Automated Magnetic Bearing Controller Calibration

PCB Automatica

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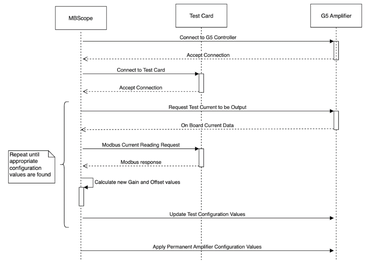
The Problem

- **Background**: Magnetic bearings are bearings that support a load through magnetic levitation. However, to maintain stable speeds, accurate DC current needs to be supplied to these bearings. This is achieved through a magnetic bearing amplifier, which is a component of a magnetic bearing controller.
- **Problem Statement**: Our sponsor, SKF, manufactures magnetic bearings and their associated controllers. They have a manual calibration procedure for the bearing amplifier to increase the accuracy of the current output. However, this manual calibration takes over an hour for each controller and involves tedious data entry.
- **Design Goal**: Our team's goal is to completely automate the calibration process of each bearing amplifier within these controllers. We will use an embedded PCB-based solution combined with software to take accurate measurements and autonomously calculate calibration parameters.

Software Design

The software design portion of our project was split into two parts:

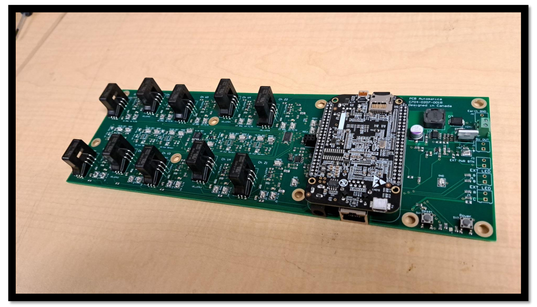
- The PCB integrates a Linux-based microcontroller, for which a software image is installed which can take and convert measurements via ADC inputs.
- An extension to SKF's controller software for PCs was developed to automate the calibration process. The software communicates with the calibration device and the controller to calibrate the bearing amplifier using requested data.



Electrical Design

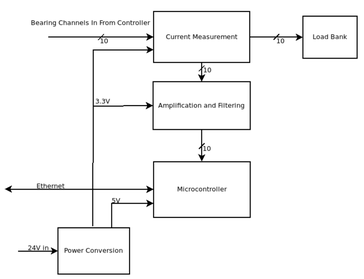
The electrical design work mainly involved designing and laying out the PCB. The following are some key features of the design:

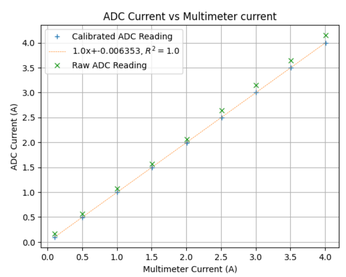
- The PCB has 10 current transducers installed for accurately measuring actual DC current.
- Each measurement channel has an op-amp based filter and gain section to reduce noise and periodic properties before sampling at the ADC inputs.
- Power distribution is achieved via a 5V regulator to step down DC input power from 24V to 5V. The 5V power is used to power digital components and is further stepped down to 3.3V to provide power to analog components.



Additional electrical design work was done beyond PCB design and layout, which included:

- Incorporating large inductors that simulate the load bank used by SKF for testing and calibration.
- Adding an unmanaged Ethernet switch for communication between the controller, the calibration device, and the PC running the calibration.
- Specifying correctly gauged and insulated wiring for routing the bearing amplifier channels.





Results and Calibration

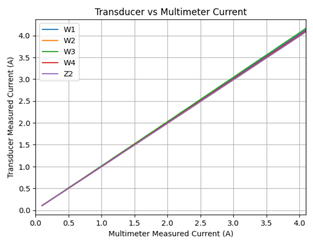


Figure 1

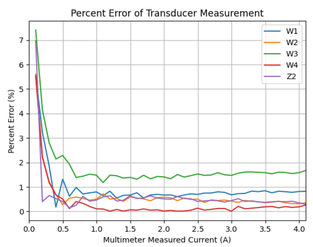


Figure 2

- Figure 1 shows the current sweep measured on 5 channels by our device compared to a reference power supply. The lines have an R^2 value of 1 and a slope within ±1.5% of 1, indicating accurate measurements.
- Figure 2 shows the percentage of error in our device's current measurements prior to calibration on 5 channels compared to a reference meter. The error is high at low currents but decreases to less than 2% for all channels as the current increases. It's worth noting that these low currents are much lower than the calibration requirement.

Mechanical Design

- The calibration setup has a 19-inch rack format enclosure that functions to prevent user contact with electrical hazards, protect the test equipment, and to support the load inductors for the bearing amplifier.
- The enclosure will be screwed close to prevent disassembly since access to parts inside it is not required for the calibration of the bearing amplifier.

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