BRADLEY UNIVERSITY
Department of Electrical & Computer Engineering
Mini-Project 2006

Closed-loop Control of DC Motor Drive System

Motor drive systems have been an integral part of our senior capstone projects for the last six years especially in the autonomous vehicle projects. Several design aspects of an open-loop DC motor drive system were examined in the 2005 mini-project. The 2006 mini-project will focus on closed-loop control. The drive system can be readily applied to other application areas such as the drive system for wheelchairs and robot arms. DC motors are normally driven from batteries or regulated supplies using a pulse-width modulation method for high power efficiency. Motor velocity information can be supplied from a digital rotary encoder. The objectives of the mini-project are to design the interface electronics and software to create a pulse width modulation signal to drive a DC motor and to measure motor velocity via a rotary encoder. The velocity feedback information and desired output velocity will be used with proportional and integral controllers. In addition to the EMAC keypad, a video-game type joystick will be used as an external user interface.

Parts and systems that are provided for the project are a GM9236C534-R2 Pittman DC-geared motor/encoder, a National LMD18200 H-Bridge, a modified Logitech Wingman Attack 2 joystick, a 20VDC external supply for motor drive, and the 80515 microcontroller EMAC development system. The EMAC's LCD will be used to supply motor and joystick parameters to the user. The keypad and joystick will allow the user to specify the mode of operation and controller gains. Low-cost off-the-shelf hardware should be used in the design. All project documents are located on the H drive:\ee450\mini2006 directory and on Blackboard (EE450). Also see the Mini-Project Web site for grading criteria and previous grading results: http://cegt201.bradley.edu/~gld/miniproj.html.

The product specifications are given below. Five lab periods are provided to **research**, develop, design, construct, and test the system. Students will submit a preliminary report the 3rd mini-project period (8 A.M.). The notebook (includes a summary report) will be submitted to the instructor the lab period immediately following the five week project (5 PM).

Product Specifications:

1) 2-Line LCD Format:	Mini-Project 2006	On power up, hold on LCD for 0.75 seconds
		Normal display mode (HOME):
	RPM=WWW	(Line 1: Measured parameters)
	PWM=YYY.Y%	(Line 2: Command parameters via joystick buttons)
		WWW=000 to max RPM, YYY.Y=000% to 100%
		Duty cycle fraction=0.2% or less increments
		Keypad entry mode: (enter this mode with "C" key)
	A=HOME **D**=GAIN **E**=P/PI	
	F=JOYSTICK SCAN	
		Controller gain mode:
	Enter Kp:000-255	check for valid entry, if not display error message
		Controller mode:
	Enter 1=PRO, 2=PI	check for valid entry, if not display error message
		Joystick scan mode:
	Enter ms:005-250	check for valid entry, if not display error message

2) Display Refresh:	display update time = 0.5 seconds
3) Keypad:	see above display modes for key definitions
4) Power Supply:	20VDC provided to students
5) PWM timing:	Fixed period waveform (1 millisecond), variable duty cycle (0 to 100% in 0.2% or less increments)
6) Motor Velocity:	display accuracy $\pm$ 40 RPM (battery voltage 0 to 20V), display updated every 0.5 seconds
7) Joystick:	Serviced every 40 ms (default), keypad selectable from 5 to 250ms, powered by EMAC's 5V regulator.

(Over)

Product Specifications (continued):

8) Joystick Operation:	**PWM Commands:** **D2 Button:** RPM up mode if Trigger is pressed **D3 Button:** RPM down mode if Trigger is pressed **D4 Button (multi-use):** (1) Motor brake (2) Exits from closed-loop control. (3) Enable closed-loop control if Trigger active, regulate at last commanded velocity. **Trigger Button:** Enables D2 and D3 buttons. Enables closed-loop control if D4 is active.
9) Closed-loop Operation:	(a) center (regulated) velocity set via joystick buttons, (b) if error signal exceeds software limits, controller should revert back to original PWM duty cycle at center velocity and remain in closed-loop mode, (c) determine proportional controller gains for maximum motor supply voltage range, record velocity accuracy versus supply voltage, (d) output a scaled version of the error signal on a D/A channel to monitor: zero error =2.5V, select scale such that 0.2V change is approximately 20RPM change, for overflow or underflow set D/A to appropriate limit of 0 or 5V.
10) Product Temperature:	0 to 40 degrees C
11) Port 4.0:	update an external LED at LCD refresh rate
12) Port 4.1:	flip pin to show 1 ms timing
13) Port 4.2:	flip pin to show joystick scan rate
14) Port 4.3:	show 1 ms interrupt execution time

The following items are required:
(1) interrupt-driven software where program timing is based on microcontroller crystal
(2) modular programming methods

The following items will be considered in grading:
(1) Analysis of hardware/software interface for high-volume production
(2) Analysis of motor drive components
(3) Motor velocity versus supply voltage data
(4) Displayed RPM versus supply voltage data (0 to 20V, 2V increments)
(5) Displayed RPM versus PWM duty cycle
(6) Range of velocity control for P and PI controllers, accuracy of velocity with supply change
(7) Accuracy calculations and documentation for RPM measurements
(8) Documentation of PWM method
(9) Software and hardware accuracy calculations and documentation
(10) Scope validation waveforms of software/hardware performance
(11) Simulink model of system and comparison with experimental results. Record gain that results in an unstable system.
(12) Cost of product and design for high-volume production (see Instructor for any questions)
(13) Documentation of software (flowcharts or equivalent high-level description) and hardware.
(14) Software/hardware for test/diagnostic purposes
(15) Better specifications than requested.
(16) Additional features will be considered in grading. See instructor before implementing extra features.

Additional notes:
See H:\EE450 or Blackboard EE 450 site for mini-project documents and data sheets for new components for this project. See H:\ DataSheets and H:\ MicroPac 535 for microcontroller and device data sheets.

The mini-project grading percentage is shown below:

preliminary report =	5%
notebook =	50% (attendance will be included into notebook grade)
final summary report =	15% (included in notebook, typed)
demo =	30% (110% score is maximum for demo with extra features, score based on working percentage)