Outline

- Goals
- Project Description/Requirements
  - Block Diagram, Functional Description, Requirements
- Equipment
- Implementation
- Progress Summary
- References

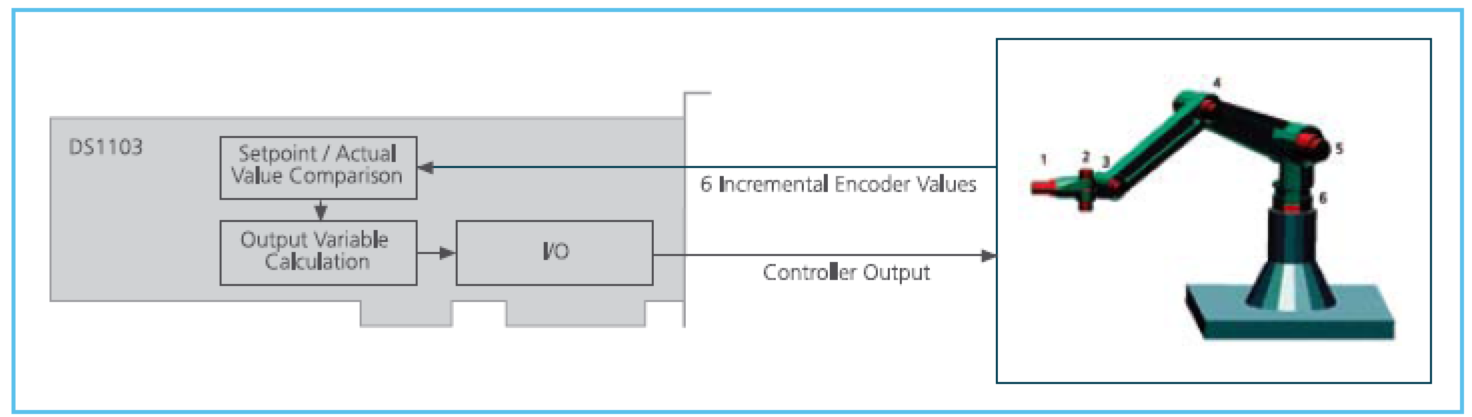
Goals

Decrease the learning curve for the use of the dSPACE DS1103 Workstation by future students by:

- Writing a Tutorial for use of the new DS1103 Workstation.
- Designing a controller to control the speed of a DC motor.
- Implementing the controller design using the DS1103 Workstation.

Suggested DS1103 Uses

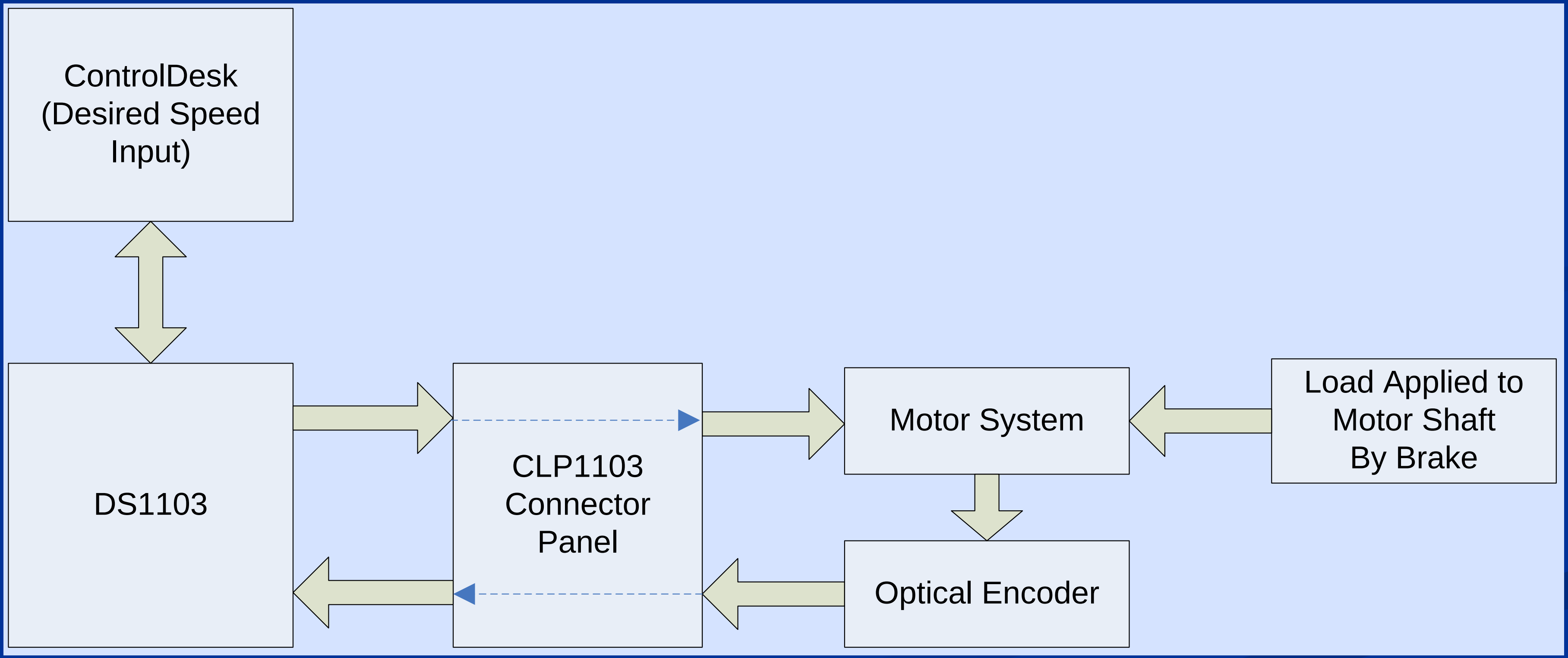
- Motor Control
- Robotics
- Automotive
- Magnetic Suspension Systems



Calculating a control algorithm for robotics on a DS1103 PPC Controller Board.

Project Description

Block Diagram



Description/Requirements I

- ControlDesk software:
  - Installed on PC.
  - Downloading, Monitoring, Changing (Speed) Inputs.
- Controller:
  - One or more designs.
  - Simulink and RTI blocks.
  - PWM Output.
  - Optical Encoder Input.

Description/Requirements II

- Motor System:
  - PWM Signal sent through Control Panel and Additional Hardware before entering motor.
- Optical Encoder:
  - Optical Encoder Input directly to Incremental Encoder Input of Control Panel.
- CLP1103 LED/Connector Panel:
  - Connect Inputs/Outputs between DS1103 Board and Hardware.

Controller Requirements

- DC motor speed controller designed/simulated using Simulink and dSPACE blocksets, Matlab-to-DSP interface libraries, the Real-Time Interface to Simulink, and Real-Time Workshop.

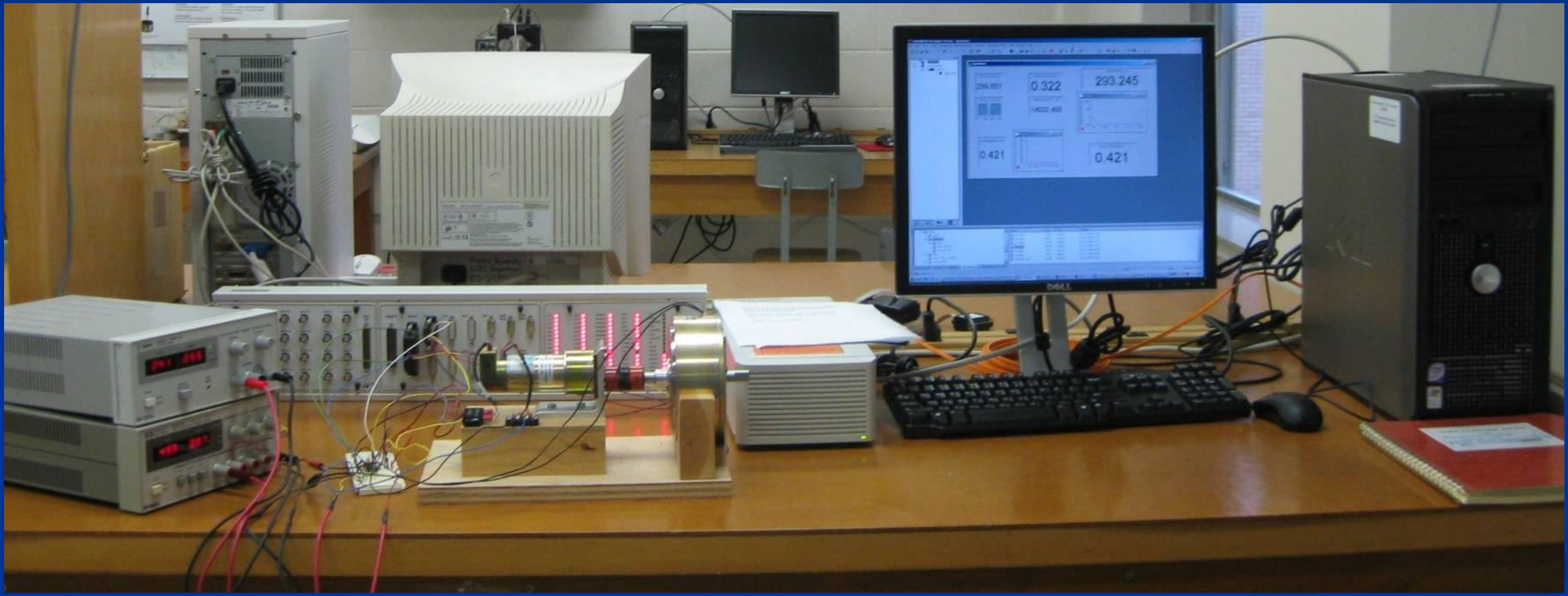
- Overshoot less than or equal to 5%.
- Rise time less than or equal to 110 ms.
- Minimize Steady-state Error.

Equipment: Workstation

- $14,000 dSPACE DS1103 system consisting of:
  - DS1103 Board.
  - Expansion Box.
  - CLP1103 PPC Connector and LED Panel.
  - ControlDesk Version 3.2.2/Other dSPACE provided Software Applications.

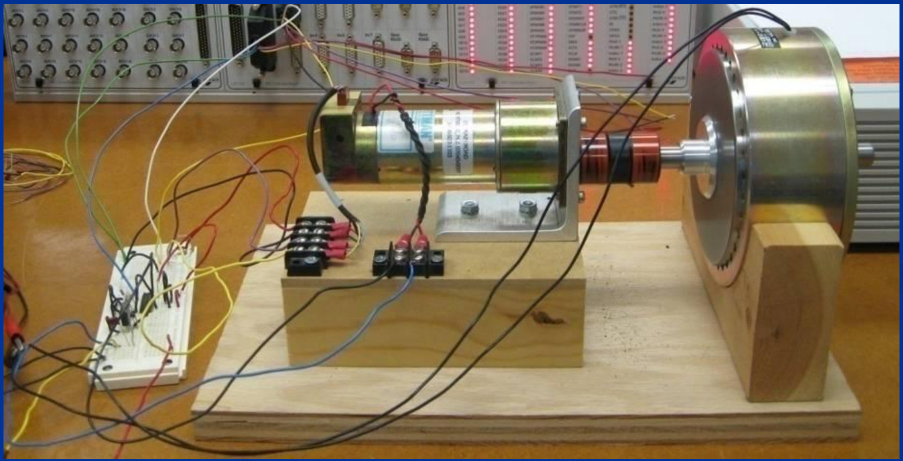
- PC dedicated to the workstation containing other software applications required (Matlab/Simulink Version R2008a and libraries).

DS1103 Workstation

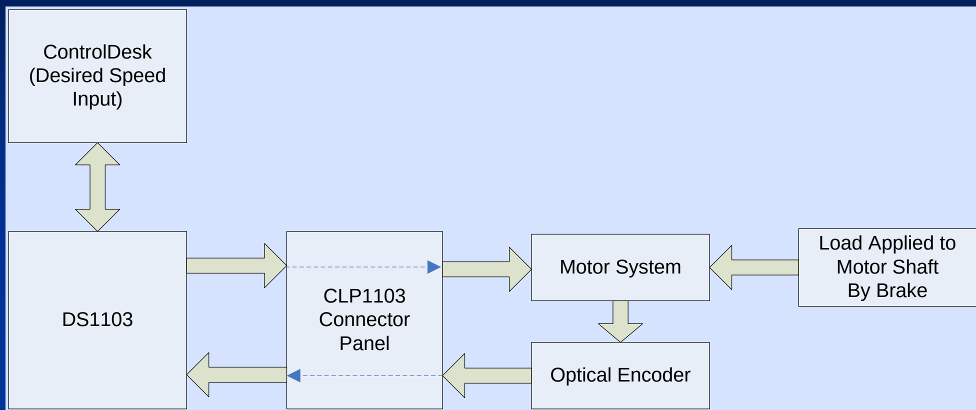


Equipment: Other

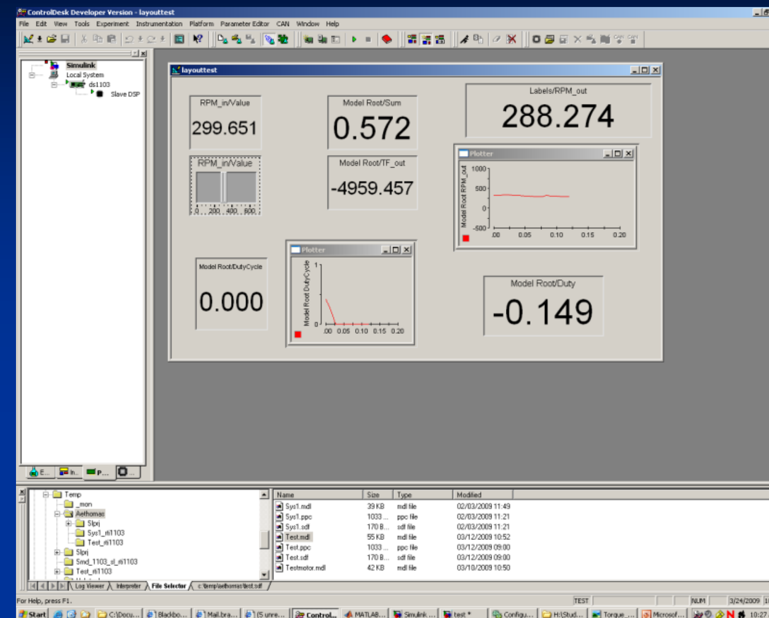
- Pittman GM9236C534-R2 DC Motor.
- Magtrol HB-420 Brake.
- TIP120 Transistor.
- IN4004 Diode.
- SN7407 Hex Inverters.
- Other electronic components, power supplies, and measurement devices.



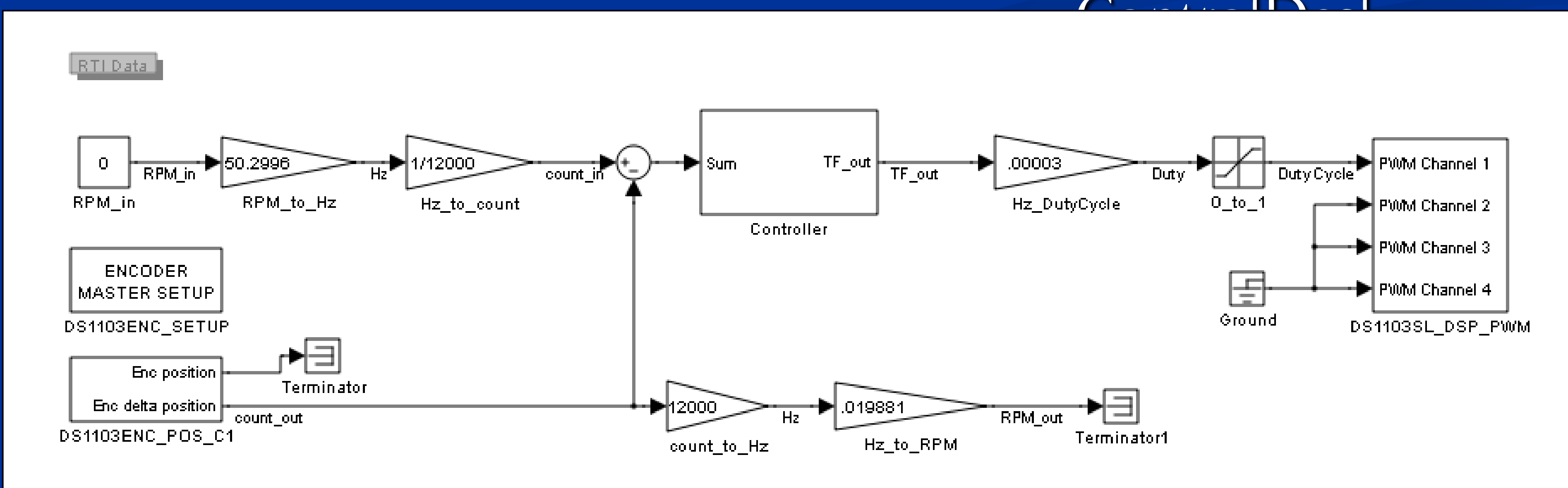
Implementation



Block Diagram

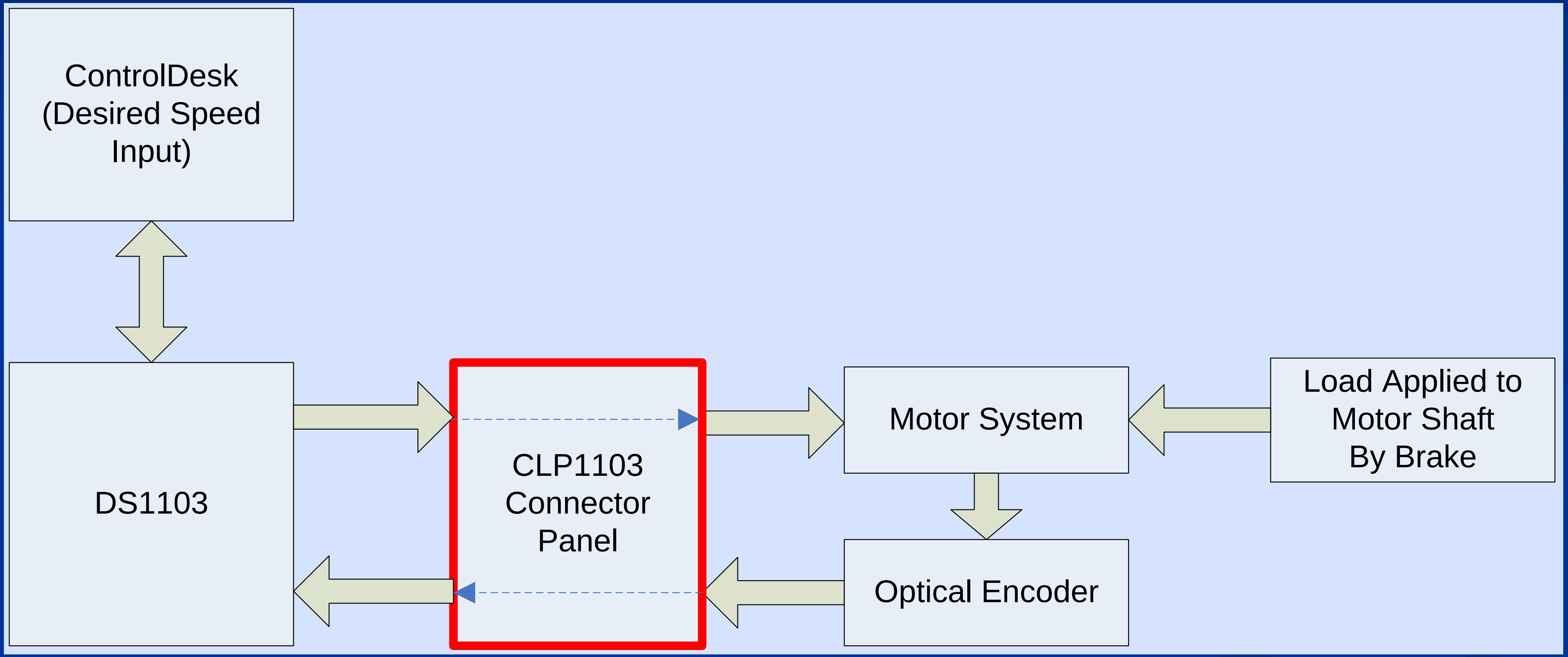


ControlDesk



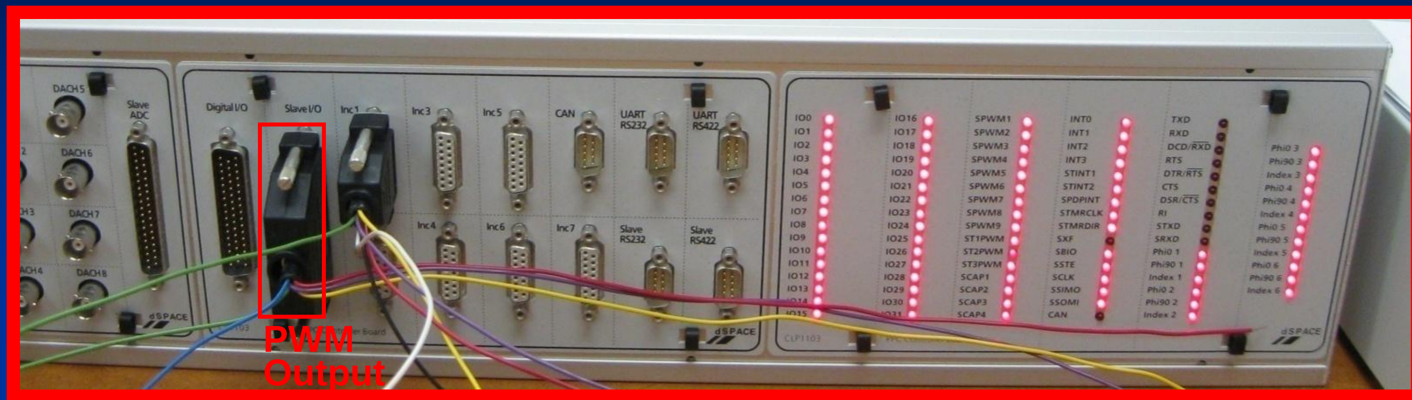
Simulink Model

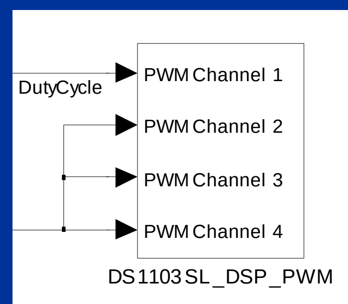
Connector Panel

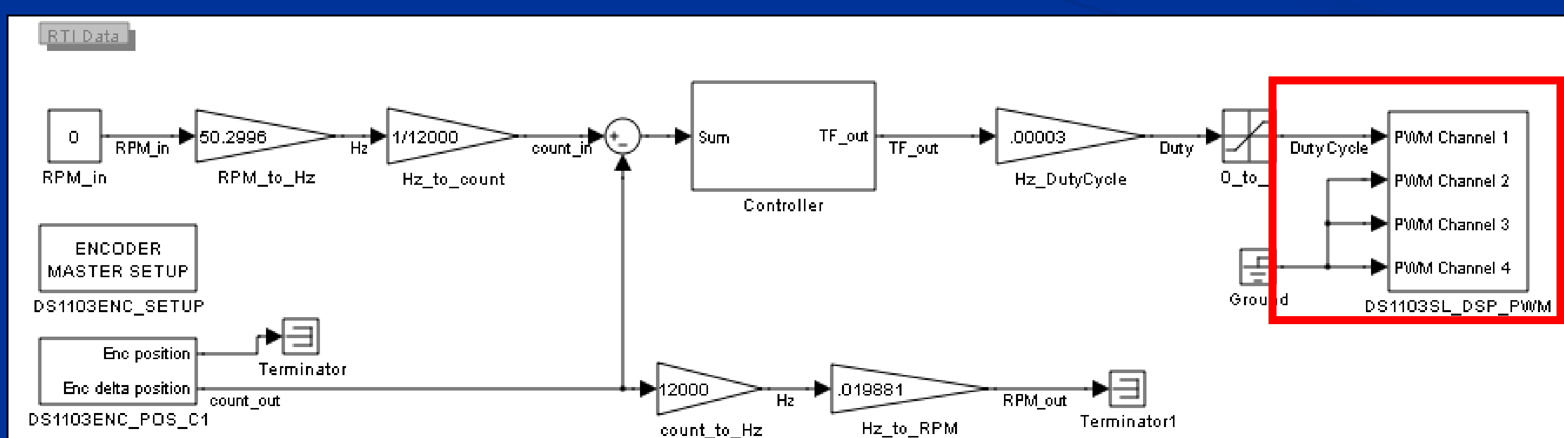


- PWM Output to Motor
- Incremental Encoder Input

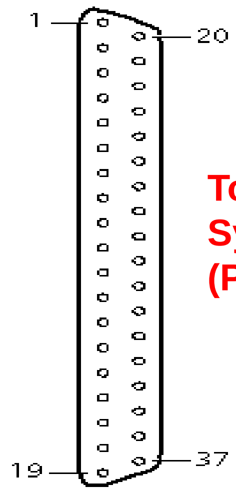
PWM Output I


PWM
Output


DutyCycle
PWM Channel 1
PWM Channel 2
PWM Channel 3
PWM Channel 4
DS1103SL_DSP_PWM


RTI Data
0
RPM_in
RPM_in
50.2996
RPM_to_Hz
Hz
1/12000
Hz_to_count
count_in
Sum
TF_out
Controller
TF_out
.00003
Hz_DutyCycle
Duty
0_to_
Duty Cycle
PWM Channel 1
PWM Channel 2
PWM Channel 3
PWM Channel 4
Ground
DS1103SL_DSP_PWM
ENCODER MASTER SETUP
DS1103ENC_SETUP
Enc position
Enc delta position
DS1103ENC_POS_C1
Terminator
count_out
12000
count_to_Hz
Hz
.019881
Hz_to_RPM
RPM_out
Terminator1

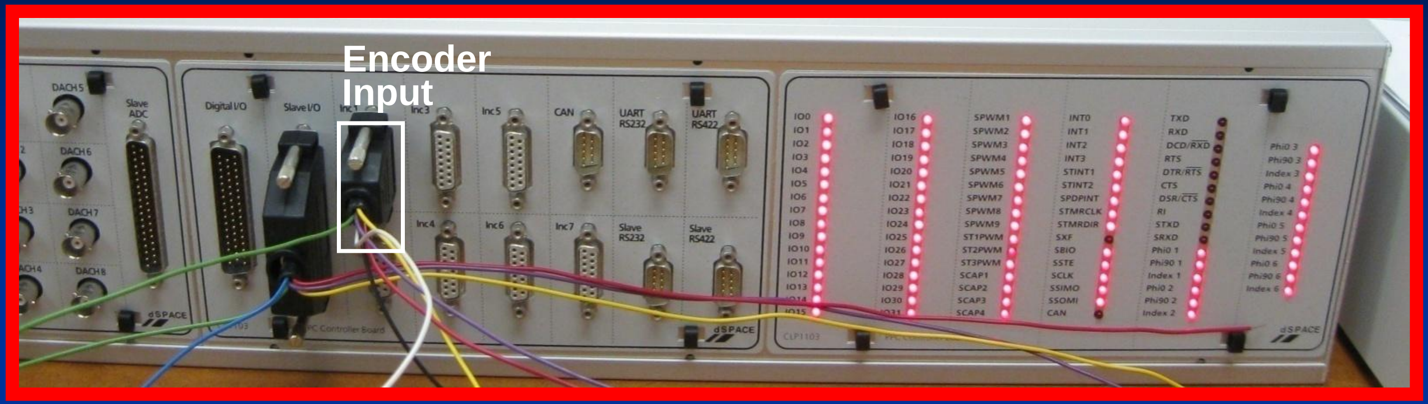
PWM Output II

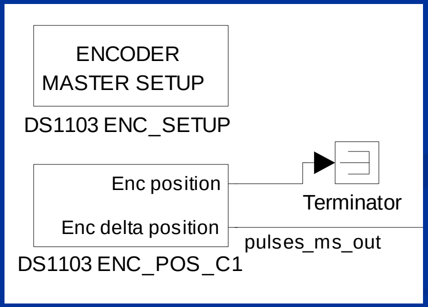


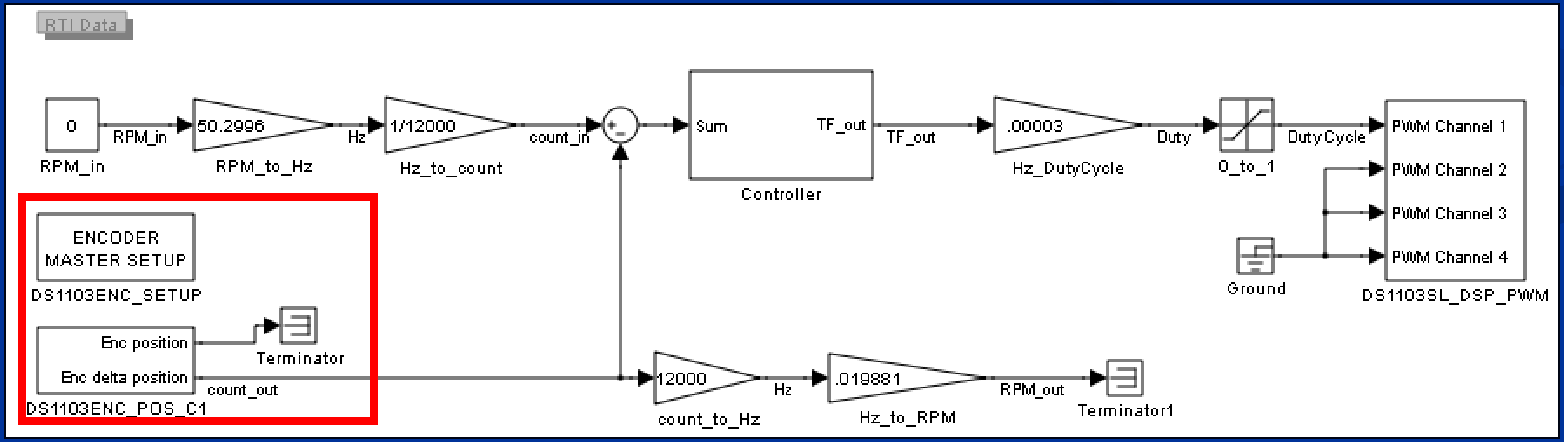
Slave I/O Connector (CP31)	Pin	Signal	Pin	Signal
	1	GND		
	2	SCAP1	20	GND
	3	SCAP3	21	SCAP2
	4	GND	22	SCAP4
	5	ST2PWM	23	ST1PWM
	6	GND	24	ST3PWM
	7	SPWM1	25	GND
	8	SPWM3	26	SPWM2
	9	SPWM5	27	SPWM4
	10	SPWM7	28	SPWM6
	11	SPWM9	29	SPWM8
	12	STMRCLK	30	GND
	13	GND	31	STMRDIR
	14	STINT1	32	SPDPINT
	15	GND	33	STINT2
	16	SSIMO	34	SSOMI
	17	SCLK	35	SSTE
	18	SXF	36	SBIO
	19	VCC (+5 V)	37	GND

To Motor System (PWM Ch. 1)

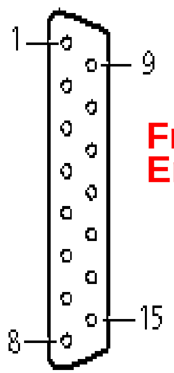
Incremental Encoder Input I



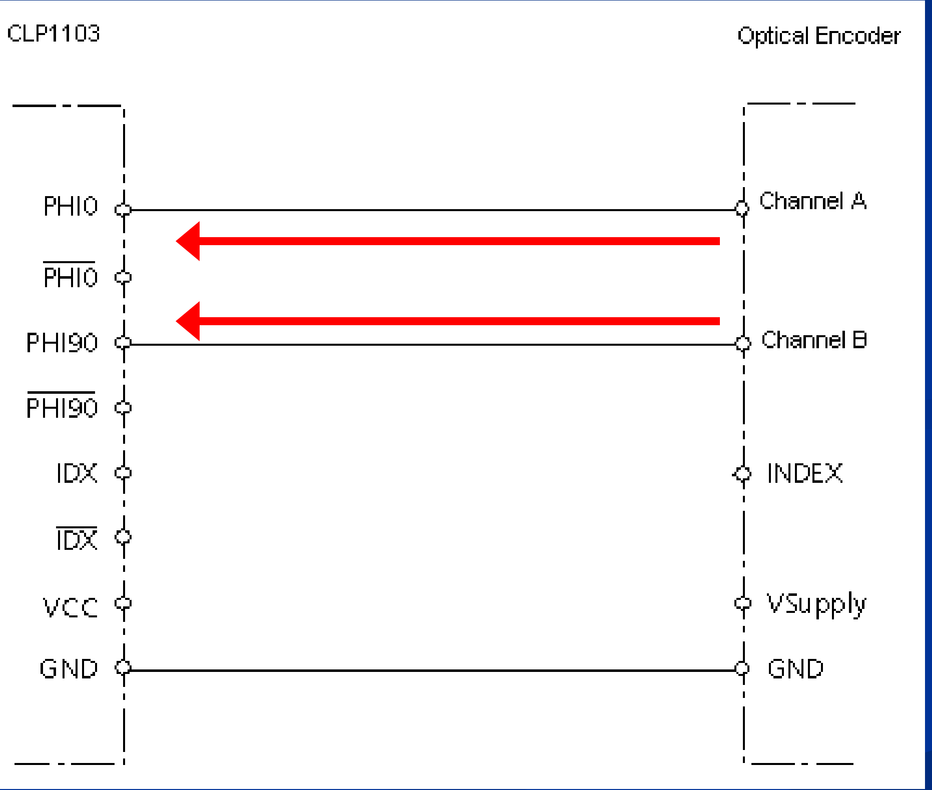




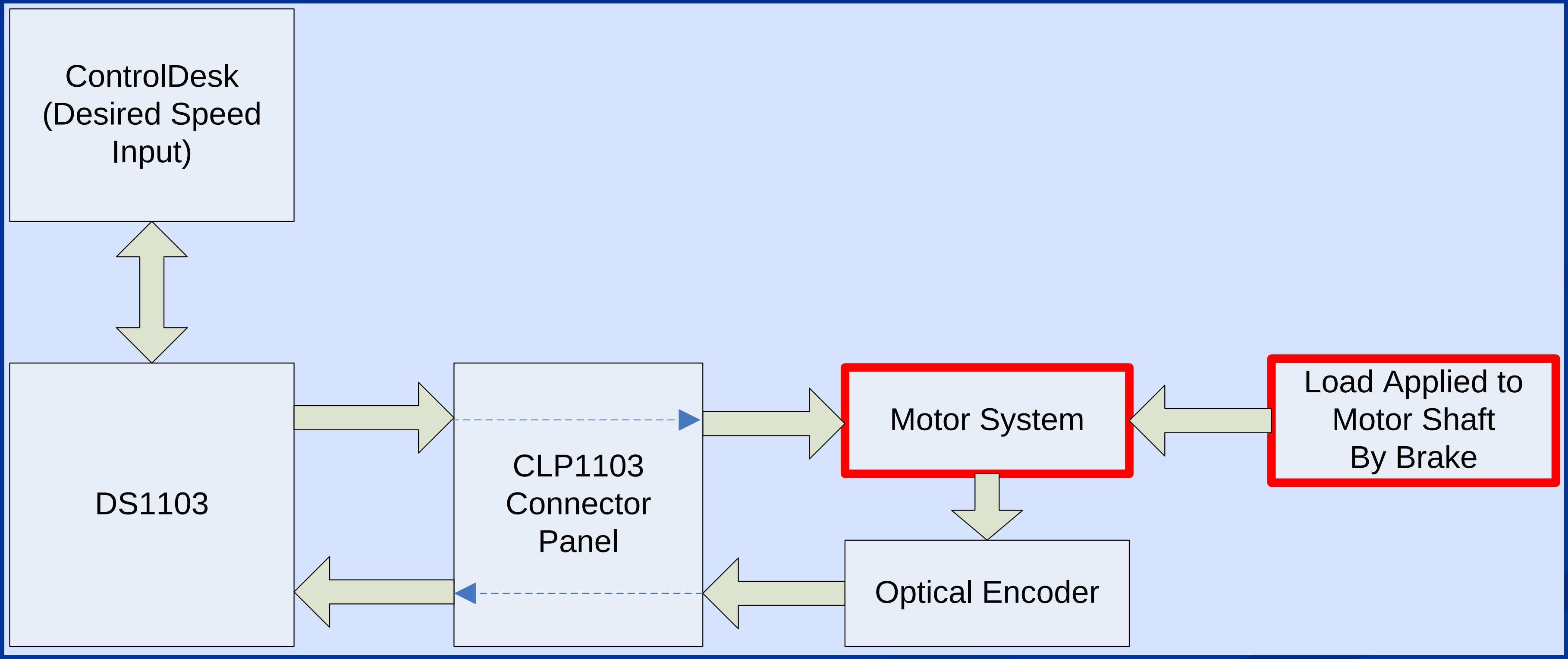
Incremental Encoder Input II

Connector (CP19, CP20)	Pin	Signal	Pin	Signal
	1	VCC (+5 V)		
	2	PHI0(x)	9	VCC (+5 V)
	3	$\overline{\text{PHI0(x)}}$	10	GND
	4	PHI90(x)	11	GND
	5	$\overline{\text{PHI90(x)}}$	12	GND
	6	IDX(x)	13	GND
	7	$\overline{\text{IDX(x)}}$	14	GND
	8	GND	15	GND

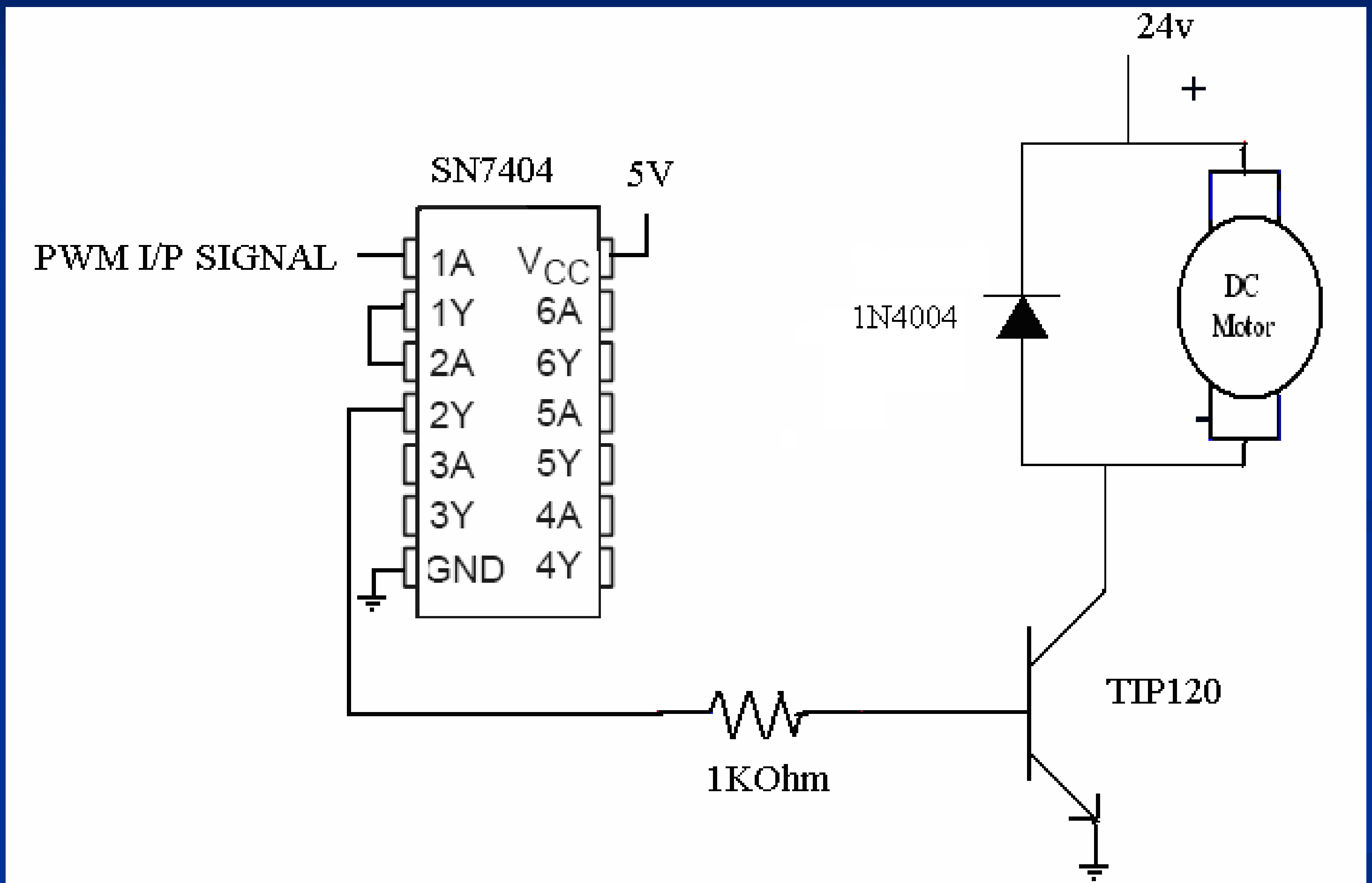
From Encoder



Motor System & Brake



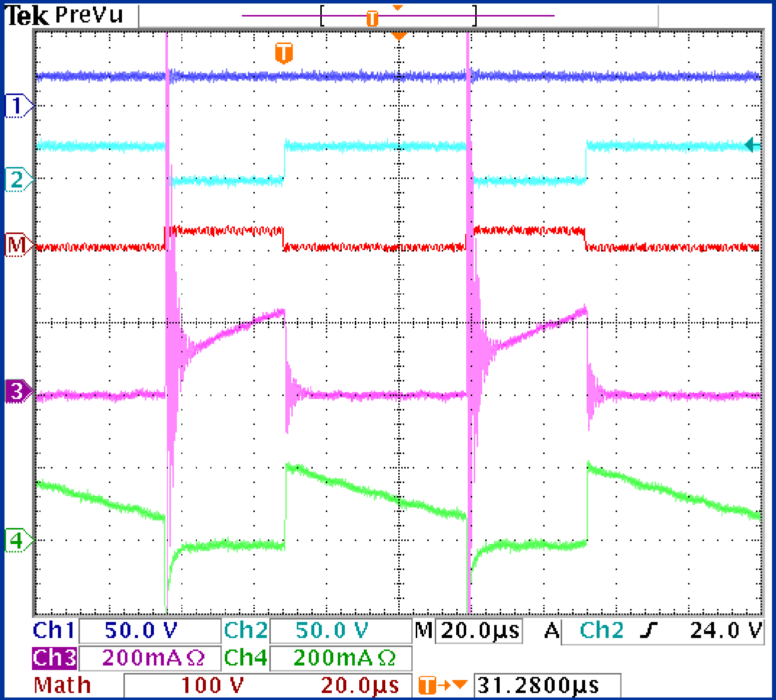
Motor System



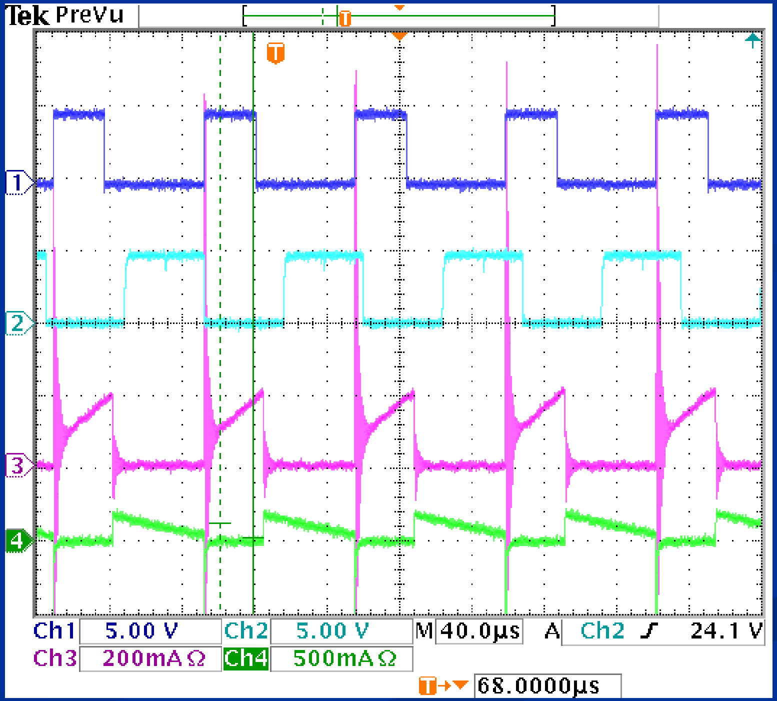
Hex Inverters (Buffer), NPN Darlington Transistor, and Diode

Unit Step (238.57 RPM) Input

- Ch 1: Supply Voltage
- Ch 2: Voltage at Collector
- MATH: Motor Voltage

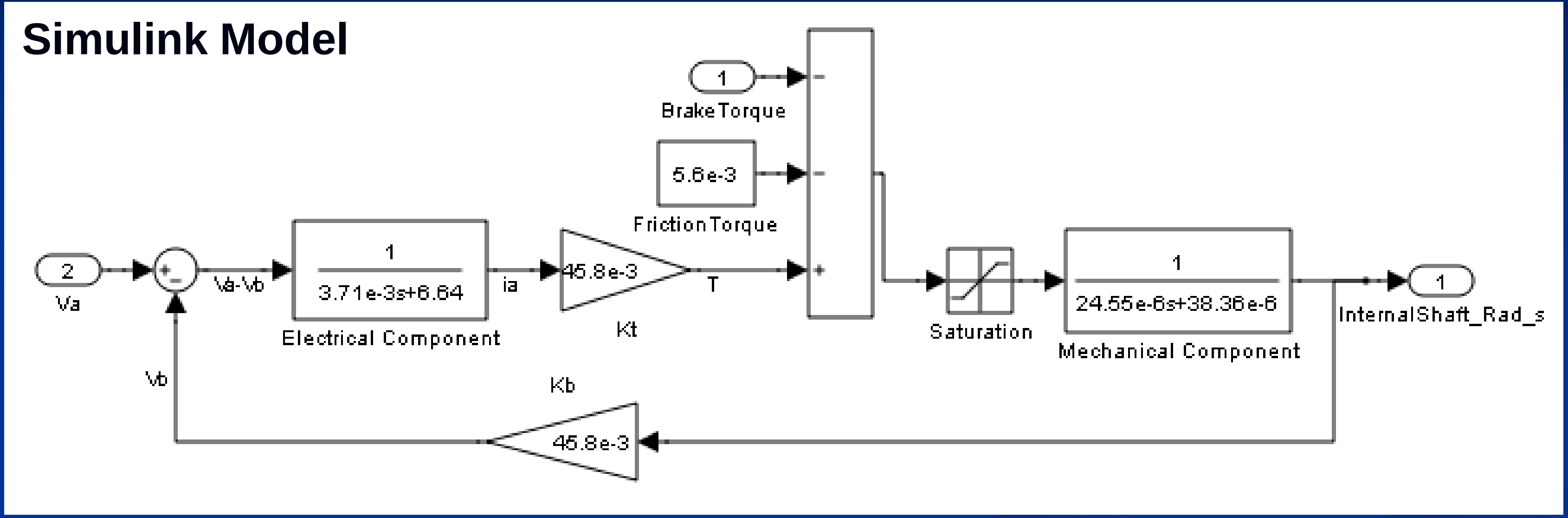


- Ch 1: PWM
- Ch 2: Encoder



- Ch 3: Motor Current
- Ch 4: Diode Current

Motor Model

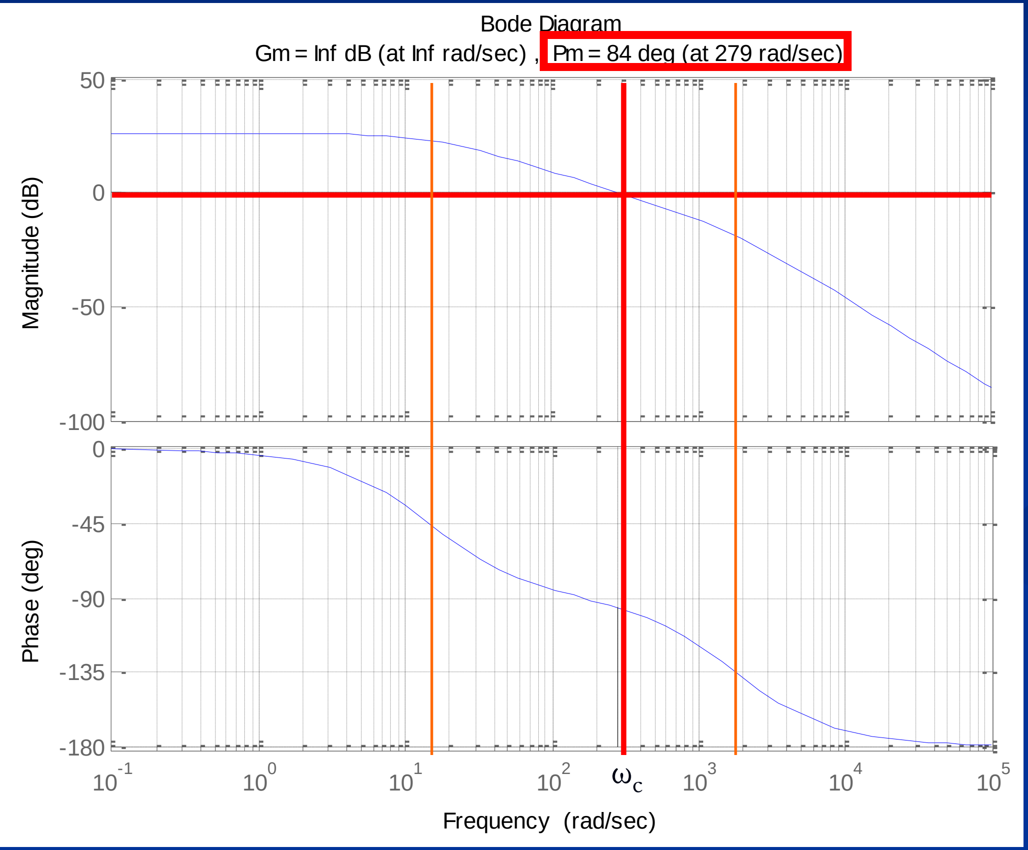


See "Current Motor Model" reference on Reference II slide.

Transfer Function (Torque components ignored):

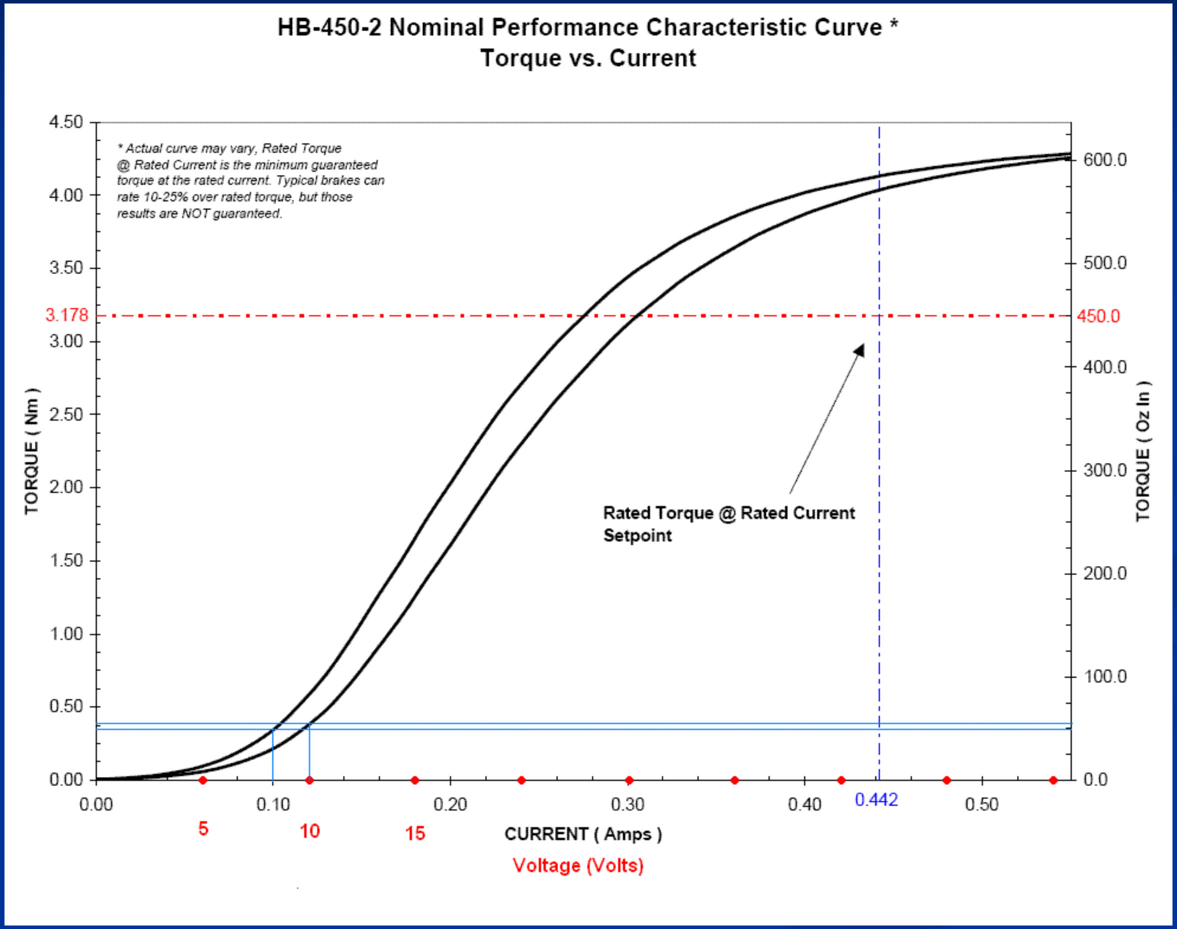
$$\frac{502852}{(s+14.54)(s+1776.78)} \cong \frac{19.4699}{\left(\frac{s}{14.54}+1\right)\left(\frac{s}{1776.78}+1\right)}$$

Motor Model Response



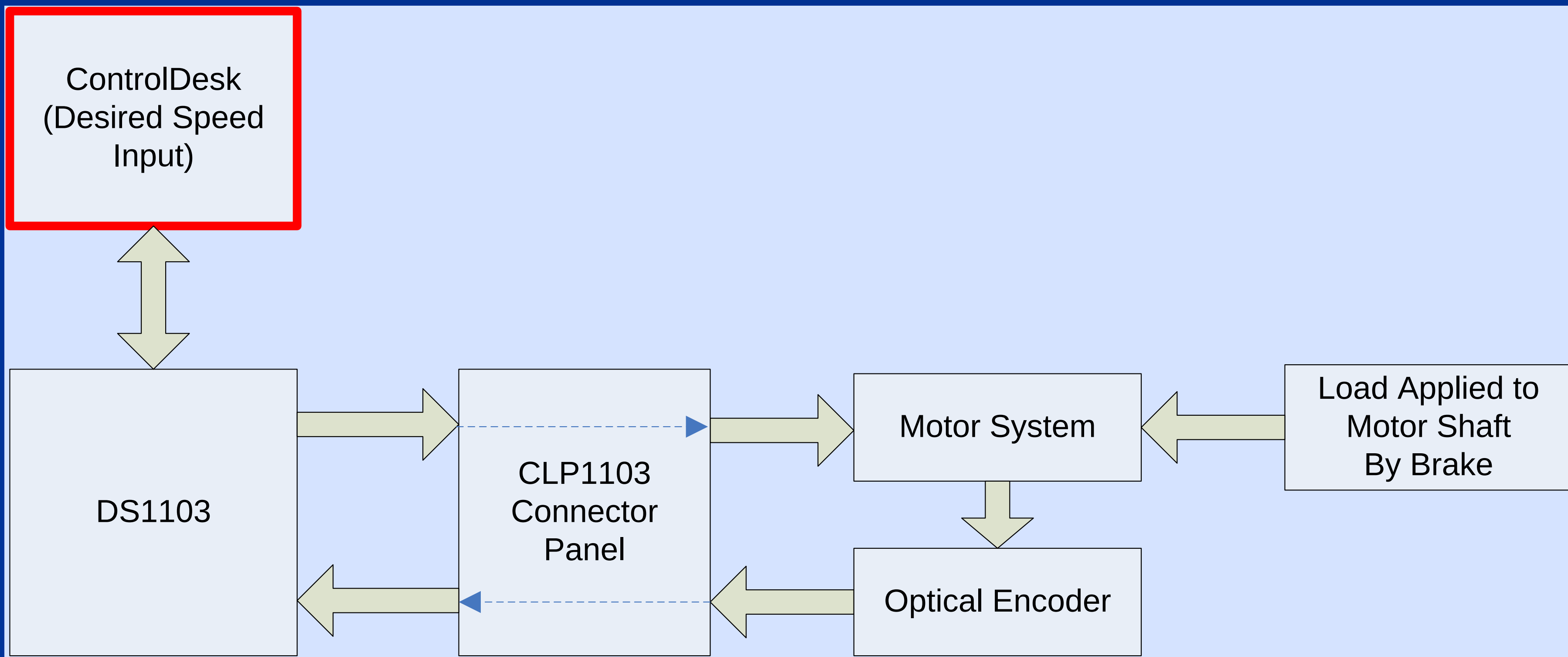
- Phase Margin = 84°.
- $\omega_c = 279$ rad/s

Brake

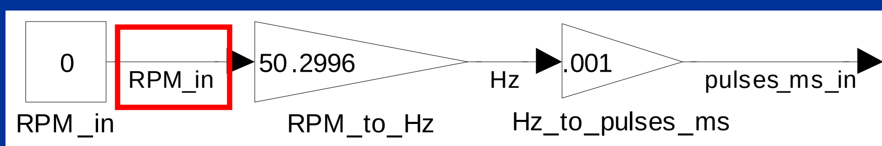


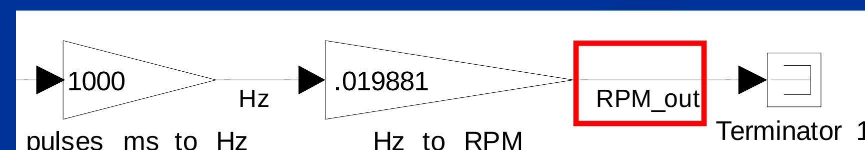
- Systems Stops at approximately:
  - 0.375 Nm -OR- 50 OzIn

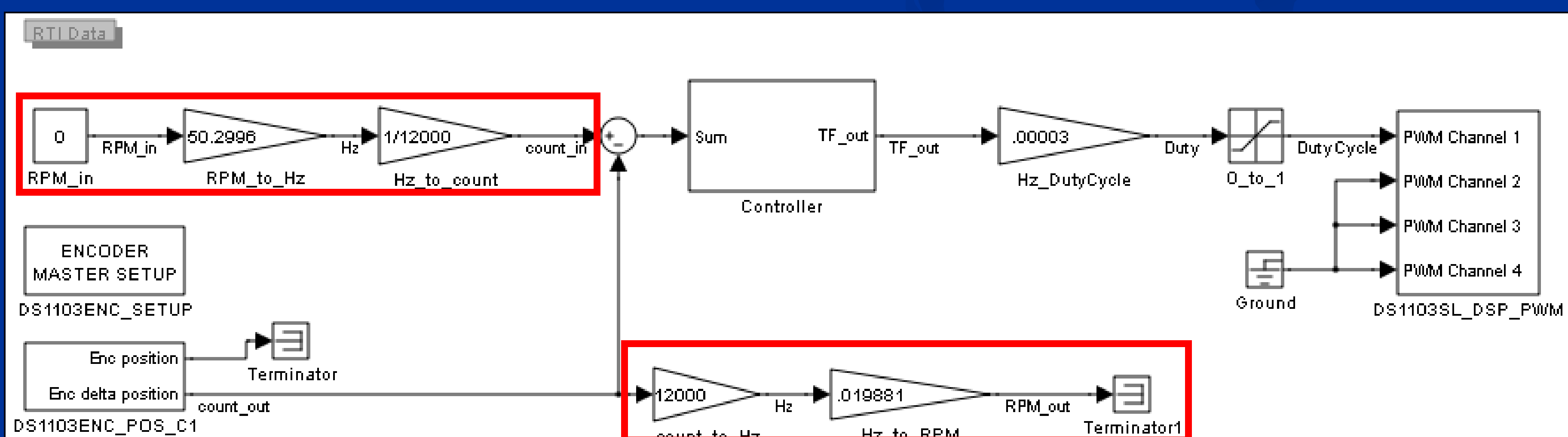
Speed Input/Output I



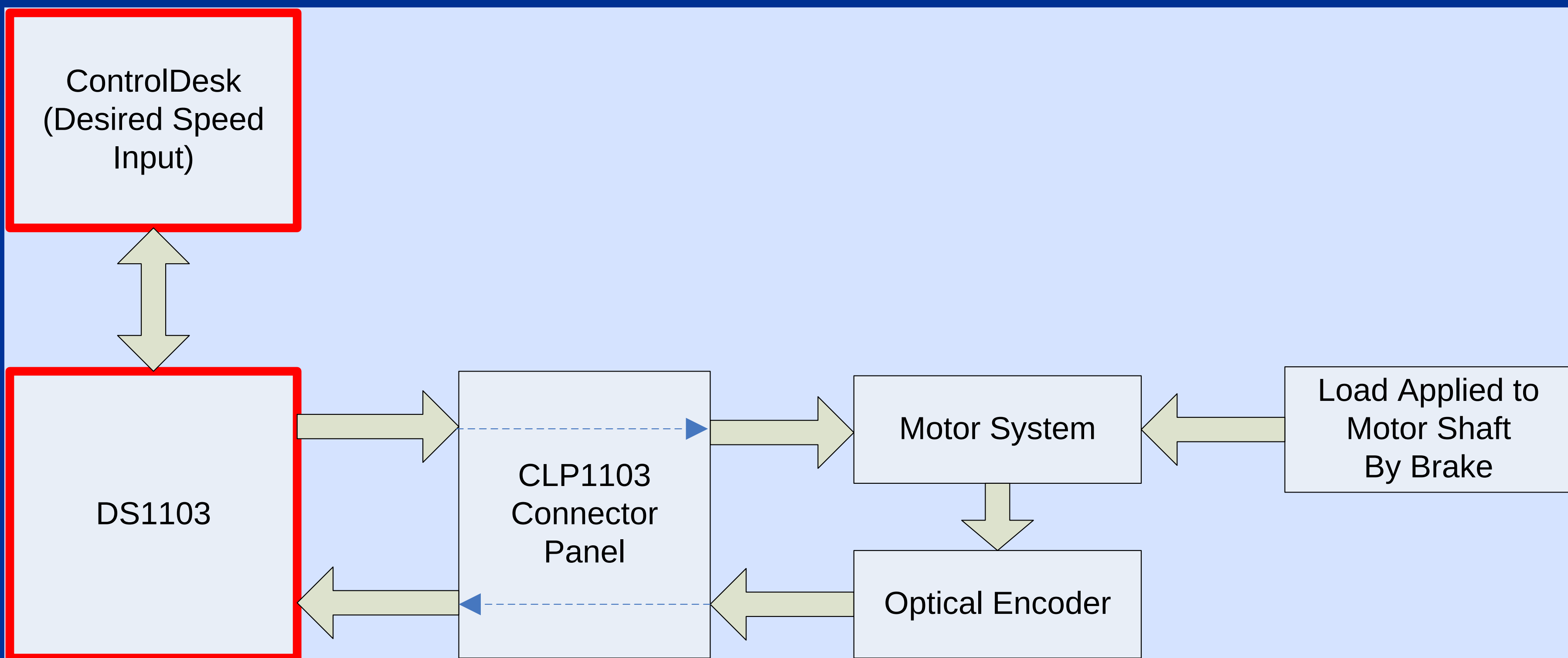
Speed Input/Output II



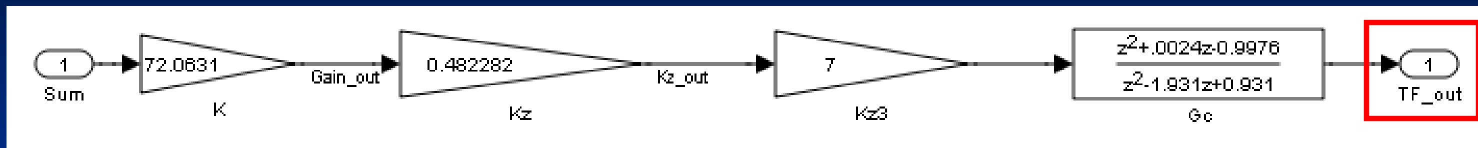


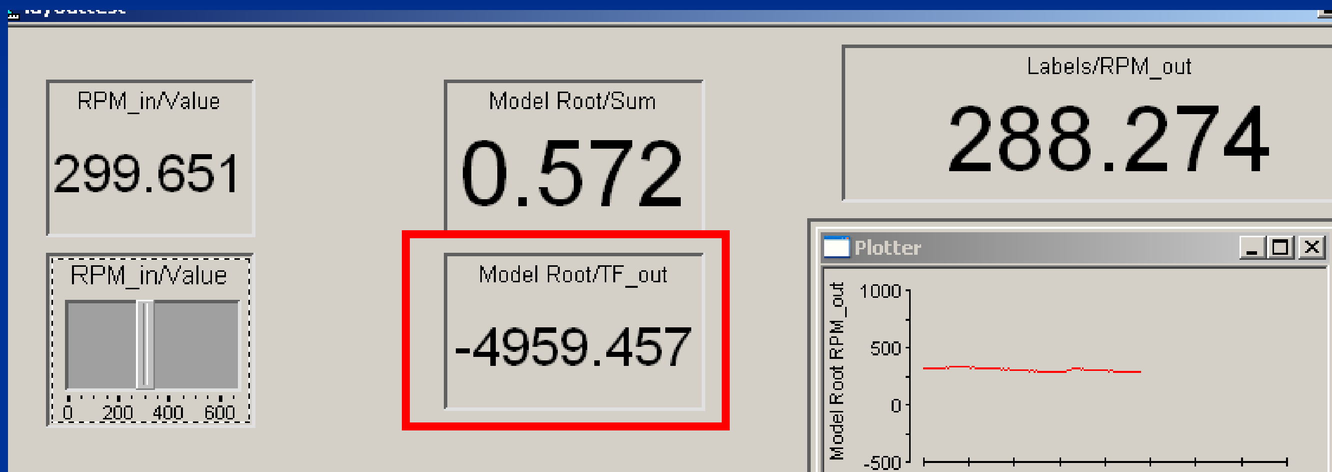


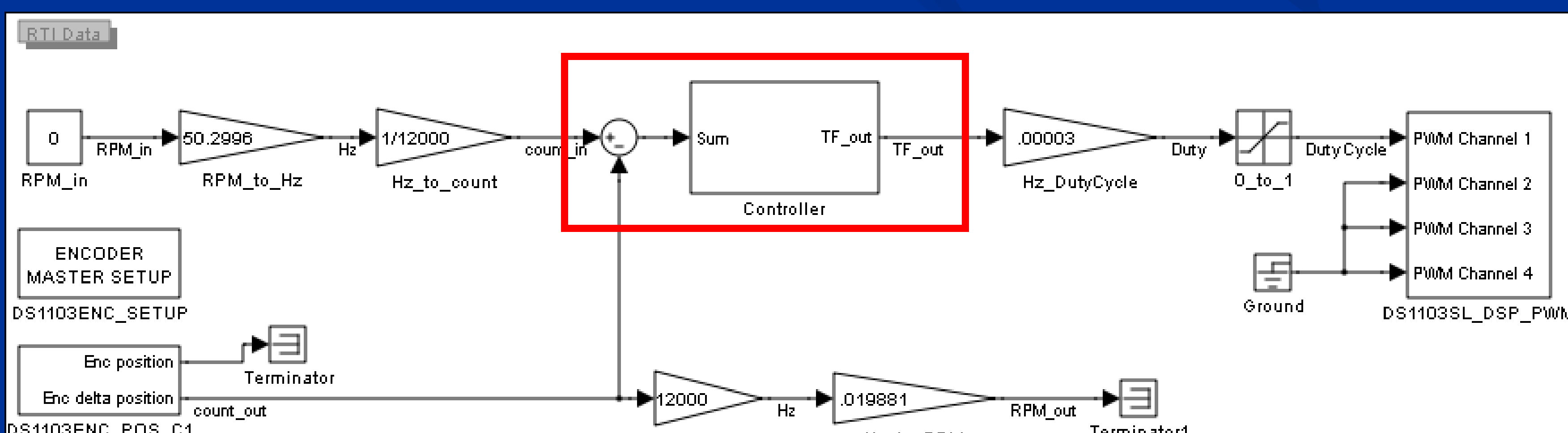
Controller I



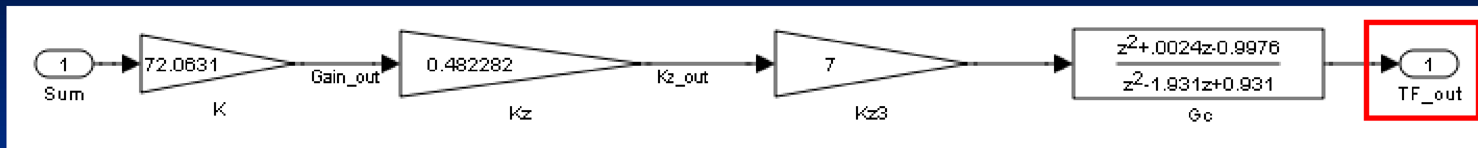
Controller II

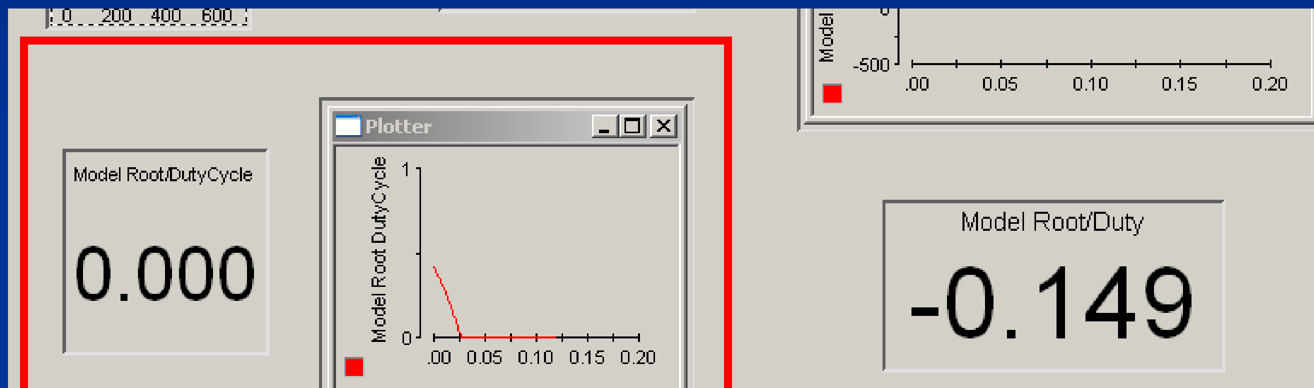


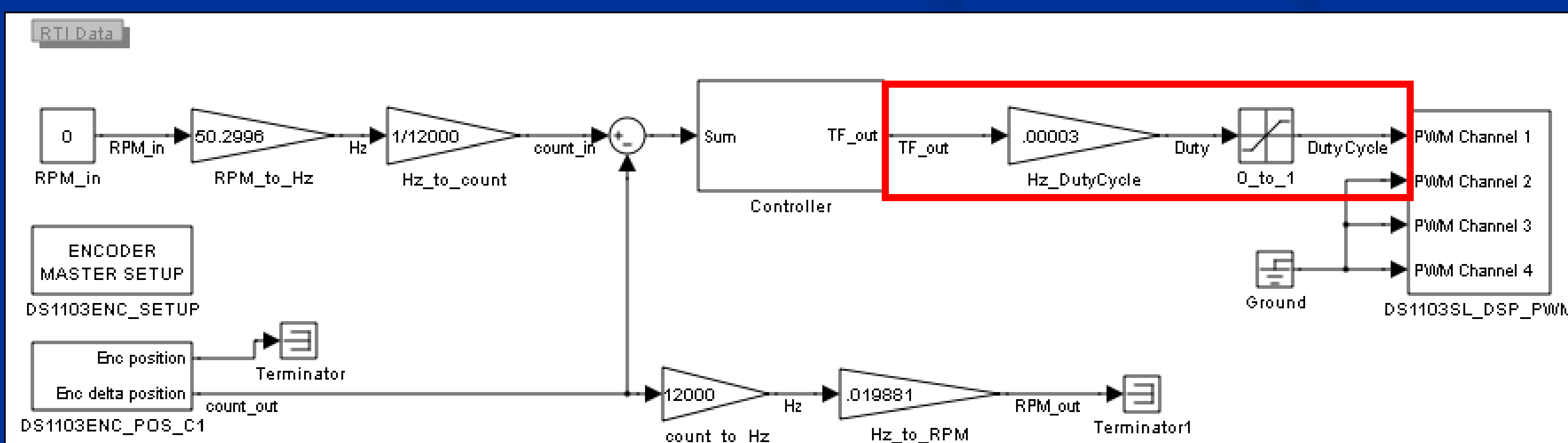




Controller III







Controller V

- Overshoot less than or equal to 5%.
- Rise time less than or equal to 110 ms.
- Minimize Steady-state error.

Controller VI

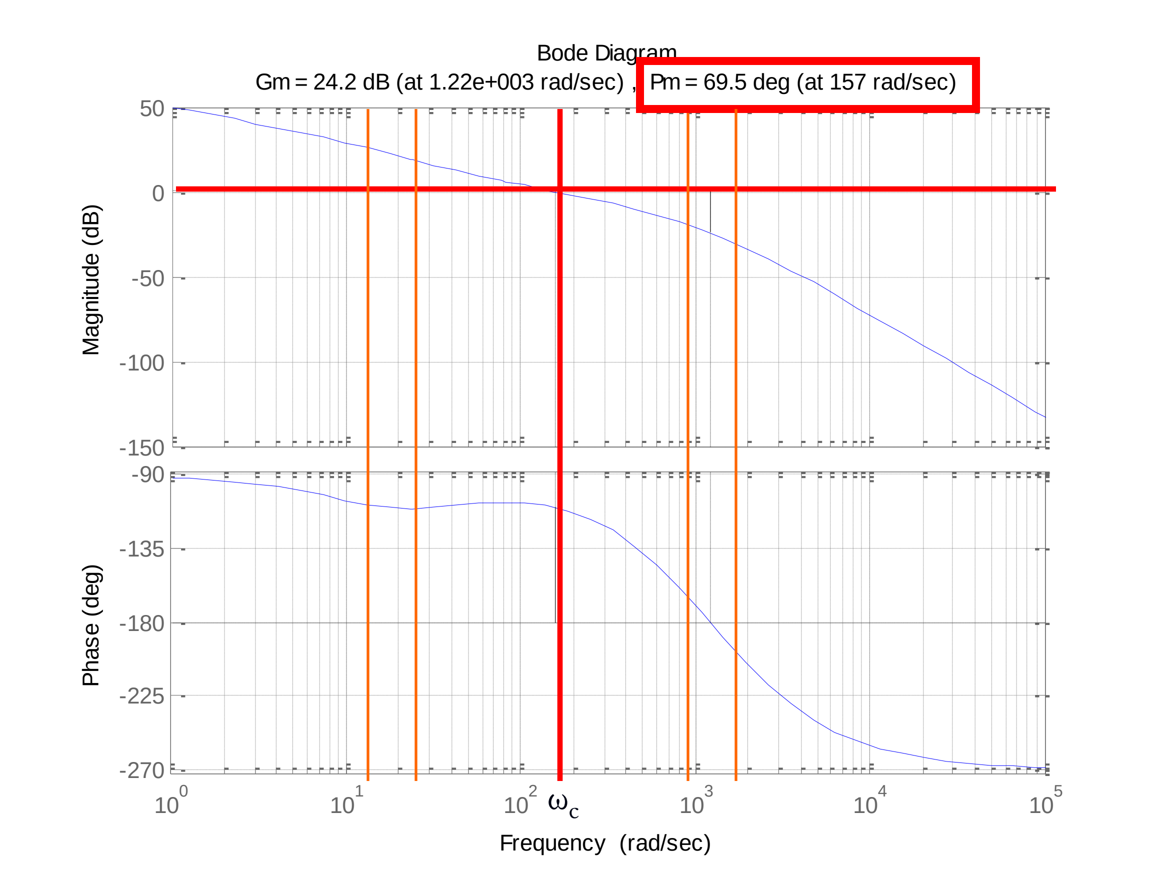
- Analog Controller designed and pre-warping and bilinear methods used to convert to a Digital Controller.
- 12kHz Sampling Frequency

$$\frac{72.0631(0.482282)}{(0.000040278)}\frac{(s+28.8)}{s(s+857.6)} \rightarrow 72.0631(0.482282)\frac{(z+1)(z-0.9976)}{(z-1)(z-.931)}$$

$$\approx 72.0631(.482282)\frac{z^2+0.0024z-0.9976}{z^2-1.931z+0.931}$$

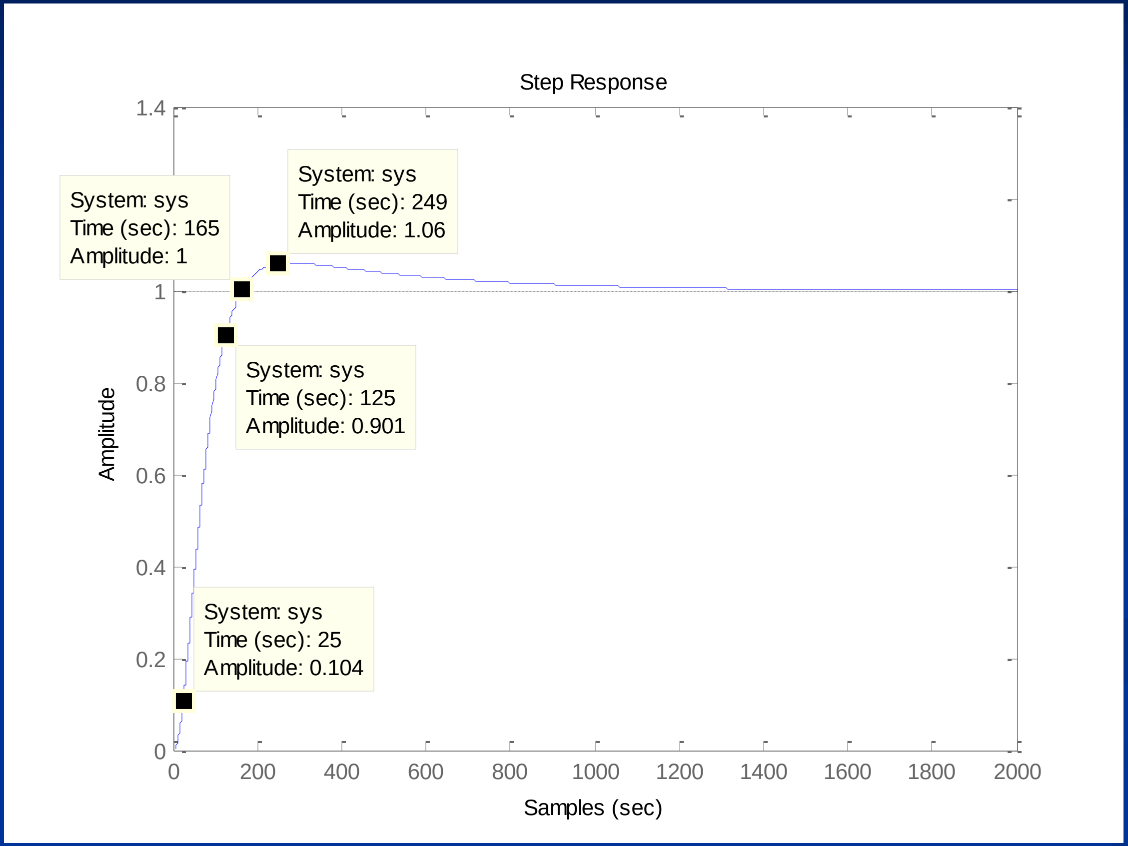
Additional Gain adjustments have been made in MATLAB calculations and Simulink Models.

MATLAB: Motor Model and Controller



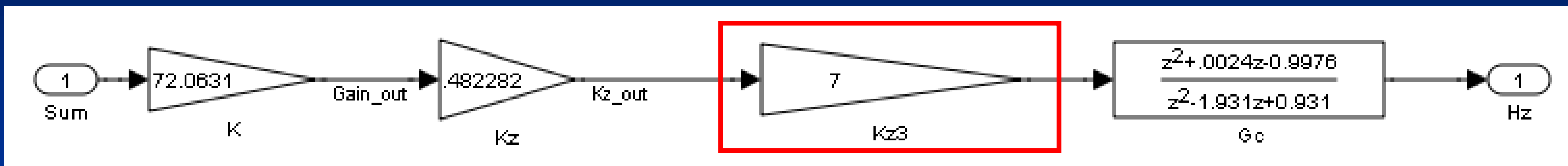
- Actual:
  - Phase Margin = 69.5°.
  - ω_c = 157 rad/s.
- Designed for:
  - Phase Margin = 69.01°. (5 % O.S.)
  - ω_c = 157.08 rad/s. (20 ms Rise Time)

MATLAB: Step Response

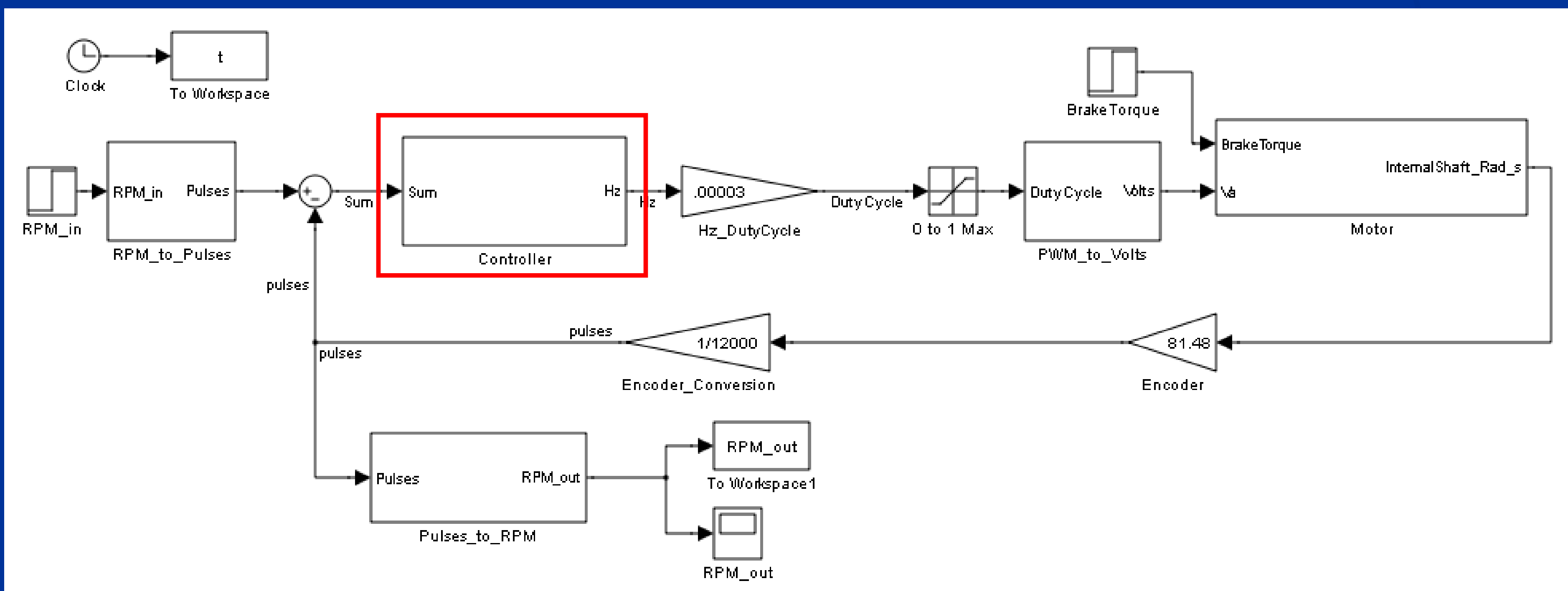


- Overshoot = 6%
- Rise Time = 8.33 ms

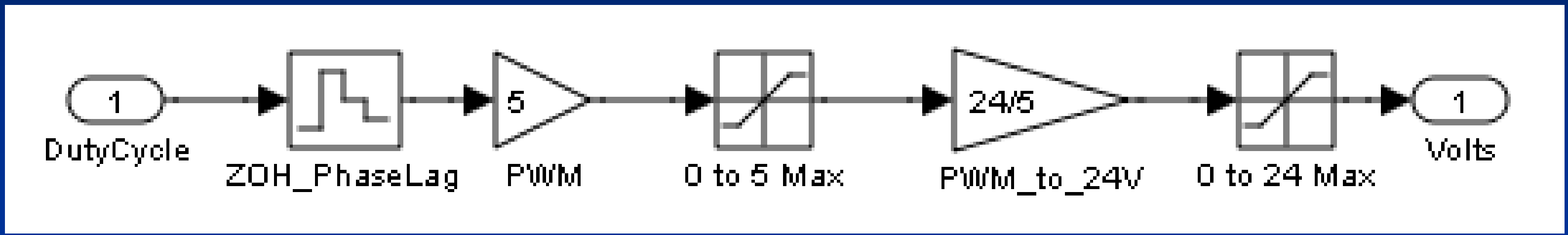
Simulink: Model I

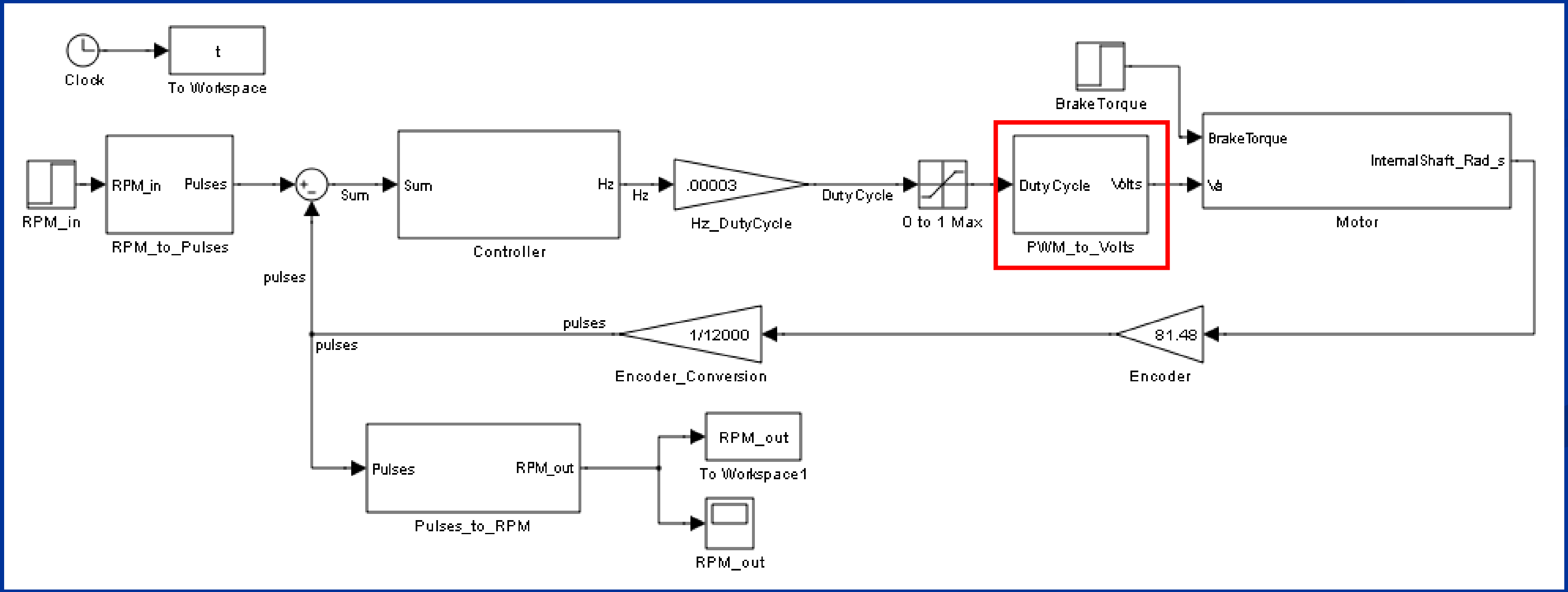


MATLAB controller with added Gain of 7 Block

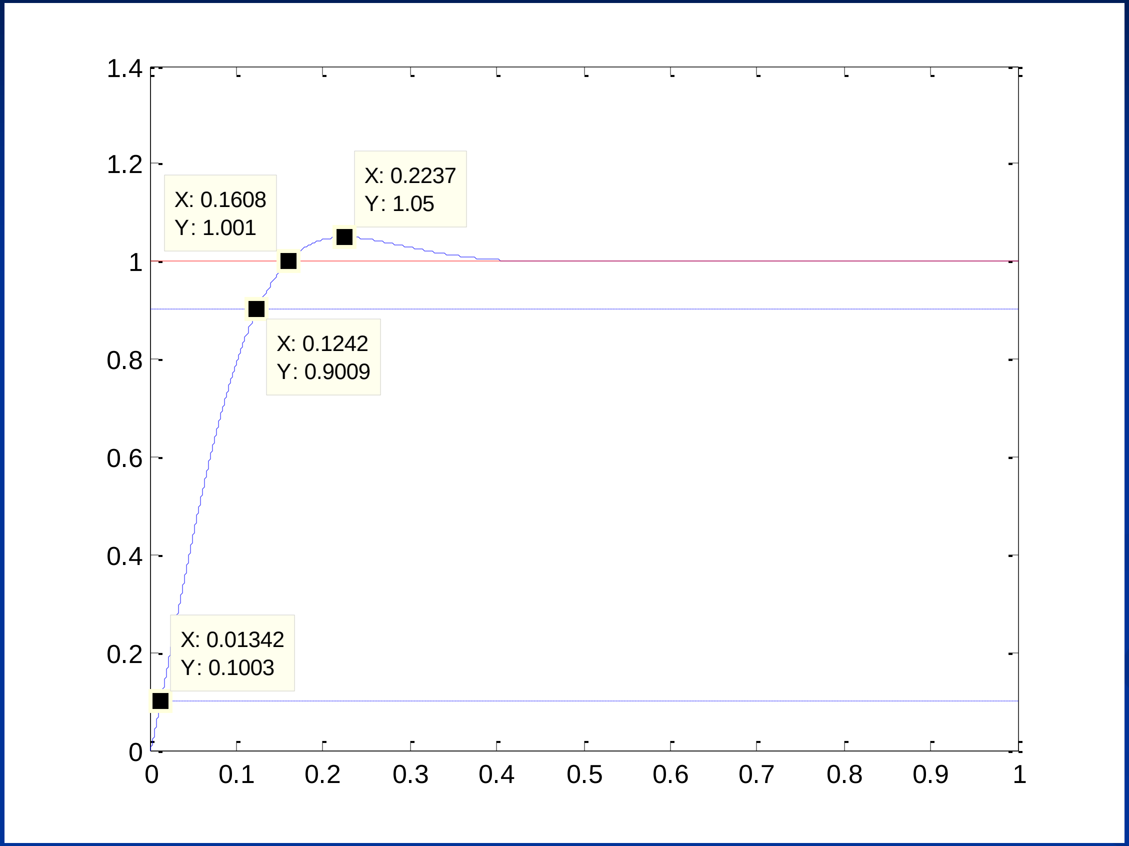


Simulink: Model II





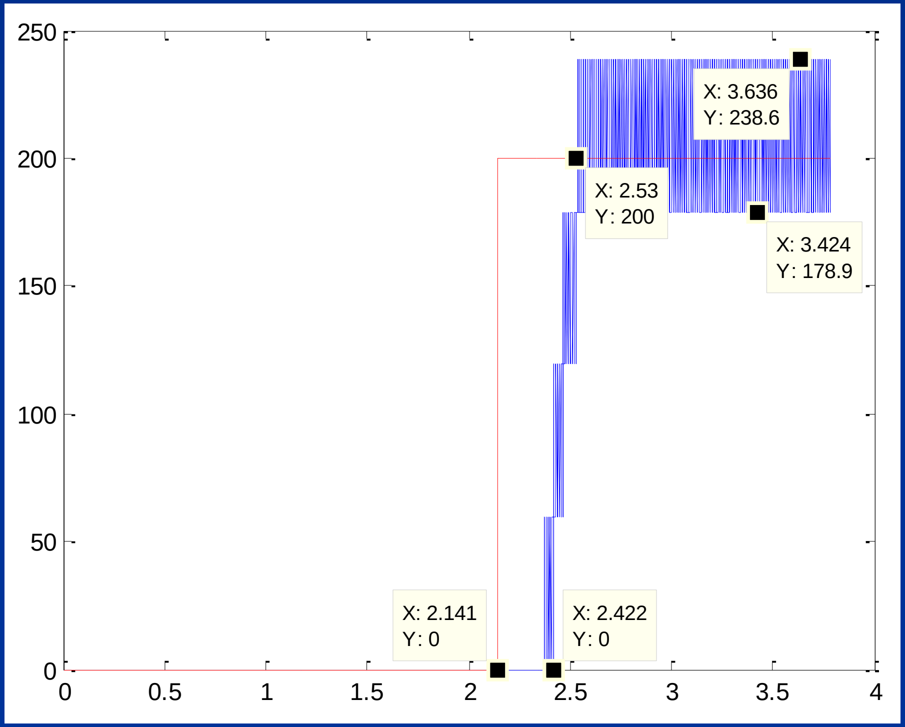
Simulink: Step Response

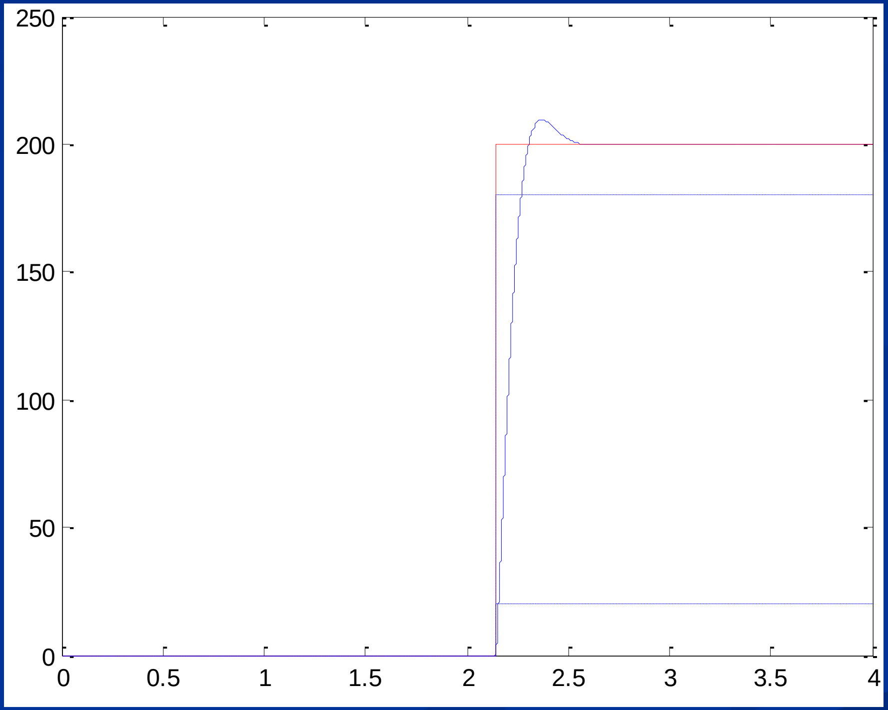


- 238.57 RPM = 1 pulse_in
- Overshoot = 5%
- Rise Time = 110 ms

System Response I

(200 RPM Input, 2.14 second Step Time)



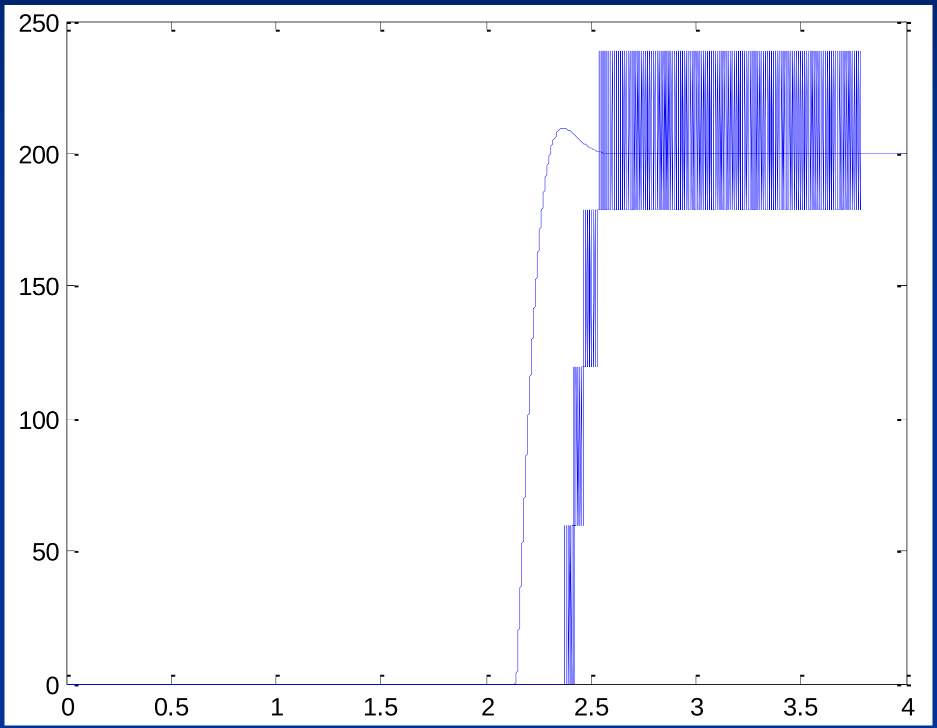


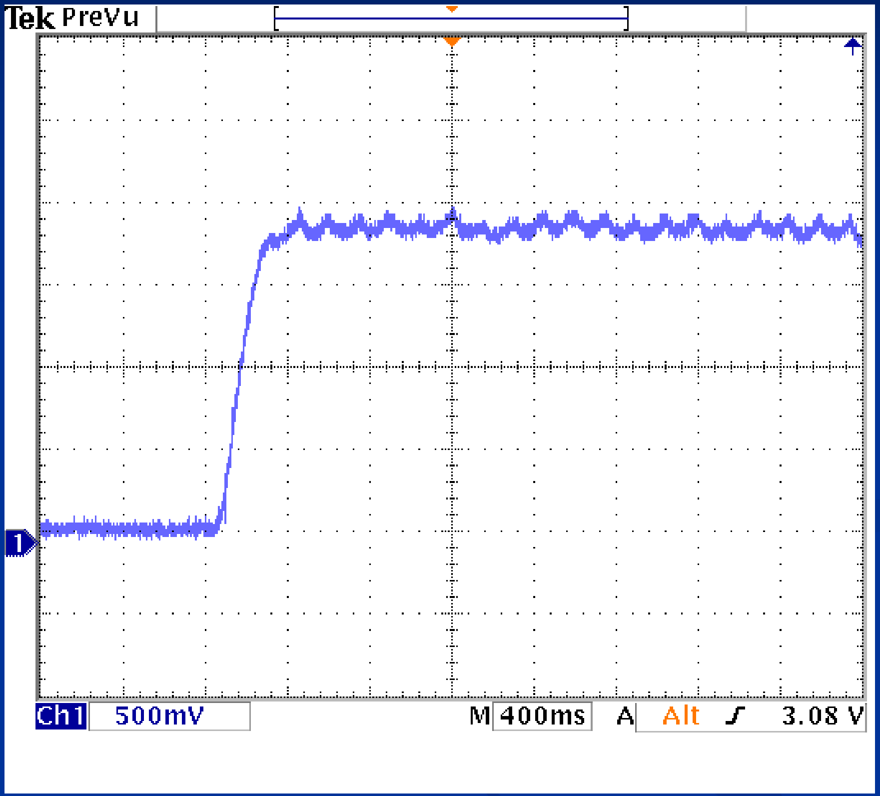
Actual System: ControlDesk

(Possible Time Delay, Rise Time < 108 ms)

Simulink Simulation

System Response II





Simulink/Actual System

(RPM Output Only, Rise Time appears similar)

Actual: Frequency-to-Voltage Converter

(No Visible Overshoot)

Project Status: Timeline

Week	Goal	Task	Completed
1	January 27	Write tutorial introduction	January 22
2	February 3	Verify motor parameters	Not Complete
3	February 10	Simulate motor model in MATLAB	February 10
		Design/Simulate controller in MATLAB	March 10
		Design/Simulate controller in Simulink	April 9
4 - 5	February 24	Make required adjustments to model and download to DS1103	March 12
6	March 3	Design/Build/Test hardware for motor subsystem	February 12
7	March 10	Design/Build/Test hardware for optical encoder system	February 17
8 - 10	March 31	Make required adjustments to controller model to work with motor and hardware and download to DS1103	March 12
11 - 13	April 21	Improve controller or Design/Build/Test additional controllers	April 23
14	April 28	Work on presentation/final report/tutorial	In Progress
15	May 5	Presentation	May 5
16	May 11	Final Report Due	In Progress

Project Status

- A Controller has been designed and implemented using the DS1103 Board.
- The Controller functions correctly but may not meet the rise time specification.
- The tutorial is still being put together but will be completed.
- The motor/brake model was verified/developed in a previous project.

References I

- Guides/Manuals:
  - *ControlDesk Experiment Guide For ControlDesk 3.2*, Germany: dSPACE GmbH, 2008, Release 6.1.
  - *dSPACE System First Work Steps For DS1103, DS1104, DS1005, DS1006, and Micro Auto Box*, Germany: dSPACE GmbH, 2007, Release 6.0.
  - *DS1103 PPC Controller Board Hardware Installation and Configuration*, Germany: dSPACE GmbH, 2007, Release 6.0.
  - *Real-Time Interface (RTI and RTI-MP) Implementation Guide*, Germany: dSPACE GmbH, 2008, Release 6.1.

References II

- dSPACE Product Descriptions:
  - "DS1103 PPC Controller Board", Germany: dSPACE, July 2008.
  - "Connector and LED Panels," *Catalog 2008*, Germany: dSPACE GmbH, 2008, p. 302.
- Current Motor Model:
  - Sabbisetti, Amulya Sabbisetti. "Discrete Time Gain Scheduled Adaptive Control of DC Motor Speed", Masters Project Report, Bradley University ECE Department, December 2008.

Acknowledgments

- Mr. Nick Schmidt:
  - Motor/Brake System Construction
- Mr. Mattus:
  - Initial Setup of DS1103 Workstation
  - Construction of Slave I/O and Encoder Connectors
- Larry Kendrick of Caterpillar:
  - Funds for purchase of DS1103 system.