Controller Design for a Linearly Actuated Active Suspension System

Senior Project Written Proposal

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Date: December 16, 2013

Abstract

Active suspension systems control the vertical movement of a vehicle using software and hardware with the aim of reducing or eliminating disturbances. The controller design for a linearly actuated active suspension system project approaches the problem of limiting vertical movement of a vehicle using a linear actuator and hardware/software from National Instruments™. A disturbance is introduced to the system via an elliptical cam shaft attached to an AC motor. The frequency of the disturbance is determined by a frequency drive controlling the AC motor. As the controller software processes the vertical displacement of the vehicle by way of a potentiometer, software outputs a signal(s) to circuitry driving the linear actuator, lowering or raising the vehicle in response to the disturbance.

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Project Summary

The goal of this project is to design and construct a controller for an electric linear actuator-based active suspension system. Initially, a position sensor will be used to determine the location of the “vehicle,” relative to the “wheel” position. The controller will use this information to engage the linear actuator to keep the mass at a relatively constant position. If time permits, the addition of an accelerometer to the system will eventually be investigated to control the acceleration levels experienced throughout the range of available “wheel” displacement. LabVIEW will be used throughout the project as the controller and data acquisition platform.

An additional project deliverable will be the creation of a tutorial (or guide) on the use of LabVIEW for data acquisition and controller design and implementation.

Project Description

This project will involve focused efforts in power electronics design, system modeling and simulation, and feedback controller design. After the system and controller are simulated successfully utilizing Simulink, National Instrument hardware and software will be used to implement the feedback controller and provide control signals to the power electronics driving the linear actuator of the active suspension system.

Block Diagram

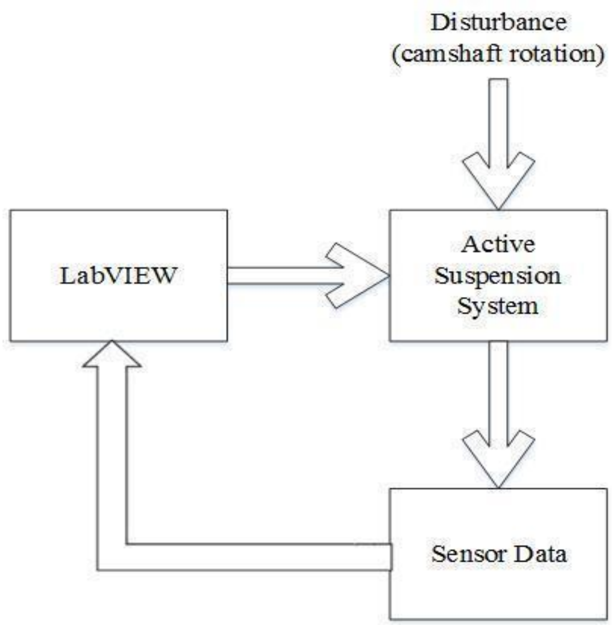

FIGURE 1: Complete system block diagram

A high-level block diagram of the process is shown in figure 1. Disturbances will be introduced to the system by a camshaft attached to an AC motor with a variable speed drive designed to provide external inputs to the suspension system. The controller will be developed using National Instrument's hardware and software (LabView™). Sensors will provide data to the National Instrument's module to provide feedback to the system controller.

Functional Requirements

- The controller shall drive the linear actuator to maintain a midpoint level, yet to be determined, and minimize displacement for a disturbance input with a maximum frequency of 5 Hz.

- The system shall minimize displacement of the cab from the midpoint to ± ⅛" (3.175 mm) with no load weight applied to the platform.

- The system shall minimize displacement of the cab from the midpoint to ± ¼" (6.35 mm) with a load.

National Instruments Hardware

- NI cDAQ-9174 NI CompactDAQ 4-slot USB 2.0 Chassis, 9 V - 30 V Input Voltage Range
- NI 9401 Digital Input/Output Module
- NI 9215 4-Channel Differential Voltage A/D Module (16-bit resolution), 100 kS/s/ch sample rate, ± 10 V
- NI 9221 8-Channel Voltage A/D Module (12-bit resolution), 800 kS/s/ch sample rate, ± 60 V
- NI 9211 4-Channel Thermocouple Module (24-bit resolution), 14 S/s/ch sample rate, ± 80 mV

H-Bridge and Gate Driver Hardware

- Two Fairchild Semiconductor FMG2G75US60 (or equivalent) IGBT Power Modules
- Two IR2110 Drivers, (500 [V] maximum isolation voltage)
- Four 6N137 High Speed 10MBit/s Logic Gate Optocouplers

Controller Flow Chart

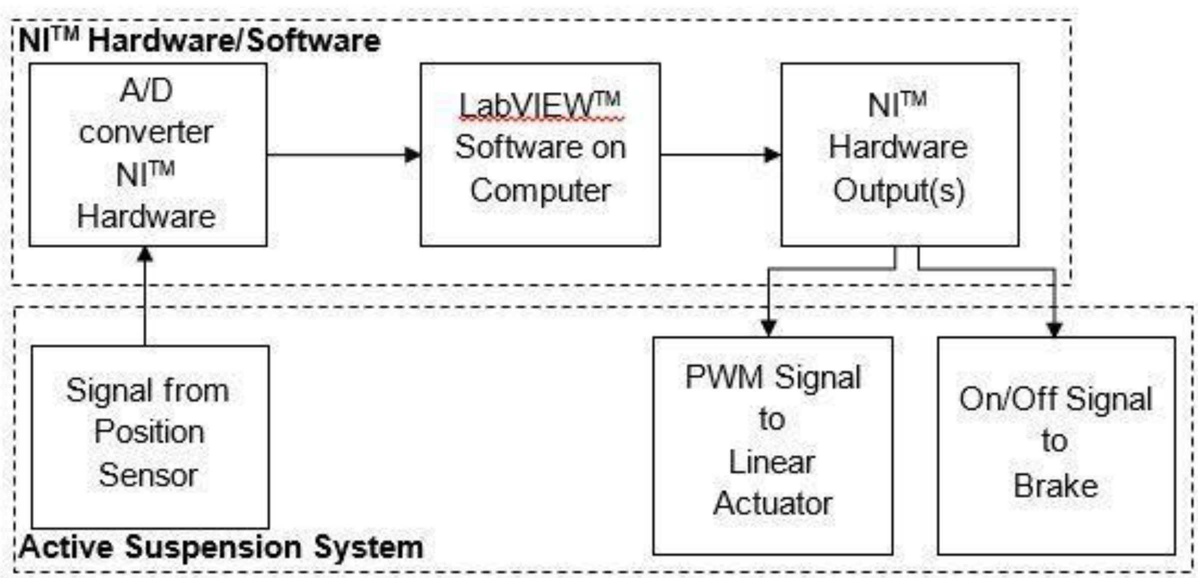

FIGURE 2: Controller Flow Chart

As disturbances are introduced to the system, a signal from the potentiometer is fed through an A/D converter in order to be processed by the controller software. The controller sends signals to the linear actuator to respond to the disturbance.

Preliminary Experimental Work

The first test conducted in the laboratory was to observe the disturbance on an oscilloscope. To ensure that the disturbance applied to the system was a pure sinusoidal signal. The results are pictured in figure 3 below. An oscilloscope Fast Fourier Transform (FFT) analysis on the waveform obtained from the disturbance indicated there was a second harmonic present in the signal. This means that the disturbance isn't a pure sinusoid, but it is still a viable input signal for the system.

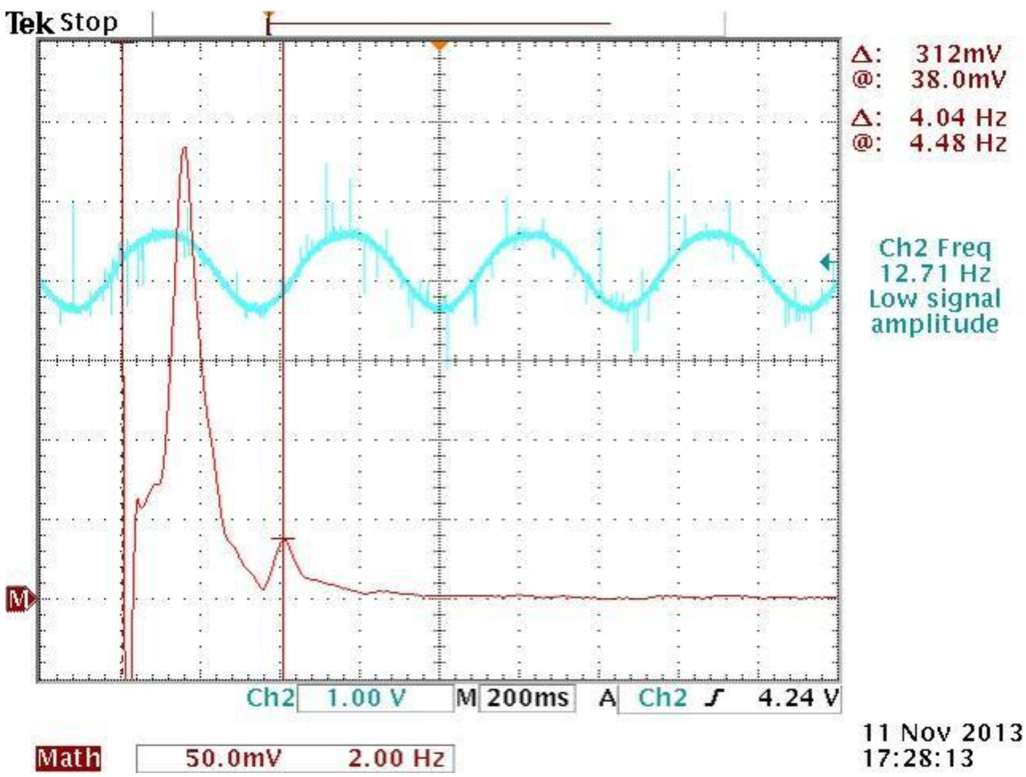

FIGURE 3: Disturbance Analysis

FFT analysis of the output from the position sensor (potentiometer) reveals that the disturbance is not a true sinusoid.

Disturbance equations [1]: r(t)=0.0127sin(ωt) [m]

or

r(t)=0.5sin(ωt) [in]

According to FFT analysis (Figure 3), the disturbance contains at least one other sine term.

Linear actuator torque to force equation:

$$F = \frac{T * 2\pi}{16\ [mm]}$$

Related Circuitry

The system will require isolation circuitry to protect the controller hardware from the relatively high voltages present in the suspension system. A schematic diagram of this circuitry is shown in figure 5. In addition to the protection circuitry, the H-Bridge will be constructed from two half-bridge modules. The resulting H-Bridge will be driven by an IR2110 driver as shown in figure 4 below. The IR2110 driver circuit requires the bootstrap arrangement consisting of the diode and capacitor as shown.

Bootstrap Circuit

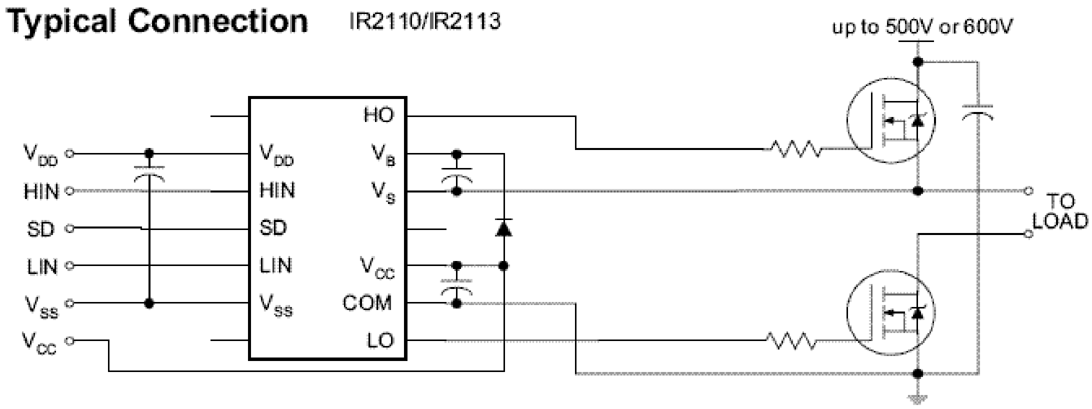

FIGURE 4: Bootstrap Circuit

Optical Isolator Circuit

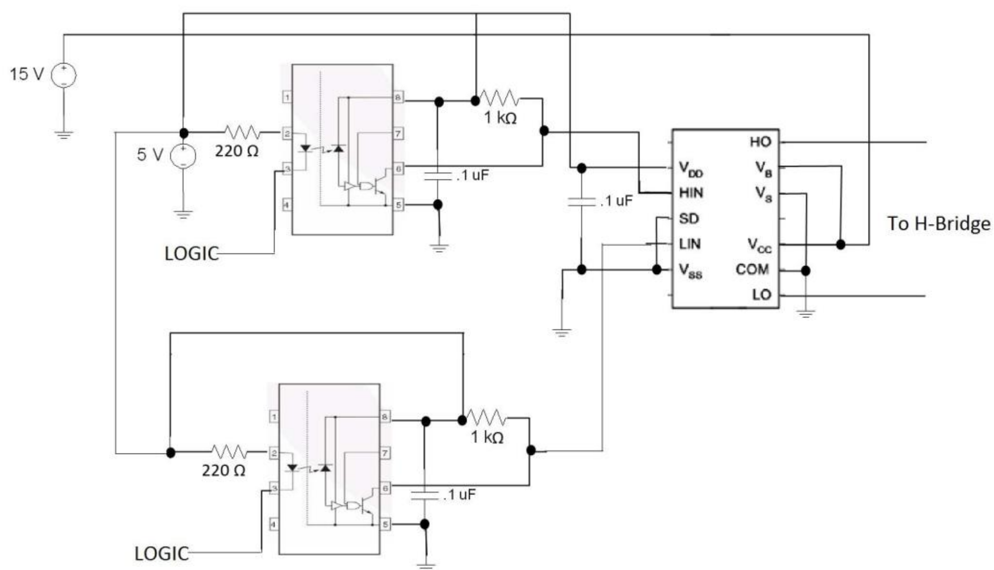

FIGURE 5: One Side of Logic/H-Bridge Isolation Circuit

Schedule

Work on the H-bridge and gate driver circuit will begin the semester along with system identification of the linear actuator. Once a model is obtained of the system, controller design will begin. After simulations of the controller and system model are successful, the H-bridge will be interfaced with the linear actuator and integration with the controller hardware and software can begin. As the schedule below shows, this integration will take place around week seven. During this time, work on the instruction manual will continue. If the controller design works as predicted by the last few weeks of the semester, an accelerometer will be added to the system and time will be dedicated to making the necessary adjustments.

Week 1	Start to Assemble H-bridge and gate driver circuit.
1/26/13 - 2/01/13	
Week 2	Finish Assembling H-bridge and gate driver circuit. Begin incorporating
2/02/13 - 2/08/13	National Instrument hardware to the system.
Week 3	Get Labview installed and communicating to the National Instrument hardware.
2/09/13 - 2/15/13	Begin to familiarize ourselves with the Labview software.
Week 4	Begin testing the Labview softare using the position sensor while sending
2/16/13 - 2/22/13	the system a disturbance.
Week 5	Begin programming to control the linear actuator to cancel out disturbances.
2/23/13 - 3/01/13	
Week 6	Continue programming for the controller. Possibly incorporating the use of an
3/02/13 - 3/08/13	accelerometer to the system.
Week 7	Begin producing a Labview tutorial.
3/09/13 - 3/15/13	
Week 8	Depending on progress, make possible addition of accelerometer to further accuracy
3/16/13 - 3/22/13	and precision of system
Week 9	Work on integration of accelerometer if time permits, otherwise continue
3/23/13 - 3/29/13	tuning controller
Week 10	Work on integration of accelerometer if time permits, otherwise continue
3/30/13 - 4/05/13	tuning controller
Week 11	Finish designing project web page. Also, have a working tutorial for LabVIEW
4/06/13 - 4/12/13	
Week 12	Make any corrections to tutorial and wrap up project
4/13/13 - 4/19/13	
Week 13	Finish and practice presentation.
4/20/13 - 4/26/13	

Equipment List

- Tektronix Agilent oscilloscope
- DC power supply
- NI cDAQ-9174 NI CompactDAQ 4-slot USB 2.0 Chassis, 9 V - 30 V Input Voltage Range
- NI 94012 Digital Input/Output Module
- NI 9215 4-Channel Differential Voltage A/D Module (16-bit resolution), 100 kS/s/ch sample rate, ± 10 V
- NI 9221 8-Channel Voltage A/D Module (12-bit resolution), 100 kS/s/ch sample rate, ± 60 V
- NI 9211 4-Channel Thermocouple Module (24-bit resolution, 100 kS/s/ch sample rate, ± 60 V
- Two Fairchild Semiconductor FMG2G75US60 (or equivalent) IGBT Power Modules
- Two IR2110 Drivers, (500 [V] maximum isolation voltage)
- Four 6N137 High Speed 10MBit/s Logic Gate Optocouplers

References

[1] Blake Boe and Tyson Richards. “Active Suspension System”, Senior Project, Electrical and Computer Engineering Department, Bradley University, May 2006, http://cegt201.bradley.edu/projects/proj2006/actss/

[2] IDC Motion EC2 Series Linear Actuator Data Sheet

[3] National Instruments Hardware Data Sheets