ECEn 445 **Laboratory Experiment 5** **D. T. Comer**
10/19/2004 **The D/A Converter**

Objectives:

1. Familiarize student with a D/A converter in a typical application (stair-case generator).
2. Use students' breadboard circuit from laboratory experiment 2 to generate driving signals for their DAC.
3. Increase students' understanding of settling time, least significant bit and propagation delay. Understand how these specifications affect mixed signal applications.
4. Increase students' understanding of data sheets.

References:

Chapter 11 of *Introduction to Mixed-Signal VLSI,* especially pps 360-367 is a good reference on data converters. Class notes should be beneficial, and the accompanying data sheets will help with connecting your circuit correctly and answering a few questions from the lab.

Materials:

1. Breadboard
2. Digital binary counter (SN74393 or SN74LS393)
3. 741 Op-Amp (LM741 or equivalent)
4. Discrete resistors, capacitors, and BJTs
5. Digital to Analog Converter (DAC08)
6. Oscilloscope, signal generator, and digital voltmeter (DVM)
7. Adjustable power supply (5V and ±12V)

Procedure:

1. Verify the correct operation of your multivibrator/counter circuit from laboratory experiment 2.
2. Connect the circuit as shown in Fig. 1. Adjust the potentiometer R_x to produce a $V_{REF} = 5.000$ V. Measure as accurately as possible using a DVM.
3. Verify the correct operation of your DAC and op-amp. The output of the op-amp should be a "staircase" signal which will appear as a saw tooth waveform when viewed with low resolution.
4. Record the following data and answer the following questions:

Binary Counter

A. Include waveforms showing edge/phase relationships between B7 and B8. How long does it take from the point B8 changes for B7 to change? How does this compare to the data sheet?

B. Determine the propagation delay of B8 through the binary counter. (determine from the data sheet at what value the clock must drop below to activate the counter. From this point how long does it take for B8 to reach a 'high' value) How does this value compare with the data sheet?
C. Determine the propagation delay of B1. How does this compare with B8? How does this compare to the data sheet?

DAC

D. Show an oscilloscope waveform of the output, both a large picture (a few cycles of the waveform) and a small picture (blow up near 0 dc and record a few steps).
E. What is the full-scale output of your circuit? (zoom in and take accurate measurements) How would you increase it to 10V?
F. Calculate what the value of the LSB of your circuit should be. Measure the value of the LSB. How do these values compare?
G. Note the point on your output where the major carry between B2 and B1 occurs. Observe the Vo settling time (within ½ LSB) resulting from this transition. (You may want to use AC coupling to determine when the output reaches ½ LSB. If you include the DC value, measuring within ½ LSB may be difficult)
H. Measure the full-scale to zero settling time of Vo. How does this compare to the specs in the data sheet? (Don't forget you've got extra circuit elements attached to the output of your DAC that aren't included in the data sheet)
I. Determine K, the scaling factor of your DAC.
J. What would you expect your output current to be when your digital input is 10000001? Measure your output current with this digital signal and compare to expected value. (An easy way to measure output current is to find the output voltage at that point and divide by R_{span} Why is this?)

<u>Hints:</u>

1. To change between AC and DC coupling, press the "Vertical Menu" button on the o-scope and then the "coupling" button. If you're having difficulty 'zooming in' on the waveform with DC coupling, use vertical offset, also in this menu, to lower or raise your waveform so it stays on the screen while you're zooming in.
2. In the "Trigger Menu" you can select which edge to trigger. To get "close ups" near 0 dc on the output it's useful to trigger on the falling edge of the waveform. It is also useful to trigger on the falling edge of the clock since the binary counter is low asserted.
3. If you are having trouble syncing two waveforms (one keeps running across the scope) trigger on the lower frequency waveform (either manually or by attaching it to channel one and pressing "autoset.")

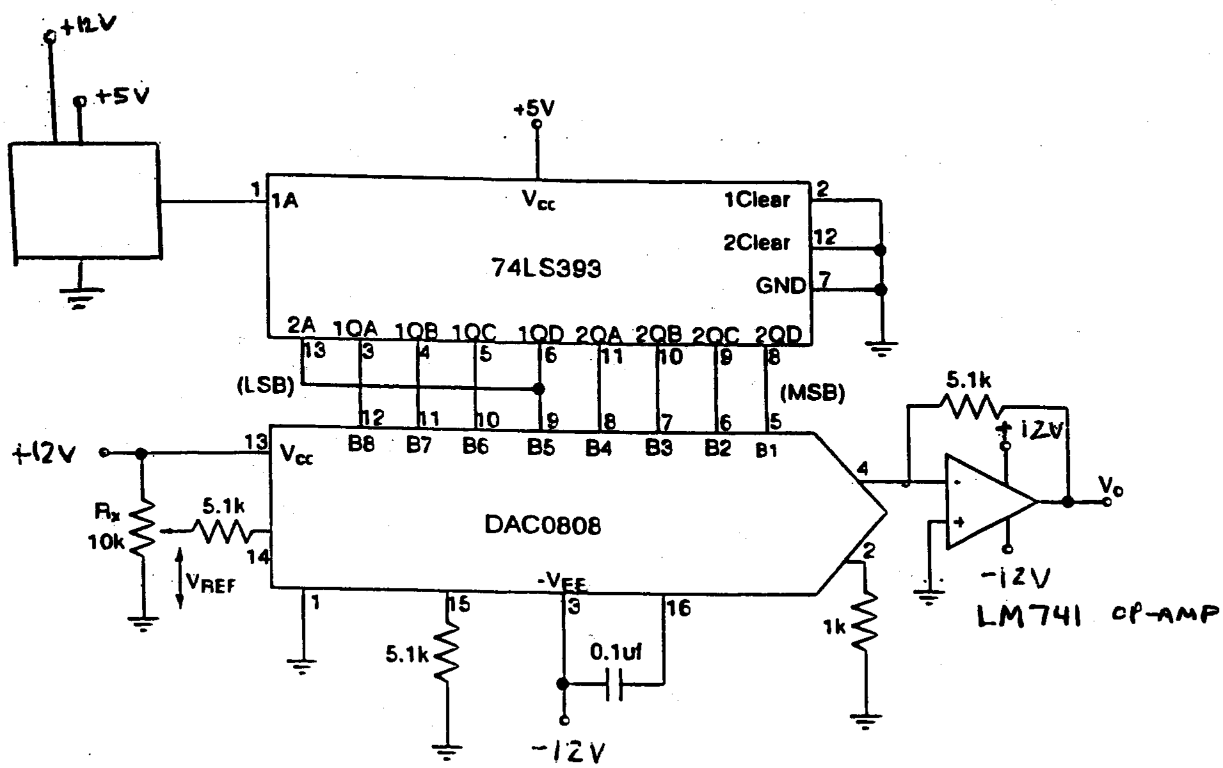

Figure 1: DAC experimental circuit