

# **Active Suspension System Test Platform**

**Bradley University  
Department of  
Electrical & Computer Engineering**

**By:**

**Brian Groth & Melanie Hagar**

**Advisor:  
Steven Gutschlag**

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## **Abstract**

The control system will use the EMAC Inc. Micropac 535 Development board to obtain user input as well as to provide control signals and timing to the power electronics. This year, we will be purchasing an integrated circuit H-Bridge to control the motor directions. An accurate model of the 1/3 hp motor and linear actuator combination will also be delivered.

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## Introduction

The system controls platform motion through the use of a position feedback loop. Platform motion is specified through the application of an external analog signal to the microcontroller board. This provides flexibility in selecting desired frequency and amplitude of the signal. Examples of the overall platform motion include: step, sinusoidal and ramp. Inputs to the total system will be the analog signal applied to the A/D converter as well as the keypad input which will allow the user to select the operating mode. The position of the linear actuator will read by the A/D converter as a voltage across the potentiometer, this will constitute the third input to the system. The two outputs of the system will include the movement of the linear actuator as well as the LCD display which will update the user on the status of the system.

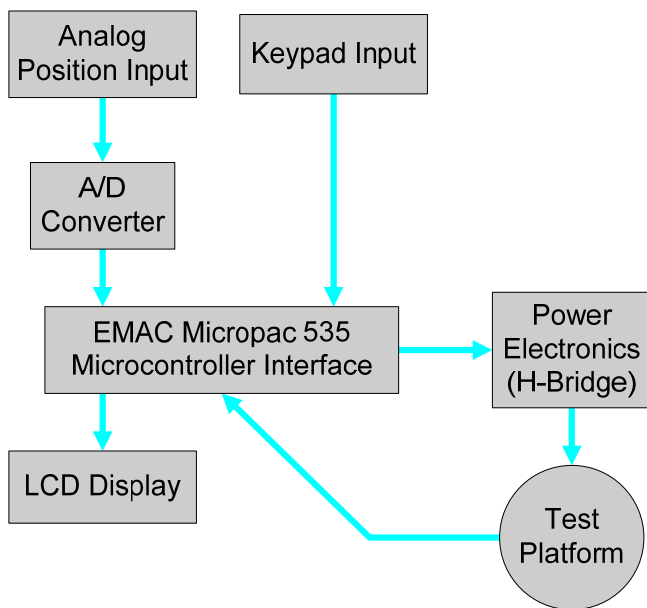


Figure 1-1: System Block Diagram

*Hardware Subsystem*

Shown in the figure below is the Hardware Subsystem Block Diagram. The input signals to the Hardware Subsystem are the four PWM signals from the Microprocessor. The output signals are the position sensor (feedback to the Microprocessor) and the platform movement.

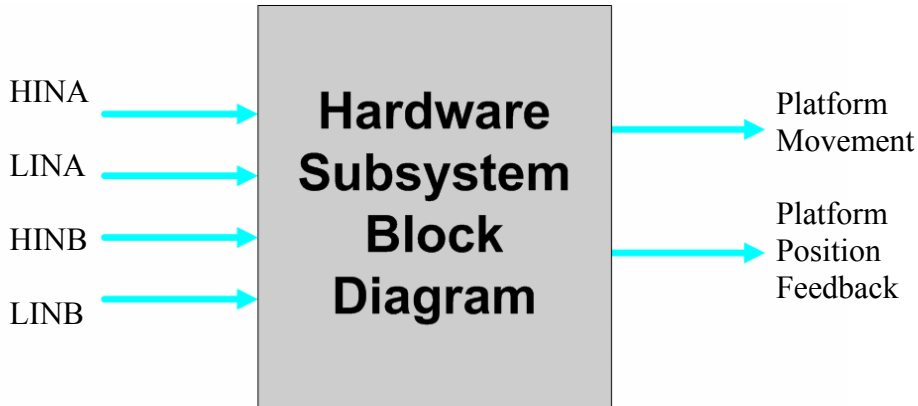


Figure 2-1: Hardware Subsystem Block Diagram

*Software Subsystem*

The input signals to the Software Subsystem are the analog input signal representing the desired motion, position sensor (feedback from the platform), and the user keypad interface. The four PWM output signals are applied to the 4N25 optical isolators.

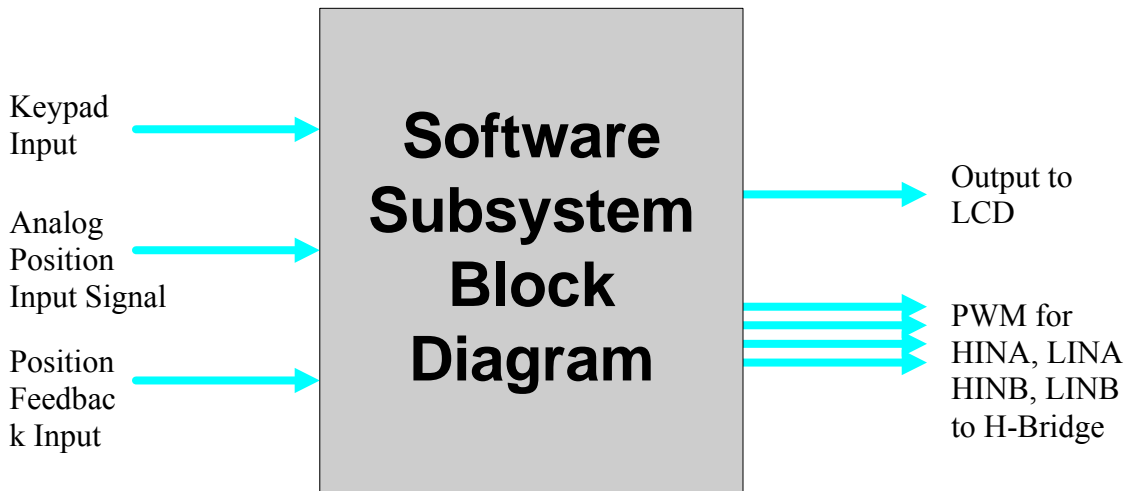


Figure 2-1: Software Subsystem Block Diagram

## Actuators

### *Nook Screw Jack*

A Nook Industries 0.5HL-ESJ screw jack was provided for use in this project. The purpose of this device is to convert the angular motion provided by the 1/3 Hp DC motor into linear motion. The following information pertains to the specifications as well as the maximum limits of this device:

- 18 Inches of Stroke Length
- Gear Ratio 5:1
- Turns of worm per inch travel = 10
- Max Horse Power 1/3
- Max load = 1000 Lbs
- Max worm speed at rated load = 868 RPM
- Max load at 1750 RPM = 496 lbs
- Assembled with a top plate

### *Electrak Linear Actuator*

For demonstration purposes as well as software testing an Electrak linear actuator was used. Specifications of the internal position sensor (potentiometer) are listed:

- Potentiometer 9.8 [k $\Omega$ ]
- Fully Extended 2.8 [VDC] with R=5.5 [k $\Omega$ ]
- Fully Retracted 0.5 [VDC] with R=100 [ $\Omega$ ]

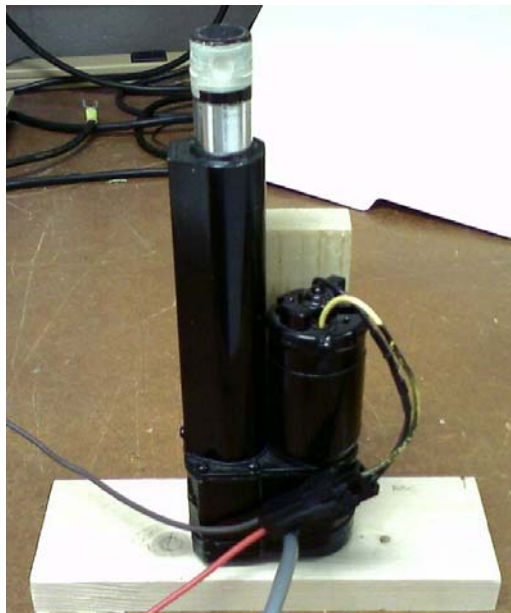


Figure 3-1: Electrak Linear Actuator

## Design Equations and Calculations

### Motor Calculations

- EE Side
  - $1/(s*La+Ra)$ 
    - $R_a$  = Resistance of Armature as Measured in Lab
    - $L_a$  = Inductance of Armature as computer by time constant
- ME Side
  - $(1/B)*(1/(\tau s+1))$ 
    - $B = T_{ss}[Nm]/\omega_{ss}[\text{rad/sec}]$
    - $T_{ss} = K_t[Nm/Amp]*I_{ass}$
    - $\tau$  = Time Constant Found at  $\omega_{ss}*63.2\%$
- $K_t = K_v$

### Duty Cycle Computations

Duty cycle reload values for timer 2 on the microcontroller were implemented through the use of a look up table. The correct values for the user or software (automatic mode) desired duty cycle were pointed to by the data pointer then moved from the accumulator into the CCH2 and CCL2 registers of the microcontroller.

### Snubber Circuitry Calculations

$$C_s = (I_{cso} * t_f) / (\text{sqrt}(12) * V_{off})$$

$$R_s < (D_{min} * T_s) / (3 * C_s) \quad \text{AND} \quad R_s < (V_{BRceo}) / (I_{cso})$$

$$t_f = t_f - t_D$$

$$P_{RS} = 0.5 * C_s * V_{off}^2 * f_s$$

$$V_{BRceo} = I_{cso} * R_s$$

$$\tau_s = R_s * C_s$$

- $t_D$  = Delay time from switch off until current begins to drop
- $t_f$  = Time it takes the current to go to zero from the moment it begins to drop
- $I_{cso} = I_{amax}$  = Collector current at time of turn off
- $V_{off}$  = Maximum voltage applied at turn off
- $D_{min}$  = Duty cycle of 10% =  $0.1 [\text{Cycles/Second}]$  from Prof. Gutschlag

## Hardware

### *H-Bridge*

The MSK4227 H-Bridge is an integrated circuit package capable of driving a motor rated up to 200[V] at 20[A] using TTL level input signals.

When driving the motor forward the blue arrows shows the follow of the current through the transistors in the H-Bridge and the motor. For reverse, the current follows the red arrows. V+ in the figure for the system is +115 [VDC]. The motor was connected across pins 13 and 18 from the H-Bridge.

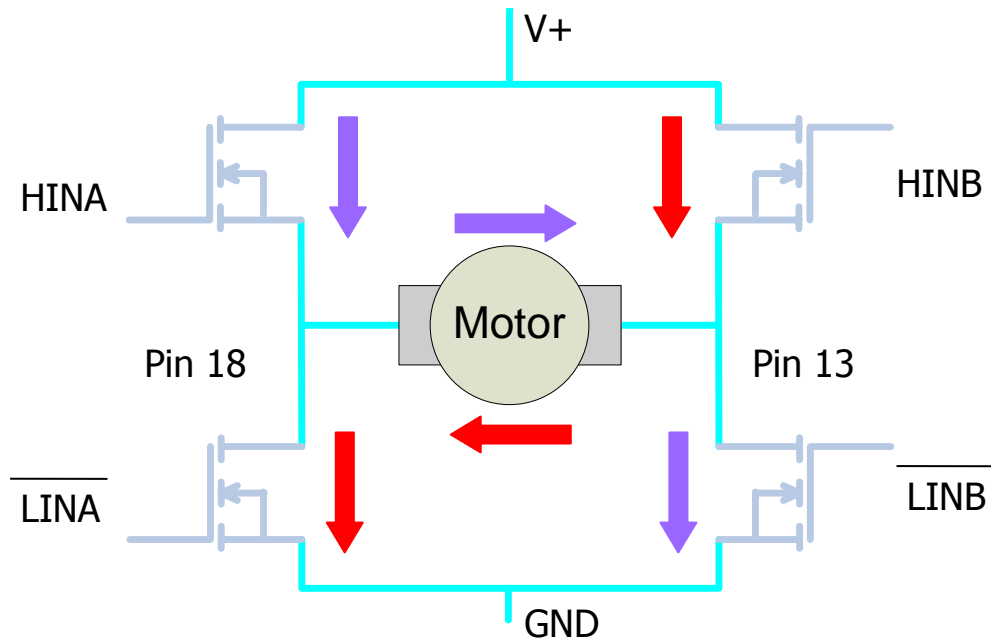


Figure 5-1: H-Bridge with Motor Theory

In the figure below shows the basic setup of the PWM (microcontroller), H-Bridge, and Motor.

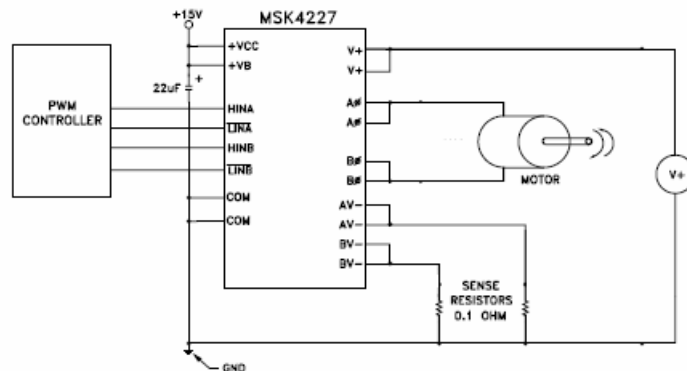


Figure 5-2: H-Bridge with Motor and Controller Setup



### Snubber

The snubber circuit in the figure below was designed for the 115 [VDC] motor driven by a 100 [Hz] PWM signal. Two snubber circuits were made, one for each side of the motor. The function of this circuit is to eliminate the voltage spikes, which can be found across the motor, from destroying the H-bridge and the 115 [VDC] motor.

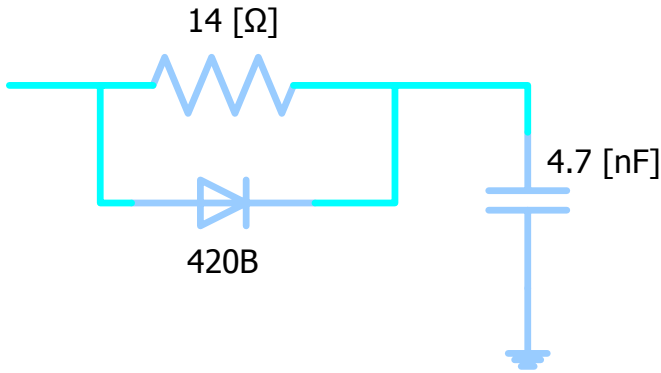


Figure 6-1: Snubber Circuit

### 4N25 Optical Isolator

The 4N25 optical isolator is used in this system to protect the microcontroller in case of a problem with the H-Bridge arises. The 4N25 can protect the input of to the chip up to 5000 volts. Using this chip isolates the EMAC board from the high voltages present in the H-Bridge.

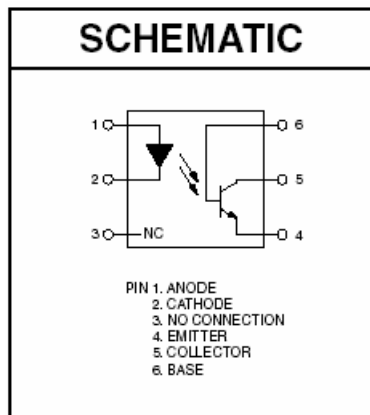


Figure 6-2: 4N25 Optical Isolator

## Software

After initialization, the LCD prompts the user to press a key (#1-8) using the keypad. The keypad operations are shown in the figure below. Once the platform has been moved to the desired starting position, the LCD will prompt the user to press another key (#8-9) using the keypad. If key #9 is pressed, the actuator will bounce. Bounce means the actuator will extend to the top then retract to the bottom and continue this cycle. If key #8 is pressed, the actuator will follow the input analog signal as long as the value of the signal is within the limit of the actuator. If the value of the input analog signal isn't within the limit, the actuator will stop. Also, at anytime the stop button (key #4) can be pressed to stop the operation.

### Keypad Flowchart

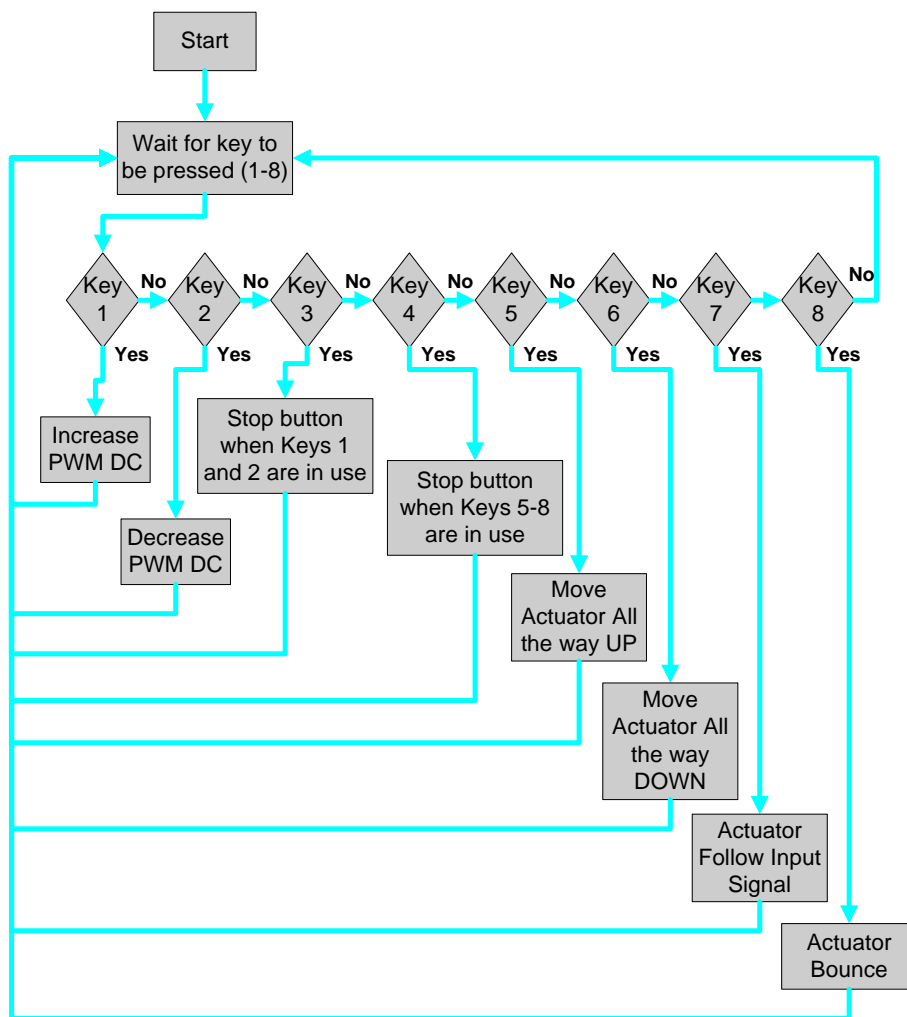


Figure 7-1: Keypad Flowchart

*PWM DCFlowchart*

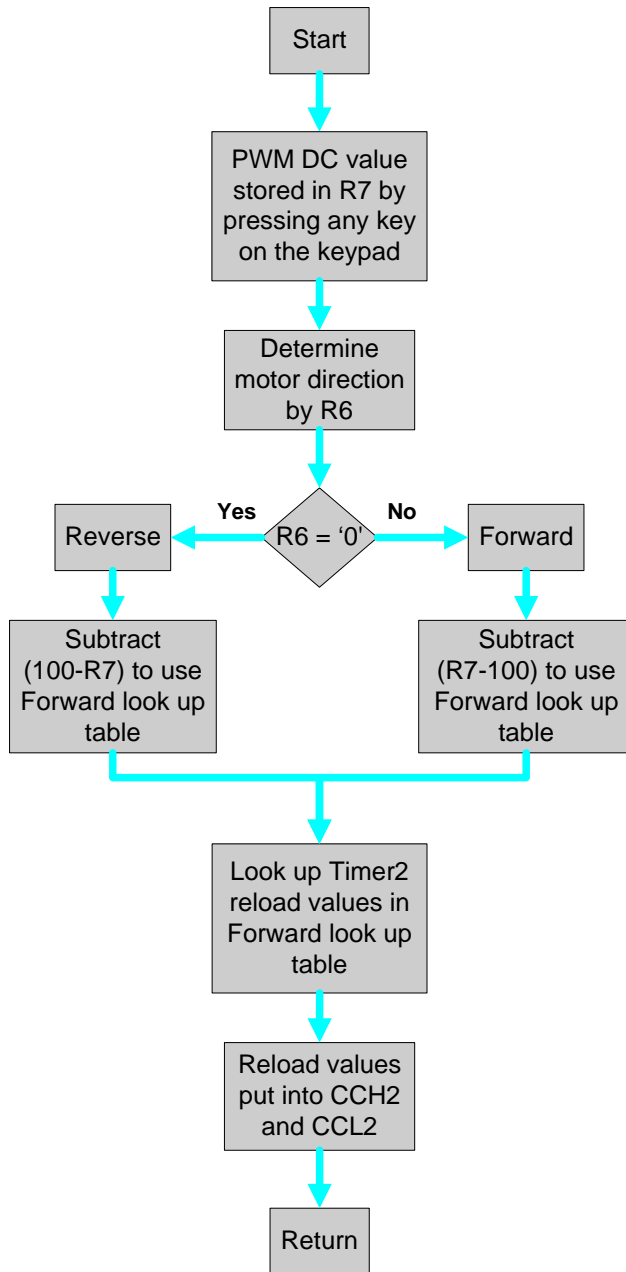


Figure 8-1: PWM DC Flowchart

*Follow Analog Input Signal Flowchart*

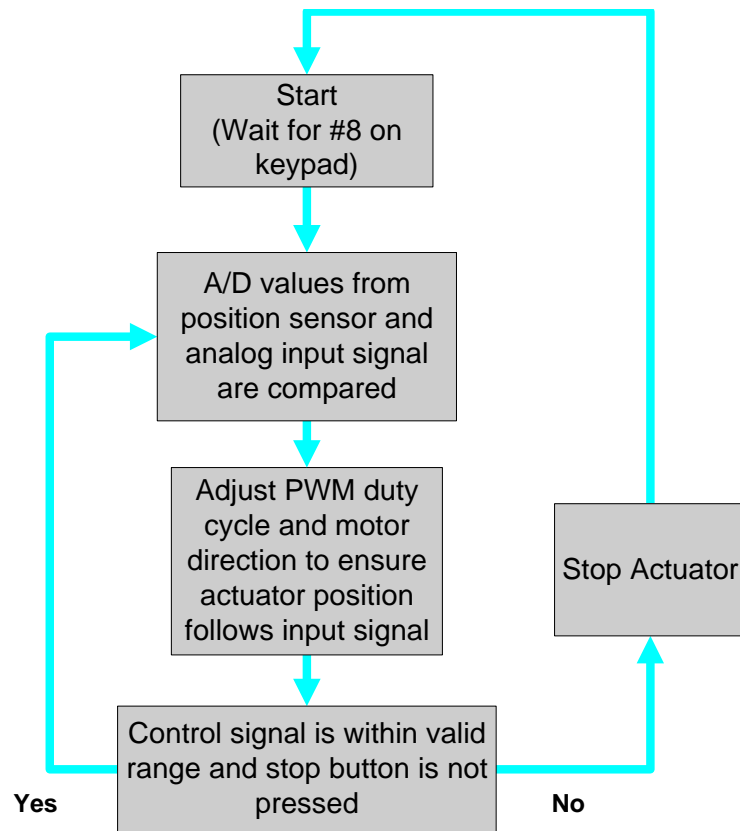


Figure 9-1: Follow Analog Input Signal Flowchart

## Preliminary Results

Using EE431 knowledge as well as data obtained through the application of a step input (varied from 30 [VDC] to 108 [VDC]) an accurate motor model was created through the use of Matlab and Simulink. Comparison of angular velocity values between simulation and laboratory data yielded a variance of less than 2% error. The Simulink model is shown in the figure below.

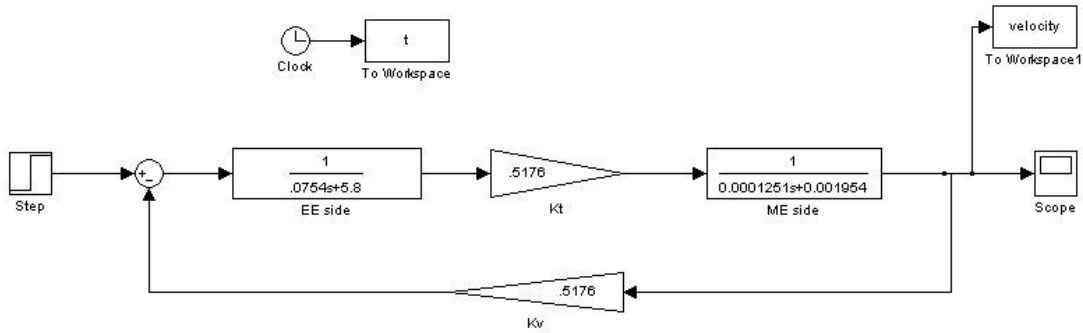


Figure 10-1: Simulink Motor Model for the 1/3 Hp DC Motor

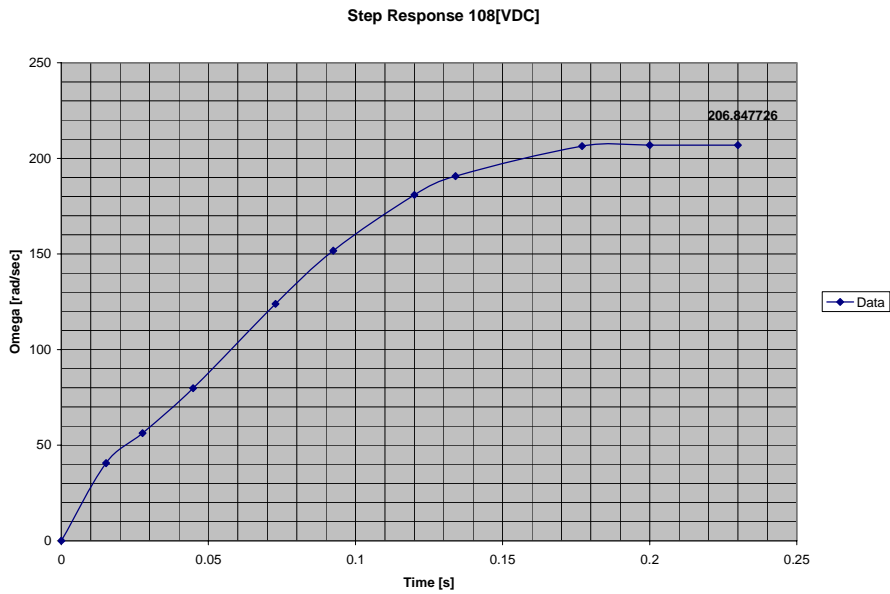


Figure 10-2: Experimental Results in lab for a 108 [VDC] step input the 1/3 Hp DC Motor

## Experimental Results

All software was tested using the Electrak linear actuator. The following scope plots show the variance of gain values from 1 to 10. A gain value of 1 caused an over-damped case while the gain value of 10 yielded a significantly less rise time and thus increased the overshoot value. The control block diagram for the system is also shown will serve as the basis for a future Simulink model of the total system. User selectable gain as well as controller transfer function for this system will be included in the electrical dynamics block of the model.

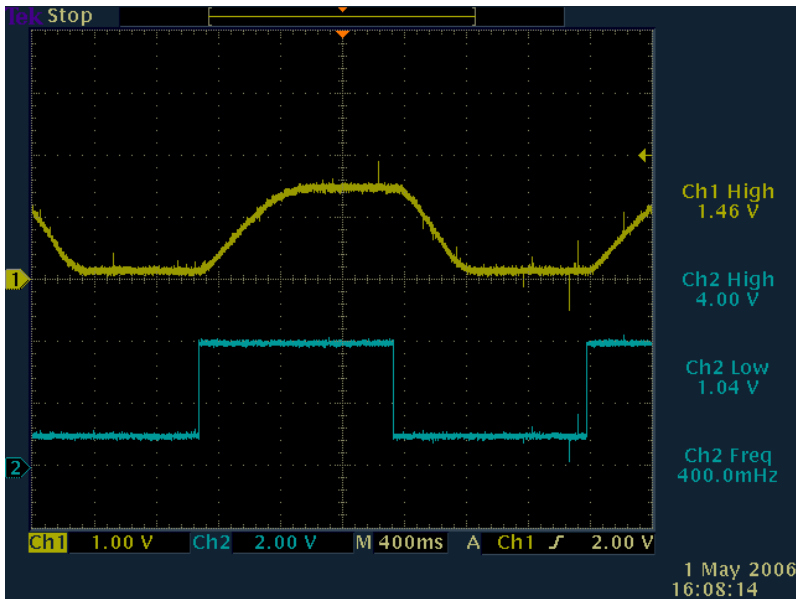


Figure 11-1: Over-damped Situation with a Gain Value of 1

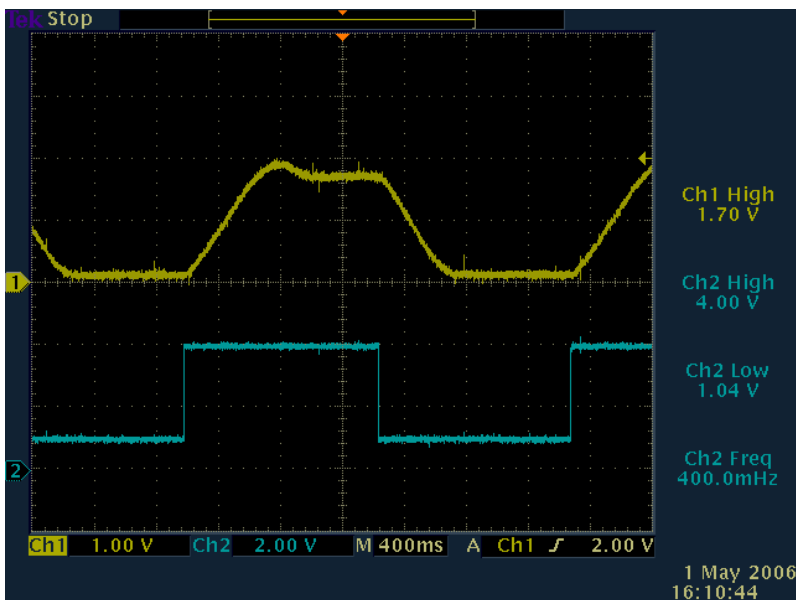


Figure 11-2: Under-damped Situation with some overshoot with gain value of 5, significantly faster than gain value of 1

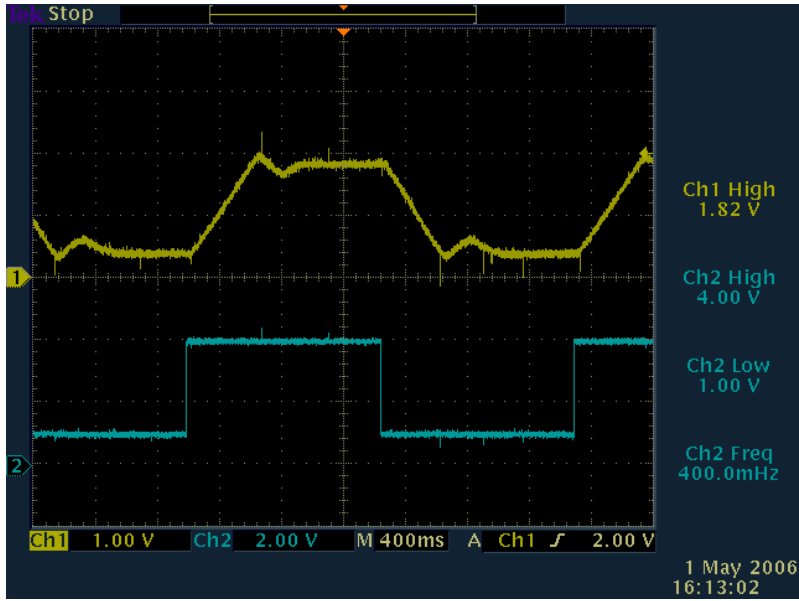


Figure 12-1: Under-damped Situation with large amount of overshoot and ringing is noticed as well, Gain value of 10

## **Analysis of Results**

Using the Electrak linear actuator we were able to obtain scope plots corresponding to a pre-selected gain value. Application of gain was implemented through the use of assembly coding and look up tables.

## **Parts List**

- Micro Pac 535
- 4N25 Phototransistors
- 115 [VDC], 1/3 [HP] Motor
- MS Kennedy 4227 H-Bridge
- Screw Jack (Nook)
- Position Sensor
- Linear Actuator (Electrak)

## **Work Schedule**

- Fall Semester
  - ACTIVEST Project Research
  - 115 [VDC] Motor Modeling
- Spring Semester
  - Week 1-2 Software Design
  - Week 3-7 Software Coding and Software Debugging
  - Week 8-11 Software Testing, System Integration of Hardware and Software Subsystems, and Platform Construction
  - Week 12-13 Research on project expansion and senior presentation preparation