Experiment #1

1.1 Abstract

The objective of this experiment is to introduce you to simple TTL logic --- you will learn to manually wire and debug the hardware on the breadboard. The experiment consists of several stages. First, a waveform generator drives a divide-by-100 counting network whose count is displayed on a two digit, 7-segment LED display. Then, you will build a one-of-four decoder with single LED outputs.

1.2 Introduction

This experiment will expose you to TTL hardware breadboarding and debugging techniques. Before you start this experiment, read the introduction and other relevant sections (such as the one on TTL logic) in the manual, it should answer many questions and help with most problems you might encounter.

This experiment consists of four hardware parts and tasks evolving around these. Proceed sequentially through each part, building and debugging each part completely before starting the next. However, plan out the layout of the chips on the breadboard in advance, so that you will have enough space for subsequent parts. Use color-coding of your wires, so that signals may be easily traced. Also cut wires so that they lay flat against the board and a minimum number of wires cross over each other. Using these techniques may take longer, but they will save you a significant amount of time in debugging problems. Remember you will be graded on the neatness of your breadboarding technique.

Figure 1.1 shows the block diagram for experiment #1. In the first stage, you will set the waveform generator to output a square wave with a frequency of 1 Hz. With the help of the oscilloscope, you will verify that the function generator is producing the correct waveform.

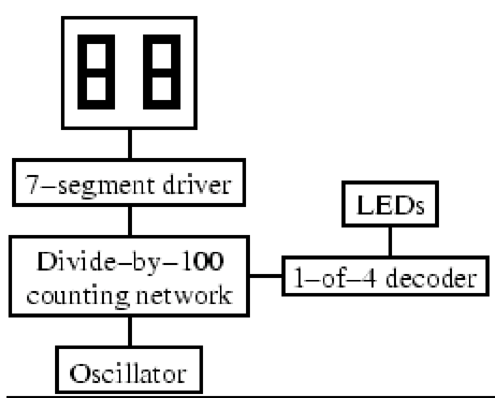

Figure 1.1: Block diagram of experiment #1

Then you will add two decade counters to the circuit and cascade them so that combined they count from 0 to~99. In the third stage, you will set up a decoder and display combination to show the count from both counters on a 7-segment LED. Finally, a one-of-four decoder will be constructed using NAND gates and inverters, and then used to drive a set of single LEDs.

1.3 Hardware

1.3.1 Board Setup

Power Supply

For most labs we will only need to use one side of the power supply, both sides are the same so just pick one. Turn on the power supply and make sure the voltage is set to 5V on the side that you will be using. Also make sure that the C.C. light is off. If this light is ever on quickly turn off the power supply as it means you have a short circuit and may be burning up chips on your board. Now put your red connector into the + red socket on the side that you chose, this will be your 5V or VDD. Now place a piece of wire between the - black terminal and the GND green terminal, this will ensure the GND you use on your board is the same ground as the common ground of the earth. Connect your black connector to the - or GND terminal (they are both the same now) to use as ground for your board. You should route VDD and GND on your breadboard along the red and blue/black lines respectively. Note that the red and blue lines are discontinuous, so you must connect all the red lines so that they all connect to each other as well as VDD from the power supply. Likewise all blue lines and GND from the power supply should be connected.

Waveform Generator

Set your waveform generator to the square wave setting by hitting *Func* then the up button until SQUA appears on the screen, then hit *Enter*. Then set the frequency of the generator to 1 Hz by hitting *Freq* then the number *1* followed by *Hz/s/V* and then *Enter*. Next, set the amplitude of the wave to 2.5V, half the voltage swing, by hitting {\it *Amp*}, then *2.5* followed by *Hz/s/V* and then *Enter*. Next, set the offset of the wave to 1.25V by hitting *Offset*, then *1.25* followed by *Hz/s/V* and then *Enter*. The offset of half the amplitude should keep the ground from the waveform generator the same as the ground from the power supply. Finally, hit the *CHN 1* button just above the socket for the coax cable. Now connect the black output of the generator to GND on the board and the red output of the generator to a wire that will soon be connected to a CKA of the Decade Counter.

1.3.2 Decade Counter

Next you will construct a divide-by-100 counting network from two cascaded decade counters. Start by setting up one counter (7490) to count from 0 to 9 and have the waveform generator drive its clock input (left part of Figure 1.2).
Do not forget to wire unused inputs, e.g. the reset inputs R0 and R9. Note that some manuals refer to the counter outputs $Q_D..Q_A$ as $Q_3..Q_0$ (MSB..LSB). Make sure to test that all outputs, Q_A, Q_B, Q_C and Q_D are correctly counting before proceeding to the next section.

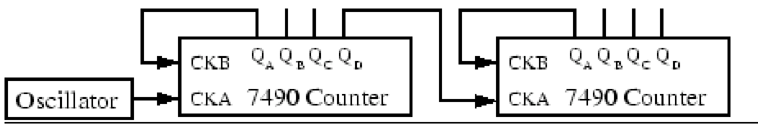

Figure 1.2: Divide-by-100 counting network from two decade counters

Waveforms

Draw a figure showing the clock and all four counter outputs in relation to each other. What is the minimum number of clock cycles you must display on your plot in order to observe each of the outputs completely? Explain why this is so. Before moving to the next section ensure that now all four outputs on each chip are correctly counting.

Cascading

Now add the second decade counter and connect it to the first one as shown in Figure 1.2. Now you have a two-digit counter that counts from 0--99. How does the cascade work? Which counter counts the “ones”, which the “tens”? How does connecting Q_D from one counter to the “CKA” (clock) input of the other achieve the correct overflow/ripple effect?

1.3.3 BCD Drivers and Displays

To display the counter output on a 7-segment LED display, add two BCD-to-7-segment decoders (7447, one for each digit) and use them to drive the 7-segment display. The pin out for the 7-segment display can be found in the 7-Segment Displays section in the Hardware Notes. You will need to determine (by trial and error) if you have a common-anode or a common-cathode display. Remember to use series resistors to drive the LEDs! Again, make sure this part is working before moving on to the next step.

1.3.4 One-of-four Decoder

In the final stage of the experiment you will construct a one-of-four decoder shown in Figure 1.3 from a NAND chip (7400) and a hex inverter (7404). Connect the decoder outputs to discrete LEDs. Do not forget the series resistors!

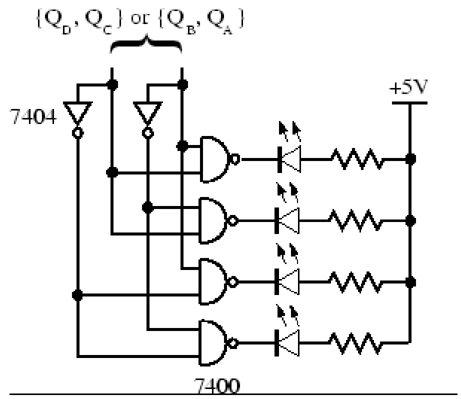

Figure 1.3: One-of-four decoder and LEDs

Decoder patterns

Use the decoder to perform two simple experiments:

1. Connect the decoder inputs to the Q_C and Q_D outputs of the least significant counter and observe the resulting LED pattern. Note that not all of the LEDs connected to the one-of-four decoder are operational. Briefly discuss in your report why this is the case.
2. Connect the decoder to QA and QB and observe the new LED pattern. Now all LEDs are operational. Why?

You might want to refer to the counter output waveforms that you plotted in the Waveforms Section. Show the LED sequence in the pattern for both cases. What are the pattern periodicities?