

Laboratory 8

Digital Circuits - Counter and LED Display

Required Components:

- 2 $1\text{k}\Omega$ resistors
- 1 $10\text{M}\Omega$ resistor
- 3 $0.1\mu\text{F}$ capacitor
- 1 555 timer
- 1 7490 decade counter
- 1 7447 BCD to LED decoder
- 1 MAN 6910 or LTD-482EC seven-segment LED digital display
- 1 330Ω DIP resistor array
- 2 NO buttons

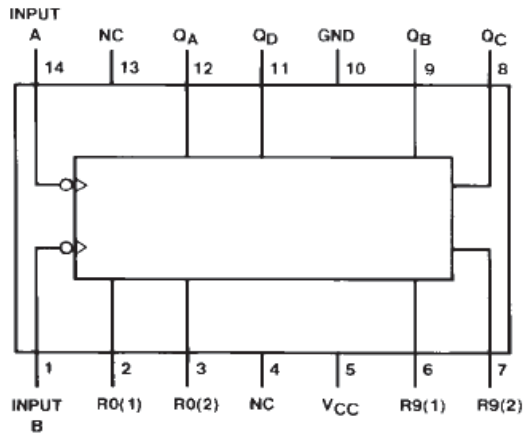
8.1 Objectives

In this laboratory exercise you will build a digital counter with a 1-digit decimal LED display. In doing so, you will learn to assemble and interconnect various integrated circuits to achieve sophisticated functionality.

8.2 Introduction

A common requirement in digital circuits applications is to count and display the number of pulses contained in a continuous TTL compatible pulse train (e.g., the output of a proximity sensor detecting parts on a moving conveyor belt or a photosensor detecting a reflection from a piece of tape on a rotating shaft). We want to count the number of pulses and output this number in binary coded form. This can be done using a 7490 decade counter. Refer to the 7490 pin-out and function information in Figure 8.1.

Connection Diagram



Reset/Count Truth Table

Reset Inputs				Output			
R0(1)	R0(2)	R9(1)	R9(2)	Q _D	Q _C	Q _B	Q _A
H	H	L	X	L	L	L	L
H	H	X	L	L	L	L	L
X	X	H	H	H	L	L	H
X	L	X	L	COUNT			
L	X	L	X	COUNT			
L	X	X	L	COUNT			
X	L	L	X	COUNT			

Figure 8.1 7490 Datasheet Information

The output of the counter is in binary coded decimal (BCD) form and consists of four bits, one bit presented by each of the four output terminals. The maximum number of combinations possible with 4 bits is 2^4 or 16. The 10 output combinations used for BCD are shown in Table 8.1. Note that here a logic high corresponds to a voltage high. A BCD counter cycles from 0 through 9, returning back to 0 after 9.

Table 8.1 7490 Decade Counter BCD Coding

Decimal Count	Binary Code Output			
	Q _D	Q _C	Q _B	Q _A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

The 7490 decade counter has four reset inputs: R0(1), R0(2), R9(1), and R9(2) that control count and reset functions. The Reset/Count Truth Table summarizing the functions of these four pins is included in Figure 8.1. There are many ways to utilize these reset inputs. A simple method is to set R0(2) = H, R9(1) = L, and R9(2) = L, where H=5V and L=0V. When R0(1) is set to L, the counter will be in count mode (see row 5 or 6 of the Reset/Count Truth Table in Figure 8.1).

When R0(1) is set to H, the counter will reset to 0 (LLLL) (see rows 1 and 2 of the Reset/Count Truth Table).

It is also convenient to display the output count on a 7 segment LED in digit form. Another device will be necessary to decode the four bits into a form compatible with the LED array. This device, the 7447 BCD-to-seven-segment decoder, converts the BCD binary number at its inputs into a 7 segment code to properly drive the LED digit (see Figure 8.2). The function table describing the input (BCD) to output (7-segment LED code) relationship for the 7447 is shown in Table 8.2. Refer to Figure 8.3 for the pin-out diagram for the device.

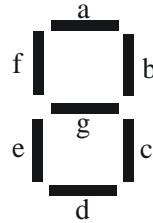


Figure 8.2 Seven-Segment LED Display (LCD)

Table 8.2 7447 BCD to 7-segment Decoder

Decimal Digit	Input				Output						
	Q _D	Q _C	Q _B	Q _A	a	b	c	d	e	f	g
0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	1	1	0	0	1	1	1	1
2	0	0	1	0	0	0	1	0	0	1	0
3	0	0	1	1	0	0	0	0	1	1	0
4	0	1	0	0	1	0	0	1	1	0	0
5	0	1	0	1	0	1	0	0	1	0	0
6	0	1	1	0	1	1	0	0	0	0	0
7	0	1	1	1	0	0	0	1	1	1	1
8	1	0	0	0	0	0	0	0	0	0	0
9	1	0	0	1	0	0	0	1	1	0	0

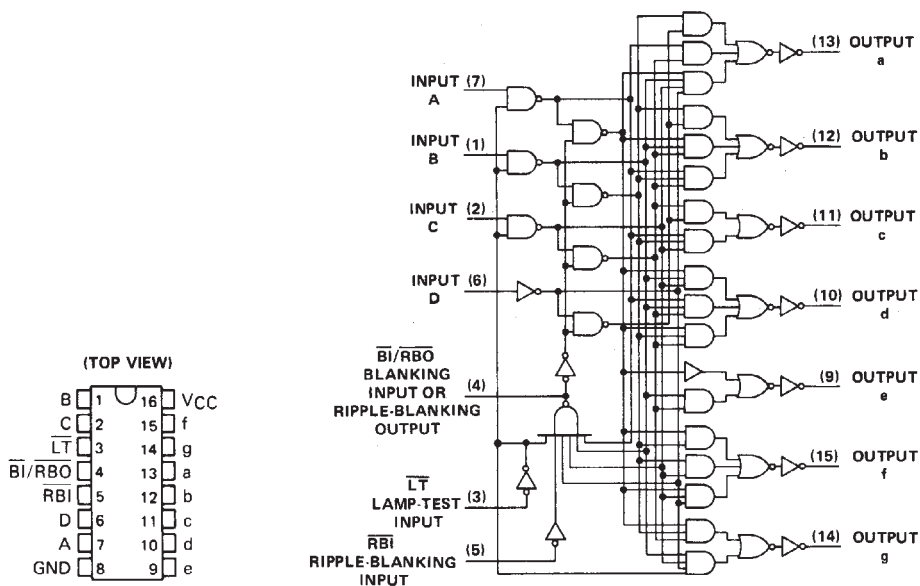


Figure 8.3 7447 Pin-out and Schematic Diagram

If the 7447 decoder driver is now properly connected to a 7 segment LED display, the count from the counter will be displayed in an easily recognizable form. It should be noted that the decoder driver does not actually drive the segment LEDs by supplying current to them; instead, it sinks current from them. Referring to Figure 8.4, the LED is on when the 7447 output is low (0), allowing current to flow to ground. The output is low when the transistor is in saturation, which occurs when the base of the transistor is high. When the transistor is in cutoff (when the base is low), the output will effectively be an open circuit. In this case, no current flows and the LED is off. 330 ohm resistors are used to limit the current that is drawn by the decoder driver and to prevent burning out of the LEDs.

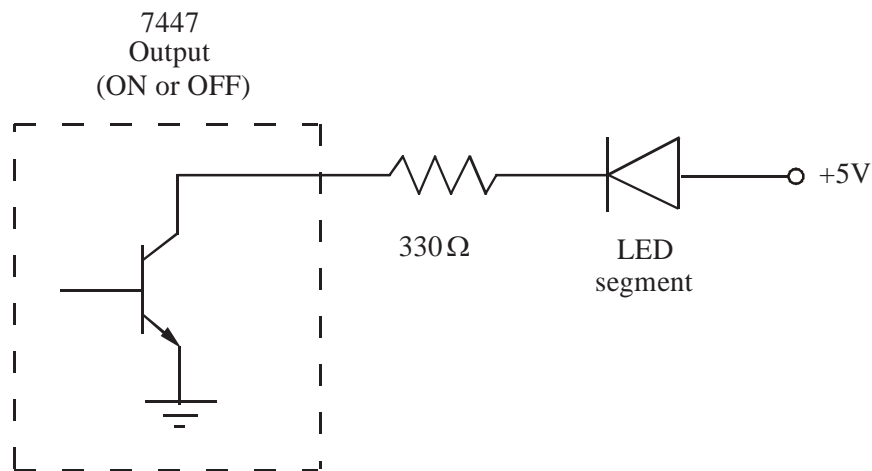


Figure 8.4 Output Circuit of 7447 and LED Driver

As shown in Figure 8.5, the 7490 and single-digit LED displays can be cascaded to count and display any order of magnitude (10's, 100's, 1000's, etc.).

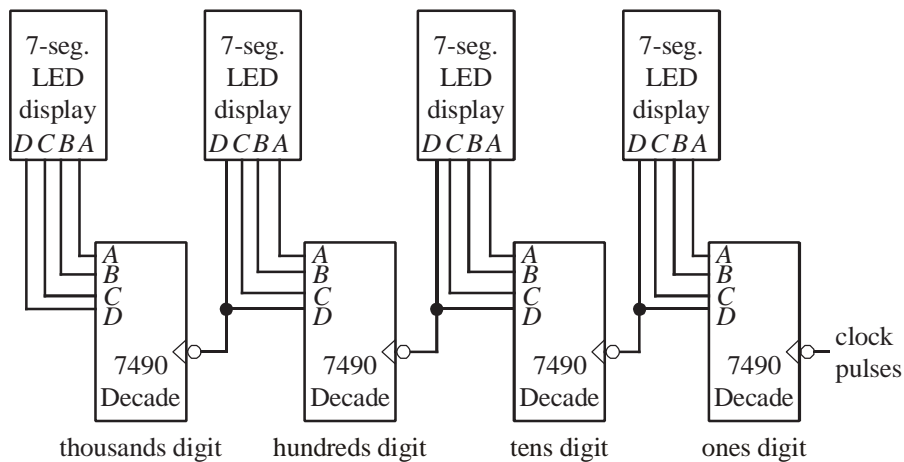


Figure 8.5 Cascading 7490s to display large count values

8.3 Procedure / Summary Sheet

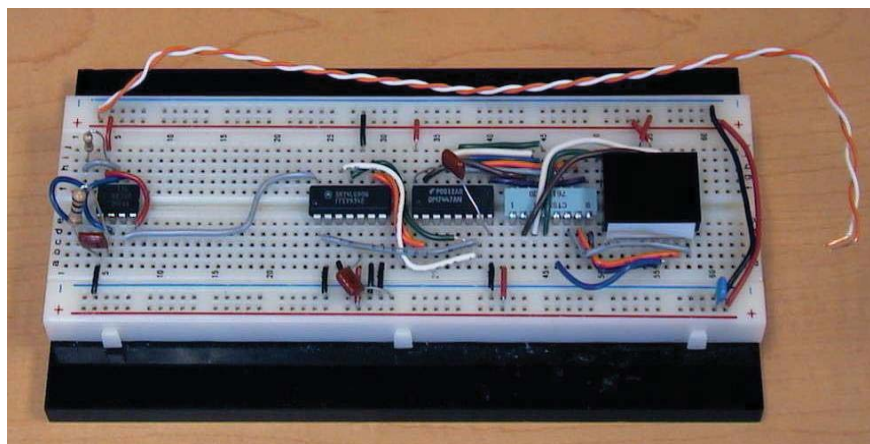


Figure 8.6 Example of Breadboard Wiring

- (1) Construct the 555 timer circuit shown in Figure 8.7 on the left side of your breadboard (see Figure 8.6). Figure 8.8 shows useful information from the 555 datasheet. Using the resistor and capacitor values shown in Figure 8.7, the output of the circuit will be a pulse train with a frequency of approximately 0.7 Hz, corresponding to a period of approximately 1.4 sec (see Section 6.12.3 in the textbook for more information).

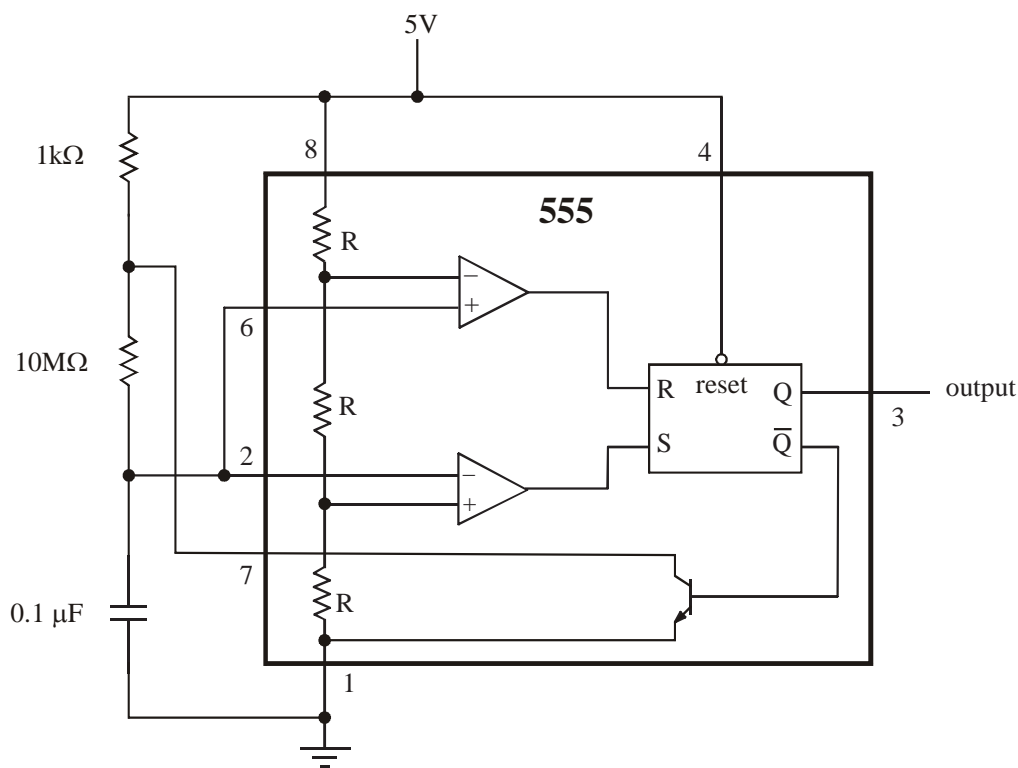


Figure 8.7 555 Timer Circuit

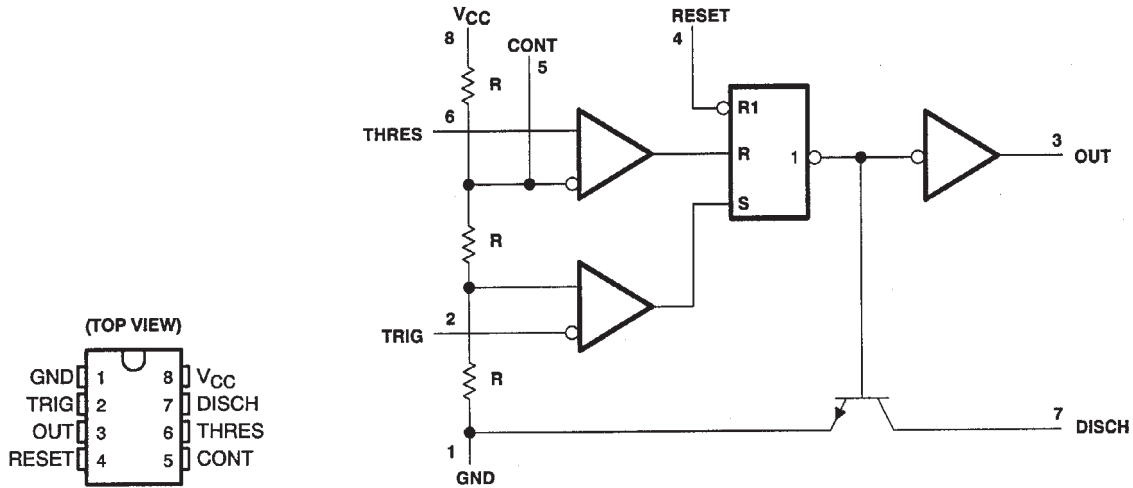
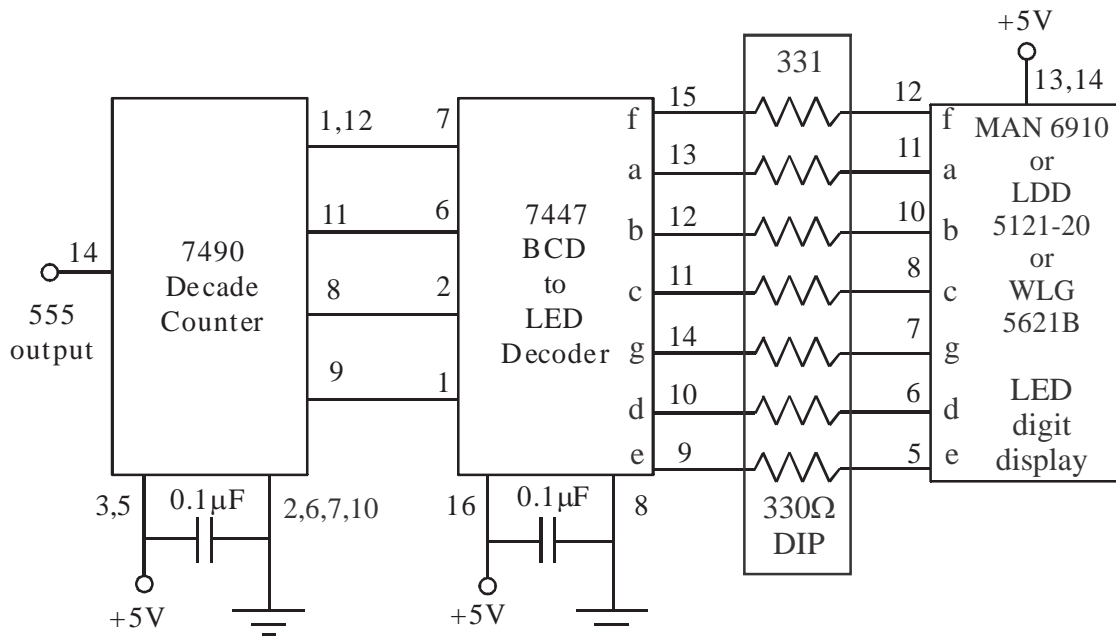


Figure 8.8 555 Pin-out and Circuit Diagram

- (2) Verify that your timer circuit is working properly by displaying the output on the oscilloscope **and** by driving an LED. Show the result to your TA before continuing. Leave this circuit on your protoboard as it will be used later.
- (3) In the steps that follow, you will construct the one-decade digital display shown on the right side of Figure 8.6. The detailed wiring diagram is shown in Figure 8.9. **Don't start building the circuit yet!** Read the information below and then follow the steps in the remainder of the procedure (starting on the next page). Each group should have a 7-segment LED display (e.g., MAN6910 or LTD482EC), a 7447, a 7490, and a 555.

When making connections, trim wires to appropriate lengths so they will lay flat against the board when inserted. A “rat’s nest” will not be acceptable. Also, if multiple wire colors are available, be purposeful with your selections (e.g., red for power, green for ground, and other colors for different signal types). Please see the TA’s board and Figure 8.6 as model examples.

Figure 8.10 includes useful reference information from the MAN6910 datasheet. If your display is not one of the model numbers listed in Figure 8.9, you might need to look up the spec sheet for your display to see which circuit in Figure 8.9 to use (by comparing the spec sheet to Figure 8.10 if necessary).



or

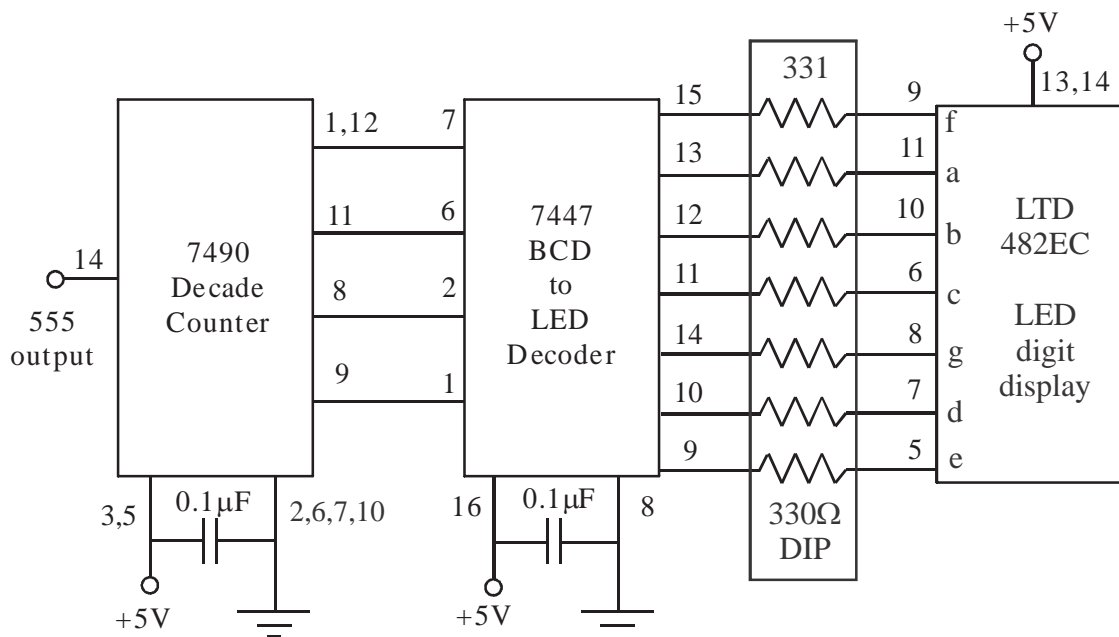


Figure 8.9 Decade Counter Wiring Diagrams

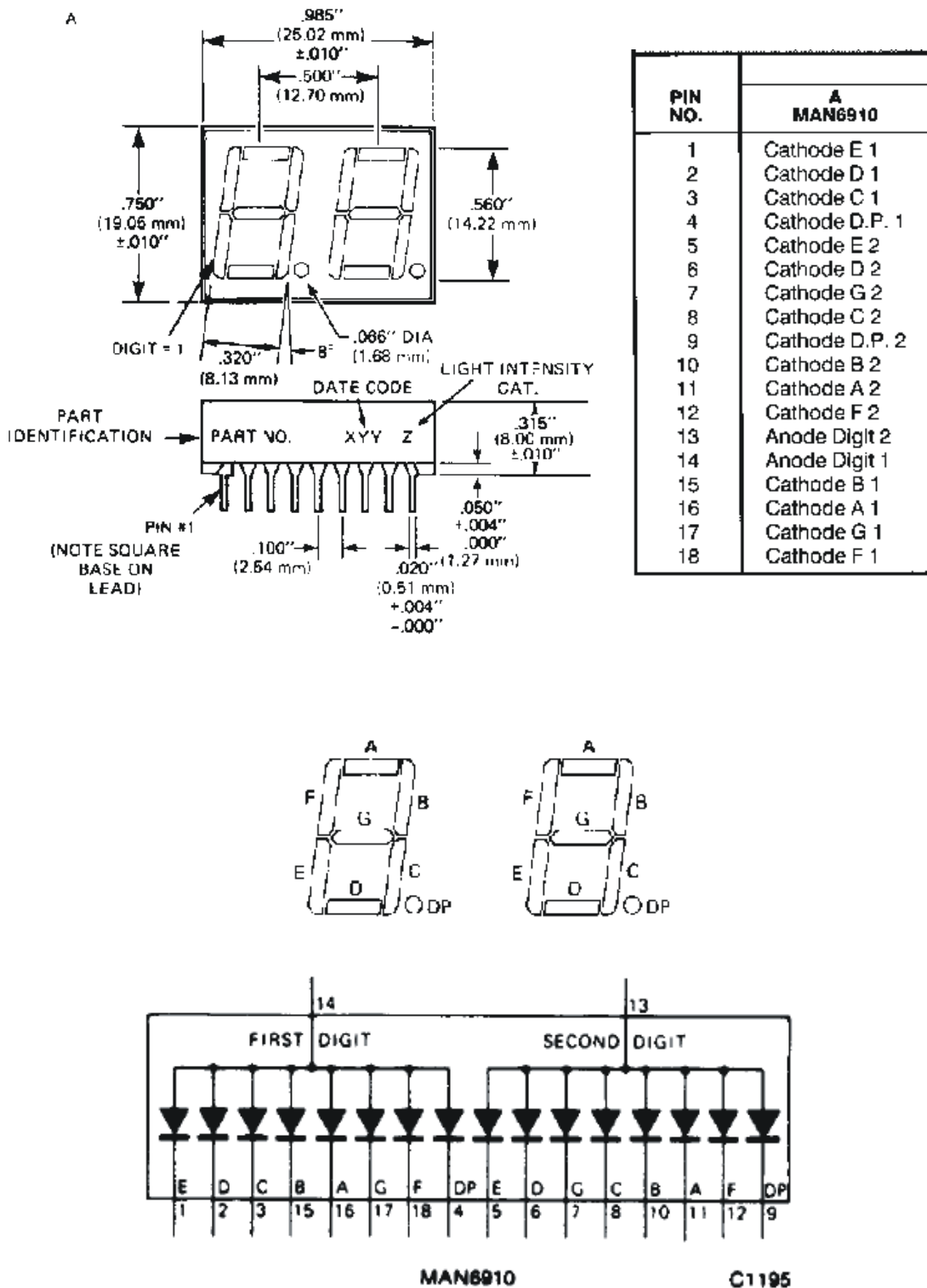


Figure 8.10 MAN6910 Datasheet Information

- (4) Wire the top and bottom two rows of the breadboard together as shown in Figure 8.6 so both power (+5V) and ground will be accessible on both sides of the board. This makes it convenient to connect to +5V and ground on either side of a component. It is good practice to leave the power supply off and disconnected while working on the circuits. Only when you are ready for a test should you turn on the power supply, check to make sure the voltage is set to +5V, and then connect to your board.
- (5) Before inserting any components in the board, be sure to lay them all out first to make sure everything will fit. Figure 8.6 shows a suggested board layout.
- (6) Insert the MAN6910 2-digit display on the right side of the board, with the corner labeled MAN6910 at the lower-left side. This label marks pin 1 on the MAN6910.
- (7) Insert the 330 Ω DIP resistor IC next to the display. Connect pins 13 and 14 of the MAN6910 to +5 V (see Figure 8.10 for MAN6910 pin-out information). Nothing more for now! As a test, connect three of the 330 Ω DIP resistors to pins 3, 15, and 16 of the MAN6910, grounding the other ends of the resistors. Double-check your circuit, and then turn on and connect the power supply. Is the displayed digit what you expected? If not, consult with your TA. When you are done with this test, turn off and disconnect the power supply until you are ready for the next test. Also remove all of the resistor connections.
- (8) Insert the 7447 IC next to the 330 Ω DIP resistor IC. Per Figure 8.9, connect the MAN6910 one's (right) digit to the 7447 and connect +5V and ground as shown.
- (9) Activate the 7447 lamp test by attaching 0V to pin 3 and 5 V to pin 4. Turn on and attach the power supply to see if all LED segments come on, as they should.
- (10) Remove the wire from pin 3 and apply +5V to pins 1, 2, 7 and ground to pin 6 of the 7447. Does the display show what you think it should? Turn off and disconnect the power supply before continuing.
- (11) Finish wiring the 7447 and 7490 as shown in Figure 8.9. Refer to the 7490 Reset/Count Truth Table and the description of the reset inputs in Section 8.2. In Figure 8.9, pins 2, 6 and 7 (R0(1), R9(1) and R9(2)) are grounded and pin 3 (R0(2)) is held high, putting the 7490 in count mode. To be able to reset the counter, wire up a normally-open (NO) button to pin 2 (R0(1)) so the signal is low when the button is not pressed (see Question 2 below). When R0(1)=L, the counter will be in count mode, and when R0(1)=H (when the button is pressed), the counter will reset to 0.
- (12) Attach the output of your 555 to the input of the 7490. Double-check your entire circuit! Then turn on and attach the power supply to see if your circuit is working properly. If not, see Section 7.4 in the previous Lab for debugging advice.
- (13) Demonstrate to the TA that your display can increment properly from 0 to 9. At the same time, also demonstrate that you can reset the counter to 0.
- (14) Now disconnect the 555 circuit and wire up a button with a pull-up resistor to the 7490 input instead. Press the button a few times and describe what happens and why in Question 3 below.

8.4 Troubleshooting Advice

Often, when assembling complicated circuits like those in this Lab and in your Project, things rarely work the first time because you will often make mistakes. Also, sometimes your connections won't be reliable. When this happens, try to remain calm and logically "debug" or troubleshoot the problem.

Any time you have any problem with any circuit, especially with your Project, carefully follow all of the troubleshooting advice outlines in Section 2.3 in Lab 2, Section 7.4 in Lab 7, and Section 15.5 in Lab 15.

