Phy 335, Unit 7
Analog meets Digital: Comparitors, Converters and Computers

Note: This unit also has extra documentation describing additional digital circuitry needed for this lab. The documentation is linked from the course web page. Read the extra documentation before reading this part and starting the lab.

Mini-lecture topics planned

- **Comparitors, Schmitt trigger**
- **Digital-to-Analog conversion**
- **Analog-to-Digital conversion**
- **Computer interfacing, and details for the last part of this lab.**

1. Analog to Digital Conversion: Comparators and Schmitt triggers. The simplest analog to digital conversion circuit uses an open-loop Op Amp comparator to produce a ±DC output signal depending on whether the input is negative or positive compared to a reference voltage. In this part, the reference is 0V. Using a TL082 Op Amp, build a comparator without feedback, grounding the non-inverting (V+) input. Provide a slow input from the signal generator (SG) for triangular, sinusoidal and square waves. Observe the output and measure the low and high output voltages. Try to observe the switching speed when using an extremely slow input signal. Explain and sketch what you see.

Switch to the specialized Op Amp LM311 with a grounded emitter and a pull up resistor connected to +5V. Provide a voltage divider to set the threshold (V_{REF}) at 2.5 V instead of 0 V. Drive it as above and explain what you see. Observe the changed threshold and measure the output swing. Is the output stable as the signal crosses the threshold voltage.

Using the LM311, build a zero-crossing detector (See Fig. 1) with symmetrical thresholds around 0V. Specifically, build a Schmitt trigger with ±15 V output swing (use –15V on the output emitter lead and +15 V on the pull up resistor). Choose the positive feedback voltage divider R1 and R2 so that the thresholds around zero are set to ±0.5 V.

Test the circuit. Sketch the input and output. Observe the difference made by introducing a positive feedback. Try to observe the switching speed. Is it higher or lower than in the first part above? Why? Is the output stable as the signal cross the threshold voltage.

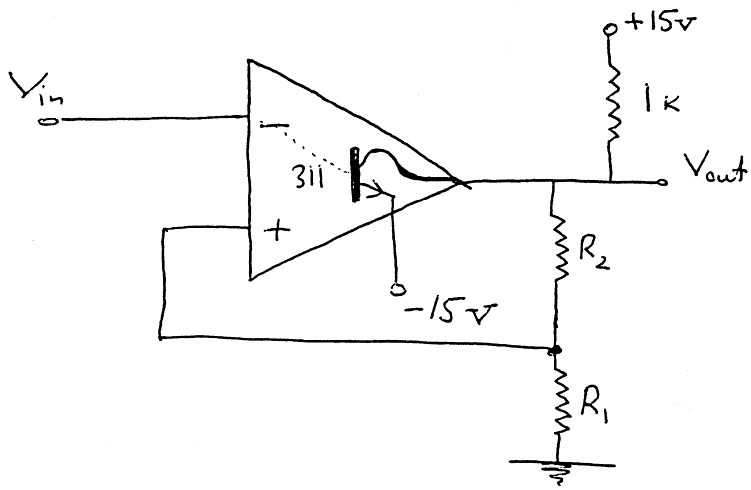

Fig. 1: A symmetric zero cross detector built using a Schmitt trigger circuit.

2. Digital to Analog conversion: (See also the instructions for this part in the "extra" material.) Use a DAC0802 chip and the development board[1] to convert binary numbers in the range 0 – 255 to a voltage between 0V and (approximately) 5V. The DAC circuit we'll use is shown in Fig. 2. *(In your lab report, explain the choices of the specific resistor values based on information from the DAC data sheet.)* The extra material describes the set up connections between the development board and the usual bread board.

Measure the DAC output voltage, V_{out}, for a variety of DAC input values. Check the linearity of the conversion by plotting V_{out} as a function of the input number. Fit a straight line. What are the offset and slope and their uncertainties? The DAC input numbers are generated by the Digital Logic Development Kit as explained in the extra documentation.

3. Analog to Digital conversion: Use the output voltage from part 2 as the input to an ADC0804 in free running mode (See Fig.3 below and/or an ADC0804 data sheet for the control connections to set the ADC in free-run mode). Compare the output binary number from the ADC to the input number to the DAC. Check the linearity of the two conversions by plotting the output number as a function of the input number. The output from the ADC is displayed on two of the 7-sgement LEDs.

4. Complex example, temporarily storing a set of results from an ADC (e.g. for later computer readout)**.** This is a standard way to temporarily buffer input for later read out by a computer. The digital portion of the circuit is preprogrammed into the development boards.

[1] For an explanation, see Unit7 extras on the class web page.

(a) Test without storing: Use the signal generator to drive a 0 to 5V sine wave to the ADC. Also connect the SG output to the scope. Choose the frequency of the sine wave such that the 1024 word FIFO would fill completely[2] after one period. (HINT: How long does it take the ADC to make one conversion, and thus how long would it take the ADC to make enough conversions to fill the 1024 memory location FIFO.). Connect the DATA OUT pins to the DAC input, and display the result from the DAC on the scope. Compare this with the original analog input. Does it match the input? How could the jaggedness be reduced (assuming you could use a different ADC and DAC chip of your own specification).

(b) Store conversion data: Use the "run once" mode of the scope with the start signal as an external trigger to record the sine wave for one period. Draw this in your lab book. Then push the "Store Data" button on the development board to record the (next) sine wave data in the development board.

(c) Read back conversion data: Connect the DAC output to the scope and use the read button on the development board as an external trigger to the scope in run once mode. Push the read button, and verify that you see what you expect on the scope.

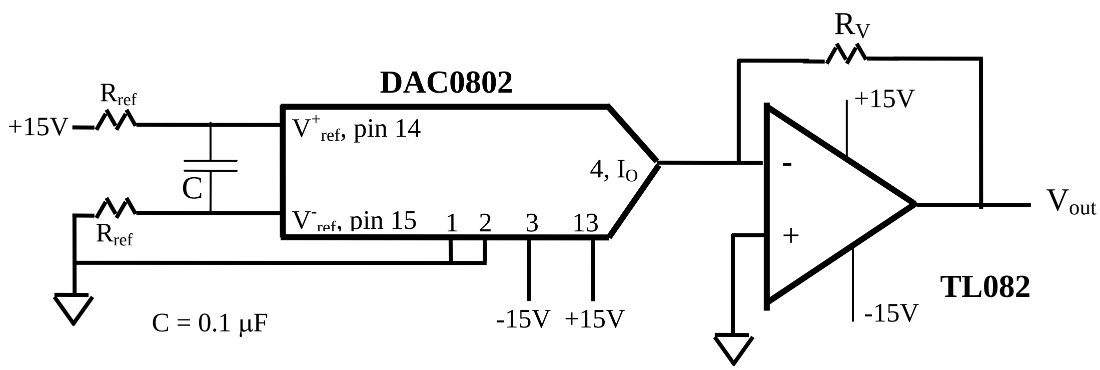

Fig. 2: The DAC power supply connections. The resistor values are chosen such the $I_{ref} = +15V/R_{ref}$ is in the range 1 mA <= I_{ref} <= 4 mA, and $R_V = R_{ref}/3$. The digital input lines are not shown but, of course, must be provided.

[2] The FIFO has 1024 storage words. Measure the time between conversions of the free-running ADC, and use this and the FIFO capacity to choose the frequency of the sine wave.

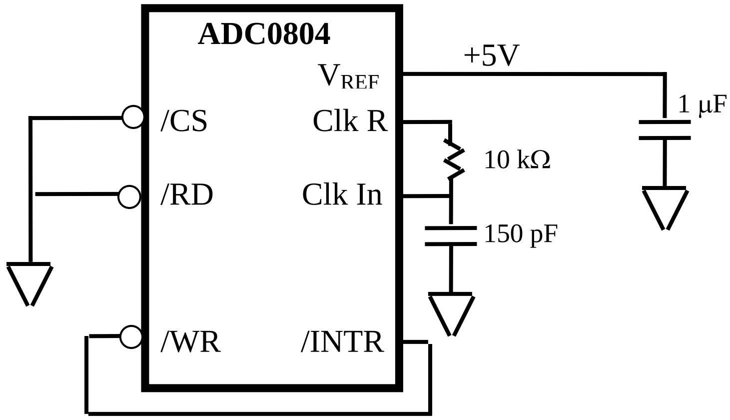

Fig. 3: The power and control signal connections for an ADC0804 running in self-clocking mode with an analog input between 0V and +5V. For full connections, see the "free running connections" figure in an ADC0804 data sheet (e.g. from National Semiconductor). The analog inputs and digital data outputs are not shown. *The /INTR signal must be momentarily grounded to start the ADC running.*