Integrated DC motor driver with digital speed controller

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Abstract

This work presents the design of a DC motor H-Bridge driver with a closed loop digital speed controller, using quadrature encoders commonly found in this kind of device. The controller is composed of several building blocks that filter and process the encoders' signals. We adopt a PI control to modulate a PWM signal which, in turn, is injected into the motor driver circuit.

I Introduction

Small DC motors are being increasingly used in small robotics systems such as mobile robots. In these applications it is often required to precisely set the speed of these actuators in order to control the motion of the device. A discrete measurement of the motor's speed is obtained using quadrature encoders connected to the motor shaft or the wheel. Numerous microcontroller-based implementations of this type of controller exist, however, this generally requires specialized resources (timers, interruptions) and program code [1]. For these reasons, the speed control is often not implemented.

The goal of this project is the design of a fully integrated digital speed controller with a complete output power stage, which simplifies the adoption of a closed loop speed control in low-cost devices without adding additional circuitry. Using a digital speed tachometer also provides some advantages over conventional analog speed transducer such as immunity to temperature variations, component changes and noise [2].

The scope of this poster is the design, modelling, simulation and final layout of the described design which is being fabricated through MOSIS service.

II Methodology

A high level model of the complete system, which includes the DC motor, quadrature encoder, decoder, PI control and PWM generator, was created using ScicosLab [3]. By comparing the output of this high level model to the one obtained by the transistor level simulation of the controller, the schematic circuit design was validated.

This project was undertaken as the final assignment of a post-graduate course on integrated circuit design and a full custom methodology was required. This design was carried out using an EDA suite for IC design targeting the MOSIS ONC5 process. The digital basic cells designs were based on the proposed schematics in [4].

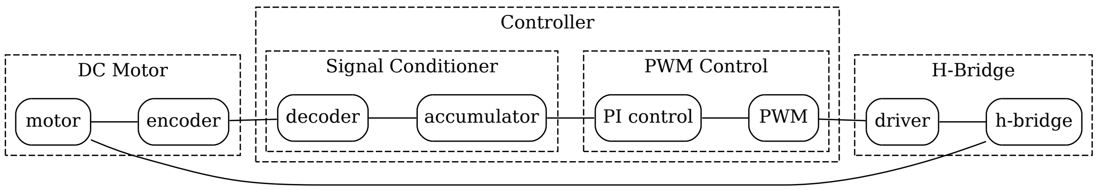


Figure 1: System model.

III System Model

The complete system model is shown in Figure 1. The electrical model of a DC motor presented in [2] is used.

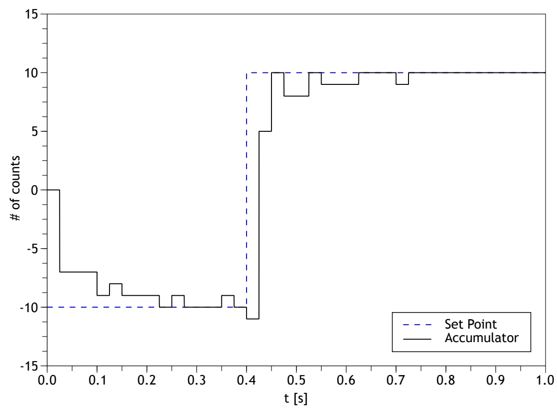
III-A Signal Conditioner

The enconder's signal must be filtered before any processing can be done in order to improve the noise immunity. Voltage spikes on top of the signals are eliminated by a Schmitt trigger and a debounce circuit.

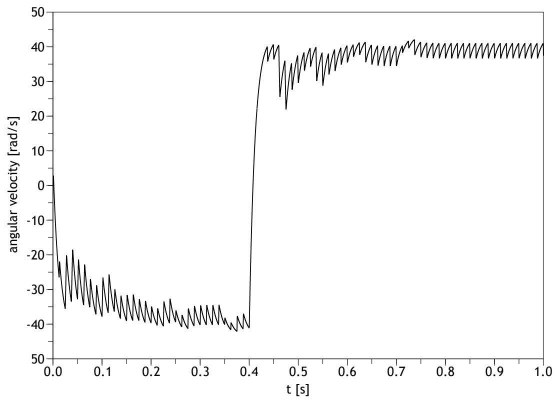
III-B PWM Control

The proposed controller employs a classic PI control architecture to generate the PWM duty cycle. This design was chosen because of its few adjustable parameters and to avoid the stationary error of a simple P controller [5].

Using the high level model we were able to verify that the designed speed measurement and control functioned correctly. Figure 2 shows the results of a simulation of the step response of our proposed control and the motor's angular velocity.



(a) PI control set point and accumulator output.



(b) Angular velocity of the motor shaft.

Figure 2: Simulation results.

III-C H-Bridge

The need to drive motors in both directions imposes the usage of a full-bridge topology. This was implemented with high-voltage MOS transistors in order to supply up to 9V to the motor. An overcurrent protection circuit is integrated to prevent device failures.

References

[1] Wu, H.; Chen, X.; Hu, L. "Embedded System of DC Motor Speed Control Based on ARM," Computing, Communication, Control, and Management, 2008.

[2] Maloney, T.J.; Alvarado, F.L. "A Digital Method for DC Motor Speed Control," Industrial Electronics and Control Instrumentation, IEEE Transactions on. 1976.

[3] Campbell; Chancelier; Nikoukhah. "Modeling and Simulation in Scilab/Scicos with ScicosLab 4.4". Springer, 2009.

[4] Rabaey, J.M. "Digital Integrated Circuits: A Design Perspective". Prentice Hall, 1996.

[5] Katsuhiko Ogata. "Modern Control Engineering". Prentice Hall, 1996.