Control Homework 2

ENSC 384

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1 Introduction

Throughout the design process it is assumed that the controller output signal corresponds linearly to the voltage at the motor terminals. An amplifier circuit transforms the low-power DAC output signal to a signal capable of controlling the motor using a PWM power amplifier. As a subsystem, the desired amplifier response should be linear as shown in figure 1. In the figure, amplifier gain is assumed to be one; any amplifier gain can be modeled external to the compensator block at a later time. The amplifier does not naturally have the response shown in figure 1 and as such new compensator subsystem is needed to account for amplifier non-linearities. This compensator must account for two system characteristics. First, the amplifiers gain, offset and dead zone. Second, motor back EMF and the fact the amplifier is not a voltage amplifier but an open loop power amplifier. The observed amplifier transfer function is similar to that shown in figure 2.

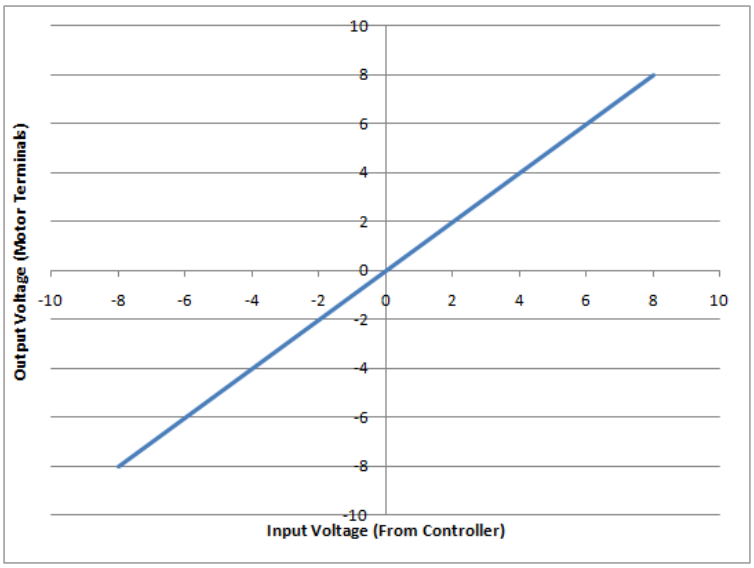

Figure 1: Desired Amplifier Transfer Function

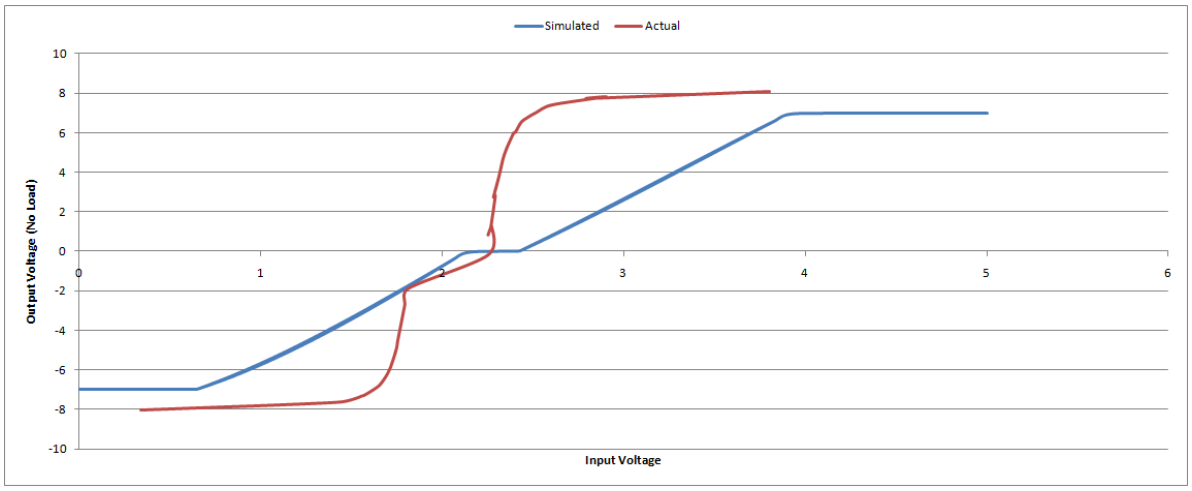

Figure 2: Observed Characteristics with Motor Load

2 Basic Compensation

The first compensation stage accounts for basic amplifier characteristics which make it not-linear. Figure 3 shows the amplifier output voltage (y axis) vs input voltage (x axis) for a resistive load. Three characteristics of the curve should be noted. First, it has a dead-zone where output voltage is zero for a range of input voltages. Second, the input voltage which produces a zero output voltage is not zero. Finally, in the linear regions, gain is not one. A simple block diagram to compensate for these effects can be seen in figure 4 and the full Simulink block in figure 10.

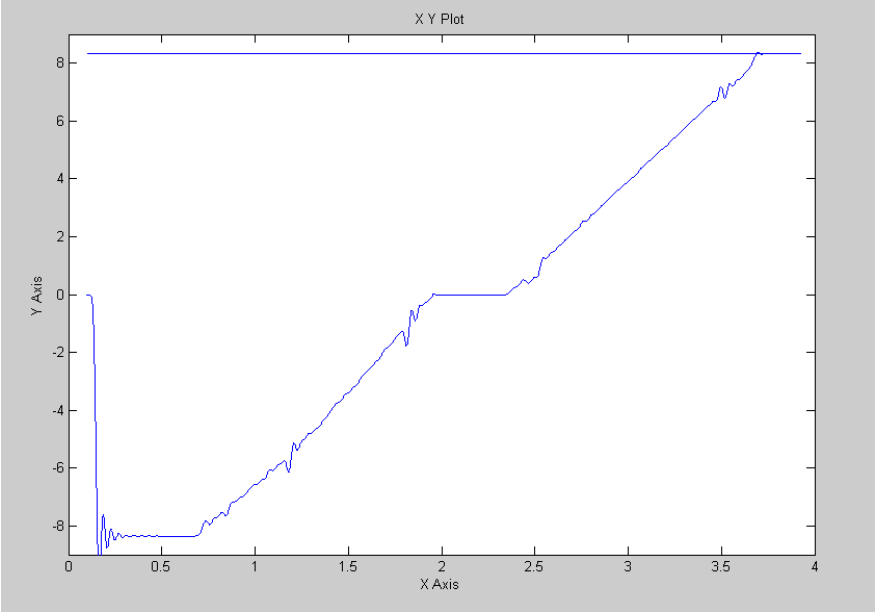

Figure 3: Amplifier Input Voltage vs Output Voltage for Resistive Load

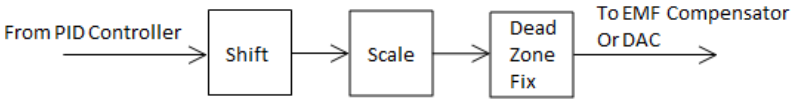

Figure 4: Basic Compensation Block Diagram

The input-output relationship when using these compensation steps may be seen in 5. It can be seen that when using the compensator, the amplifier response (given a purely resistive load) is far more linear. This compensation mechanism is dependent on accurately known the saturation and dead zone limits of the amplifier. A simulink to block automatically calibrate parameters may be seen in 11.

3 Motor Back EMF

After the compensation steps outlined in section 2, the amplifier behaves more or less linearly given a resistive load. The nonlinearity and difference from simulated curve in figure 2 is caused primarily by motor back EMF. A PWM amplifier, the type of amplifier being used here, is essentially an open-loop power amplifier that allows current to pass for a certain fraction of each oscillation period. It does not inherently control voltage and the voltage seen at the amplifier terminals depends on the characteristics of the load.

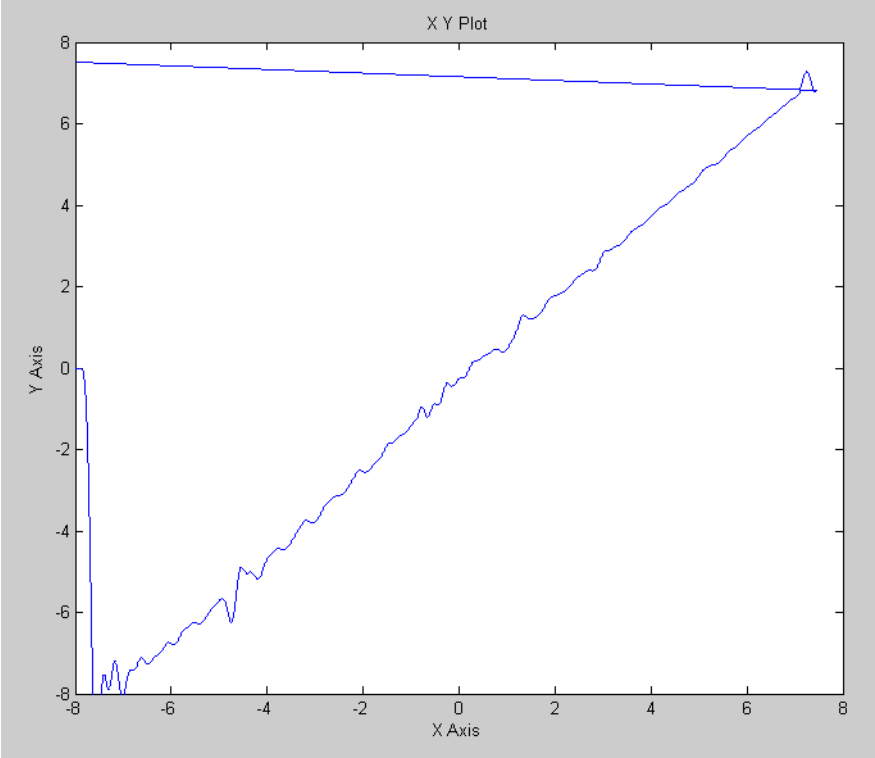

Figure 5: Compensated Amplifier Input Voltage vs Output Voltage for Resistive Load

It is possible to account for back EMF given that the speed of the motor is known by way of encoder feedback. A simple compensation block diagram to account for back EMF is shown in figure 6. The actual simulink block used, including both basic and back EMF compensation, may be seen in figure 10. Due to the dependence on having an actual motor to test, no data has been collected to test the back EMF compensator. The gain shown in figure 6 is the motors K_b parameter assuming speed is measured in radians per second.

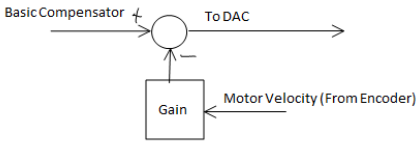

Figure 6: Back EMF Compensation Block Diagram

4 Impact on Speed and Position Control

The compensator discussed up to this point is tightly coupled to the physical system and requires certain amplifier characteristics to be experimentally determined. In order to simulate amplifier and motor non-linearities a lookup table method for linearizing the system was used. The measured nonlinearities and compensator curves may be seen in figure 7.

Position control and speed control experiments were performed using only the lookup table and repeated with lookup table and compensation curve. Using only the lookup table (with no compensation) corresponds to the case of assuming amplifier linearities in the presence of non-linear characteristics. When the lookup table and compensation curve were used together, they were seen to cancel and functionally appear not

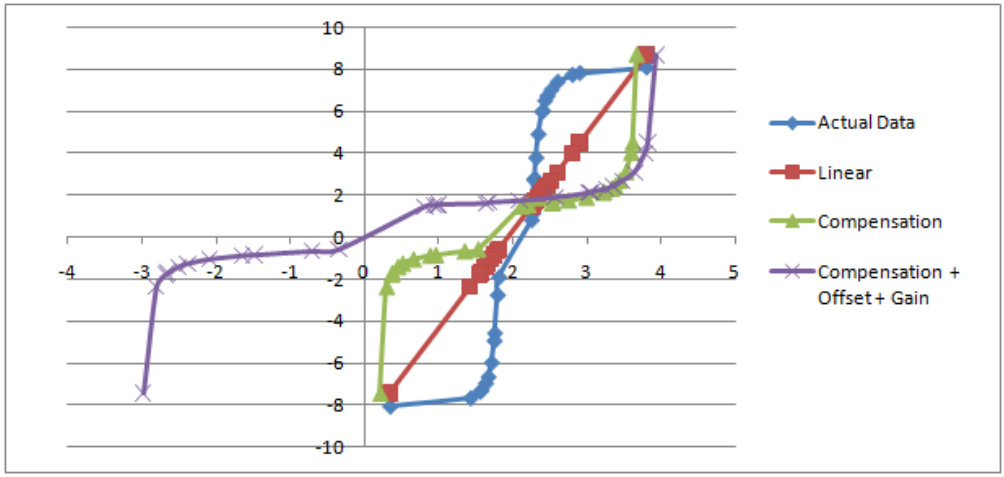

Figure 7: Amplifier Non-Linearities and Compensation Curves

to exist. This is due to the fact both lookup tables were created from the same set of data and perfectly canceled each other in the simulation. Results for both experiments can be seen in figure 8 and figure 9.

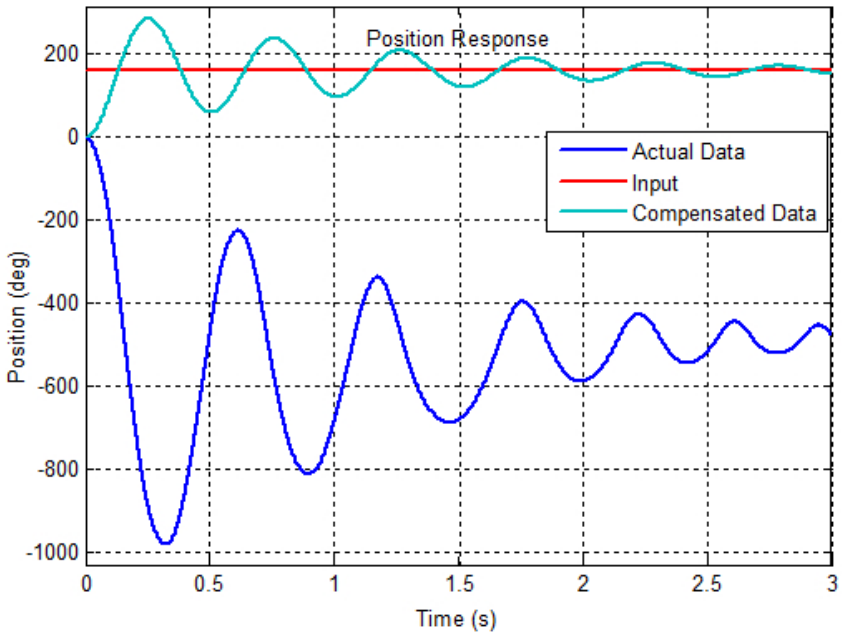

Figure 8: Speed Control Experiment results

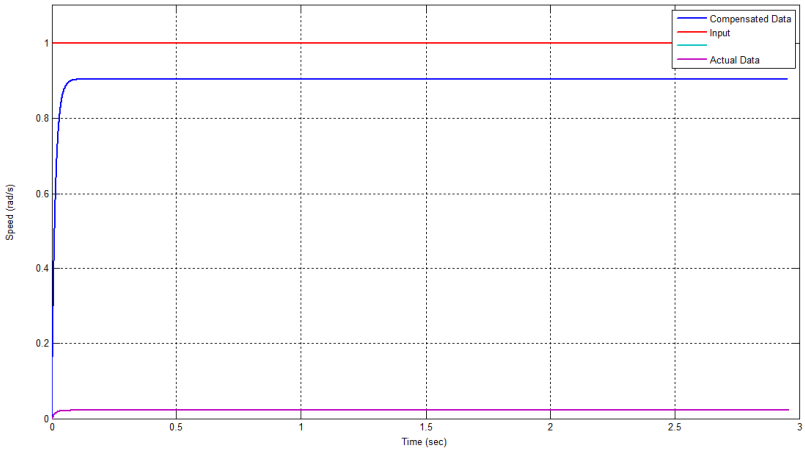

Figure 9: Position Control Experiment results

A Simulink Block

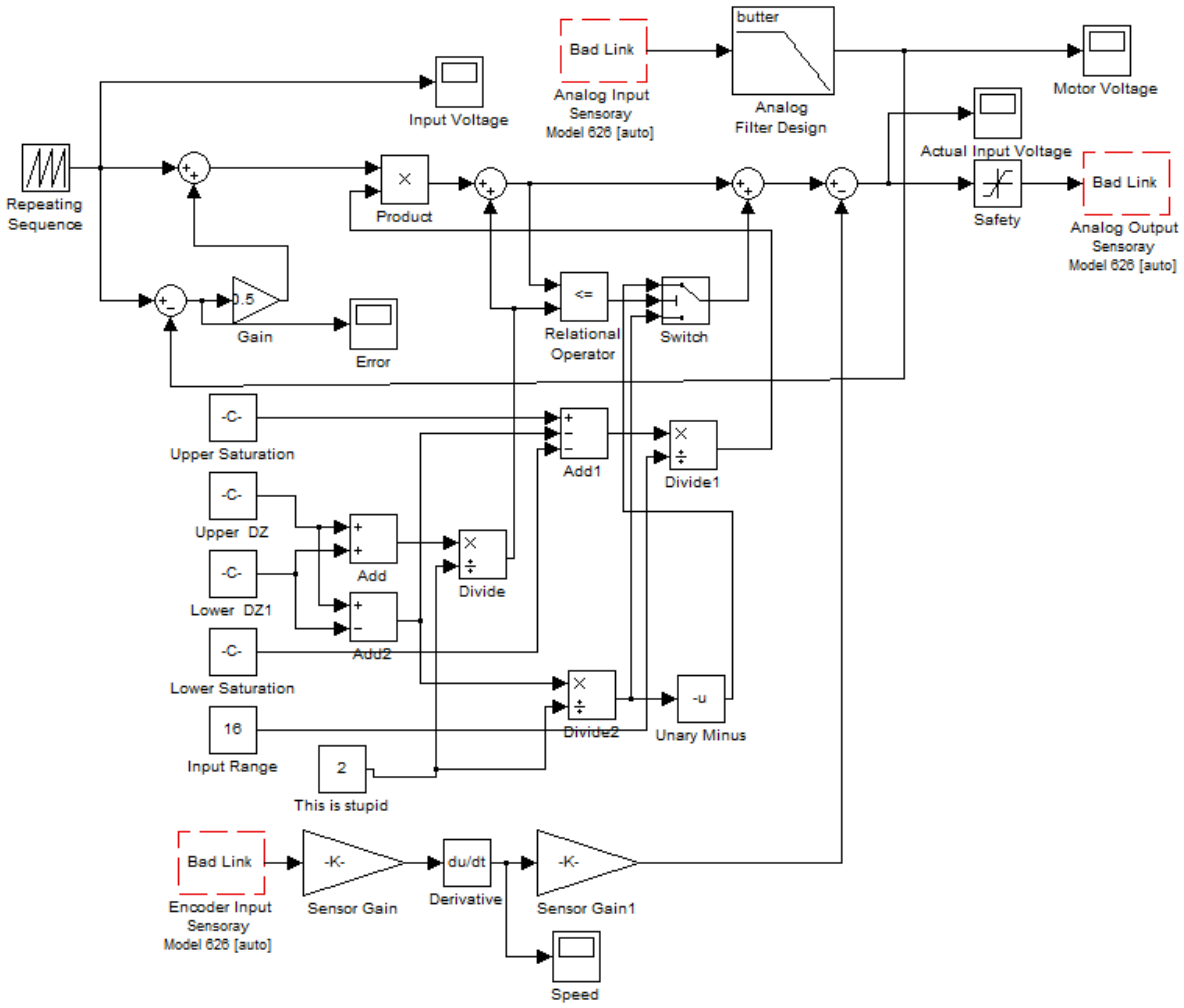

Figure 10: Actual Simulink Compensator Block

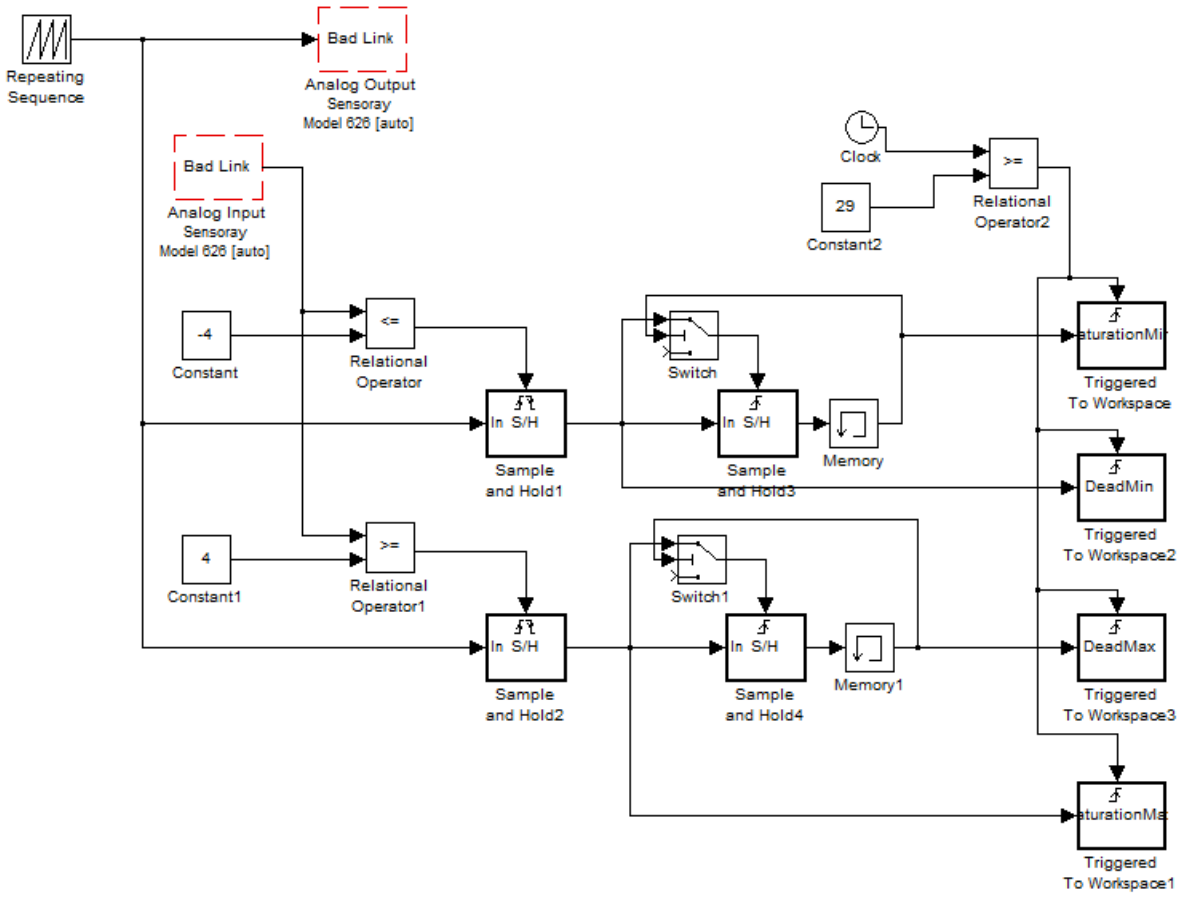

Figure 11: Simulink Block to Determine Amplifier Limits