Bradley University
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FPGA Implementation of a PID Controller with DC Motor Application

Functional Description

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Basic Project Narrative

In all fields of engineering, many different solutions can be presented for the same problem. The goal of an engineer is twofold. The first and most distinct goal is to identify and design possible solutions to a complex problem. The second goal, which is perhaps less obvious, is to choose which solution is best suitable to most economically meet project specifications. This project deals with the general field of Electrical Engineering. Its primary goal is to implement a digital "Proportional-Integral-Derivative" (or PID) controller in an existing DC motor system with this unwritten economical specification that cost must be minimized.

The existing DC motor system which will be used as our closed loop system "plant" was designed in the Fall 2001 Senior Mini-Project. This system utilized an 80C515 microcontroller to control the speed of a 30-Volt DC motor by pulse width modulation. This system was considered to be an "open-loop" system because no information was fed back to the microprocessor with the express purpose of improving system performance. Two major problems arose due to the open-loop nature of this system. The first problem was system non-linearity that arose due to the nature of the hardware. The second problem was system unreliability when the DC motor load was varied. This project will attempt to address both of these problems by means of a PID controller.

A PID controller, as its name suggests, provides proportional, integral, and derivative compensation to an existing system. These three forms of compensation increase system performance in a variety of ways. Proportional control can both increase gain margin and stabilize a potentially unstable system. Integral control can minimize steady state error. Derivative control can increase system speed by increasing system bandwidth. One drawback of PID control is overall complexity. This results in very expensive means of implementing a digital version of a PID controller. Of the many possibilities, digital signal processors (or DSP's) are the most widely used to solve this problem, however other possibilities exist which may be more cost-effective.

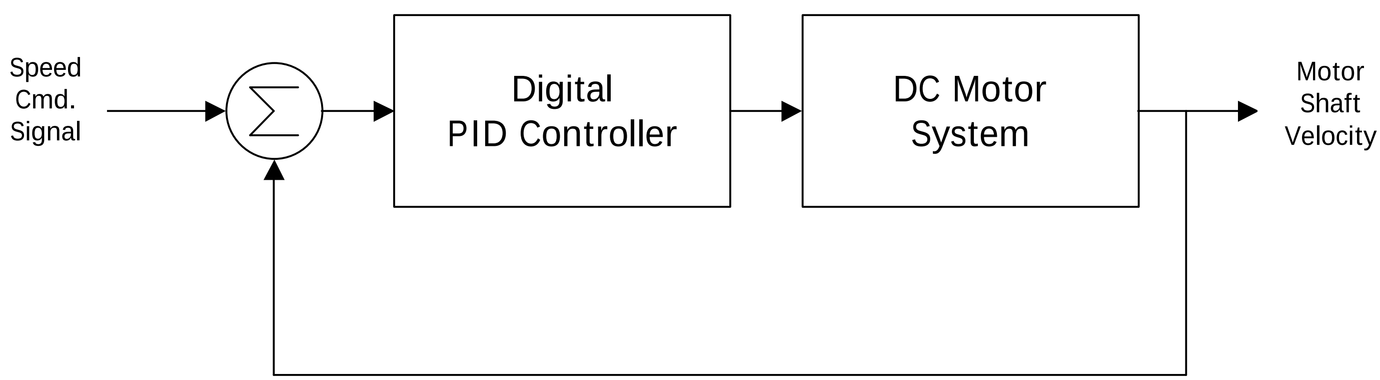
Implementation of any complex digital controller must be done by means of some form of computer. Typical microcontrollers, while cheap, do not normally provide enough processing power to effectively perform all but the most simple calculations real-time. Digital signal processors, on the other hand, are designed to implement complex algorithms quickly. The major drawback of DSP's, however, is cost. This project will attempt to find a median between these two extremes of performance and cost. The proposed solution is to design a special-purpose computer whose only purpose is to quickly execute the complex PID algorithm. This computer will be designed using the IEEE 1076-1987 standard known as VHDL (or Very High Speed Integrated Circuit Hardware Description Language), and will be implemented on an FPGA (or Field Programmable Gate Array).

System Inputs and Outputs

Inputs	Outputs
Speed Command Signal	Motor Shaft Velocity
	System Display

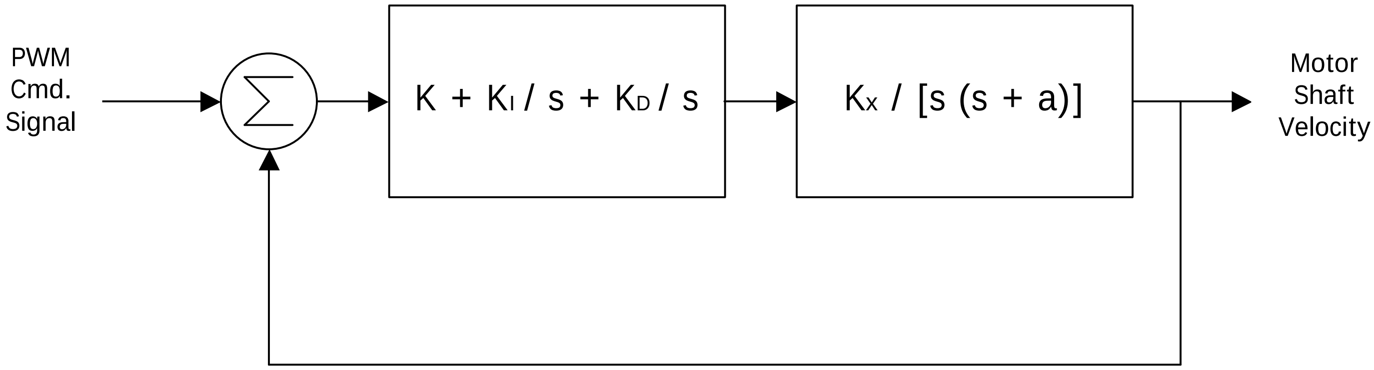
The Speed Command Signal is inputted to the microcontroller, which in turn controls the speed of the motor. The Motor Shaft Velocity is simply the speed at which the motor turns. The System Display provides vital information about the system including both the current PWM Command Signal setting and the current motor speed measured in revolutions per minute (RPM).

Top-Level System Block Diagram



The top-level system block diagram illustrates the Digital PID Controller and DC Motor System in a closed loop configuration. The Motor Shaft Velocity will be fed back and confirmed with the Speed Command Signal to drive the system by means of an error signal.

Detailed Top-Level Block Diagram



This more detailed look at the Top-Level Block Diagram of the overall system illustrates the basic forms that the block transfer functions will follow. As more detailed models of the PID Controller and DC Motor are derived, this diagram will increase in complexity. Also, a method of creating an error signal based off the Speed Command Signal and Motor Shaft Velocity Signal will need to be developed.