ECE 203 – LAB 4
MOTOR SPEED CONTROL

BEFORE YOU BEGIN

PREREQUISITE LABS
• ECE 201 and 202 Labs
• ECE 203 Lab 3.

EXPECTED KNOWLEDGE
• Linear systems
• Transfer functions
• Step and impulse responses (at the level covered in ECE 222)
• Block diagram algebra (as covered in ECE 223)

EQUIPMENT
• Oscilloscope
• Programmable Power Supply
• Arbitrary Function Generator

MATERIALS
• Motor
• Generator
• Foam Pad
• Rubber Band
• Faceplate
• Coupling Hose
• Motor Mounting Screws
• Faceplate Mounting Screws
• TIP41 Power Transistor
• Large heat sink with screw and nut
• Assorted Resistors and Capacitors
• Operational Amplifiers

OBJECTIVES
In this lab you will gain knowledge of different types of compensation and how to implement each of these types using analog circuits. You will learn how to select components for each type of compensation and how the compensation affects the output of the system.
INTRODUCTION

Automatic control is a vital part of modern engineering and science. It is used in space vehicle systems, missile guidance, aircraft, robotics, and modern manufacturing processes. The system to which the controller is applied is called the plant. In this lab, you will design a controller for the DC motor plant from Lab 3.

There are many different types of feedback controllers. In the following sections you will work with four different types of feedback controllers: the proportional compensated, the proportional compensated with derivative, the proportional compensated with integral, and the proportional compensated with derivative and integral. Each controller tries to make the output of the closed loop system as close as possible to the input of the system. Using techniques you in Lab 3 you will be measuring the performance of each of these controllers. It may be beneficial if you have a copy of Lab 3 for reference.

PRELAB

Answer Questions 1 – 5.

PROPORTIONAL COMPENSATION

The gain of a system can be adjusted by introducing proportional compensation, $k_p$. Figure 1 shows the block diagram of such a system. $k_p$ is the proportional compensation, or gain, of the compensator. $H(s)$ is the transfer function of the plant. Using block diagram algebra, the transfer function for such as system can be determined as follows:

$$G(s) = \frac{k_p H(s)}{1 + k_p H(s)}$$

Figure 1. Unity Feedback System with Proportional Compensation.

Figure 2 shows the schematic that you will use when building the proportional controller. The circuit consists of three op amps: a differential amplifier, an inverting amplifier and a voltage follower. The differential amplifier subtracts the input signal from the output, or feedback, signal. As you can see from Figure 2, a gain of 10 was chosen for the compensator. This value was chosen so that the plant would operate at approximately the same operation point of the previous section, but with a lower input voltage. The lower input voltage is needed to keep the
inverting op amp from saturating. The inverting amplifier is used to determine the gain, or proportion, of the compensation. The voltage follower (aka current buffer) is used to ensure the output voltage is connected to a high impedance source and is therefore not directly affected by the circuit that it is connected to.

**Answer Questions 6 – 12.**

You should have found that the output voltage closely tracks the input voltage at low frequencies. The DC gain should be approximately 1.

![Figure 2. Schematic for Proportional Compensation.](image)

**PROPORTIONAL COMPENSATION WITH DERIVATIVE**

Proportional compensation with derivative, PD, is a more flexible form of compensation than proportional. This type of compensator contains two parameters to adjust a fixed gain and a gain that is proportional to the derivative of the system error, \( e = x - y \). This adds a zero to the open-loop transfer function.

The block diagram for a PD system is shown in Figure 3. The schematic that you will use for the PD is shown in Figure 4. As you can see, the PD can be created from the proportional compensator by adding a capacitor in parallel with 100 kΩ resistor.

The zero added by the PD is located at \( \frac{-1}{A} \), where \( A = R_c C_1 \).

**Answer Questions 13 – 18.**

© 2001 Department of Electrical and Computer Engineering at Portland State University.
PROPORTIONAL COMPENSATION WITH INTEGRAL

Like PD compensation, proportional compensation with integral is a more flexible form of compensation than proportional. This type of compensator contains two parameters to adjust a fixed gain and a gain that is proportional to the integral of the system error, \( e = x - y \). This adds a pole to the open-loop transfer function.

The block diagram for a PI system is shown in Figure 5. The schematic that you will use for the PI is shown in Figure 6. The PI can be created from the proportional compensator by adding a capacitor in series with the 1 MΩ feedback resistor of the inverting amplifier.

The zero added by the PI is at \( s = -a \) where \( a = R_z C_z \) and the pole is added at \( s = 0 \).

Answer Questions 19 – 24.
PROPORTIONAL COMPENSATION WITH INTEGRAL AND DERIVATIVE

Proportional compensation with integral and derivative, PID, is a combination of PD and PI compensators. Figure 7 shows the block diagram for a PID compensator; the schematic is shown in Figure 8.


Figure 7. Block Diagram for PID System.
Figure 8. Schematic for PID.

CONCLUSION