Physics 623
Digital to Analog and Analog to Digital Conversion
January 16, 2023

1 Prelab Worksheet

1) In section 4 of the lab write-up, we are going to build an Analog to Digital converter using the Digital to Analog converter IC MC1408 in a negative feed- back loop. The circuit of Fig. 3 will only track toward increasing negative voltage. Can you modify the circuit so that it will track in both directions? 2) This modification introduces a problem called "hunting" where the count

changes back and forth by one or two counts. Can you think of a way to stabilize the display to make it easier to read? (We can talk about this in lab – the most straightforward solution isn't obvious.)

2 Lab Instructions

2.1 Purpose

- To examine some of the techniques used for analog to digital and digital to analog conversion.

- To illustrate one application of electronics used to interface instrumentation to digital computers.

2.2 Discussion

The Integrated Circuits you need are:

MC1408 — an eight bit "R-2R" DAC which accepts TTL inputs;

74193 — a synchronous 4-bit Up/Down TTL counter;

TIL 311 — an LED Hexadecimal "Hex" display Integrated Circuit;

LM311 — an Analog Comparator and the;

7400 — a quad NAND TTL gate.

In this experiment we will use an IC digital to analog converter (DAC) to create an analog voltage level proportional to a number held in a TTL digital register. In order to obtain an Analog-to-Digital (ADC) function, the DAC must be placed in a negative feedback loop. The analog voltage generated by the DAC is compared to the unknown analog voltage and the number in the register adjusted, depending on the difference, until the difference is less than the voltage corresponding to one bit.

3 Procedure

1. Wire a single 74193 TTL 4 bit counter with a TIL-311 7-segment display and toggle it with one of the debounced spring loaded switches on the bread-board panel. Verify that the counter is sequential over the 16 step range from zero to F and that it can count both up and down.

2. Connect two 74193 units together to make an 8-bit counter with two display readouts. The appropriate connections are shown in Fig. 1.
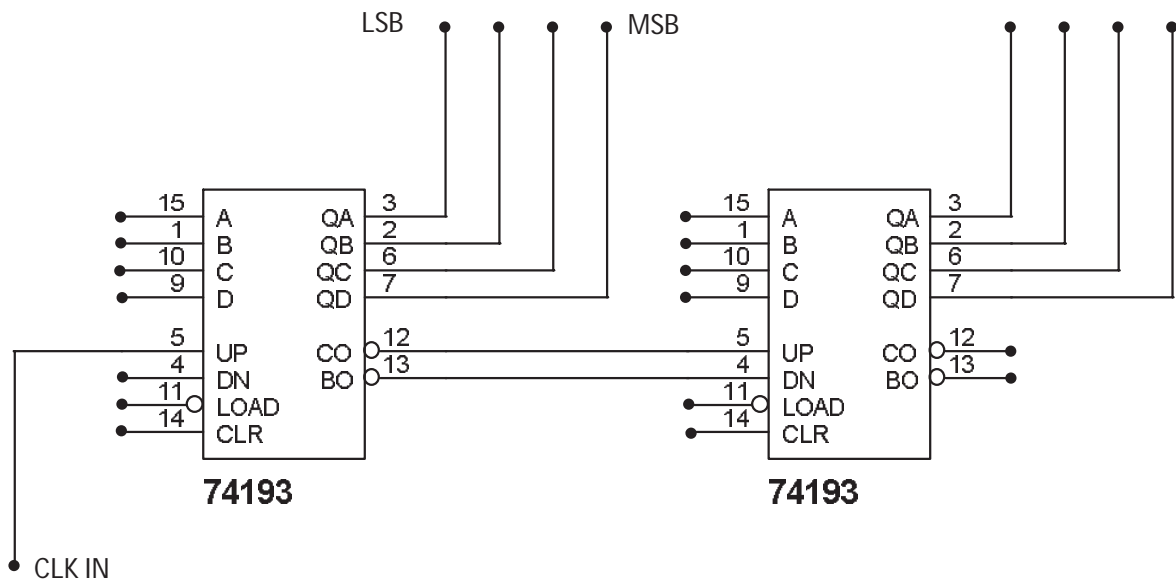
L	+5V
R	High to clear, Low otherwise
CLK UP and	Use one or the other to clock,
CLK DOWN	the unused one must be <u>high</u>.

Fig. 1: 8 bit Binary Ripple Counter

3. Now wire up the MC1408 DAC as shown in Figure 2 and connect the input data lines to the output of the 8-bit counter. Run the entire system as a DAC, driving the counter with the pulser. The DAC will give approximately 0-4 Volts over the full 8-bit range. (Note that on the Motorola version of the MC1408, pin 1 is a range input and must be left <u>open</u>. A1 is the MSB.) Using the pulse generator square wave output to drive the counter, examine the DAC output ramp on the scope. Expand the trace until you can see the individual steps, as well as verifying the linearity of the entire cycle.
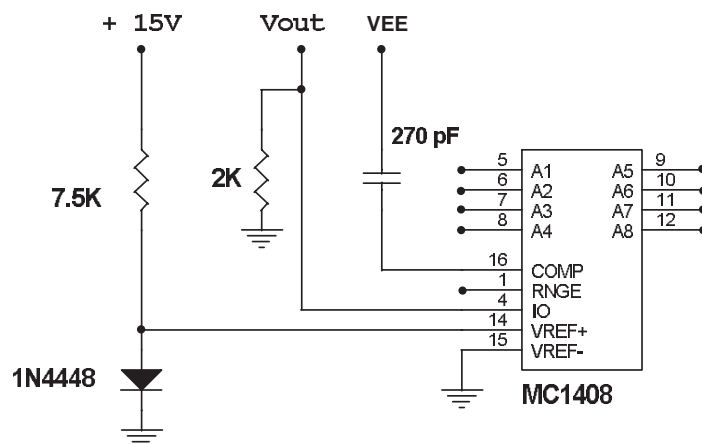
4. If a comparator circuit is added, as shown in Figure 3, you have a tracking analog to digital converter (ADC). The LM311 comparator compares this with the DAC output and stops the clock when the comparator changes state. Note that a NAND gate must be added. Add two TIL 311 Hex displays to get a hexadecimal two digit readout (See Fig. 4).
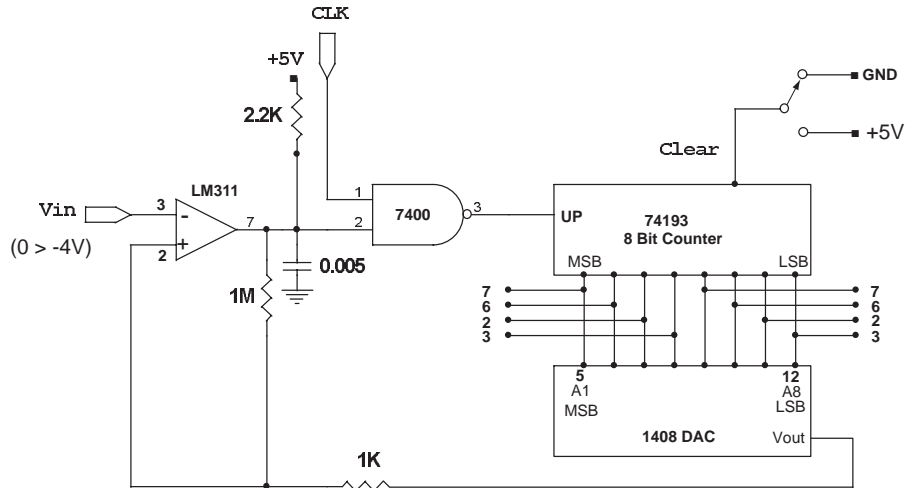

Fig. 3: Analog to Digital Conversion Circuit

5. Determine the response characteristics of the circuit by measuring the counter output as a function of V_{in}. Note that the $+$ and $-$ pin assignment numbers of the LM311 analog comparator are reversed from those of the non-inverting $(+)$ and inverting $(-)$ pin numbers of the 741 operational amplifier.

6. This circuit will track only towards an increasing Negative Voltage. Can you modify this circuit so that it will track in both directions?

7. This modification introduces a problem called "hunting" where the count changes back and forth by one or two counts. Can you think of a way to stabilize the display to make it easier to read?
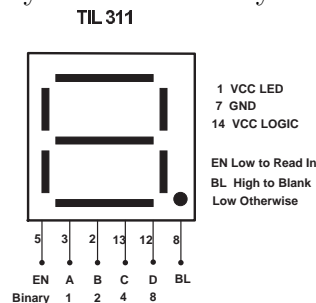

Fig. 4 : TIL 311 Hexadecimal Display

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