Lab 2:
Breadboard Implementation of a 7-segment Display Decoder

ELEC1710

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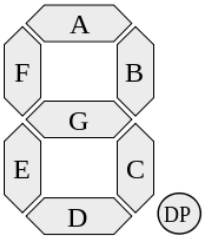
1 Introduction

When builing an electronic device, whether for electrical, medical or mechatonic engineering projects, it is quite likely you would want to display a numerical value to its users. A simple way to do this is using a 7-segment LED display.

The segments of a 7-segment display are referred to by the letters A to G. Each segment of the display is turned 'on' or 'off' depending on which digit is to be displayed as shown in Figure 1. Often an eigth segment, referred to as DP, is also available for use as a decimal point to display non-integer numbers.

Digit	Display	a	b	c	d	e	f	g
0	0	on	on	on	on	on	on	off
1	1	off	on	on	off	off	off	off
2	2	on	on	off	on	on	off	on
3	3	on	on	on	on	off	off	on
4	4	off	on	on	off	off	on	on
5	5	on	off	on	on	off	on	on
6	6	on	off	on	on	on	on	on
7	7	on	on	on	off	off	off	off
8	8	on	on	on	on	on	on	on
9	9	on	on	on	on	off	on	on



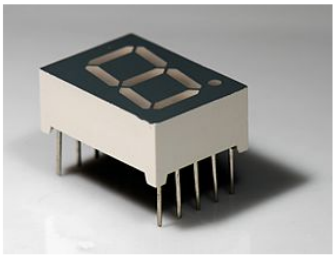


Figure 1: 7-segment display (https://en.wikipedia.org/wiki/Seven-segment-display) To display a '1' the LEDs labelled 'b' and 'c' are turned on while all other LED segments are turned off.

In this lab you will implement a pre-designed logic circuit on a breadboard which takes a 4-bit binary number as an input and outputs the appropriate decimal digit on a 7-segment display. Prior to the lab please review the 4-bit binary representation of the decimal numbers from 0 to 9.

2 Equipment

This lab will require the following parts:

- 1x 7-segment display
- 1x CD74HC4511 7-segment display decoder/driver
- 7x 330Ω resistors (orange-orange-brown-gold)
- 4x 10kΩ resistors (brown-black-orange-gold)
- 4x Tactile push button switches
- Multiple jumper wires

3 7-segment Driver Description

This lab makes use of the CD74HC4511 BCD-to-7-segment latch/decoder/driver intergrated circuit (IC). This device latches (remembers) binary coded decimal data present on the data input pins (D0, D1, D2 & D3) and generates appropriate signals on outputs a,b,c,...,f to display a decimal digit on a 7-segment display. The device is called a 'driver' because it is capable of supplying the (relatively) high currents required to drive LEDs in a 7-segment display (about 5-10mA, depending on voltage).

The device also contains three control pins:

- $\overline{\text{LT}}$ - Lamp Test, active low. If low all segments become lit.
- $\overline{\text{BL}}$ - Blank, active low. If low all segments are switched off.
- $\overline{\text{LE}}$ - Latch Enable. When this pin is low data on D0-D3 is decoded to a 7-segment number. As this pin goes high the binary data on D0-D3 is internally remembered (latched) and changes on D0-D3 are ignored.

The full truth table for the CD74HC4511 is shown in Figure 2.

FUNCTION TABLE

INPUTS							OUTPUTS							
$\overline{\text{LE}}$	$\overline{\text{BL}}$	$\overline{\text{LT}}$	D_3	D_2	D_1	D_0	a	b	c	d	e	f	g	DISPLAY
X	X	L	X	X	X	X	H	H	H	H	H	H	H	8
X	L	H	X	X	X	X	L	L	L	L	L	L	L	Blank
L	H	H	L	L	L	L	H	H	H	H	H	H	L	0
L	H	H	L	L	L	H	L	H	H	L	L	L	L	1
L	H	H	L	L	H	L	H	H	L	H	H	L	H	2
L	H	H	L	L	H	H	H	H	H	H	L	L	H	3
L	H	H	L	H	L	L	L	H	H	L	L	H	H	4
L	H	H	L	H	L	H	H	L	H	H	L	H	H	5
L	H	H	L	H	H	L	L	L	H	H	H	H	H	6
L	H	H	L	H	H	H	H	H	H	L	L	L	L	7
L	H	H	H	L	L	L	H	H	H	H	H	H	H	8
L	H	H	H	L	L	H	H	H	H	L	L	H	H	9
L	H	H	H	L	H	L	L	L	L	L	L	L	L	Blank
L	H	H	H	L	H	H	L	L	L	L	L	L	L	Blank
L	H	H	H	H	L	L	L	L	L	L	L	L	L	Blank
L	H	H	H	H	L	H	L	L	L	L	L	L	L	Blank
L	H	H	H	H	H	L	L	L	L	L	L	L	L	Blank
L	H	H	H	H	H	H	L	L	L	L	L	L	L	Blank
H	H	H	X	X	X	X	†	†	†	†	†	†	†	†

X = Don't care
† Depends on BCD code previously applied when $\overline{\text{LE}}$ = L
NOTE: Display is blank for all illegal input codes (BCD > HLLH).

Figure 2: Truth table for the CD74HC4511

4 Procedure

1. Ensure that the power supply module is switched off and that both output voltage jumpers are set to +3.3 V.

2. Follow the schematic in Figure 3 to complete the following steps:

   a) Insert the push button switches into the breadboard. It is recommended that they are inserted in a group however space them out enough to facilitate easy operation and removal.

   b) Open the Lab 1 document and find the push button pinout shown in Figures 3 and 4.

   c) Connect one terminal of each switch to the positive supply rail.

   d) Connect the other terminal to GND via a 10kΩ resistor.

   e) Insert the CD74HC4511 into the breadboard approximately 1cm away from the nearest switch.

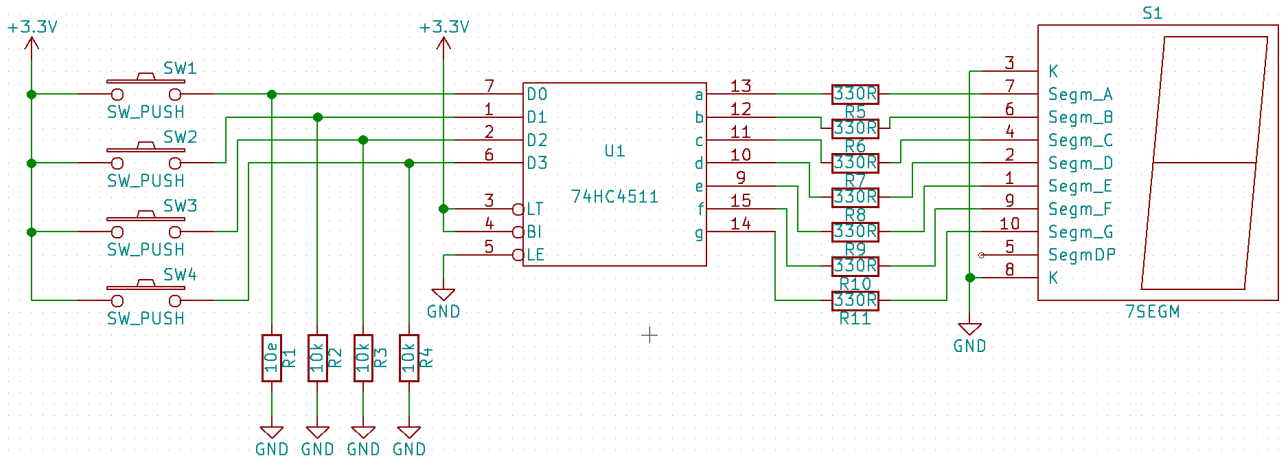


Figure 3: Full circuit schematic

3. Observing the schematic in Figure 3 and CD74HC4511 pinout in Figure 4 make the following connections:

   a) Connect pin 16 (Vcc) to the positive supply rail

   b) Connect pin 8 (GND) to ground

   c) Connect the four switch outputs to the D0, D1, D2 & D3 inputs (pins 7, 1, 2, & 6 respectively) on the CD74HC4511.

   d) Connect $\overline{\texttt{LT}}$ (pin 3) to Vcc

   e) Connect $\overline{\texttt{BL}}$ (pin 4) to Vcc

   f) Connect $\overline{\texttt{LE}}$ (pin 5) to GND

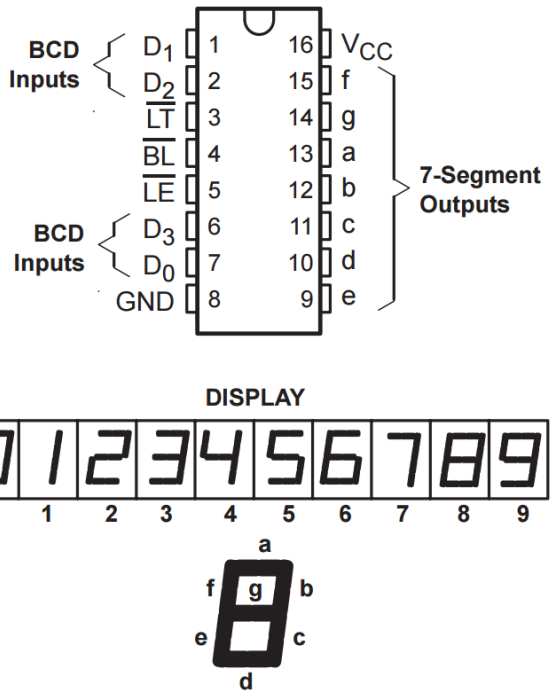


Figure 4: CD74HC4511 Pinout

4. Observe Figure 5. Pins 3 and 8 of the 7-segment display are the common cathode pins, connect each of these to GND with jumper cables.

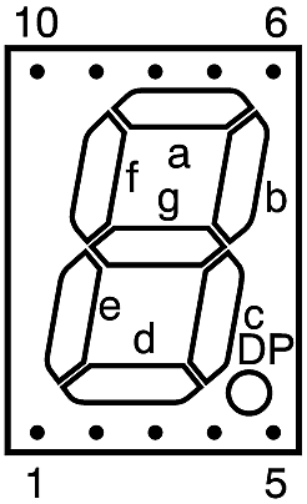


Figure 5: Pin numbering on the 7-segment display

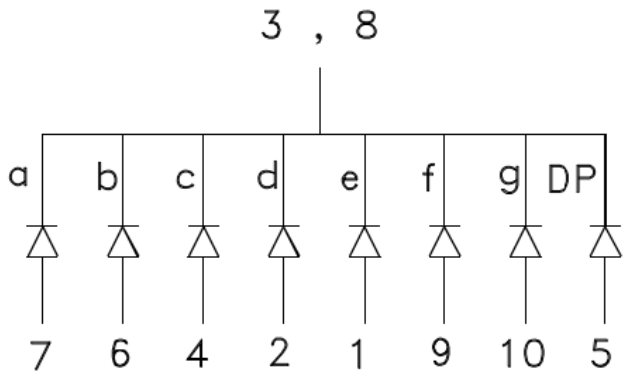


Figure 6: Internal schematic of the 7-segment display. Note that the cathode (negative) of each LED is connected to a common point on pins 3 and 8.

5. Following the schematic in Figure 3, CD74HC4511 pinout in Figure 4, 7-segment pinout in Figure 5 and 7-segment internal schematic in Figure 6 connect a 330 Ω resistor from each segment driver pin on the CD74HC4511 (a,b,..,g) to its respective input on the 7-segment display.
6. Turn the breadboard power supply on and confirm that the display shows a number 0.
7. Count in binary on the push buttons and ensure that all digits are displayed correctly.
   NB: Entering a number greater than 9 will cause the display to go blank.
8. Use the Saleae analyser to measure the delay between the input bits changing and the corresponding output appearing. You will have to set the capture rate to maximum (500 MS/s) and use the trigger function on an input pin. Don't capture more than about 5 seconds of data as the lab PC will run out of RAM and possibly freeze.

   Compare this measurement with the CD74HC4511's specification of 25 ns. At 500 MS/s the sample period is 2 ns so you can add annotations to the Saleae plot to take measurements with +/- 1 ns accuracy.