CS/EE 3720
Spring 2005
Myers

Handout #10

LAB #10: Analog Interfacing

You must checkoff this lab during your lab section of the week of April 18th. Lab writeup is due in class on April 26th. **NO LATE CHECKOFFS OR LAB REPORTS WILL BE ACCEPTED.**

1 Objectives

- Demonstrate a simple digital-to-analog converter.
- Gain experience with power transistors and op amps in reversed-input configuration.
- Understand a simple circuit that will use a high-impedance voltage output to control a 12V DC motor.
- Demonstrate analog control of a DC motor using the 68hc11 and an R-2R resistor ladder.
- Demonstrate that you can control (relatively) high voltage circuits without totally destroying sensitive digital circuits.
- Use the 68hc11 A/D converter system to capture arbitrary waveforms.

2 Reading

- Read Chapter 11 on analog interfacing.

3 Parts

- You likely will need an additional breadboard for your external circuitry.
- Resistors to build a 6-bit D/A converter using an R-2R ladder. You should use R equal to 10K.
- To build your motor driver you will need the following:
  - 50K variable resistor (anything in 5K to 100K range should work)
  - 10K resistor (+/- 50
  - 741 op amp
  - TIP120 NPN transistor
  - 1N4004 diode
  - 47-200 uF
  - 12V DC servo motor (available for checkout in the lab).
- A 1K-10K resistor will be needed for the PE0 analog input.

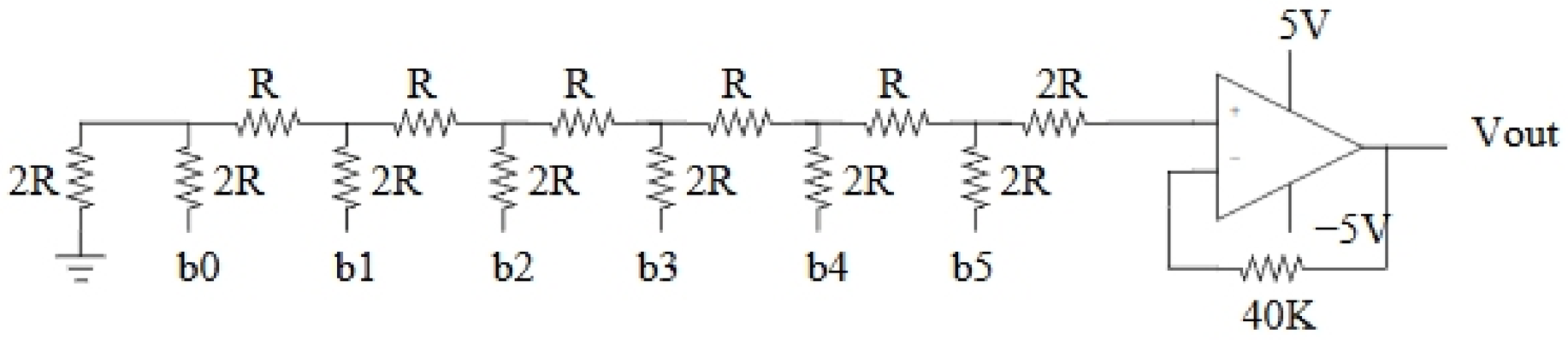

Figure 1: 6-bit D/A converter using an R-2R ladder.

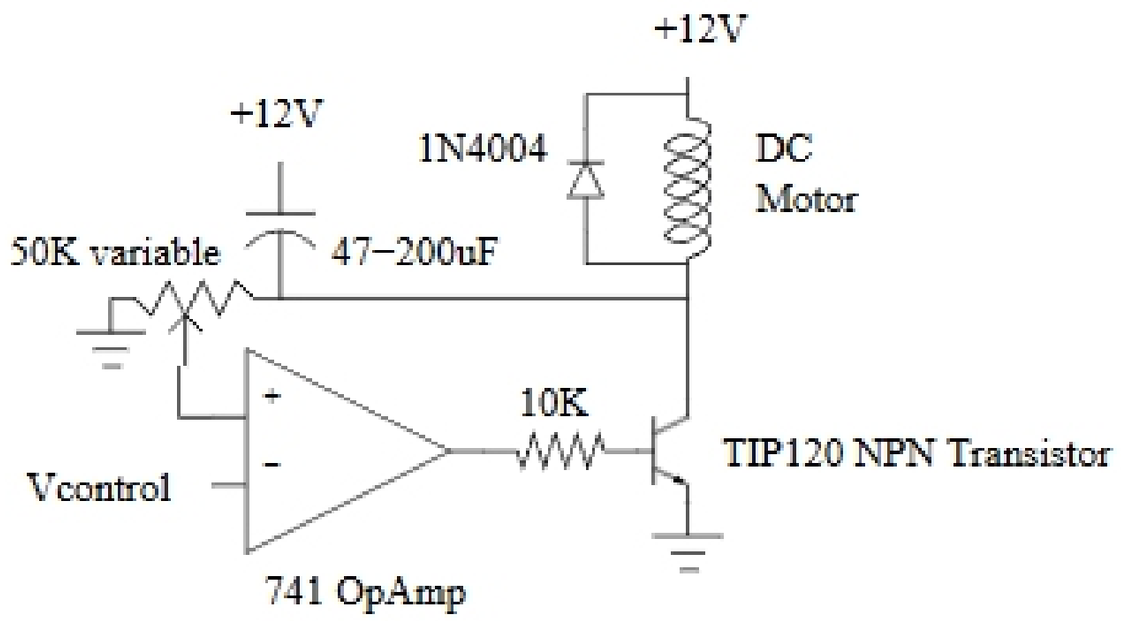

Figure 2: Motor driver circuit.

4 Background

In this lab, you will be building a 6-bit D/A converter using an R-2R ladder (see Figure 1), use it to control a 12V DC servo motor, and use the 68hc11 A/D converter system to check the value of your analog output signal. Your design will be controlled via commands over the serial port (hint: you can likely start with the lab2 assembly code to handle the serial interface). Your interface should accept the following commands:

- a nn - set the output value connected to your D/A converter.
- t - create a triangle wave
- p hhhh - set the sample update period
- n hhhh - capture specified number of samples
- r - retrieve wave file; transmit ascii-hex over serial link

You should use PortC to connect to your D/A converter. The "a nn" command will be used to set the 6-bit value (where "nn" is 0 to 63) that will be sent to your D/A. The "t" command simply starts from 0 and counts up to 63 outputing each value to the port connected to your D/A. You should wire the output of your D/A back through PE0 to be sampled by the 68hc11 A/D converter. The "p hhhh" command sets how many cycles you want to wait between samples. The "n hhhh" command sets how many samples you want to take (each sample should be stored into RAM). Finally, the "r" command causes the program to perform the sampling, and when it is done to tranmit the results back over the serial port. The last step is to construct the moter control circuit shown in Figure 2, and to control the motor speed using the "a nn" command.

CAUTION: Be very careful when building the motor driver circuit for this lab. The +/- 12V power supply for the op amp and DC motor can damage or destroy the integrated circuits in the

digital portion of your circuit. If possible, use a separate breadboard for the circuit above. Then only share the GND and D/A output lines between the two circuits. When connecting power to the 12V DC motor, be sure to use the power input connectors, not the tachometer output connectors. The power inputs are the pair nearest the shaft.

5 Prelab

1. Write new code or modify lab2 code to parse the commands described above, set the PortC value to your D/A converter, and perform sampling of the analog signal using the 68hc11 A/D converter system.

2. Answer the following questions about the motor driver circuit before starting the lab.

   (a) Assuming the TIP120's collector voltage is 0.7V when the transistor saturates, and assuming the coil resistance of the DC motor is 15 ohms, what is the maximum current draw (i.e., the stall current) of the motor?

   (b) Assuming the DC current gain (h_{FE}) for the TIP120 is 1000, what is the base current that corresponds to this collector current?

   (c) Assuming the maximum output of the op amp is 11.3V, and base voltage of the TIP120 is 0.7V, what is the largest value for the resistor connected to the transistor that will permit a base current up to the value computed in part b?

   (d) Typically, an op amp is configured with the feedback signal entering at the negative input. Why does this circuit have the feedback signal entering the positive input? Explain, in qualitative terms, what happens in this circuit when the Vcontrol input decreases by a small amount, e.g., from 2.5V to 2.4V.

   (e) Does the maximum motor current correspond to a Vcontrol value of 5V or 0V? Assume the motor is not loaded in either case.

   (f) When the Vcontrol input is 0V, what value would you expect to see at the TIP120's collector? If the variable resistor is set to its midpoint, what value do you expect to see at the positive input to the op amp? What value would you expect at the op amp's output? Explain your reasoning.

   (g) To completely turn off the motor, we would like to drive the op amp to its negative power rail when the Vcontrol input is 5V. What requirement does this place on the value of the op amp's positive input for a Vcontrol input of 5V? (You may simplify by assuming the the op amp has infinite open-loop gain.) If the TIP120's collector current is cutoff when the Vcontrol input is 5V, what is the collector voltage in this case? (You may assume negligible current through the variable resistor, for this question.) How does the variable resistor need to be set so that our requirement for the op amp's positive input is met? Express you answer as a percent, where 0% corresponds to a wiper position at the ground end of the resistor.

Each group can complete the prelab problems together. Group solutions to these problems are due at the beginning of the lab section during the week of April 19th.

6 Lab Tasks

1. Build a 6-bit D/A converter using an R-2R ladder. Use PortC to provide the digital signal to your D/A converter. Note: if you're feeling ambitious and would like to experiment with more resolution, feel free to implement a converter with 8 bits instead of 6.

2. Implement a serial port command "a nn" that will set the digital value of your D/A converter. Measure the voltages produced for at least 8 output values, including the minimum and maximum values.