

**dSPACE DS1103 Control Workstation Tutorial and DC
Motor Speed Control**

Project Proposal

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Table of Contents

Introduction	1
Project Summary	1
Functional Description	1
<i>Controller.....</i>	<i>3</i>
<i>ControlDesk.....</i>	<i>3</i>
<i>CLP1103.....</i>	<i>3</i>
<i>Motor System.....</i>	<i>3</i>
<i>Optical Encoder System.....</i>	<i>4</i>
<i>Speed Input.....</i>	<i>4</i>
Requirements	4
<i>Overall System Requirements.....</i>	<i>4</i>
<i>Controller Requirements.....</i>	<i>5</i>
<i>Other Requirements.....</i>	<i>5</i>
Current Progress	6
Schedule for Completion	6
Equipment.....	7
<i>Workstation.....</i>	<i>7</i>
<i>Other Equipment</i>	<i>7</i>
References	7

Introduction

The dSPACE DS1102 was first used at Bradley University in the year 2000 when a user's manual and a workstation based on this board were developed. Since then, a newer dSPACE DS1103 board has become available. With grant from the Bradley College of Engineering of \$2,000 and additional funds of \$12,200 provided by Dr. Larry Kendrick at the Caterpillar Technical Center, a dSPACE DS1103 board and additional equipment required have been purchased to set up a DS1103 workstation. Initial setup has been completed by Mr. Chris Mattus. The object of the *dSPACE DS1103 Control Workstation Tutorial and DC Motor Speed Control* project is to develop a tutorial for use of the new dSPACE DS1103 Workstation by implementing a DC motor speed control system. The tutorial will minimize the time required for future students to become proficient in using the workstation, therefore increasing the time they can spend designing and implementing more complex control systems.

Project Summary

The goals of the *dSPACE DS1103 Control Workstation Tutorial and DC Motor Speed Control* project are the following:

- Determine and implement any additional setup that may be required for the dSPACE DS1103 control workstation.
- Write a tutorial for use of the workstation, paying particular attention to details related to the DS1103 board using a DC motor speed controller as the example application.
- Design a controller to control the speed of a DC motor.
- Implement the designed DC motor speed controller on the dSPACE DS1103 system using the Simulink and the dSPACE blocksets, the Matlab-to-DSP interface libraries, Real-Time Interface to Simulink, and Real-Time Workshop.

Functional Description

The design portion of this project involves designing and implementing a motor speed controller using the dSPACE DS1103 board. The controller will be designed and simulated using the Simulink and the dSPACE blocksets, the Matlab-to-DSP interface libraries, Real-Time Interface to Simulink, and Real-Time Workshop on a PC. The controller will then be downloaded onto the Texas Instruments' TM320F240 DSP [1] located on the DS1103 board. Inputs to the DS1103 will include the desired motor speed and the output of an optical encoder connected to the motor. Outputs from the DS1103 will include the input to the motor, possibly a PWM signal, and a display of the actual motor speed. Inputs to and outputs from the DS1103 will pass through the CLP1103 [2] connector panel for the DS1103 board. The motor's speed should remain steady for any reasonable amount of load torque applied to it by a braking system. A general block diagram for the system is shown in figure 1 below.

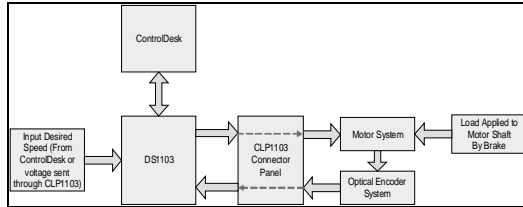


Figure 1: Motor Speed Control System Block Diagram

Testing of the initial controller design can be done by modeling the “Motor System”, “Optical Encoder System”, and “CLP Connector Panel”, shown in figure 1 above, in Simulink. A simple motor model is shown in figure 2 below. From this model, a closed loop control block diagram can be generated with a transfer function for the input voltage to the motor, V_a , in relation to the output, w , in radians per second, which can then be easily converted to other formats such as RPM (revolutions per minute). A simple transfer function that can be used to model the motor in the frequency domain, in terms of s , is:

$$w / V_a = K_t / [(R_a + s * L_a) * (B + s * J) + K_t * K_v] \quad (1)$$

where R_a and L_a are the electrical resistance and inductance of the motor, J and B are the mechanical inertia and damping/friction of the motor, and K_t and K_v are the torque constant and back emf constant of the motor. These values will be found in the motor’s datasheet(s) and verified experimentally.

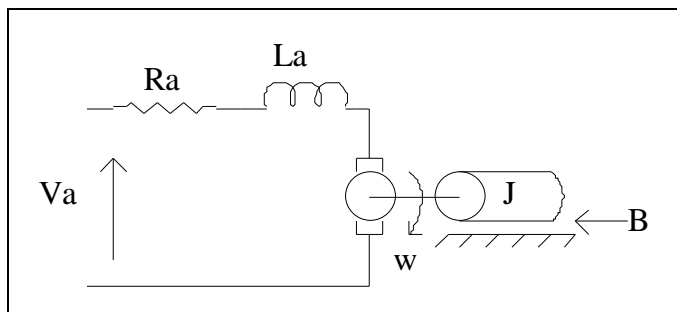


Figure 2: Simple Motor Model Schematic

Controller

The controller will be designed using the various development and simulation tools found on the PC for the workstation. It will then be downloaded to the DSP in the “DS1103” shown in figure 1 on the previous page using the “ControlDesk” software package also on the PC. The complexity and other specifications of the motor speed controller design have not yet been determined. A simple proportional (P) controller design would probably be implemented first to gain experience and knowledge with the overall system, and then one or several more complex controllers would probably be designed and implemented. The output from the DS1103 is currently expected to be a PWM signal.

ControlDesk

“ControlDesk” in figure 1 on the previous page serves multiple uses. It provides the interface for downloading controller models designed in Simulink onto the DSP. The Instrument Panel feature of ControlDesk can be used as an input device for the system and as a data output device. It may be possible to control the input value for the Simulink model using the Instrument panel, but more research in this area is needed to be certain of this. The output from the “Optical Encoder System” can definitely be sent through the CLP1103 and DS1103 to the computer and various measurements can be displayed on the PC screen. [3] Initially, measurement of the system response (the actual motor speed) will be measured by connecting the output of the Optical Encoder to an oscilloscope.

CLP1103

The “CLP1103” shown in figure 1 on the previous page serves as an interface between the DS1103 and the external hardware portion (“Motor System”, “Optical Encoder System”, and possibly the Desired Input) of the overall system. The CLP1103 contains connector for twenty (20) Analog-to-Digital inputs, eight (8) Digital-to-Analog outputs, several other connectors that can be used for Digital I/O, Slave/DSP I/O, Incremental Encoder Interfaces, CAN interface, and Serial Interfaces. [2]

Motor System

The “Motor System” identified in the block diagram in figure 1 on the previous page will include the motor and additional analog components. The analog components will include either a transistor or an H-bridge to further process the output from the DS1103 board (passed through the CLP1103 Connector Panel) before it enters the motor.

Optical Encoder System

The “Optical Encoder System” shown in figure 1 on page 2 may be just an optical encoder connected to the motor and necessary pull-up resistors and power/ground connections, but additional analog components might be added to convert the optical encoder output signal into a form that can be more easily handled by the DSP.

Speed Input

A means of inputting the speed at which the motor is desired to operate is needed. This is shown as the “Input Desired Speed Block” in figure 1 on page 2. The speed could be hard coded into the controller or an external signal could be used to vary the desired operating speed. Initial design and implementation will most likely use a hard-coded value, but eventually it should be possible to control the desired speed by using a DC voltage supply or some other type of input. Current research is inconclusive, but it might also be possible to set desired input using the Instrument Panel Feature of ControlDesk, see “ControlDesk” section on the previous page. This would be the preferred option if it is possible.

Requirements

Overall System Requirements

- Requirements and specifications for the overall system shown in figure 1 on page 2 are as follows:
- The operating range of the system shall be 0 to 40 degrees C.
- The system shall use a 30 VDC or smaller power supply.
- The motor used shall be a Pittman DC Motor Model Part # GM9236C534-R2.
- The values for the motor model to be used for design and simulation in Simulink shall be determined from the datasheets and verified experimentally.
- A control panel shall be created in the “ControlDesk” application to monitor the inputs and the outputs of the system.
- The output from the “DS1103” to the “Motor System” shall be passed through a PWM output located on the “CLP1103 Connector Panel”.
- The output from the “DS1103” to the “Motor System” shall be a 12 kHz PWM signal.

- The input to the “DS1103” from the “Optical Encoder System” shall be passed through an Incremental Encoder input located on the “CLP1103 Connector Panel”.
- The input to the “DS1103” from the “Optical Encoder System” shall be converted to RPM for display purposes.
- The RPM measurement displayed using a control panel in “ControlDesk” shall be within ± 10 RPM of the actual value.
- There shall be a method to input/control the desired speed of the motor.
Note: The desired speed can be input as an RPM value using a control panel in “ControlDesk” or a voltage input through an Analog-to-Digital Converter input of the “CLP1103 Connector Panel”.
- The desired maximum speed/velocity that shall be input is 834 RPM.
- Load Torque shall be applied to the motor shaft using a HB-420 Brake.
Note: The maximum load torque that can be applied should be limited to reasonable values.
- The designed controller shall be downloaded onto the Texas Instruments’ TM320F240 DSP [1] located on the “DS1103” board using “ControlDesk”.

Controller Requirements

Requirements and specification applicable to the controller functionality are as follows:

- The DC motor speed controller shall be designed/simulated using Simulink and dSPACE blocksets, Matlab-to-DSP interface libraries, the Real-Time Interface to Simulink, and Real-Time Workshop.
- Overshoot shall be less than or equal to 5%.
- Rise time shall be less than or equal to 20 ms.
- Steady-state error shall be less than or equal to 5 RPM.

Other Requirements

Other requirements particular to this project are as follows:

- A tutorial shall be written on the use of the workstation using the DC motor speed controller as the example application.

Current Progress

Lab periods up to this point have been spent primarily on reading large portions of the manuals/guides provided by dSPACE explaining the abilities, functions, and relationships between the DS1103, ControlDesk and Simulink, and exterior analog/digital systems [3,4,5]. Notes about pages/sections that are important have been recorded with some notes to make it easier to find them later if they are needed. *dSPACE System First Work Steps For DS1103, DS1104, DS1005, DS1006, and Micro Auto Box* [4] and *ControlDesk Experiment Guide For ControlDesk 3.2* [3] have been thoroughly reviewed. A review of *Real-Time Interface (RTI and RTI-MP) Implementation Guide* [5] is still in progress. The DS1103 board has been successfully found and registered in ControlDesk. A simple model has also been begun to be designed in Simulink. This model applies gain to an Analog-to-Digital Converter input and sends the output through a Digital-to-Analog Converter. It is also being used as a mechanism to better understand some of the basic interactions between settings in a Simulink model, ControlDesk (downloading and instrument panel function), and the DS1103 board, before moving onto the greater complexities involved in motor speed controller simulation and implementation. This work will probably not be completed until the beginning of the Spring 2009 semester.

Schedule for Completion

At this point in time, the primary research for this project is nearly completed. Most of the Spring 2009 semester will be spent applying what has been learned by designing a controller to control the speed of a DC motor and implementing it using the DS1103 Board. A proposed schedule for the Spring 2009 semester is shown in Table 1 below. (Most Weeks begin on Wednesday and end on Tuesday.)

Week	Week End Date	Task
1	January 27	Write tutorial introduction
2	February 3	Verify motor parameters
3	February 10	Design/Simulate motor model and controller in Simulink
4	February 17	Make required adjustments to model and download to DS1103
5	February 24	
6	March 3	Design/Build/Test hardware for motor subsystem
7	March 10	Design/Build/Test hardware for optical encoder system
8	March 17*	Make required adjustments to controller model to work with motor and hardware and download to DS1103
9	March 24*	
10	March 31	
11	April 7	Improve controller or Design/Build/Test additional controllers
12	April 14	
13	April 21	
14	April 28	Work on presentation/final report
15	May 5	Presentation

Table 1: Schedule of Tasks for the Spring 2009 semester.

* Spring Break is March 14 – March 22, 2009

Equipment

Workstation

The dSPACE DS1103 control workstation contains the following:

- The \$14,000 dSPACE DS1103 system consisting of:
 - A DS1103 Board.
 - An Expansion Box to house the DS1103.
 - A CLP1103 PPC Connector and LED Panel.
 - ControlDesk Version 3.2.2 and several other software applications provided by dSPACE.
- A PC dedicated to the workstation containing all software applications required for controller design (Matlab/Simulink Version R2008a and libraries) and implementation in the DS1103 (ControlDesk).

Other Equipment

Equipment particular to this project includes:

- A Pittman DC Motor (Model Part # GM9236C534-R2).
- A Magtrol HB-420 Brake.
- A Transistor or H-Bridge.
- Other electronic components as needed.

All of this equipment should already be available at Bradley University.

References

- [1] “DS1103 PPC Controller Board”, Germany: dSPACE, July 2008.
- [2] “Connector and LED Panels,” *Catalog 2008*, Germany: dSPACE GmbH, 2008, p. 302.
- [3] *ControlDesk Experiment Guide For ControlDesk 3.2*, Germany: dSPACE GmbH, 2008, Release 6.1.
- [4] *dSPACE System First Work Steps For DS1103, DS1104, DS1005, DS1006, and Micro Auto Box*, Germany: dSPACE GmbH, 2007, Release 6.0.
- [5] *Real-Time Interface (RTI and RTI-MP) Implementation Guide*, Germany: dSPACE GmbH, 2008, Release 6.1.