

LAB #10: Analog Interfacing

You must checkoff this lab during your lab section of the week of April 14th. Lab writeup is due in class on April 22nd. **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 6812 and an R-2R resistor ladder.
- Demonstrate that you can control (relatively) high voltage circuits without totally destroying sensitive digital circuits.
- Use the 6812 A/D converter system to capture arbitrary waveforms.

2 Reading

- Read Chapter 11 on analog interfacing.

3 Parts

- Resistors to build a 6-bit D/A converter using an R-2R ladder. 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 capacitor
 - 12V DC servo motor (available for checkout in the lab).
- A 1K-10K resistor will be needed for the PADO analog input.

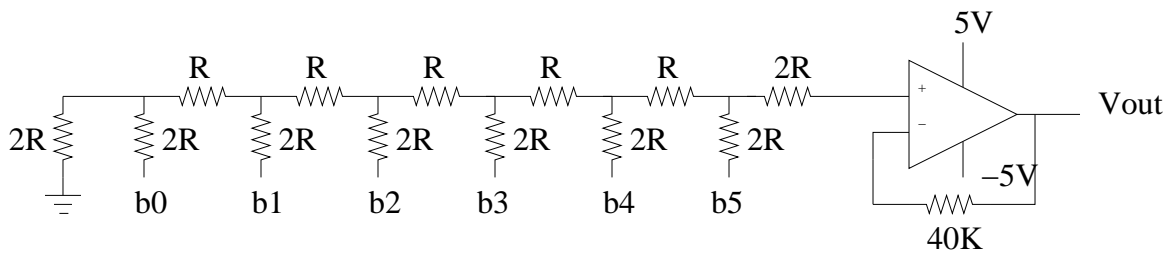


Figure 1: 6-bit D/A converter using an R-2R ladder.

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 6812 A/D converter system to check the value of your analog output signal. Your design will be controlled via commands from the keypad. Your interface should accept the following commands:

- 1*nn# - set the output value connected to your D/A converter
- 2* - create a triangle wave
- 3*nnnn# - set the sample update period
- 4*nnnn# - capture specified number of samples
- 5* - output the captured wave; transmit decimal values for the captured wave to the LCD at a constant, viewable period with numbered samples of the form `sample #:value` (e.g. 1:20 → 2:24)

The "1*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 "2*" command simply starts from 0 and counts up to 63 and back to 0 outputting each value to the port connected to your D/A. You should wire the output of your D/A back through PAD0 to be sampled by the 6812 A/D converter. The "3*nnnn#" command sets how many cycles you want to wait between samples. The "4*nnnn#" command sets how many samples you want to take (each sample should be stored into memory). Finally, the "5*" command causes the program to perform the sampling, and when it is done to display the results on the LCD. The last step is to construct the motor control circuit shown in Figure 2, and to control the motor speed using the "1*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 half of the 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 code to parse the commands described above, set the port value connected to your D/A converter, and perform sampling of the analog signal using the 6812 A/D converter system.

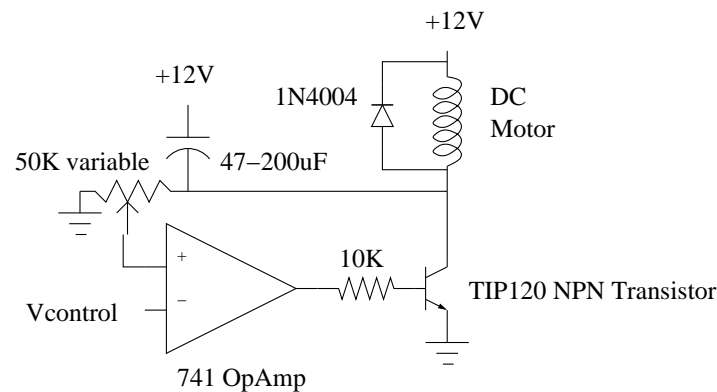


Figure 2: Motor driver circuit.

6 Lab Tasks

1. Build a 6-bit D/A converter using an R-2R ladder. Use an output port 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 the command "1*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.
3. Implement the "2*" command to create a repeating triangle wave by ramping up and down through all possible output values. Using HP Benchlink, capture a complete cycle of this waveform on the oscilloscope.
4. Check out a 12V DC motor and build the above motor driver circuit. Use +12V for the 741's VCC power supply, and -12V for the 741's VEE power supply. Do not connect this circuit to your 6812 circuit yet.
5. Adjust the variable resistor to the midway point. Verify that grounding the Vcontrol input results in maximum motor speed.
6. Now apply 5V at the Vcontrol signal. Put a scope on the collector of the TIP120. Adjust the variable resistor to control this collector voltage. Note how the voltage on the scope corresponds to the speed of the motor and to the variable resistor's wiper position. Experiment with the full range of the variable resistor.
7. Adjust the variable resistor to the point where the 5V control input is just high enough to drive the op amp all the way to its negative power rail. This will cut off current to the motor. Leave the variable resistor at this setting for the next step.
8. Power down the motor control circuit. Connect the ground of 6812 circuit to the ground of the motor driver circuit. Be careful not to connect any point in your 6812 circuit to +/- 12V. Connect the output of your 6-bit D/A converter to the negative input of the op amp. Make sure you don't confuse the -12V supply with GND.
9. Power up your 6812 circuit. Load and run your program, and set the output of the D/A to its maximum value (almost 5V). Verify the Vcontrol input is approximately 5V.

10. Power up the motor driver. The motor should be off. With the maximum D/A value for Vcontrol, again adjust the variable resistor so that this input is just high enough to drive the op amp to the negative power rail.
11. Decrease the D/A output a step at a time and monitor the output of the op amp. You should be able to adjust the variable resistor so that the max value (\$3F) completely cuts off current to the motor, but smaller values (e.g., #3C and below) put the op amp into its linear range and allow current through the motor.
12. Experiment with different D/A values from the maximum value down to 0. Notice the point at which the motor starts to turn. By looking again at the op amp output, make a note of the D/A value at which the op amp saturates, allowing maximum current through the motor. Also note the value(s) of the op amp output when it's operating in its linear range (i.e., not driving to either power rail).
13. Set up your 6812 circuit with an "A/D sampling in progress" LED.
14. Provide 5V to the 6812's VRH pin and 0V to the VRL pin.
15. Provide an under-voltage protection resistor (1K to 10K) at the PAD0 input.
16. Connect the output of your D/A converter to PAD0 through the resistor you added in the previous step.
17. Implement the "3*nnnn#" and "4*nnnn#" commands to obtain the sample update period and number of samples from the user.
18. Implement the "5*" command to obtain the number of requested samples from PAD0 at the desired update period. The samples should be copied into memory during sampling, and the LED connected to PA7 should be on during sampling. When sampling is complete, these sample values should be output to the LCD.
19. Set your output to your D/A to some fixed value, and obtain a small number of samples to check that it works. Are the values constant? Next, set your output to your D/A to be a triangle wave and again obtain samples.
20. Check-off the final working system with your TA.

7 Writeup

Include the following items.

1. Include a printout of your final programs and your HP Benchlink capture file.
2. Provide a graph of D/A output voltage versus digital value for the data you collected. On the same graph, provide the expected outputs for these digital values. Discuss/explain the discrepancies.
3. Describe any problems you encountered or unexpected observations you made.
4. Answer the following questions.
 - (a) Assuming a 6-bit D/A converter and a voltage range of exactly 0 to 5 volts, what is the resolution of the output, in volts? (i.e., what voltage is associated with the least significant bit?)

- (b) At what D/A digital values does the op amp completely cut off motor current? At what values does it drive the transistor into saturation?
- (c) How much does the output of the op amp vary for different D/A values when it's operating in its linear range?
- (d) When you held the voltage input constant, what was the range of A/D values recorded?