction

Motivation - Quantum state tomography reconstructs the density matrix of a quantum system from measurement statistics obtained in multiple bases. In interferometric fiber systems, the tomographic reconstruction is severely degraded by phase noise and optical path drifts.

Objective - These effects can be mitigated by an optical phase-locking loop, which actively stabilizes the phase by a piezoelectric actuator (fiber stretcher, FS). A low voltage operational amplifier drives a transistor stage that provides the required voltage and current to drive a capacitive load, representing the FS. The final design provides a linear high voltage output for phase modulation and stabilizing in fiber-optic system applications.

Background

Fiber stretchers are employed in many optical systems in order to adjust physical lengths and phase differences. These FS's create physical displacement under an applied voltage. In interferometric fiber applications, the length difference between two branches creates a delay between the two signals such that they either constructively or destructively recombine at the output.

Goal - This approach uses an Arduino Giga to monitor the interference between two branches. After a certain threshold, a 0-5V signal is sent to the high voltage amplifiers input, which is amplified to the required 0-150V range to drive the FS.

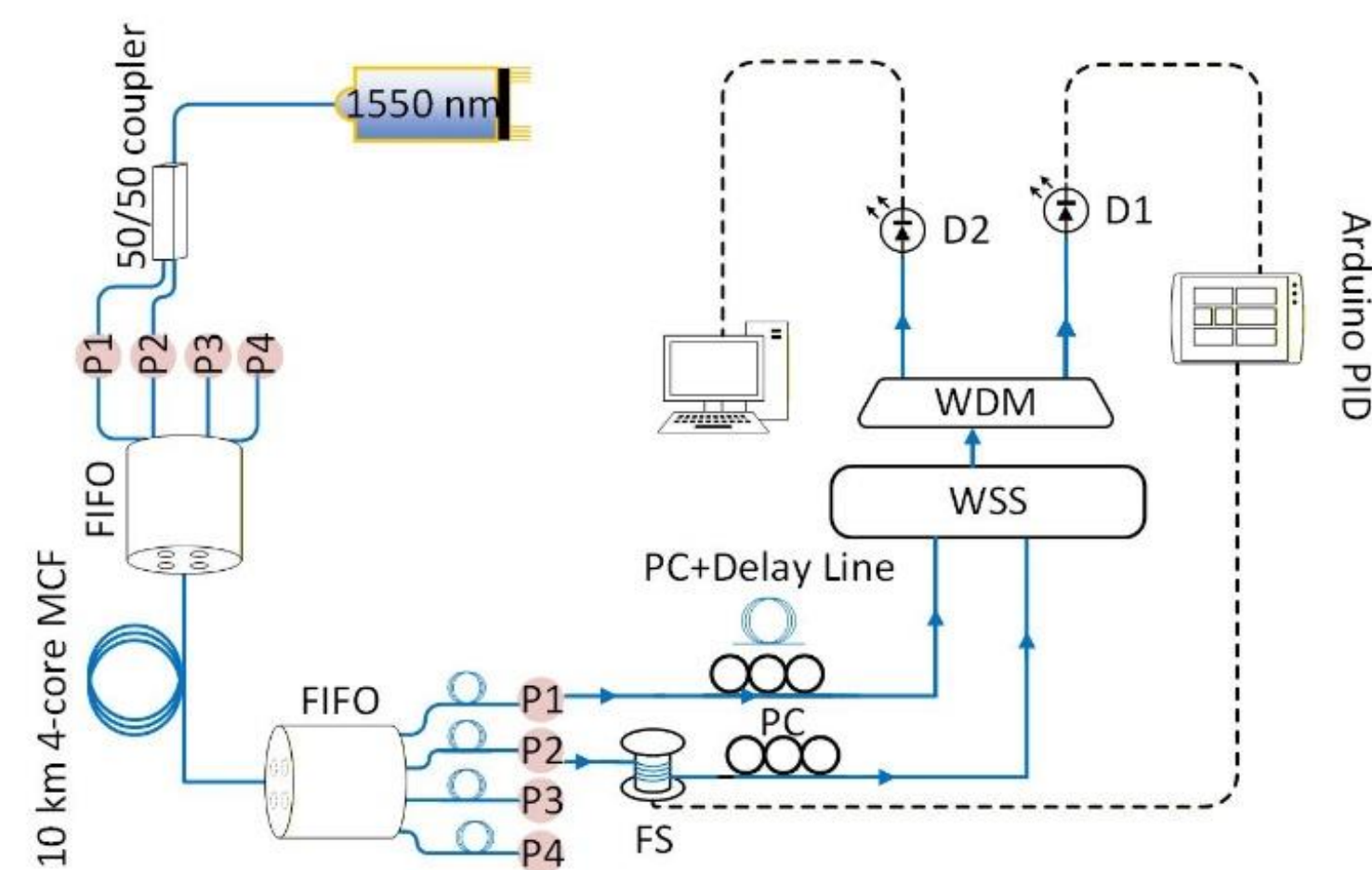


Figure 1. Optical phase-locked loop (OPLL) between 2 cores of a 10-km-long four-core fiber. D1 and D2: optical detectors, FIFO: fan-in / fan-out, PC: polarization controller, FS: fiber stretcher.

Circuit Design

The circuit accepts the 0-5V control signal from an Arduino Giga, which first goes through an inverting op-amp stage then into a second op-amp that compares the difference between input and output voltages through a feedback resistor network. The feedback network sets the closed loop to a gain of 30, such that the 0-5V can be scaled up to the 0-150V. The op-amp output drives the transistor stage, eventually reaching the output transistors Q1 and Q2. These two transistors form a complementary push-pull emitter follower that provide the voltage required to drive the FS. Since the FS behaves as a capacitive load of around 2 μ F, the output transistors must source and sink enough current in order to achieve the desired modulation bandwidth.

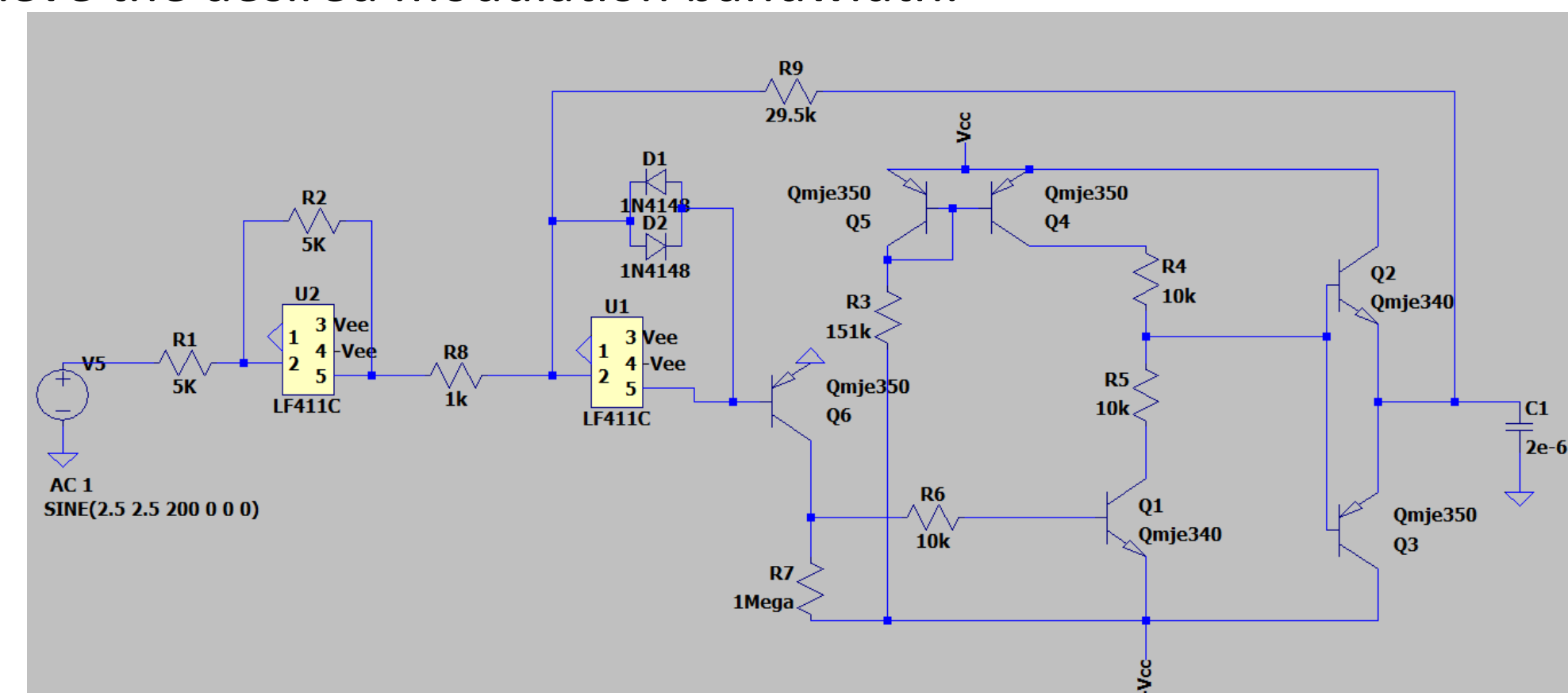


Figure 2. Circuit Diagram

Simulation

As evident from Fig. 3, the circuit simulation proves the circuit can operate linearly in the desired range. A 0-5V sinusoidal input produces a scaled output that ranges from 10-150V, equivalent to the intended gain of around 30. The scaled output maintains the same sinusoidal shape as the input, indicating the feedback loop is successfully regulating the output while keeping the push-pull amplifier stage operating in the linear region. The output exhibits an offset of about 10V which arises from biasing conditions at the output stage and voltage drops across driver transistors.

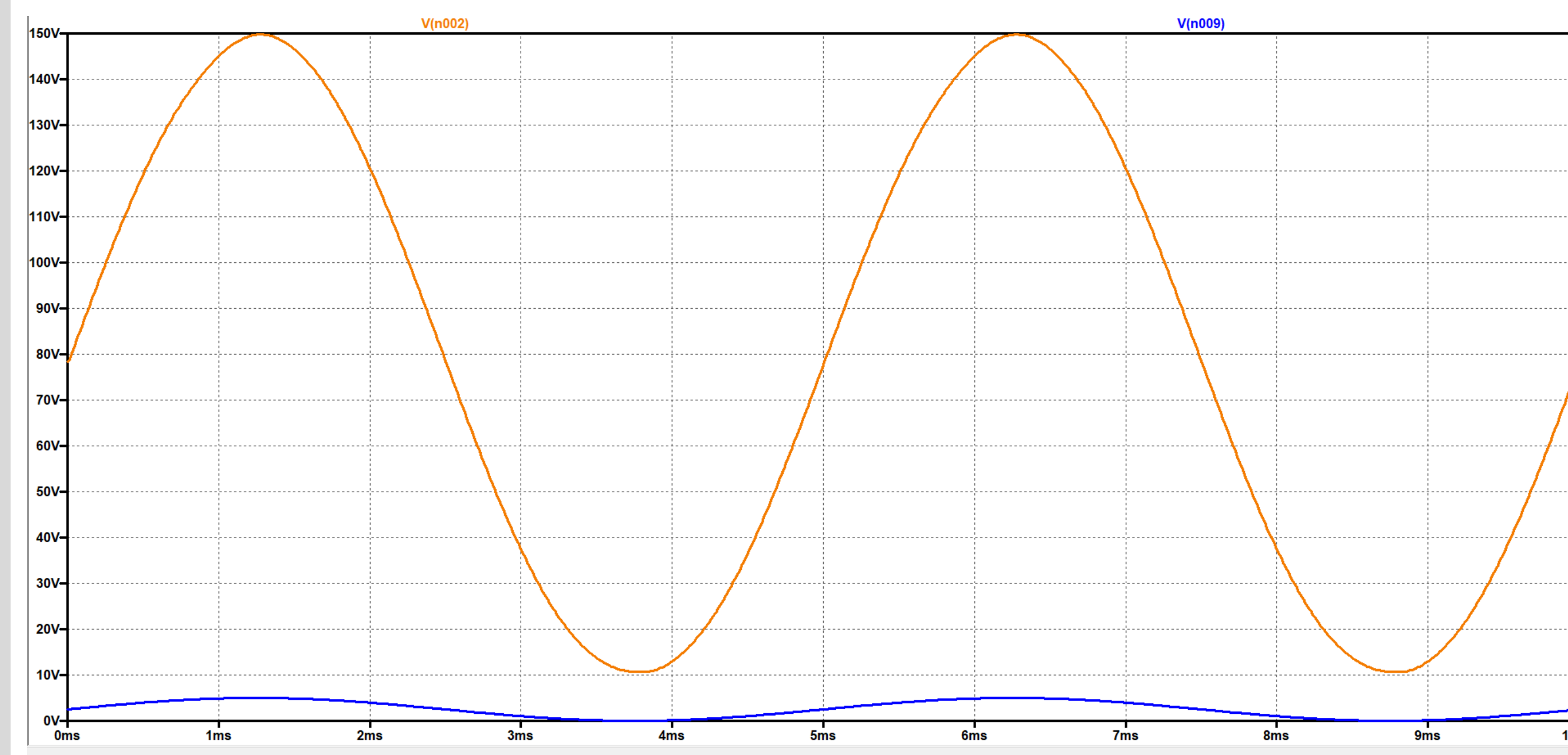


Figure 3. Simulated input (blue trace) and output (orange trace) at 200Hz

Experimental Results

The circuit was finally tested on breadboard to verify the simulations were accurate and still attainable in real world conditions. After confirming results, the finalized circuit was designed on a one-sided PCB. The design implemented a voltage regulator and voltage inverter to generate the required supply rails for the op-amps, reducing the amount of power supplies needed. The PCB layout was designed using Fusion360 (figure 4) was fabricated and tested. Measured results matched the simulated behavior, seen in Fig. 5.

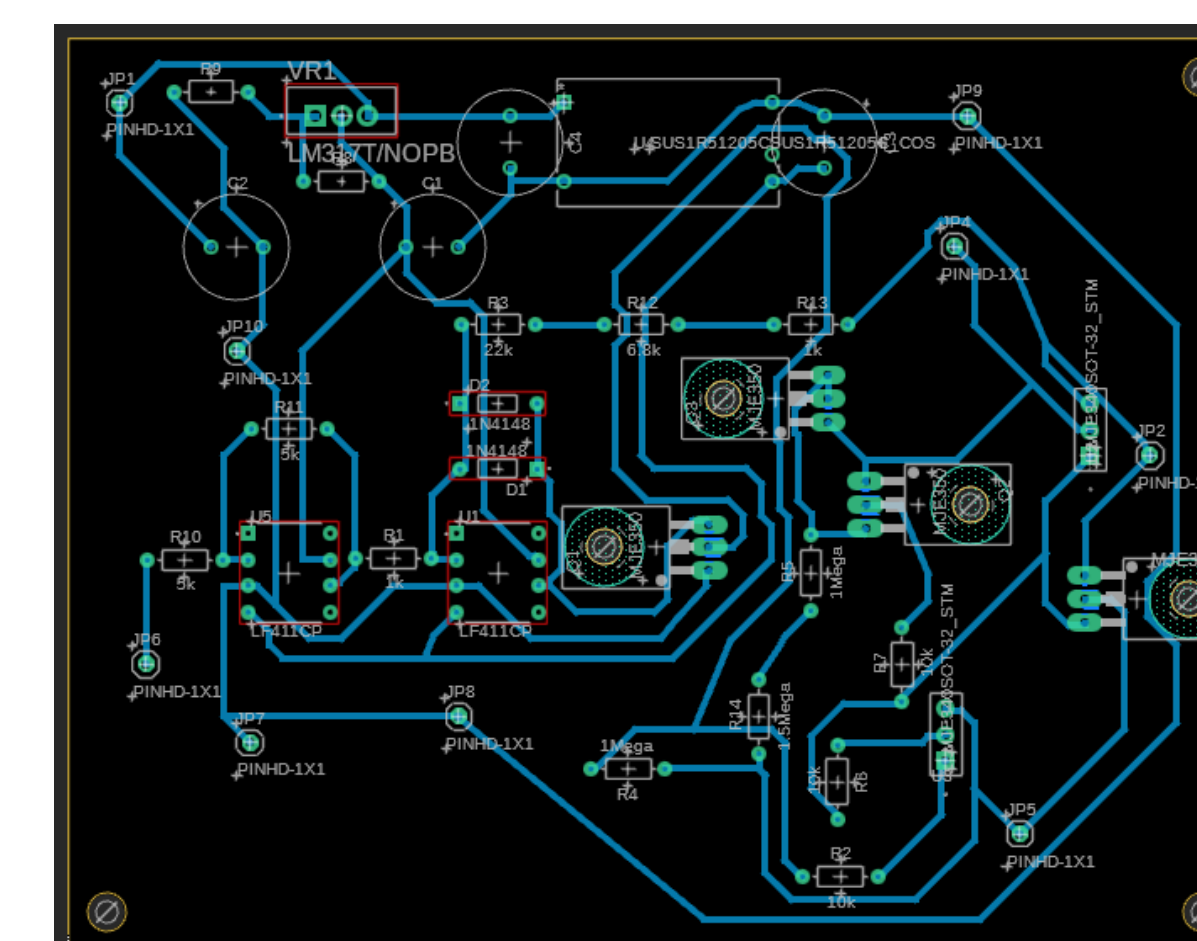


Figure 4. PCB Design

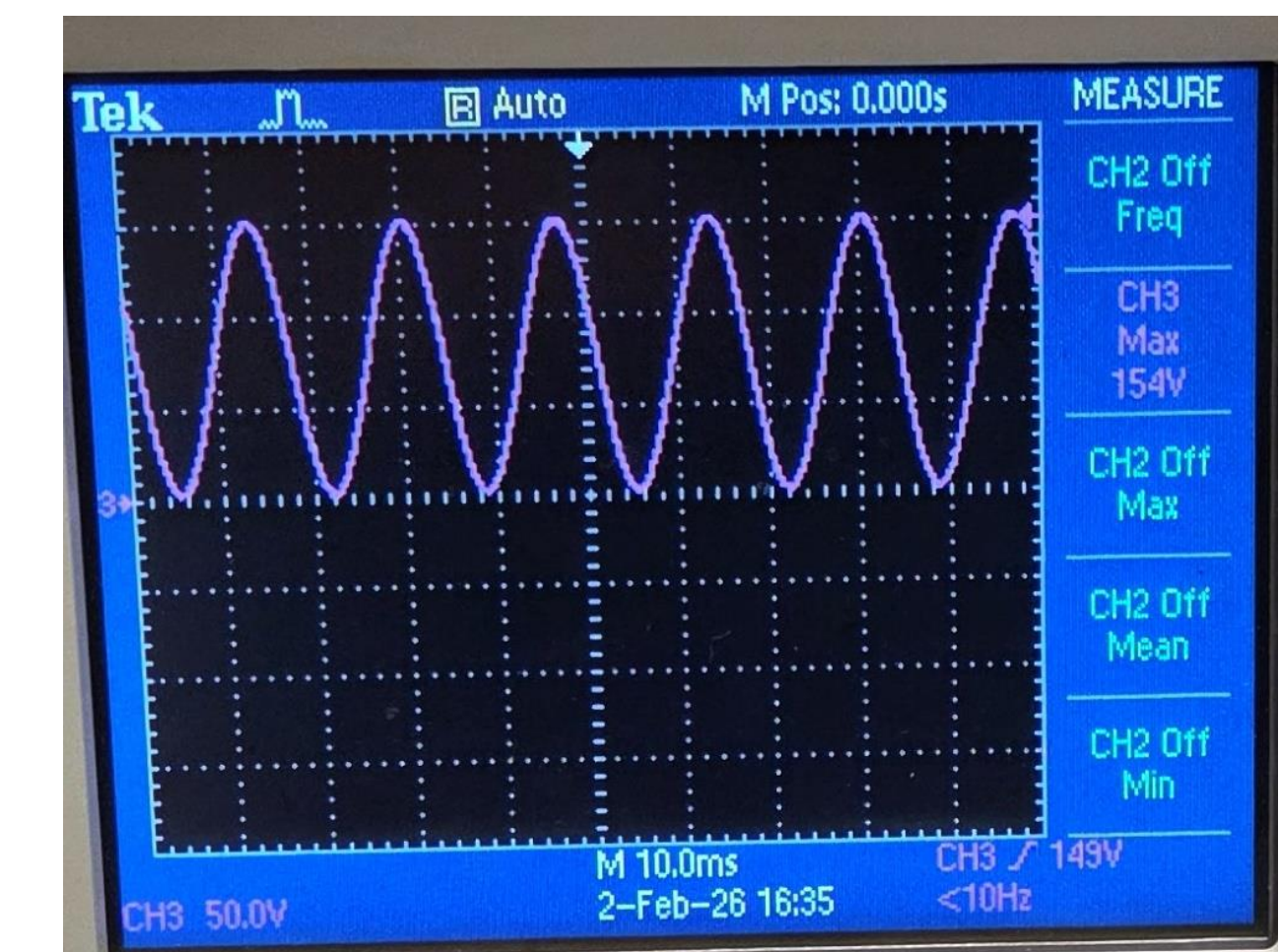


Figure 5. PCB Output at 60Hz

Conclusions

The results matched and met the required design specifications with the only limitation being the low-end offset output, which restricts the displacement range of the FS. Despite this, the available range remains sufficient for the intended application. Future work will focus on integrating the amplifier into the optical system and evaluating the resulting optical output to characterize the bandwidth and stability of the OPLL.

References

- 1) "High-voltage amplifier drives piezo tubes," EDN, [Online]. Available: <https://www.edn.com/high-voltage-amplifier-drives-piezo-tubes/>. Accessed: Mar. 16, 2026.
- 2) A. Azaridoodaran, M. Awwad, C. Guo, and M. Vasilyev, "Toward Long-Haul Distribution of Multidimensional Spatially-Entangled Photons over Multicore Fibers," *IEEE MetroCon conference*, Hurst, TX, November 13, 2025; DOI: 10.1109/Metrocon66796.2025.11405846 .
- 3) A. Azaridoodaran, M. Awwad, C. Guo, and M. Vasilyev, "Progress on the Multidimensional Distribution of Spatially-Entangled Photons over Multicore Fibers," to be presented at the *Workshop on Applied Quantum Computing and Quantum Circuits & Systems (AQ-QCAS) at the 19th IEEE Dallas Circuits and Systems conference*, Southern Methodist University, Dallas, TX, April 10–12, 2026.