MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
Fall 2001

Lab 4: Audio Playback System

Introduction

In this lab, you will construct, test, and demonstrate the audio playback system which you designed in Problem Set 11. The lab consists of two parts: pre-lab exercises and in-lab exercises; there are no post-lab exercises. You should complete the pre-lab exercises in your lab notebook before coming to lab. Then, carry out the in-lab exercises between November 28 and December 7. After completing the in-lab exercises, have a TA check your work and sign your lab notebook. You may hand in your lab notebook for grading at that time.

Pre-Lab Exercises

(4-1) Copy your design for the clock from Problem 1 of Problem Set 11 into your lab notebook. Label all resistor and capacitor names and values.

(4-2) Next to your design for the clock, copy the graph from Part (E) of Problem 1 of Problem Set 11 into your lab notebook. You will use this information to determine whether the clock you construct during In-Lab Exercise 4-1 works correctly.

(4-3) Copy your design for the digital-to-analog converter from Problem 2 of Problem Set 11 into your lab notebook. Label all resistor names and values.

(4-4) Next to your design for the digital-to-analog converter, make a table showing the expected converter output v_{DAC} for the eight cases where one of the data-bit input voltages is 5 V and the others are all 0 V. Base the table on the actual resistor values used in your design. Also, note the expected value of the offset voltage v_{OFF} required to center the converter. You will use this information to determine whether the converter you construct during In-Lab Exercise 4-2 works correctly.

(4-5) Copy your design for the low-pass filter from Problem 3 of Problem Set 11 into your lab notebook. Label all resistor and capacitor names and values.

(4-6) Next to your design for the low-pass filter, copy the graph from Part (F) of Problem 3 of Problem Set 11 into your lab notebook. Also, make a table showing the expected magnitude and phase of the filter output v_{LPF} given a 2-V peak-to-peak sinusoidal input with a frequency of 4 kHz, 8 kHz and 16 kHz. Base the table on the actual resistor and capacitor values used in your design. You will use this information to determine whether the filter you construct during In-Lab Exercise 4-6 works correctly.

In-lab Exercises

The in-lab exercises are organized so that you will construct and test one functional block at a time. *As you develop the system in this manner, it is essential that you turn off the power to the protoboard before you make modifications to your system, or begin any new construction. Also, check your wiring carefully before turning the power back on.* This will avoid damaging the components in the system, and save you considerable debugging time.

Construct the functional blocks as compactly and neatly as possible. In this spirit, you should find it easiest to use the components to wire themselves together, rather than using extra wires. This will save you considerable construction time, as well as considerable debugging time.

It is recommended that you assign the four power rail columns on the left and right sides your protoboard as follows, from left to right: -15 V, ground, +5 V, and +15 V.

(4-1) Following your design from Pre-Lab Exercise 4-1, construct the clock using the 74HC14 inverter chip in your lab kit. *It is recommended that you place the chip in rows 3 through 9 on your protoboard.* Figure 1 shows the pin assignments for the inverter chip. Use any two of the inverters in the chip, and do not connect the others.

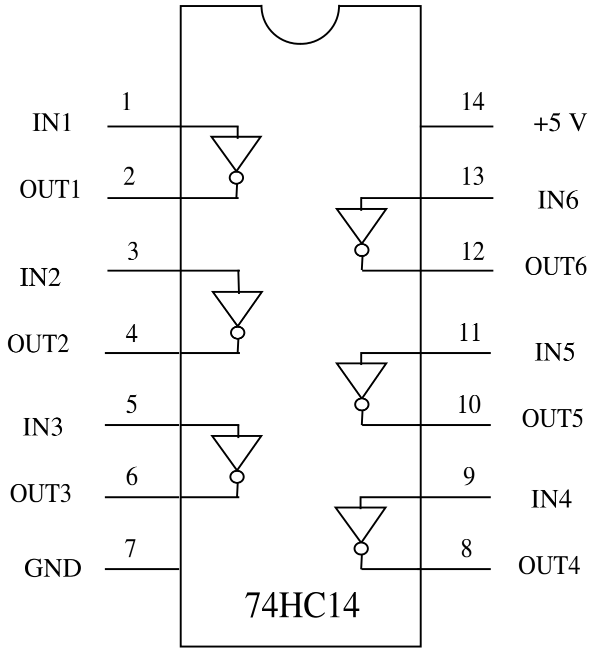

Figure 1: pin assignments for the 74HC14 inverter chip.

Use one channel of the oscilloscope to observe the oscillator output v_{OSC}, and trigger the oscilloscope from that channel. Use the other channel to observe v_{CAP} and the clock output v_{CLK}. Compare what you observe with the oscilloscope to the graph prepared during Pre-Lab Exercise 4-2 to determine whether or not the clock is functioning properly. In particular, the clock output v_{CLK} should remain between 0 V and 5 V so as not to damage the counter which it will drive.

(4-2) Following your design from Pre-Lab Exercise 4-3, construct the digital-to-analog converter.

As you build the converter, you need to leave room on your protoboard for the counter and memory which will be inserted during a later step. *Thus do not place any components into the single column of holes 11a through 45a, nor any components into rows 11 through 45 of the two power rail columns to the immediate left of these holes.* All other holes, such as those in columns b and higher, or those outside rows 11 through 45, are available for components. Furthermore, assume that when the counter/memory is inserted, the voltages v_{DB0} through v_{DB7} are applied to holes 34a through 27a, respectively.

To build the digital-to-analog converter, note that the 741 op-amp is in your lab kit, and extra resistors can be obtained from the boxes in the southeast corner of the lab. Figure 2 shows the pin assignments for the 741 op-amp. Note that pins 2 and 3 are the signal inputs, pin 6 is the signal output, pins 4 and 7 are power, and pins 1, 5, and 8 will not be connected for this lab. *It is recommended that you place the op-amp in rows 47 through 50 on your protoboard.*

Adjust the offset voltage v_{OFF} to 0 V, and connect each input (i.e., v_{DBi}) individually to the 5-V power supply while leaving the other seven inputs grounded. Then, measure v_{DAC} with the multimeter, and compare the measurements to the data in the table prepared during Pre-Lab Exercise 4-4 to determine whether the converter works correctly.

(4-3) To minimize wiring, the counter and memory are located on a pre-assembled printed circuit board. Obtain a counter/memory printed circuit board from the Instrument Desk. *You must return this board when you are not using it, as the boards are in short supply.* On the back of this board are pins that will plug into your protoboard. Figure 3 shows the pin assignments for the printed circuit board. The pins for the eight memory output data bits are on the right hand side. The pins for power and ground, and the clock input to the counter, are on the left hand side.

Plug the printed circuit board into your protoboard so that pins B0 through B7 are in holes 34a through 27a, respectively. Note that the left row of pins on the printed circuit board will hang off the left hand side of the protoboard. They can be connected to the 5 V power supply, ground, and the clock output as shown in Figure 3, using wires inserted into the holes in the top face of the printed circuit board.

(4-4) Connect the clock output of the inverter chip to the clock input of the counter on the printed circuit board. With the oscilloscope, verify that the eight data bits of the memory

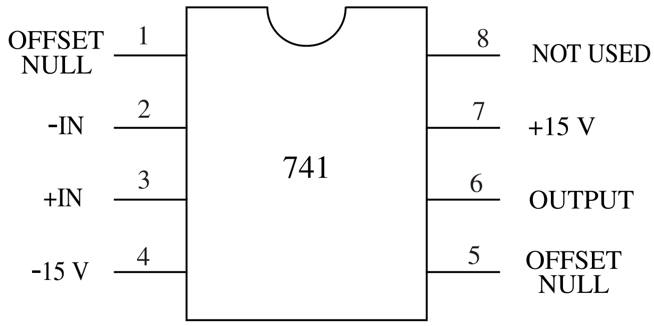

Figure 2: pin assignments for the 741 op-amp.

output are changing in time.

(4-5) Ensure that the eight data-bit inputs of the digital-to-analog converter are connected to the corresponding data-bit outputs of the memory; refer to Figure 3 for the memory pin assignments. With the oscilloscope, observe the converter output v_{DAC}. You should see an audio signal reconstructed in a piecewise-constant manner. Adjust the offset voltage v_{OFF} so that the audio signal is centered around 0 V.

(4-6) Following your design from Pre-Lab Exercise 4-5, construct the low-pass filter using a 741 op-amp. Set the function generator to produce an unbiased 1-kHz sinusoid with a 2-V peak-to-peak amplitude and connect it to the input of the filter. With one channel of the oscilloscope, observe the input to the filter, and trigger the oscilloscope from that channel. With the other channel, observe the filter output v_{LPF}. Vary the frequency of its input voltage and compare the frequency response of the filter to that predicted during Pre-Lab Exercise 4-6 to determine whether the filter works correctly.

(4-7) Connect the output of the digital-to-analog converter to the input of the low-pass filter. Using the oscilloscope, compare the output of the converter to the output of the filter. While the two outputs should look similar, the output of the filter should look considerably smoother upon detailed inspection.

(4-8) Obtain a speaker from the Instrument Desk. Complete the audio playback system by connecting the output of the low-pass filter to the speaker. You should now hear the audio signal recorded in the memory as it is played back through the speaker.

(4-9) As a final in-lab exercise, experiment with the audio playback system. For example, remove the low-pass filter and see how your perception of the audio signal changes. Also, disconnect one or more of the least significant memory data bits from the digital-to-analog converter and see how your perception of the audio signal changes. Try this with and without the low-pass filter. How may data bits are necessary to make the audio signal intelligible?

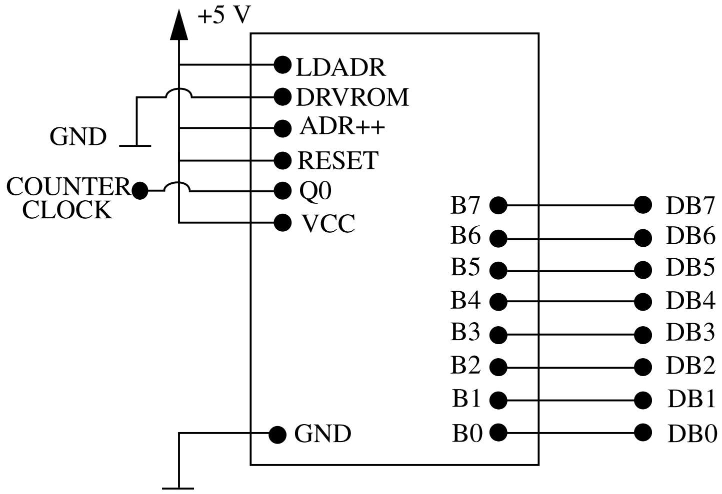

Figure 3: pin assignments for the printed circuit board that contains the counter and memory.