LAB 5 – VELOCITY CONTROL OF A DC BRUSHED MOTOR

University of New Hampshire

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***VELOCITY CONTROL OF A BRUSHED DC MOTOR***

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# Cover Letter

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Dr. Ebadi,

The following document contains an analysis of control systems for a DC brushed motor. DC motors are generally controlled via pulse width modulation and a microprocessor, however for the purpose of demonstration, we controlled DC motors with power op-amp driven proportion control, integral control, and proportional-integral control.

These control systems were compared against each other in terms of functionality- the motor parameters have been determined through experimentation.

The body of this report comprises of the results of inputs to the system and recorded system response.

Best Regards,

Jesse Feng

Simon Popecki

Reilly Webb

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# Objectives

The objective of this experiment was to compare different methods of control using a power operational amplifier. Proportional, Integral, and Proportional-Integral control systems controlled a motor under load to be measured by a second motor. The parameters of the motor were calculated, and the system response determined from experimental data. The motor back EMF, open-loop, and closed-loop response were analyzed in particular. Quantitative analysis was performed and interpreted. All relevant values are tabulated/listed. Gain values were confirmed by root locus analysis.

# Executive Summary

In this experiment three types of power op-amp control systems were used to control the speed of a DC brushed motor. Proportional control, Integral control, and Proportional-Integral control systems were used. PID control was not used in this experiment. Motors were controlled by voltage, rather than the conventional method of pulse width modulation. The objective of the control systems was to maintain motor speed regardless of the load placed on the motor. Motor speed was measured by a tachometer.

This experiment assumes that the electrical time constant was much less than the mechanical time constant – so that it may be neglected in the analysis.

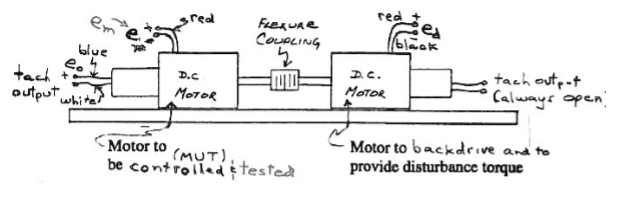
The DC motor’s back EMF constant was found to be #. This value was determined by back driving another motor, referred to in this report as the MUT (motor under test). The torque constant Kt was calculated to be # - it was assumed that Kt = Ke. The resulting motor torque value was calculated to be # oz\*in/A. This value matches the specifications provided by the motor manufacturer.

The motor’s open-loop response for a disturbance torque and input voltage step was recorded and analyzed. The time constant and system gain were calculated – a disturbance load was implemented with a switch to measure steady state error – the steady state error is the difference between the motor’s no-load speed and speed under load. The motor time constant was found to be #, and the motor gain value was found to be #. The stall torque of the motor was calculated to be #. The moment of inertia and damping constant of the system were calculated to be # and # respectively.

Closed-loop motor response to a voltage step input and disturbance torque was recorded with a tachometer in the same way as the open-loop response. The power op-amps were controlled by a 741 op-amp – proportional, integral, and proportional-integral control were implemented and analyzed. SHOW SPEEDS OF EACH CONTROL SYSTEM. In a purpose-built closed-loop system the magnitude of each control element (P,I,D) is modified such that it has a larger or smaller role to fit the individual needs of the system. Generic control parameters were used for this experiment (non-optimized).

# Theory and Experimental Methods

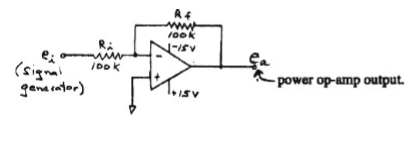
The experimental setup for the open-loop response is shown in Figure 1 below.



Figure

The motor left most is the MUT – the motor under test, and the motor on the right is the motor which is back driven and used to provide a load for the MUT. The two motors are coupled with a flex-coupling to allow for minor shaft misalignment. The MUT was supplied with power from a power op-amp. The MUT was connected to a tachometer, which outputted a voltage proportional to the rotational velocity.

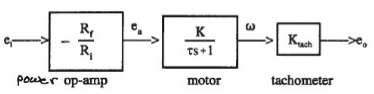
Figure 2 below shows the schematic describing the power op-amp setup.



Figure

The gain of the power op-amp is -1, which means the motor spins the opposite direction (not relevant to the results). Voltages of +15 and -15 volts. The power op-amp was supplied by BK Precision, it provides the power for the motor. Both resistors are 100 kΩ.

The open-loop block diagram of the motor is shown below in Figure 3.



Figure

The time constant of the electrical system is much shorter than the time constant of the mechanical system, it is therefore neglected. In this case, the mechanical pole is dominant.

For the open-loop DC motor analysis, the Ke value was found by back driving the MUT with a motor of identical model and manufacturer (assuming that the motor parameters are going to be similar). Different motor rotational speeds were analyzed to find the response at different voltages. Since motors have different efficiencies at different rotational speeds, the results of this test are important. Voltages were inputted between 1 V and 10 V, but it was found that the motor did not spinning until it was supplied almost 3 V. The frequency of the inputted signal was .001 Hz – the waveform was a square wave.

The motor voltage constant is shown in equation 1 below.

Eq.1:

# Results and Discussion