DEVELOPMENT AND FEASIBILITY OF OPEN-SOURCE HARDWARE AND SOFTWARE IN CONTROL THEORY APPLICATION

by

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Abstract

Control theory is a methodology investigated by many mechanical and electrical engineering students throughout most universities in the world. Because of control theory?s broad and interdisciplinary nature, it necessitates further study by application through laboratory practice. Typically the hardware used to connect the theoretical aspects of controls to the practical can be expensive, big, and time consuming to the students and instructors teaching on the equipment. This is due to the fact that connecting various hardware components such as sensors, encoders, amplifiers, and motors can lead to data that does not fit perfectly the theoretical mold developed in the controls classroom, further dissuading students of the idea that there exists a connection between developed theoretical models and what is seen in practice.

There is a recent trend in universities wishing to develop open-source, inexpensive hardware for various applications. This thesis will investigate and conduct a multitude of experiments on an apparatus known as the Motorlab to determine the feasibility of such equipment in the field of control theory application. The results will be compared against time-tested hardware to demonstrate the practicality of open-source, inexpensive hardware.

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Nomenclature

ARM Advanced RISC Machine

AMS An Austrian analog sensor manufacturer

DAEC Dynamic Angle Error Compensation

MPU Microprocessor Unit

BLDC Brushless DC

Acknowledgments

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Chapter 1

Introduction

In this chapter there examples of various features you may want to incorporate into your document. Here's an example of a figure inserted into the text:

See the file chapter1.tex for examples of the commands used to insert a figure or table, add a caption, etc. Here is an example of a table:

Table 1.1: *Caption to appear above the table*

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Col 1 Row 1	Col 2 Row 1	Col 3 Row 1
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Col 1 Row 3	Col 2 Row 3	Col 3 Row 3

1.1 Making References to Figures or Tables

It is possible to create cross-references and hyperlinks to items or sections within your paper. For example, here is a reference to Fig. **??** mentioned at the beginning of this chapter and a reference to the Table 1.1.

1.2 Making a Reference to a Chapter Subsection

In this section, we refer back to text mentioned in Section 1.1 on page 1.

1.3 Making a Citation

Chapter 2

Apparatus

Two pieces of apparatus were used to conduct the experiments in this thesis. This chapter will detail the purpose, design and recreation of the equipment. Section 2.1 will cover the new Motorlab, including the hardware implementation, design of components, and basic functionality. Section 2.1.1 will detail how a new type of position sensor works that is used for the position measurements of the Motorlab. Then, the older Motorlab will be discussed and compared to the new Motorlab in section 2.2.

2.1 New Motorlab

The new Motorlab is a reimplementation of older laboratory hardware created by Dr. Schinstock and Dr. White for Control of Mechanical Systems I at Kansas State University. The Motorlab allows users to connect the theoretical ideas of control theory with those in practice. (Maybe include applications of the motorlab and its use in the laboratory).

2.1.1 Hardware

The new Motorlab consists of several key pieces of hardware, namely a Microprocessor Unit (MPU), motor driver, and a Brushless DC (BLDC) motor. The main MPU of the Motorlab is the STM32 Nucleo, which allows Arduino attachment shields and other STM boards to be attached for added functionality. For the purposes of the Motorlab, a motor driver was required to drive a brushless DC motor, namely a [Motor Brand]. An X-Nucleo-IHM07M1 (a three-phase brushless DC motor driver) was selected to be the primary driver for the Motorlab.

2.1.2 Position Sensor

The encoder that is being used on the Motorlab consists of 14-bit on-axis magnetic rotary position sensor chip, specifically the AS5047D by AMS. The position sensor chip provides high resolution absolute angle measurements (roughly 2000 steps per revolution) through a full 360 degree range. In addition to the fast absolute angle measurement system that the position sensor provides, it also has Dynamic Angle Error Compensation (DAEC) that provides position control systems with near 0 latency [1].

The AS5047D chip is a magnetic sensor that utilizes the Hall-effect. The chip works by taking the Hall sensors and converting the perpendicular magnetic field on the surface of the chip to a voltage. The voltage signals are filtered and amplified in order to calculate the angle of the magnetic vector. In order for position measurements to be taken, a small diametrically opposed magnet must be placed on the shaft of the equipment being measured. The magnet and AS5047D are contactless, meaning there is a small air gap between the chip and magnet. As the magnet rotates above the chip (Figure 2.1), angle measurements are calculate and transmitted through the chip. The Motorlab uses the AS5047D chip primarily as a position and speed control system.

2.1.3 Motorlab Parts

2.2 Motorlab

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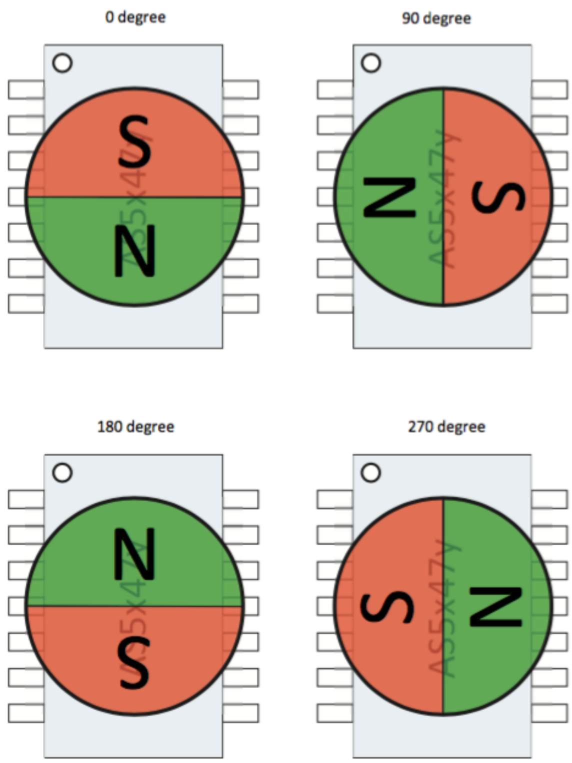

Figure 2.1: *Magnet and AS5047D*

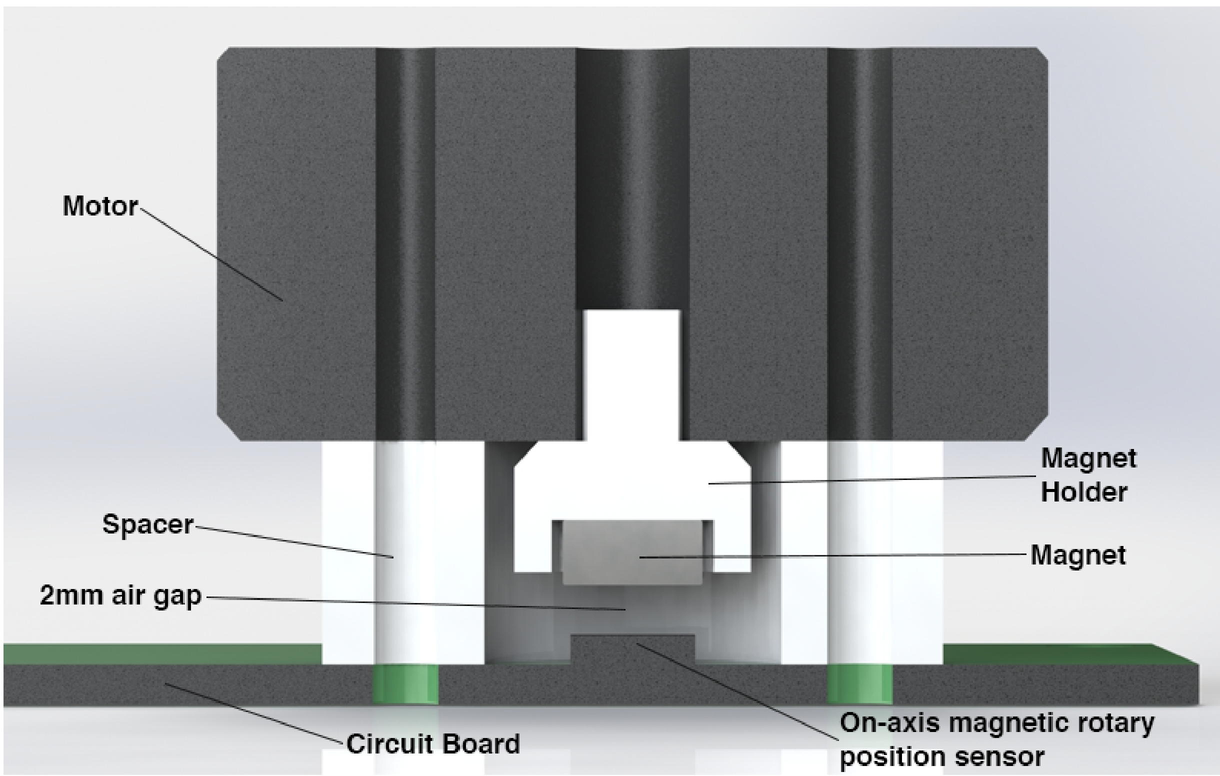

Figure 2.2: *Section View of Motorlab Assembly*

Chapter 3

This is Chapter 3

Here are more examples of references to previous sections. In Chapter 1 there were several sections, including section 1.1, section 1.2, and section 1.3.

Likewise, in Chapter 2, there are sections 2.1 and 2.2.

Bibliography

[1] AMS, *AS5047D 14-Bit On-Axis Magnetic Rotary Position Sensor with 11-Bit Decimal and Binary Incremental Pulse Count.* AMS, April 2016.

Appendix A

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Appendix B

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