Magnetic Suspension System Control Using Position and Current Feedback

Senior Project Proposal

Team: Gary Boline and Andrew Michalets

Advisors: Dr. Anakwa and Dr. Schertz

Date: November 28, 2006

Summary

Magnetic suspension systems are increasingly used in industrial rotating machinery applications. They offer a number of practical advantages such as low energy consumption, capacity for linear displacement, high rotational speeds and can operate at extreme temperatures with a longer lifespan. The absence of mechanical contacts that are present in traditional systems eliminates the problem of lubrication. The Magnetic Suspension System uses an electro-magnetic force to suspend a hollow metal ball. There are two initial inputs to the system: set point and reference input. The set point is the operating point of the system, around which a reference signal is tracked.

Goals

Unlike previous controller designs using this magnetic suspension platform, a controller will be developed to implement current feedback along with conventional position and velocity feedback to improve performance of the system. The magnetic suspension system diagram can be seen in Figure 1, and a photo in Figure 2.

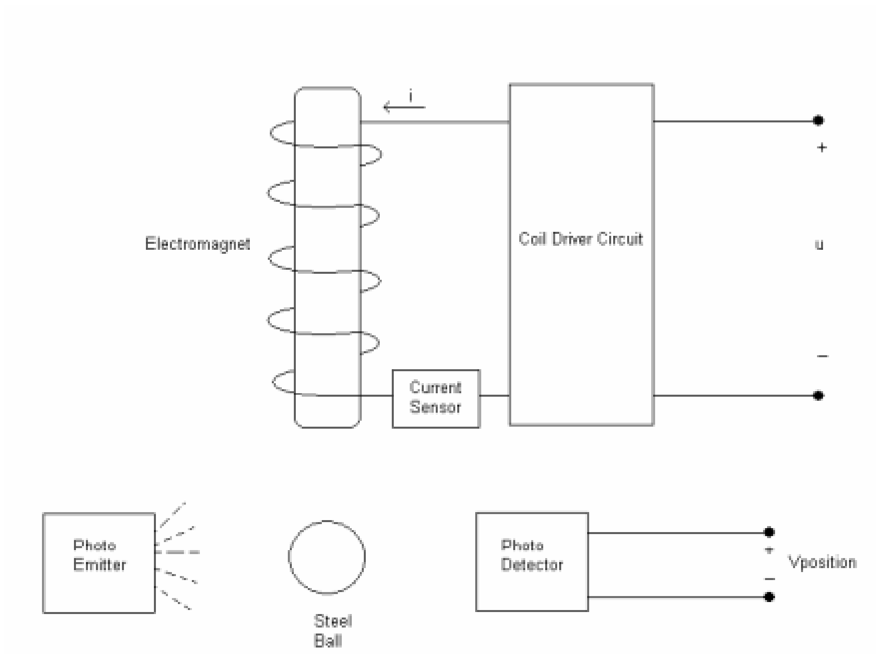

Figure 1: Magnetic Suspension Plant

Figure 2: Photo of Magnetic Suspension Plant

A high level block diagram of the system is shown in Figure 3.

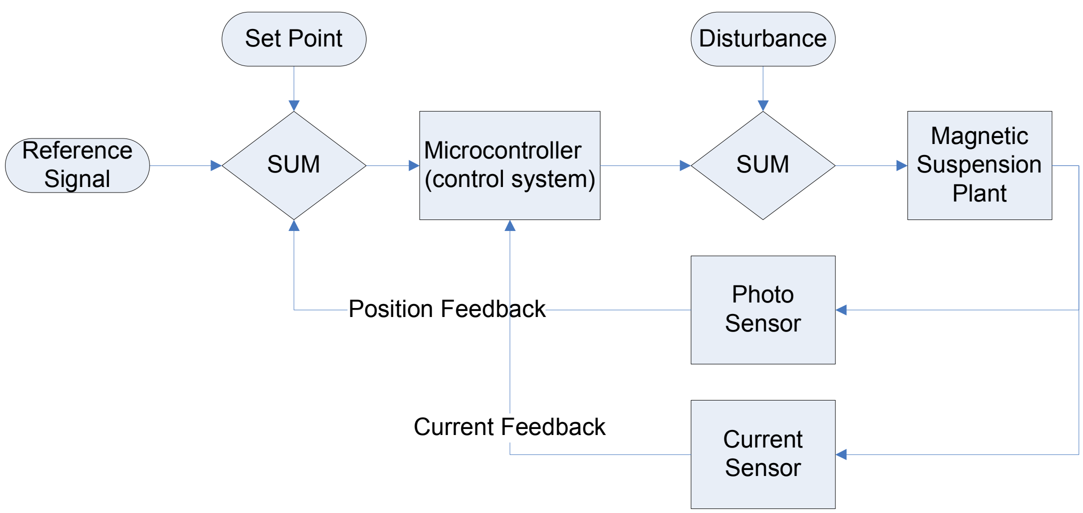

Figure 3: High Level Block Diagram

Subsystems

The magnetic suspension plant has been extensively modeled in previous projects and that will be the starting point to model the system using current, position and velocity feedback. Previous projects started with a nonlinear mathematical model of the magnetic suspension system plant and linearized it about a desired equilibrium position. The linearized plant transfer function obtained from previous projects is:

$$H(s) = \frac{7.67*0.18}{(1/961)*s^2 - 1} \qquad (1)$$

The photo sensor converts the position of the ball, suspended below the electro-magnetic coil, to a voltage. The current sensor is a 1 Ohm resistor which produces a voltage equivalent to current. The microcontroller chosen for this project is the Motorola Coldfire 32 bit microcontroller which features a floating point processor, Digital to Analog (D/A) and Analog to Digital (A/D) converters.

Specifications
The metal ball shall reach zero steady-state error with less than 0.6 seconds settling time and 20% overshoot. Sampling from the Coldfire microprocessor shall be interrupt driven with a sampling rate of 1ms. All calculations on the Coldfire microprocessor must be completed within the sampling time of 1ms using a floating point processor. The resolution of our D/A and A/D converters are unknown at this time.

I/O
The controller will primarily use the D/A and A/D converters of the Coldfire platform to create the controller. Set point and gain parameters will be user selectable along with a possible disturbance input.

Software Functionality
The software on the Coldfire platform will perform all the necessary conversions and calculations to implement the controller design. This includes discrete sampling via timers, user input, and signal output to the magnetic suspension plant.

Preliminary work
The first task that needed to be completed was to derive the current feedback plant model. Two methods were used to complete this task. Andrew used Simulink to artificially inject a sine wave into the subsystem used to derive the current output. Figure 4 shows exactly where Andrew injected the sine wave in the Simulink model of the closed loop system.

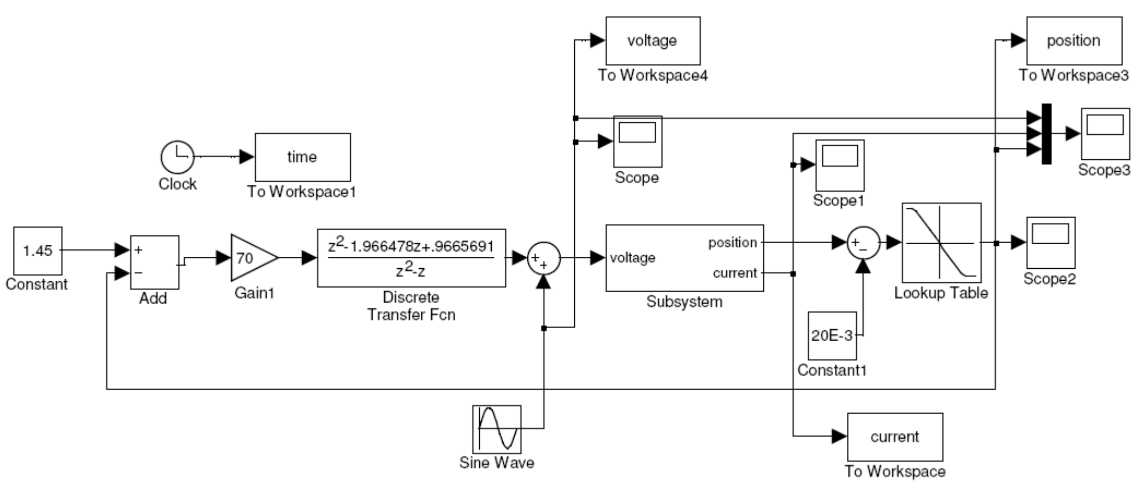

Figure 4: Sine Injection in Simulink

Gary took a different approach by adding external circuitry to the magnetic suspension system to allow a sine wave to be injected into the current input of the system. Figure 5 shows exactly how Gary achieved the injection of a sine wave into the system.

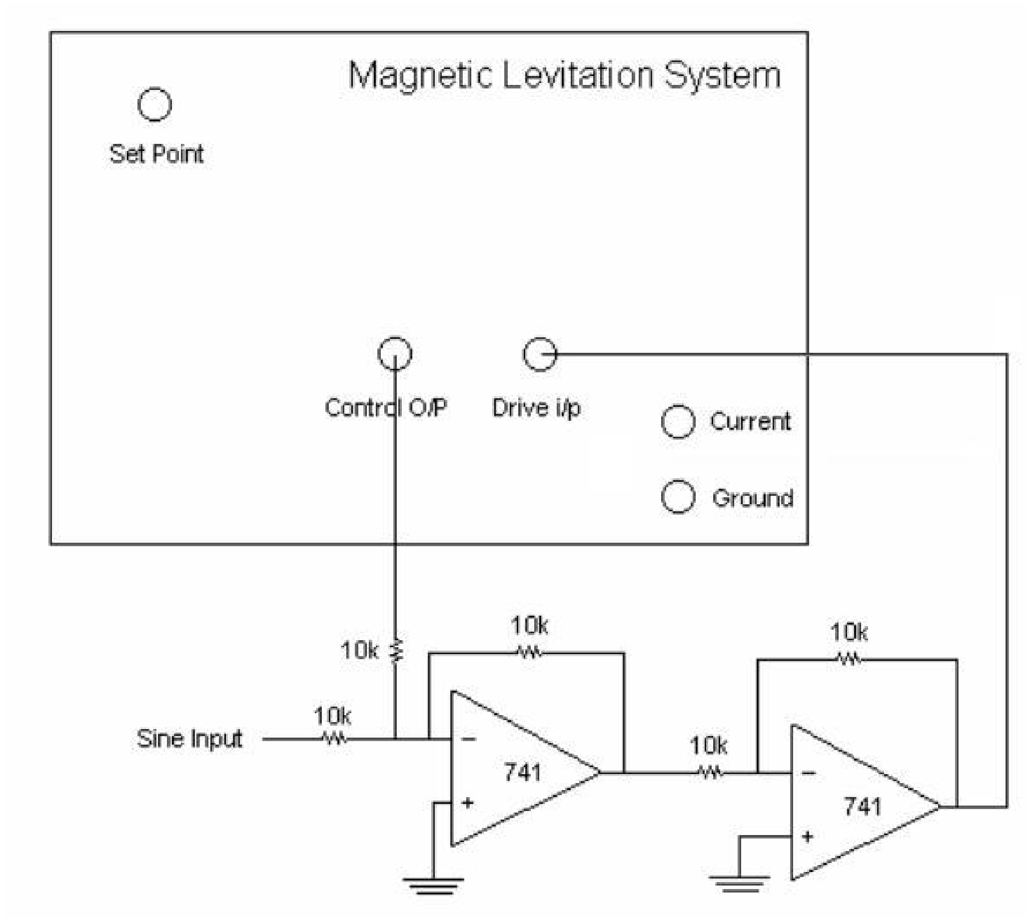

Figure 5: Sine Injection Circuitry

After completing a frequency sweep, from Figure 5, the experimental Bode Magnitude diagram shown in Figure 6 was plotted.

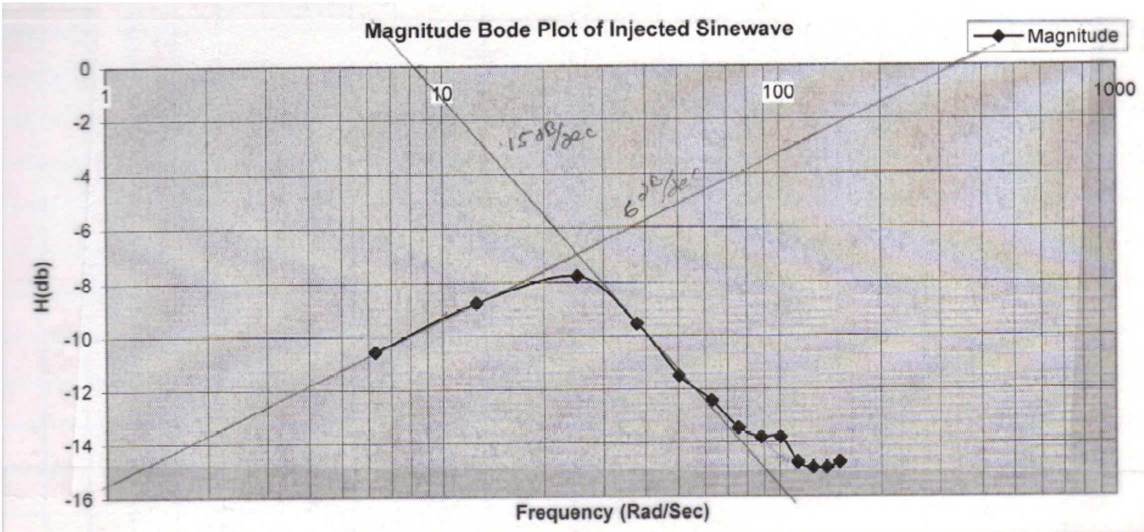

Figure 6: Magnitude Bode plot of Experimental Frequency Response

The experimental plot in Figure 6 can be compared to the Simulink plot shown in Figure 7. A current feedback plant model will be derived from these plots. An iterative approach will be used, poles and zeros will be estimated, and approximated plant model will be tested and modified until the model agrees with the experimental results.

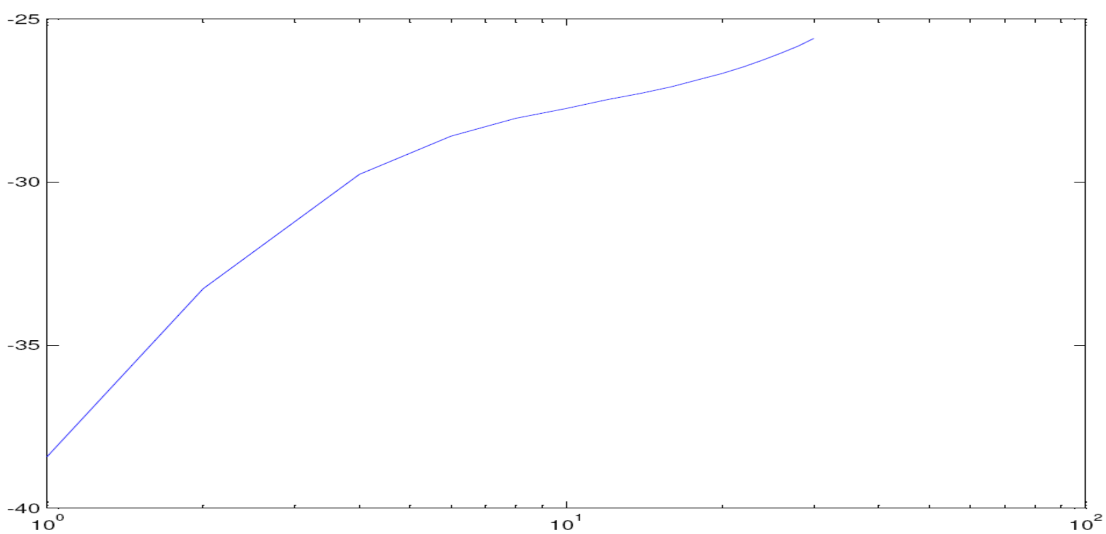

Figure 7: Simulink Bode Magnitude plot of Frequency Response

Patent Search
Patent Number: 5,923,109
NON-CONTACT MAGNETIC SUSPENSION APPARATUS USING DISTORTION OF PINNED SUPERCONDUCTOR FIELD
http://www.aml.t.u-tokyo.ac.jp/patent/sc_maglev.html
Inventors: Toshiro Higuchi, Yokohama; Yukio Tsutsui, Kawasaki, both of Japan

Magnetic levitation bed
United States Patent 6966083
http://www.freepatentsonline.com/6966083.html

Magnetic levitation and propulsion system
United States Patent 6827022
http://www.freepatentsonline.com/6827022.html

U.S. Patent No. should be 6,983,701
MAGNEMOTION GRANTED U.S. PATENT OF ITS MAGNETIC LEVITATION SYSTEM
http://www.findarticles.com/p/articles/mi_m0EIN/is_2006_August_1/ai_n16547044

U.S. Patent #5,396,136, Magnetic Field Levitation, is held by Ronald E. Pelrine
http://www.sensorsmag.com/articles/0301/30/main.shtml

Preliminary Schedule

	Lab Day Thursday:	**Activity:**
Week:	11/30/2006	Presentations
	12/7/2006	Finals
	12/14/2006	Winter Break
	12/21/2006	Winter Break
	12/28/2006	Winter Break
	1/4/2007	Winter Break
	1/11/2007	Winter Break
	1/18/2007	Winter Break
	1/25/2007	Current Feedback Plant Model
	2/1/2007	Current Feedback Plant Model
	2/8/2007	Multipath Root Locus
	2/15/2007	Multipath Root Locus
	2/22/2007	Spring Break
	3/1/2007	Implement Controller on XPC
	3/8/2007	Implement Controller on XPC
	3/15/2007	Implement Controller on Coldfire
	3/22/2007	Implement Controller on Coldfire
	3/29/2007	Implement Controller on Coldfire
	4/5/2007	Implement Controller on Coldfire
	4/12/2007	Wrap up Documentation
	4/19/2007	Prepare Presentation
	4/26/2007	Prepare Presentation
	5/3/2007	Presentation
	5/10/2007	Finals

References

[1] Dr. W. Anakwa. Control of a Magnetic Suspension System Using Position Error and Electromagnet Current. Project Proposal 2006-2007

[2] Namik K. Akyil. Control of a Magnetic Suspension System Using TMS320C31-Based dSPACE DS1102 and Simulink. IEEE 2005 International Conference on Mechatronics. July 10-12, 2005. Taipei, Taiwan.