

Laboratory 11

Digital Displays and Logic (modified from lab text by Alciatore)

Required Components:

- 2x $1k\Omega$ resistors
- 1x $10M\Omega$ resistor
- 3x $0.1\ \mu\text{F}$ capacitor
- 1x 555 timer
- 1x 7490 decade counter
- 1x 7447 BCD to LED decoder
- 1 x seven-segment LED digital display
- 1x 330Ω resistor or 2x $100\ \Omega$ resistors (for 7-segment LED)
- 2x NO buttons

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.

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 1.

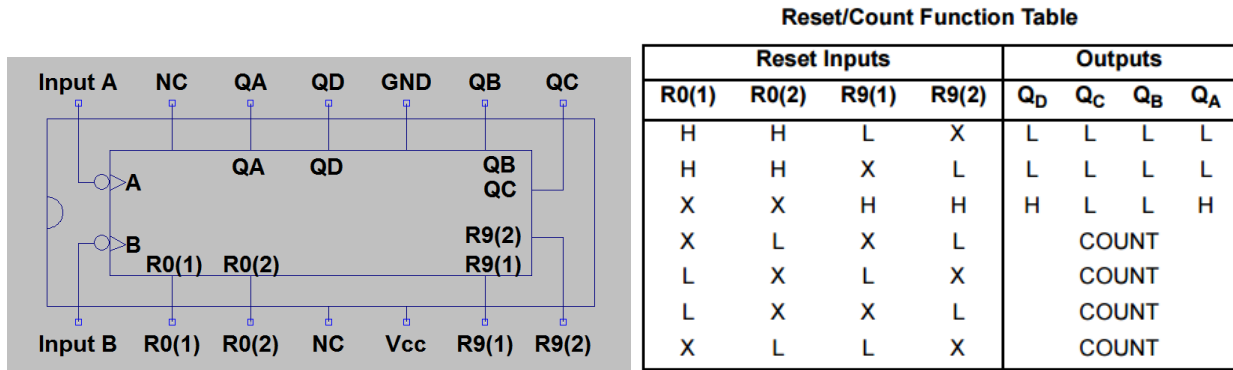


Figure 1 7490 Datasheet information, pinout and function table.

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 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.

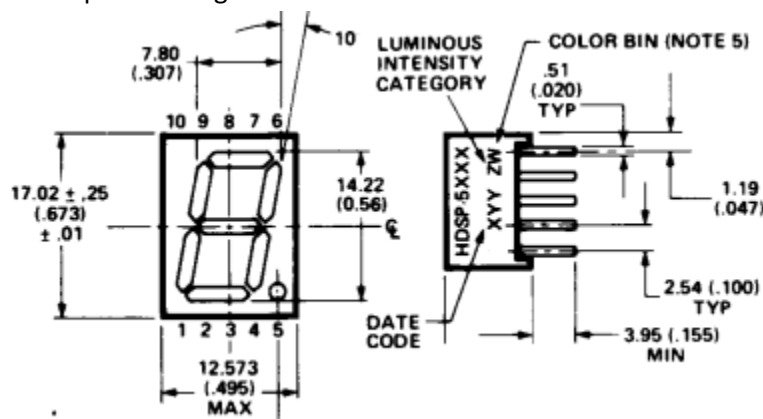
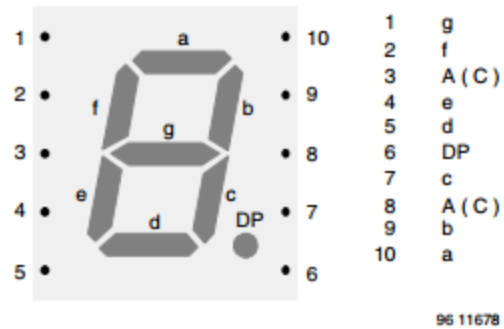
Table 1 7490 Decade counter BCD coding.

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

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We will display the output count on a 7 segment LED in digit form. Requires the information to be changed into a different format and this translation is done by another device. It decodes the four bits from the counter into a form compatible with the LED array. The 7447 BCD-to-seven-segment decoder, converts a BCD binary number to grounds for each of the 7 LED segments in the digit (see Figure 2). The function table describing the input (BCD) to output (7-segment LED code) relationship for the 7447 is shown in Table 2. Refer to Figure 3 for the pin-out diagram for the device.



| Pin | Function |
|-----|----------|
| 1 | e |
| 2 | d |
| 3 | Cathode |
| 4 | c |
| 5 | DP |
| 6 | b |
| 7 | a |
| 8 | Cathode |
| 9 | f |
| 10 | g |

Figure 2 Seven-segment LED display's available in lab include TDSG3150 (top) and HDSP-5601 (bottom). The pinout is specific to the device.

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 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.

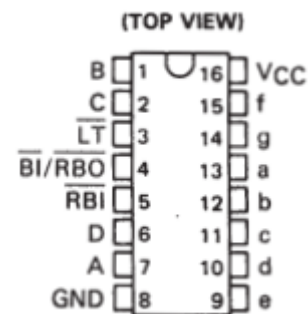


Figure 3 Pinout of 7447 BCD to 7 segment decoder. See Texas Instruments datasheet online for internal logic.

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Table 2 7447 BCD to 7-segment decoder.

| Decimal Digit | Input | | | | Output | | | | | | |
|---------------|----------------|----------------|----------------|----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | Q _D | Q _C | Q _B | Q _A | \bar{a} | \bar{b} | \bar{c} | \bar{d} | \bar{e} | \bar{f} | \bar{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 |

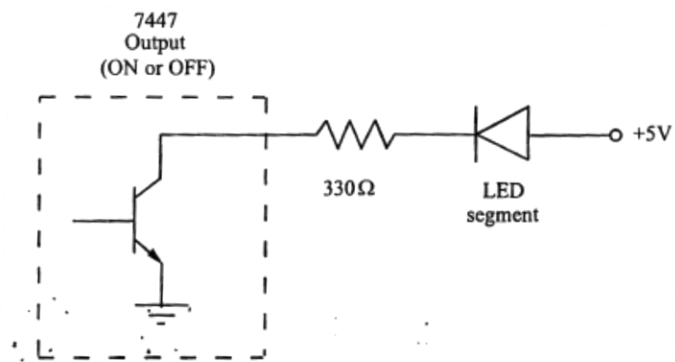


Figure 4 Output Circuit of 7447 accepting power from an LED. We will place the resistor before the LED rather than after.

As shown in Figure 5, the 7490 and single-digit LED displays can be cascaded to count and display any value.

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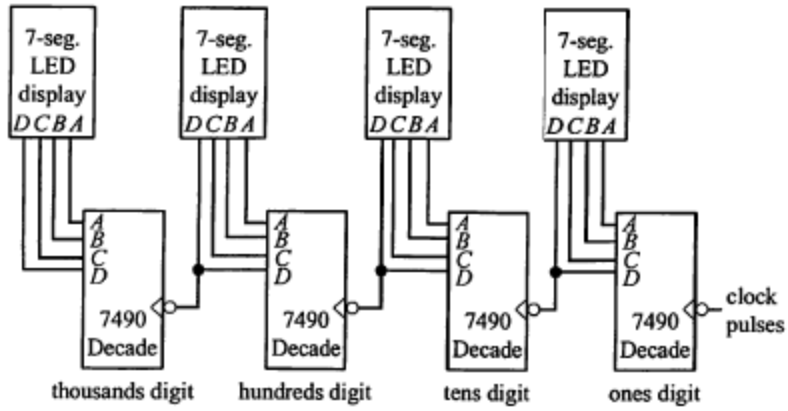


Figure 5 Cascading 7490s to display numbers larger than 9.

We will use a 555 timer to be our clock, see Figure 6 for pin-out and schematic.

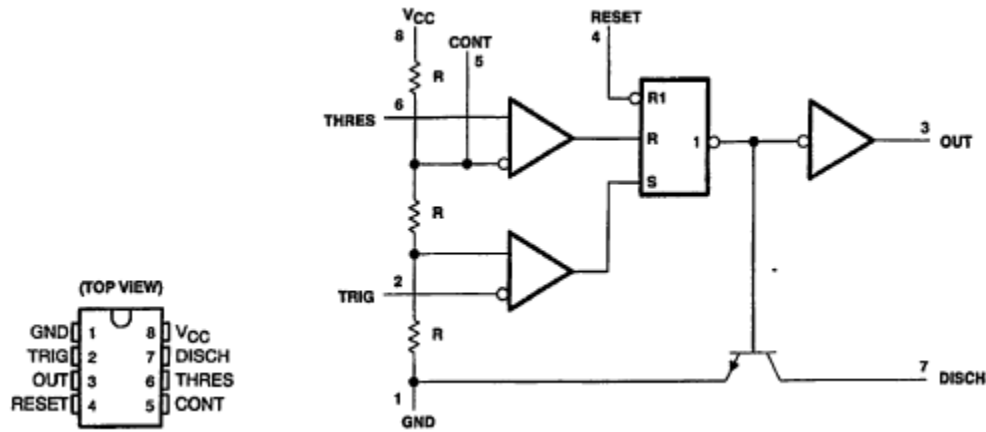


Figure 6 555 timer and schematic.

Procedure/Summary Sheet

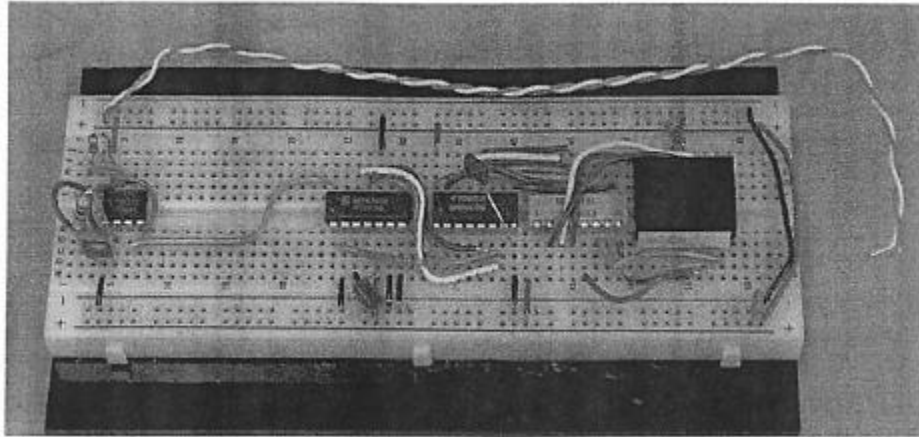


Figure 7: We will be 1 resistor on the common LED cathode instead of using a DIP resistors for all of the LED anodes.

1. Construct the timer circuit (see Figure 7) at one end of your protoboard carefully laying out the connections and wiring for easy debugging. Figure 6 shows information from the 555 datasheet. Using the components shown in Figure 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 book).

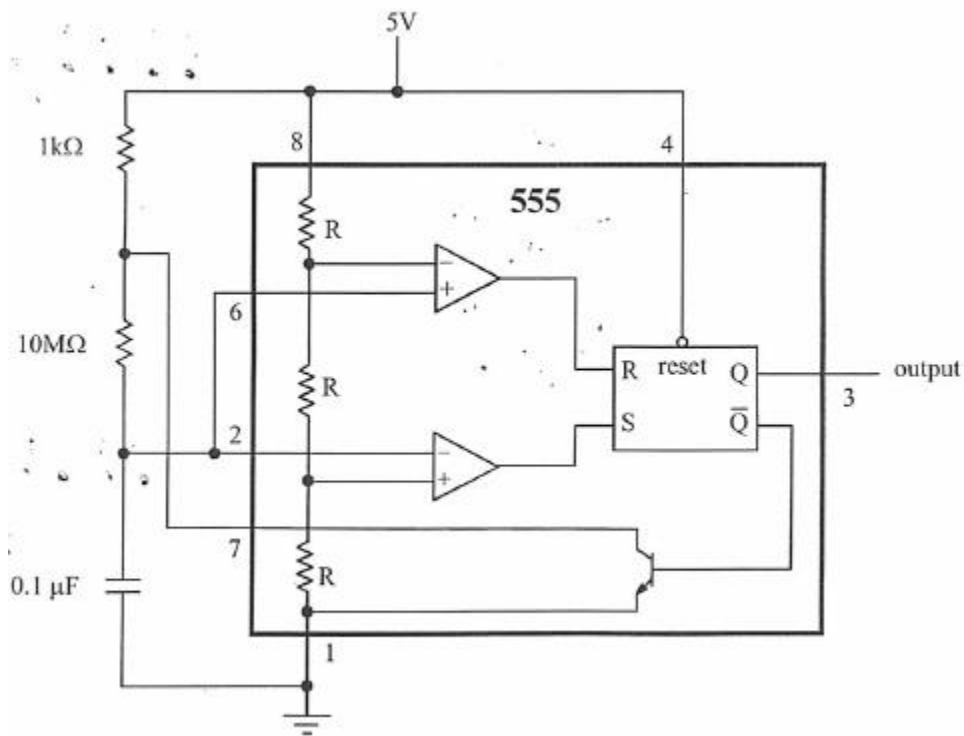


Figure 8 555 Timer circuit

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2. Verify that your timer-circuit is working properly by verifying the output on the oscilloscope or by driving an LED. Show the result to me before continuing. Leave this circuit on your protoboard to use later.
3. In the steps that follow, you will construct a one decade digital display as shown in Figure 8. **Note - don't build the circuit now (see steps 4-13 below).** Each group will be given a 7-segment LED display, a 7447, a 7490, and a 555. Carefully color code your wires, trim them to correct lengths, and insert them flat against the board. A "rat's nest" will not be acceptable. Please see the physical example in the lab (or see the photo at the start of the procedure section). Figure 2 includes useful reference information from the datasheet.

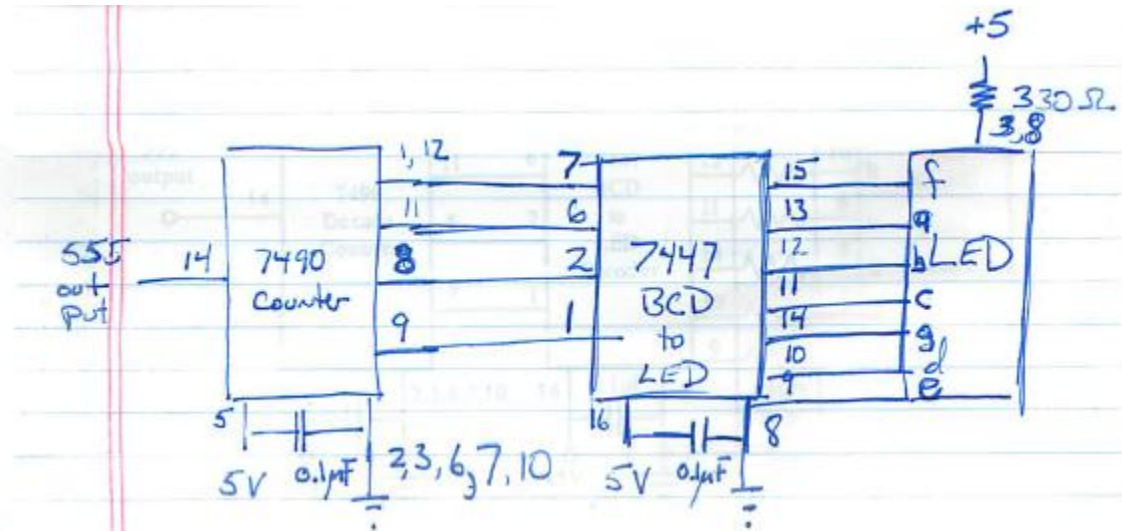


Figure 9 Decade counter circuit schematic.

Breadboard Prep

4. Wire the top two rails of the breadboard (with the long side oriented horizontally) to +5 V on the DC power supply.
5. Wire the bottom two rows of holes on the breadboard to COMMON on your triple output power supply. These rows will constitute a bus for later wiring.

LED Power and Test

6. Insert the seven segment LED display, positioning it in the center of the protoboard with the decimal point in the top right corner. Pin 1 is now in the bottom left corner. Be sure to lay out all of the other components side-by-side to make sure they will fit on your protoboard.
7. Connect the display anodes (pins 3, 8) to +5 V bus through a 330Ω resistor. Nothing more! As a test, ground three pins 7, 9 and 10 of the display. Double-check your circuit, and then turn on the power supply. Is the displayed digit what you expected? If not, consult with me. **Now remove the test grounds for the remainder of the procedure.**

LED control-7447 Install and Test

8. Insert the 7447 on one side of the display. Refer to Figure 2 for pin- out information.
9. Connect the seven segment LED to its 7447 and then attach ground and +5V to the 7447.
10. Attach the lamp test of the 7447 (pin 3,0V and pin 4,5 V). Turn on the power supply and describe what happens. Note - all LED's should light.
11. **Remove the wire from pin 3** and apply +5V to pins 1,2,7 and GND pin 6 of the 7447. Describe the display.

Counter-7490 Install and Test

12. Finish wiring the 7447 and 7490 as shown in Figure 8. Refer to the 7490 Reset/Count Truth Table and the description of the reset inputs above. In the schematic, all of the reset pins are grounded, putting the 7490 in count mode.
13. To be able to reset the counter (e.g., with a pushbutton input), set R0(2)=H, R9(1)=L, and R9(2)=L, and wire up a normally-open (NO) button to R0(1) so the signal is low when the button is not pressed. 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.

Counting clock pulses

14. Attach the output of your 555 to the input of the 7490. Double-check your entire circuit! Then turn on the power supply and see if your circuit is working properly. If not, see the "Hints for Debugging" section of last week's lab for advice.
15. Demonstrate to the lab instructor that your display can increment properly from 0 to 9. At the same time, also demonstrate that you can reset the counter to 0!
16. Understand your signals. Use the oscilloscope to look at the clock pulse on Channel 1 and the Q_A bit on Channel 2. To make it easier to see what is happening on the oscilloscope increase the frequency of your clock by a factor of 1000. Describe what is it about the clock signal that triggers the counter to count in Question 3 below.

Counting button presses

17. 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 4 below.

LAB 11 QUESTIONS

Names: _____

1. Which output pins of the 7447 should be high to display the letter "b"?
2. Draw a schematic of the circuit you used to wire up the normally open (NO) button to reset the counter to 0. Show all required added components and wiring. Also mention anything you removed.
3. What is it about the clock signal that triggers the counter to count?
4. When the button is used for the input instead of the 555 circuit, what did you observe with each press and release of the button, and why? Be specific.