

Amplifier Design for Aerospike Measurements

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Abstract—Instrumentation amplifiers are needed to amplify thrust signals produced by load cells for accurate measurements in Aerospike testing. Gains are used to increase the resolution thus providing accurate and measurable thrust data. This paper will discuss the design procedure for building a low noise amplifier box along with the results and comparisons from actual measurements.

I. INTRODUCTION

Utah State University has received funding to support the design and testing of an aerospike nozzle. This testing includes thrust measurement performed by multiple load cells contained on and supporting the test stand. Six 25-pound load cells LCCD-25 from Omega will be used to measure the thrust produced by the aerospike while four 100-pound load cells LCCD-100 will be used to measure the amount of carbon dioxide gas consumed in the test experiment by weight calculations. The resolution on the load cells are 3 mV/V, or with an excitation voltage of 10 VDC it would produce 30 mV over a 25-pound range or 30 mV over a 100-pound range. This indicates that the maximum resolution on the output signals would be 18.3×10^{-9} and 45.8×10^{-10} bits per pound respectively. All measurements are input into a National Instrument Analog Input Module (NI 9205) that has a resolution of 16 bits. The given resolution is not adequate for desired measurement accuracy. To increase the resolution of the load cells, an amplifier box was built to amplify the output signals before being entered into the analog input module.

II. REQUIREMENTS

This project contained a few initial design requirements. The main requirement given was that the system has low noise, with a good signal-to-noise ratio of no more than a 10 mV fluctuation \times gain. The only other requirement was that the system could handle up to 10 channels at a time. The rest of the design specifications were introduced at a later time to meet the above requirements.

III. AMPLIFIER BOX DESIGN

The first process in designing the amplifier box was to select the amplifier chip and design the circuitry that will amplify the load cells. The amplifier chip selected was the INA110KP instrumentation amplifier. The datasheet [?] includes a suggested schematic for differential input/differential output signals. The suggested schematic design was implemented along with some

simple modifications. This allows for both the positive output and negative output signals from each load cell to be amplified individually. Within each module the two input signals have a various gain selection of one, 10, or 100. A double pole, double throw (DPDT) slide switch is used to select the gain value for each individual amplifier block.

The amplifier has a low bias current of 50 pA and requires rail voltages of plus and minus 15 VDC. These voltages were produced by an AC-DC linear power supply from Acopian with a model number of TD15-100. The load cells' excitation voltage of 10 VDC was also produced by a similar linear power supply with a model number of B10G300. The power supplies were chosen for their size along with their low noise rating.

After the schematic design was finished (Figure ??) the parts were purchased and placed on a bread board for testing. The schematic was tested for both the amplification process along with checking for noise in the system. Initially without any amplification the system had around 10 mV of noise. After an amplification gain of 100, the noise level was around 0.8 V (See Figures ?? and ??). This indicates that the amplified signal has a better signal-to-noise ratio than the unamplified signal.

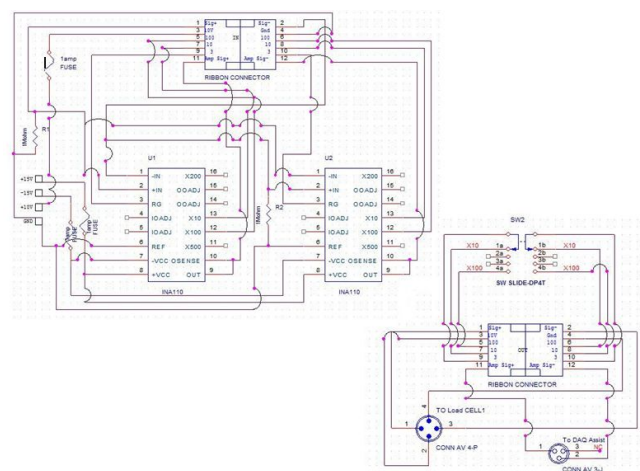


Fig. 1. Board Schematic

The next step was designing a Print Circuit Board (PCB) of the schematic. The software used was EaglePCB, which is a free software for board layouts. The main issue with the software was that not all of the footprints for the parts being used were in the software's libraries. Individual footprints for

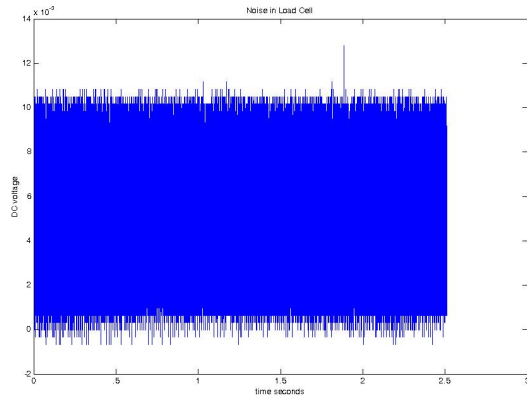


Fig. 2. Noise in Load Cell

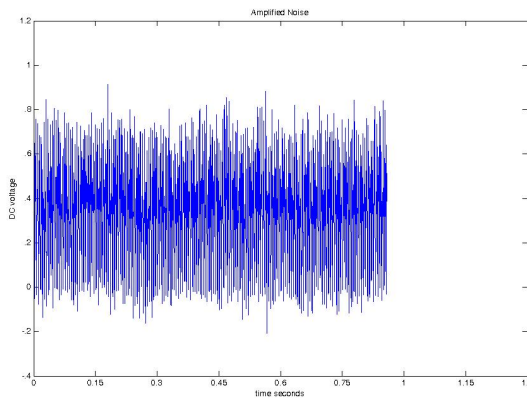


Fig. 3. Noise in Amplification

was introduced into the case along with all other connecting components, power supplies, and switches. Additional case features included LED's for power indication along with cooling fans (Figures ?? and ??).



Fig. 5. Inside View of Amplifier Box

each connector were drawn and added before the layout of the board could be designed. There are several tutorials listed online describing how to build footprints along with exporting the finished file in formats understood by Computer Numerical Control (CNC) machines used to etch the board. A two-sided board was designed and etched into a 1cm thick copper-clad board. The board contains 10 modules, each being separate from one another in case of an unexpected failure and need of replacement. See Figure ??.

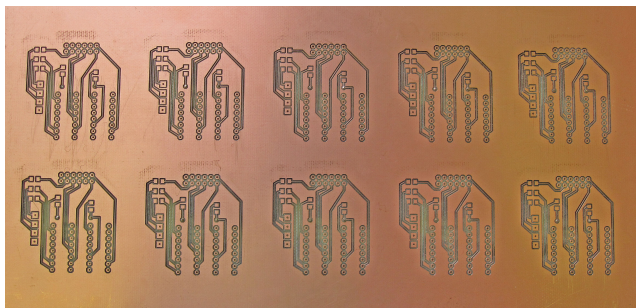


Fig. 4. Copper Clad Board



Fig. 6. Outside View of Amplifier Box

Parts were soldered to the PCB and each module was tested to make sure all connections were proper. The PCB

IV. RESULTS

The amplification worked as expected, but there was an offset voltage in the system when objects, such as your hand, touched any wiring or the circuit board. Depending on the test situation the voltage could be offset by as much as 20

mVDC. Having a floating offset can create huge problems in the calibration efforts for the test stand. The source of this offset ended up being created by grounding issues from shielding wires and the copper-clad board. The offset voltage was mitigated by constructing a earth-grounded faraday cage around the box along with having a single node ground for all amplifier modules. The result showed that by implementing the solution there was a small jump of around 1 mV x gain, which exceeded our design requirements for the amplification system.

The amplifier box was interfaced with the DAQ modules along with GUI interfaces designed in LabView. Results from the following signals are shown in Figure ??.

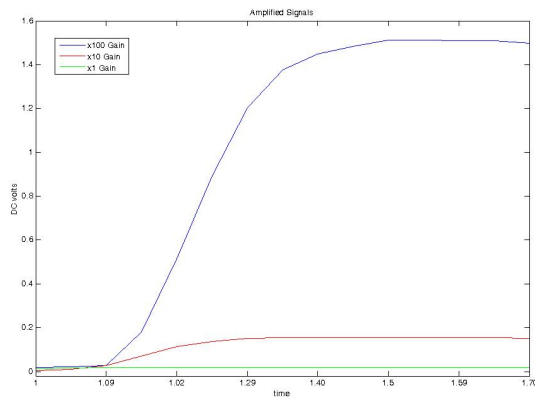


Fig. 7. Amplified Signals with gain of x1, x10, x100

V. CONCLUSION

Overall the process of designing the amplification box was simple with the exception of reducing outside noise on the system. After testing different grounding techniques, the noise was able to be eliminated by having one common grounding node along with shielding all components with an earth-grounded faraday cage. The results in Figure ?? show that the amplified signal is clean and accurate with different amplifications while increasing the system resolution overall.

VI. ACKNOWLEDGMENTS

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REFERENCES

- [1] B.-B. Corporation, "Fast-settling fet-input instrumentation amplifier data sheet," 1993.