FPGA Implementation of Multiple Controllers for a Magnetic Suspension System

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Outline Of Presentation:

- Summary
- Goals
- Functional Description
- Block Diagram
- Functional Requirements
- Lab Work (Previous and New)
- Project Schedule
- Questions?

Summary

- Purpose → to implement previously designed multiple controllers that used current and position feedback to suspend a metallic ball with an electromagnet on a FPGA board instead of a xPC Target Box or dSPACE board.
- Why? → to minimize costs!
  - xPC Target Box ~ $7,000
  - dSPACE ~ $12,000
  - FPGA Board ~Less than $1,000

Goals

- To Implement Multiple Controllers for Rejection of Multiple Disturbances
- Build Op-Amp Circuits to Shift Voltage Signals to FPGA Levels
- Implement Controllers Using FPGA Board and Xilinx Software
- Created and Tested In Simulink
- FPGA Board Serving as Controller
- Minimize Steady-State Error, Overshoot, and Settling Time

Functional Description

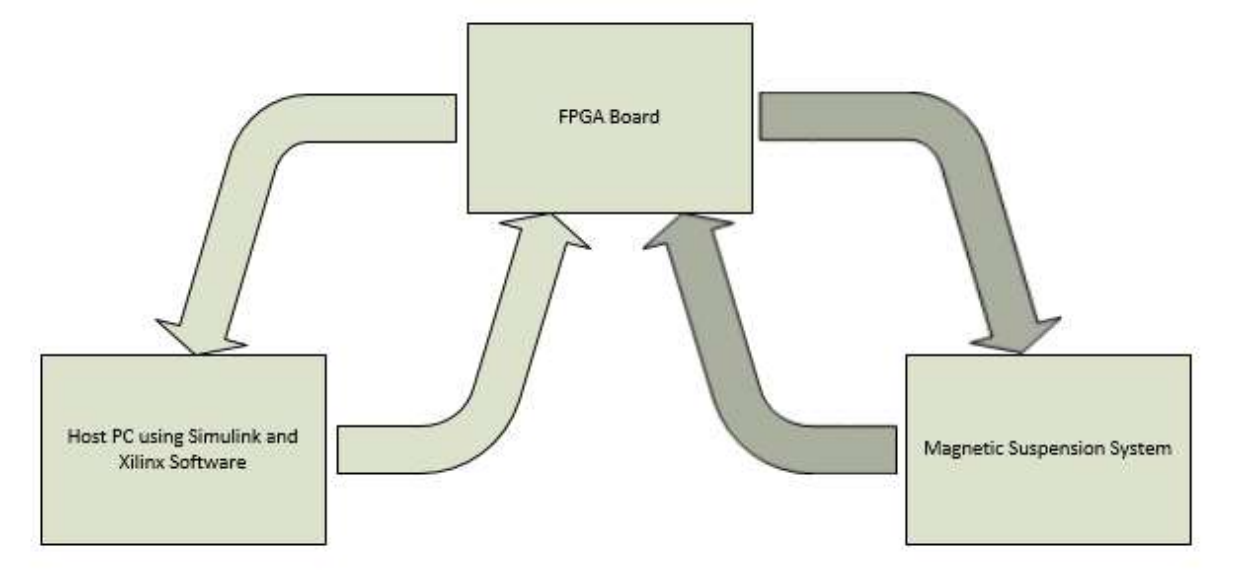
- Method of Choice:
  - Internal Model Principle

- Host PC using Simulink and Xilinx software
- FPGA Board with Controllers
- Magnetic Suspension System

Internal Model Principle

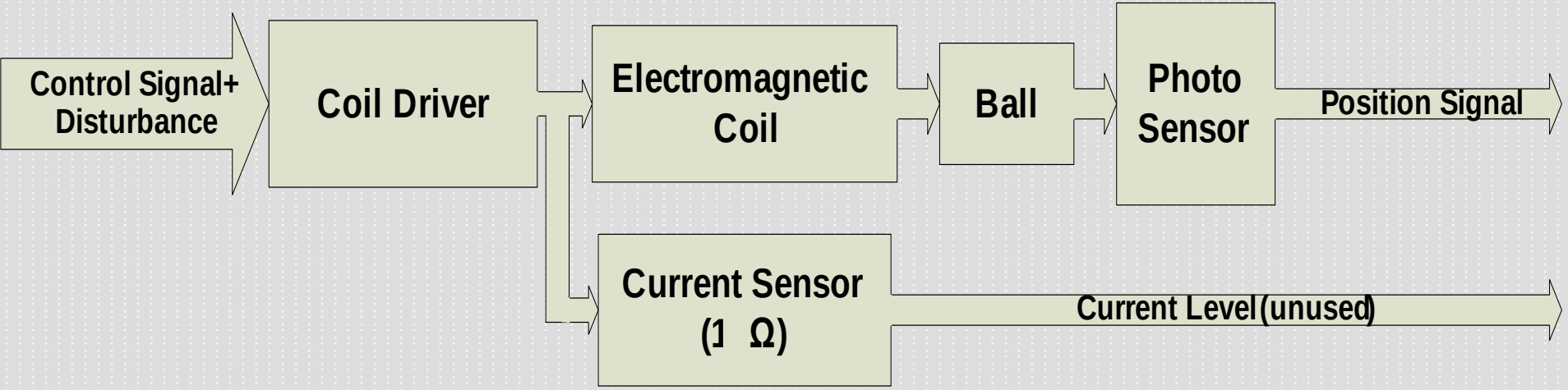
- Developed by B.A. Francis & W.M. Wonham
- Theory
  - Controller is designed to include a model of the disturbance to be rejected while also augmenting plant poles onto a desired transfer function. When disturbance is present in system, the model, having already accounted for it, rejects it and leaves the system output unchanged.

High-Level Functional Diagram



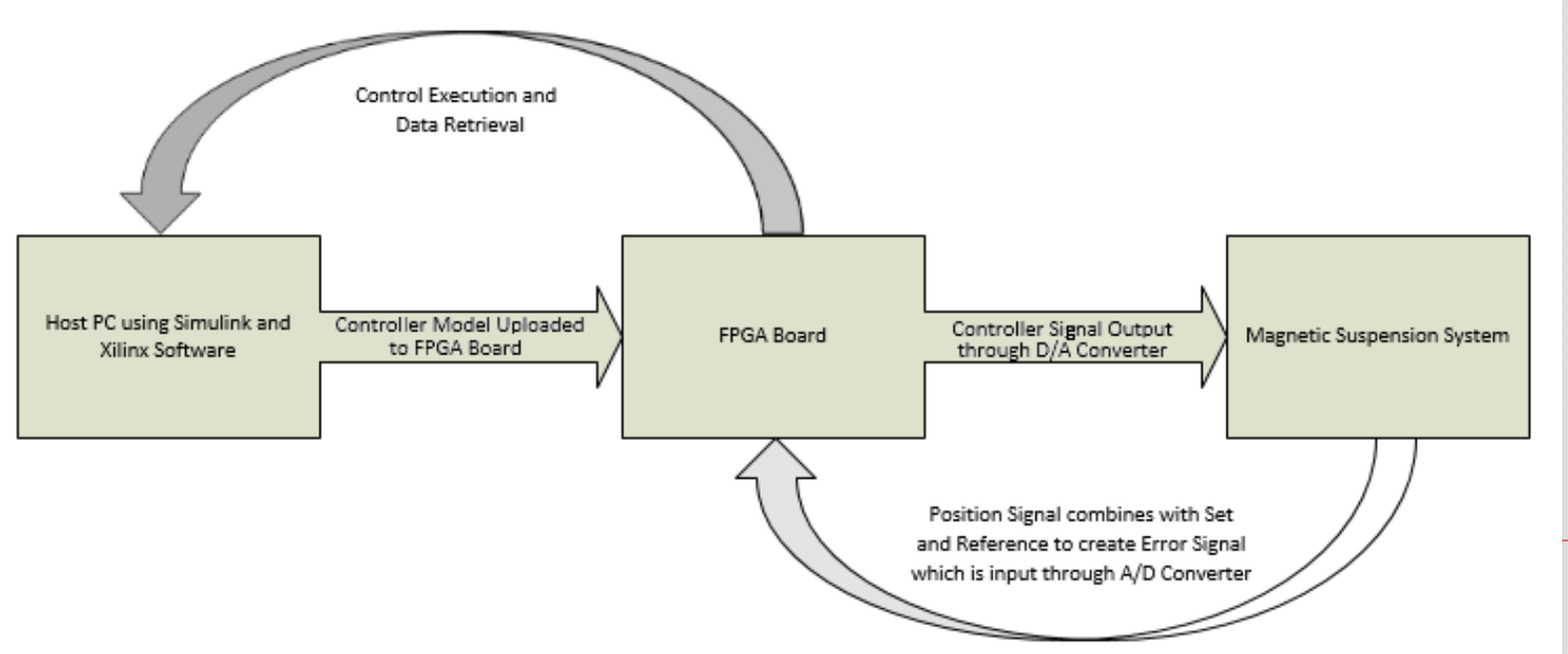
Magnetic Suspension System

- Control and Disturbance Drives Current
- Current Induces Magnetic Field
- Field Suspends Ball
- Sensor Translates Location into Voltage

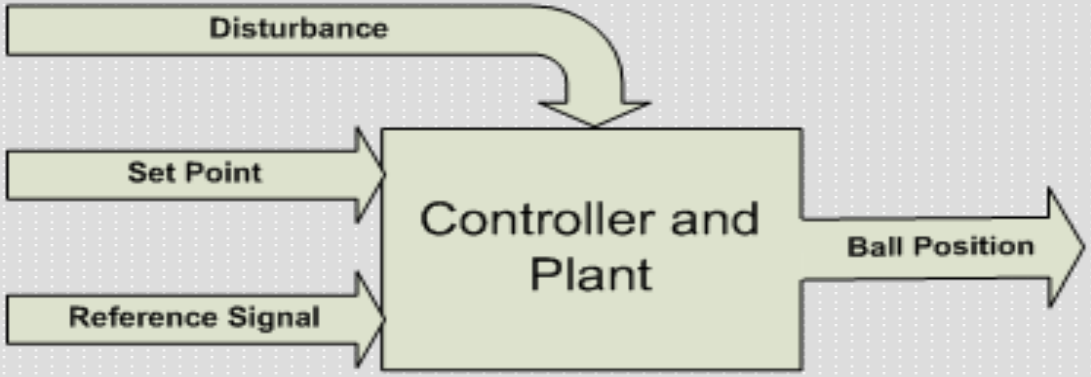


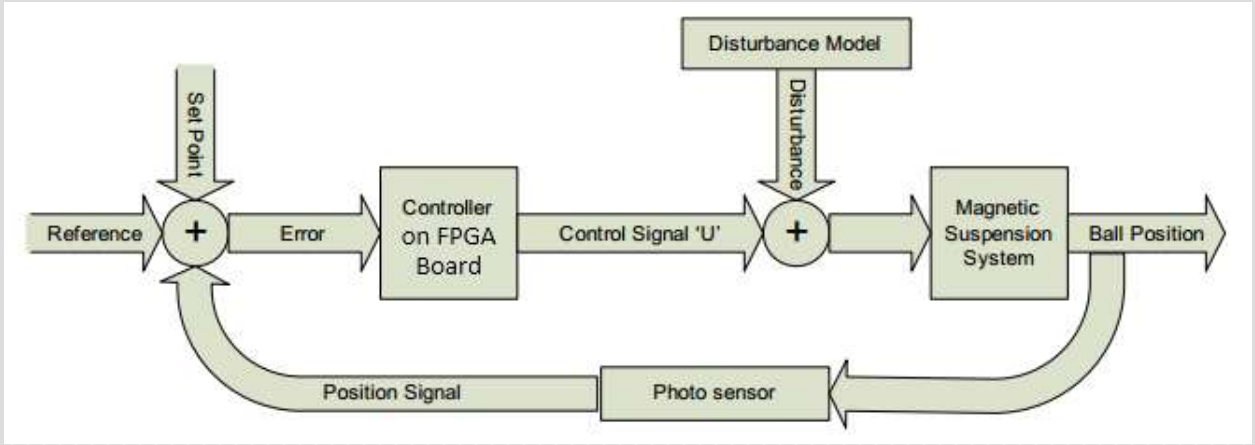
FPGA Board and Host PC

- Using 0V~3.3V ADC and DAC in FPGA Board
  - Resolution = 32 bits
- Download Controller, Upload Commands



Block Diagram



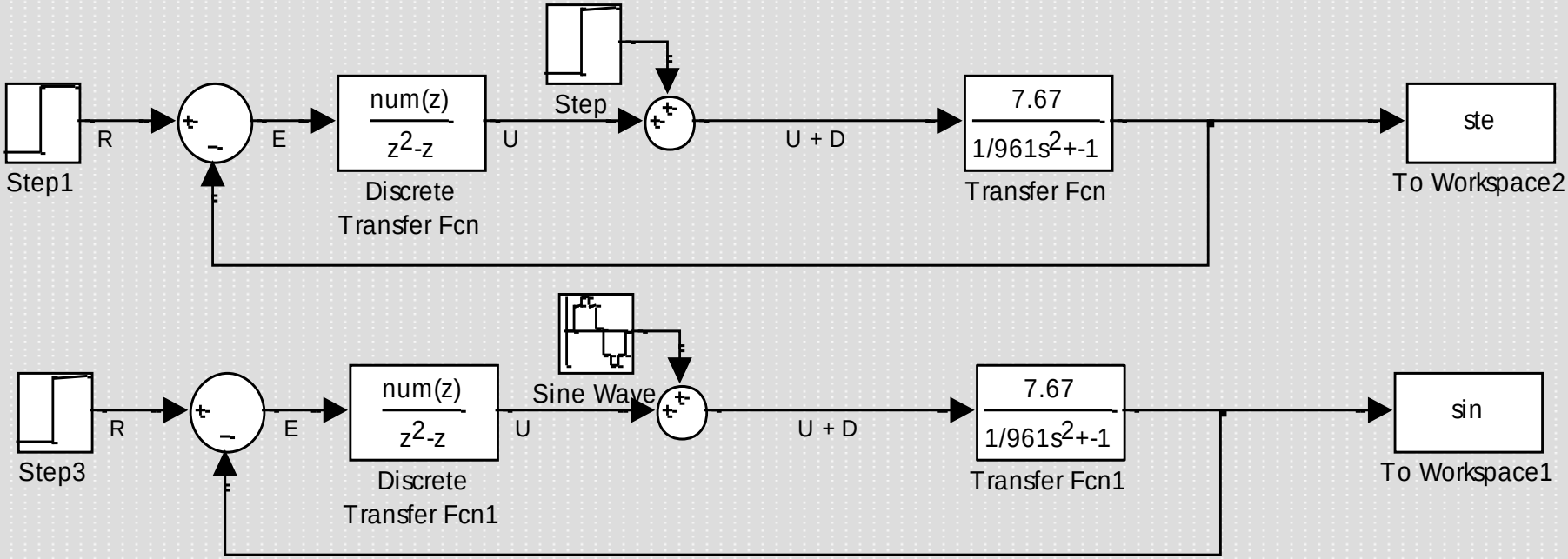


Functional Requirements

- Meet Specifications
  - Tracking of Reference Waveforms
  - Percent Overshoot
  - Settling Time
  - Steady State Error
- Input/output → User selectable
  - Sine, Square, Step Reference Waveforms
  - Set Point Ball Position
- Software Functionality → FPGA

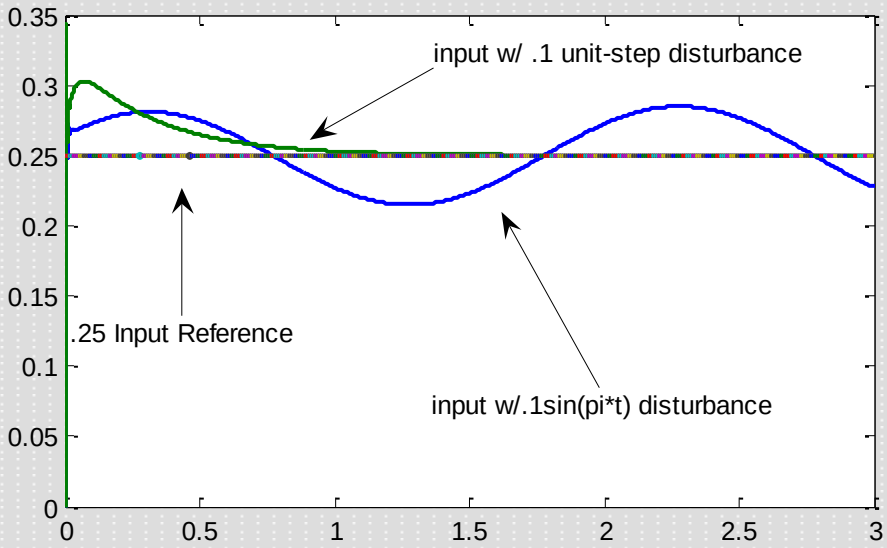
Dunlap's Previous Work

- Using Classical Controller



Dunlap's Previous Work

- Tested Classical Controller With Disturbance



- Rejected Step Disturbance

Completed Tasks

- ☑ Utilize Internal Model Principle
- ☑ Ramp and Step Disturbance
- ☑ Automated Controller Design
- ☑ Implement Controller In Simulink
- ☑ Test Voltage Ranges of Previous Controllers

Lab Work

- Tested Voltage Ranges of Multiple Controllers

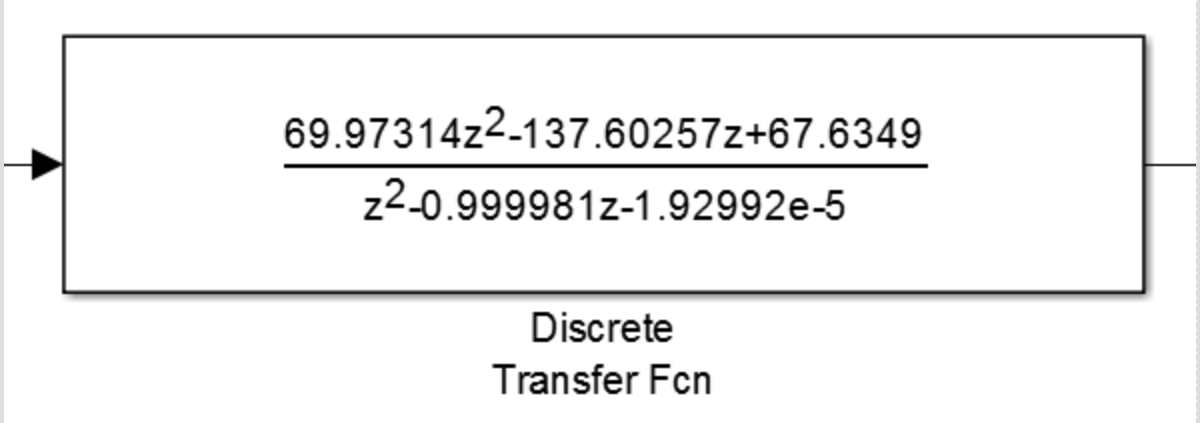
- dnlptutorialmag → -3V – 3V
- boline → -2V – 2V
- tutorialmag → -3V – 3V

- Desired Worst Case Range → -3V – 3V

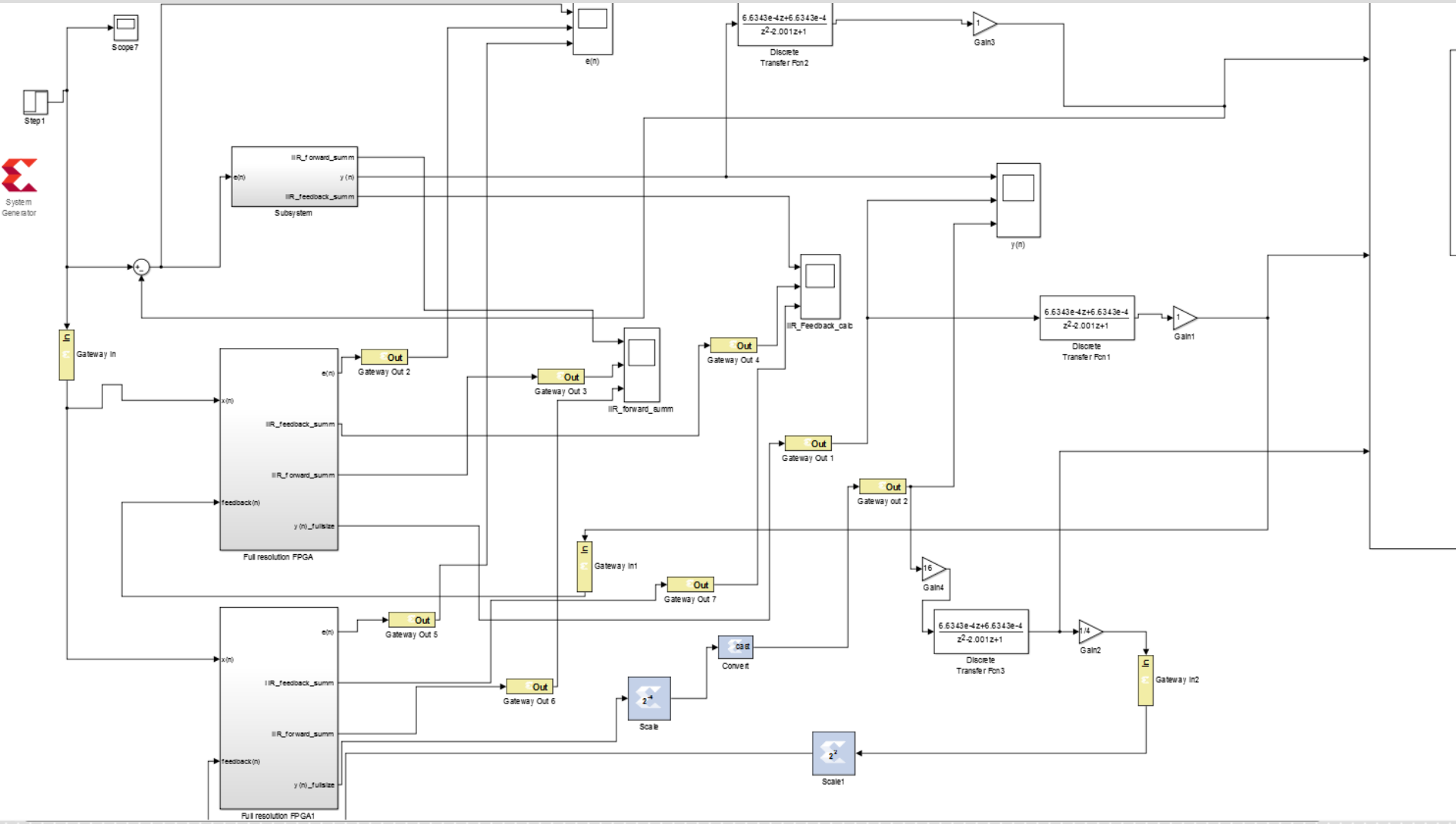
Dunlap's Simulink Controller

- Example of one Controller used

- Transfer Function

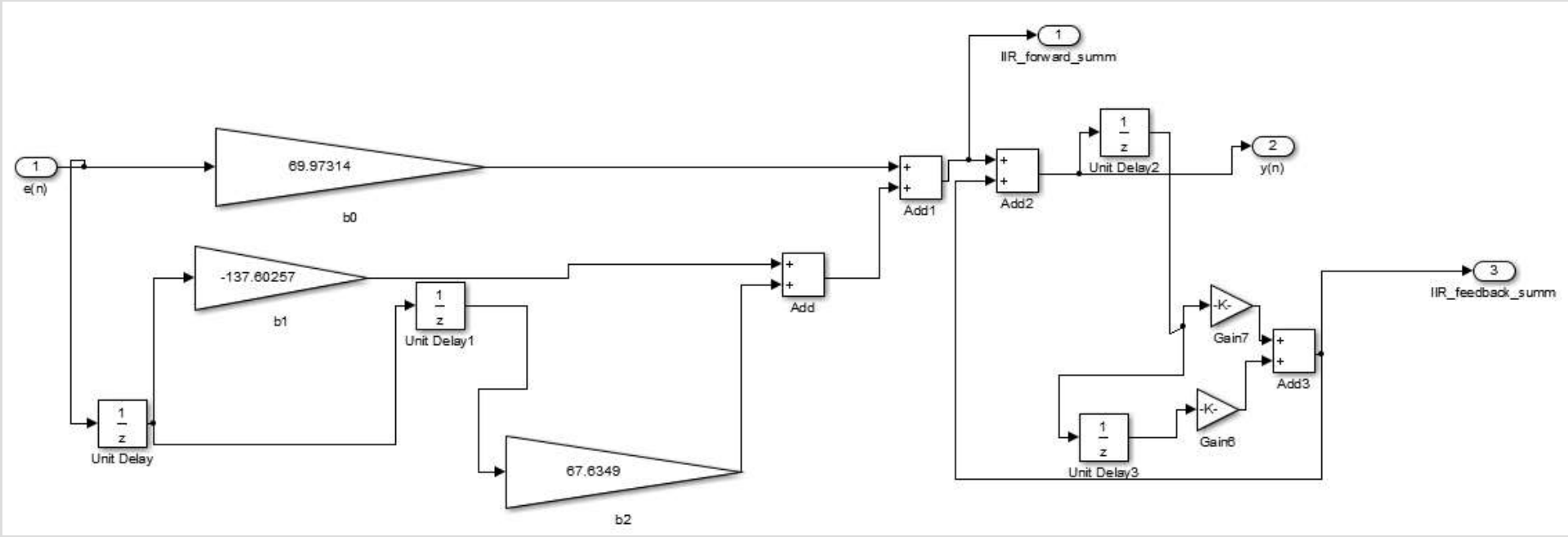


FPGA Implementation



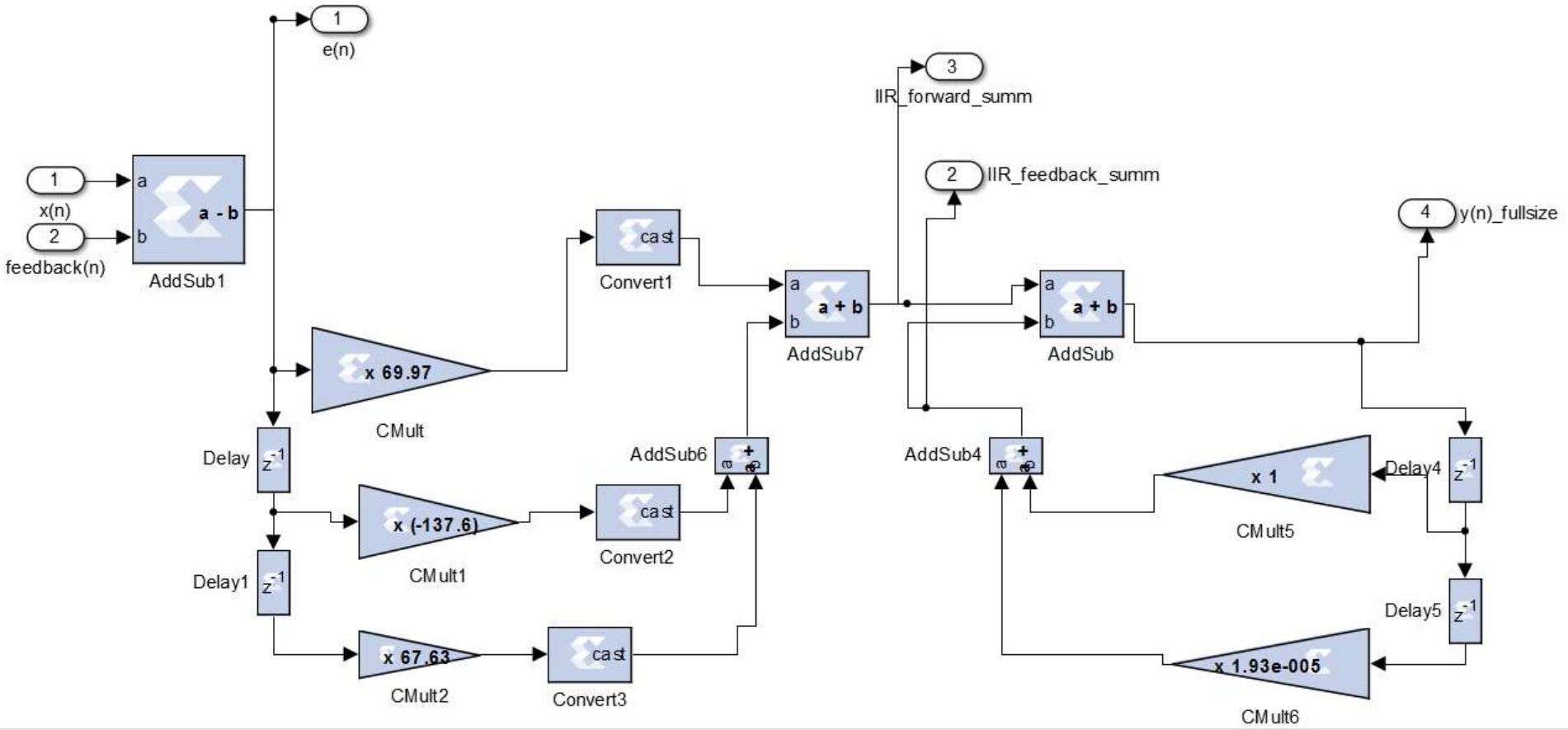
FPGA Implementation

Subsystem

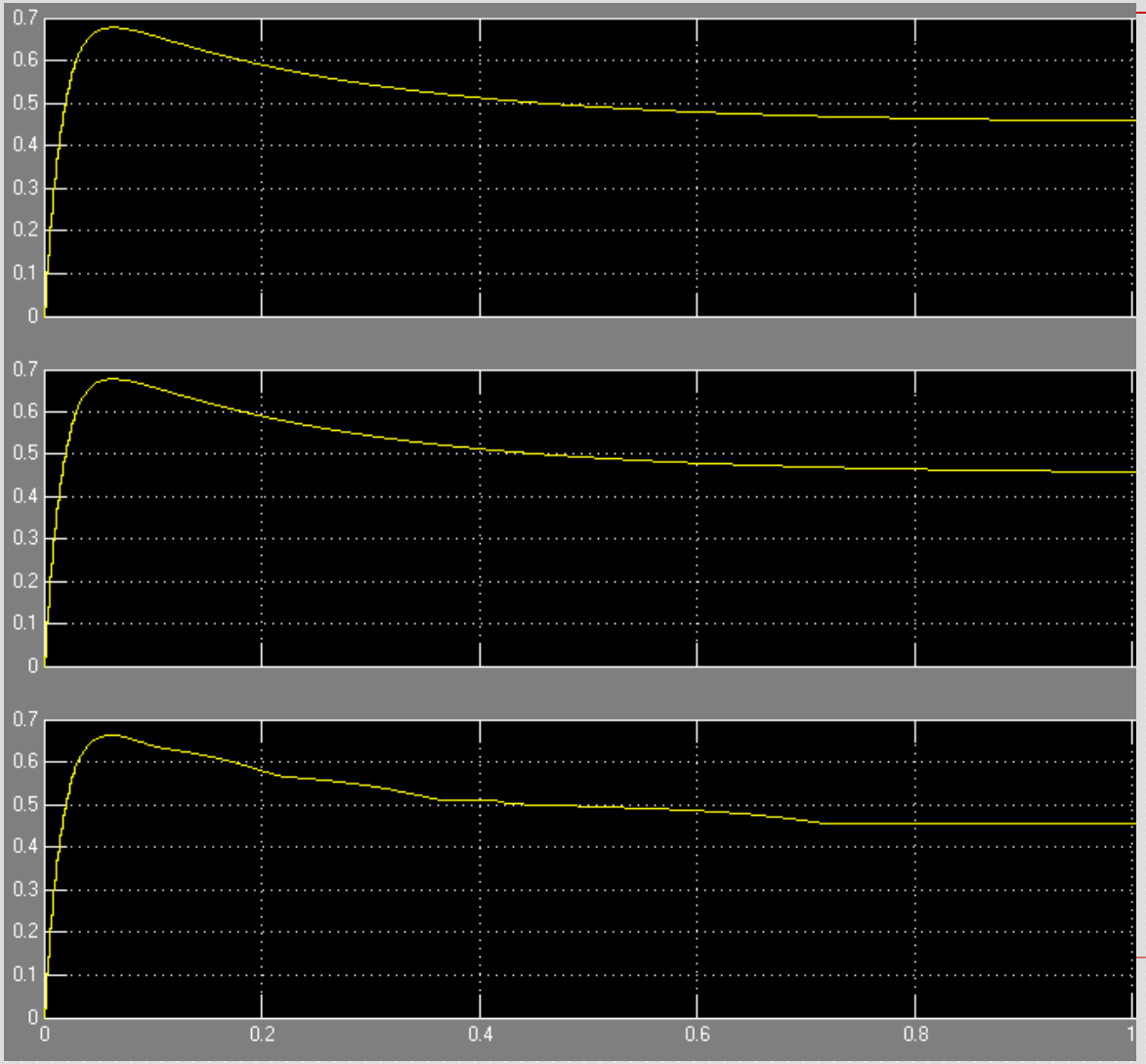


FPGA Implementation

Full Resolution FPGA (32 bits)



Simulink Results



← Original

← Using Xilinx

← Converting to FPGA Range (slight difference)

Project Schedule

- 2/27 – 3/13
  - Design, Build, and Test Op-Amp Circuits
  - Generate VHDL code and Implement on FPGA Board
  - Demonstrate Working Magnetic Suspension System
- 3/14 – 3/24
  - Spring Break
- 3/25 – 5/14
  - Final Report
  - Final Presentation
  - Project Demo
  - Student Expo??

References

[1] B.A. Francis and W.M. Wonham, “The Internal Model Principle of Control Theory,” *Automatica*. Vol. 12, pp 457-465, 1976.

[2] Jose A. Lopez and Winfred K.N. Anakwa, “Identification and Control of a Magnetic Suspension System using Simulink and dSPACE Tools”, Proceedings of the ASEE Illinois/Indiana 2003 Sectional Conference, March 27, 2004, Peoria, Illinois, U.S.A.

[4] Jon Dunlap, “Design of Disturbance Rejection Controllers for a Magnetic Suspension System”, Bradley University Department of Electrical and Computer Engineering, May 8, 2006, Peoria, Illinois, U.S.A

[4] Gary Boline and Andrew Michalets, “Magnetic Suspension System Control Using Position and Current Feedback”, Bradley University Department of Electrical and Computer Engineering, May 17, 2007, Peoria, Illinois, U.S.A

Questions?