The Seven-Segment LED

Introduction

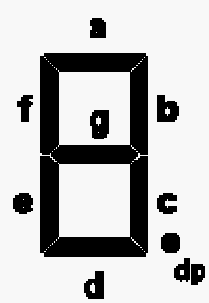
One common requirement for many different digital devices is a visual numeric display. Individual LEDs can of course display the binary states of a set of latches or flip-flops. However, we're far more used to thinking and dealing with decimal numbers. To this end, we want a display of some kind that can clearly represent decimal numbers without any requirement of translating binary to decimal or any other format.

One possibility is a matrix of 28 LEDs in a 7×4 array. We can then light up selected LEDs in the pattern required for whatever character we want. Indeed, an expanded version of this is used in many ways, for fancy displays. However, if all we want to display is numbers, this becomes a bit expensive. A much better way is to arrange the minimum possible number of LEDs in such a way as to represent only numbers in a simple fashion.

This requires just seven LEDs (plus an eighth one for the decimal point, if that is needed). A common technique is to use a shaped piece of translucent plastic to operate as a specialized optical fiber, to distribute the light from the LED evenly over a fixed bar shape. The seven bars are laid out as a squared-off figure "8". The result is known as a seven-segment LED.

We've all seen seven-segment displays in a wide range of applications. Clocks, watches, digital instruments, and many household appliances already have such displays. In this experiment, we'll look at what they are and how they can display any of the ten decimal digits 0-9 on demand.

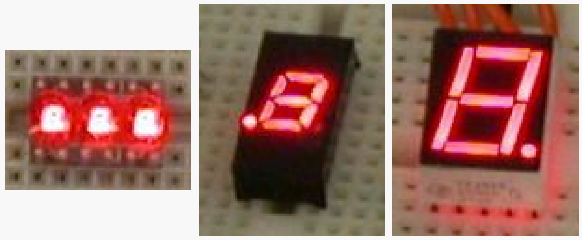
Seven-Segment Display Layout



The illustration to the right shows the basic layout of the segments in a seven-segment display. The segments themselves are identified with lower-case letters "a" through "g," with segment "a" at the top and then counting clockwise. Segment "g" is the center bar.

Most seven-segment digits also include a decimal point ("dp"), and some also include an extra triangle to turn the decimal point into a comma. This improves readability of large numbers on a calculator, for example. The decimal point is shown here on the right, but some display units put it on the left, or have a decimal point on each side.

In addition, most displays are actually slanted a bit, making them look as if they were in italics. This arrangement allows us to turn one digit upside down and place it next to another, so that the two decimal points look like a colon between the two digits. The technique is commonly used in LED clock displays.



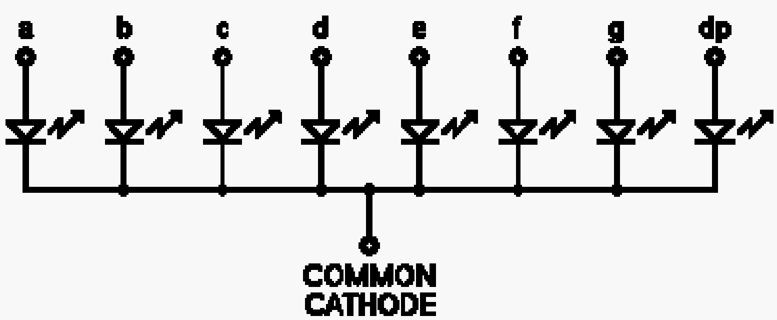
Seven-segment displays can be packaged in a number of ways. Three typical packages are shown above. On the left we see three small digits in a single 12-pin DIP package. The individual digits are very small, so a clear plastic bubble is molded over each digit to act as a magnifying lens. The sides of the end bubbles are flattened so that additional packages of this type can be placed end-to-end to create a display of as many digits as may be needed.

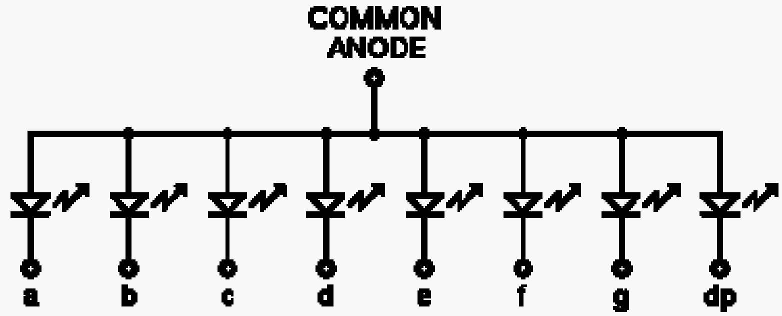
The second package is essentially a 14-pin DIP designed to be installed vertically. Note that for this particular device, the decimal point is on the left. This is not true of all seven-segment displays in this type of package.

One limitation of the DIP package is that it cannot support larger digits. To get larger displays for easy reading at a distance, it is necessary to change the package size and shape. The package on the right above is larger than the other two, and thus can display a digit that is significantly larger than will fit on a standard DIP footprint. Even larger displays are also available; some digital clocks sport digits that are two to five inches tall.

Seven-segment displays can be constructed using any of a number of different technologies. The three most common methods are fluorescent displays (used in many line-powered devices such as microwave ovens and some clocks and clock radios), liquid crystal displays (used in many battery-powered devices such as watches and many digital instruments), and LEDs (used in either line-powered or battery-powered devices). However, fluorescent displays require a fairly high driving voltage to operate, and liquid crystal displays require special treatment that we are not yet ready to discuss. Therefore, we will work with a seven-segment LED display in this experiment.

Schematic Diagram





As shown in the two schematic diagrams above, the LEDs in a seven-segment display are not isolated from each other. Rather, either all of the cathodes, or all of the anodes, are connected together into a common lead, while the other end of each LED is individually available. This means fewer electrical connections to the package, and also allows us to easily enable or disable a particular digit by controlling the common lead. (In some cases, the common connections are made to groups of LEDs, and the external wiring must make the final connections between them. In other cases, the common connection is made available at more than one location for convenience in laying out printed circuit boards. When laying out circuits using such devices, you simply need to take the specific connection details into account.)

There is no automatic advantage of the common-cathode seven-segment unit over the common-anode version, or vice-versa. Each type lends itself to certain applications, configurations, and logic families. We'll learn more about this in later experiments. For the present, we will use a common-cathode display as our experimental example.

Parts List

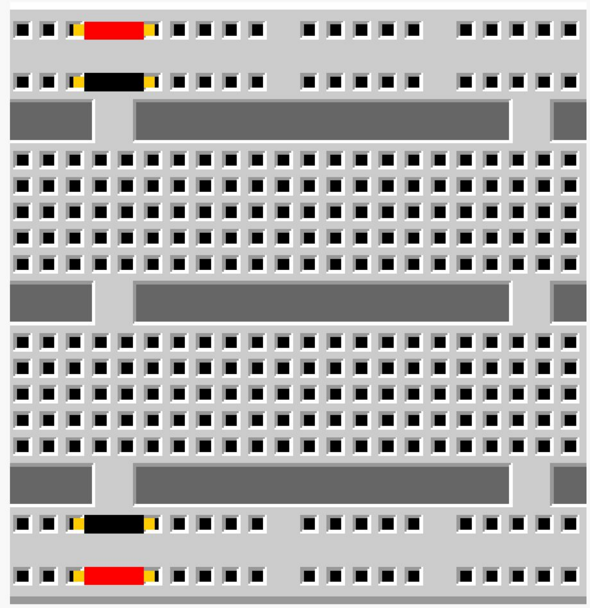
To construct and test the seven-segment LED display on your breadboard, you will need the following experimental parts:

- (1) Common-cathode seven-segment LED display (Texas Instruments TIL322A or equivalent).
- Orange hookup wire.
- Black hookup wire.

Constructing the Circuit

Select an area on your breadboard socket that is clear of other circuits. You'll need one set of five bus contacts for this project. Then refer to the image and text below and install the parts as shown.

Circuit Assembly



START

Performing the Experiment

Set all eight logic switches to logic 0, and turn on power to your experimental circuit. At this point, all LED segments should be off.

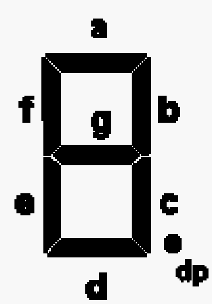
Step 1. Set S7 to logic 1 and note the result on your LED display. Referring to the figure to the right, which segment is controlled by S7? When you have determined this, set S7 again to logic 0. Locate the appropriate segment letter in the table to the right, and fill in the digit 7 (for S7) in the cell immediately to the right (under the column headed "Normal").

Repeat this action for each of the remaining logic switches. Take note of which switch controls each segment as you verify that all segments of the display work properly. Fill in the switch numbers in the table to the right, matching up each segment with its controlling switch.

Step 2. Now, set S5 and S4 to logic 1, and all other switches to logic 0. How does this affect the LED display?

Step 3. Without changing anything else, carefully remove the LED display from your breadboard socket and reverse it, end-for-end. This will put the decimal point in the upper left corner of the display. Re-insert it into the same location on your breadboard socket in its new, reversed orientation. What is the resulting display?

Step 4. Set S7, S6, S3, S2, and S1 to logic 1. This should leave only S0 set to logic 0. Note the resulting LED configuration. Now remove and reverse the LED display as you did before, thus returning it to its original orientation. What effect does this have on



Segment	Normal	Reversed
a	S	S
b	S	S
c	S	S
d	S	S
e	S	S
f	S	S
g	S	S

the displayed digit?

dp	S	S

Step 5. Set S7 to logic 0 and S0 to logic 1. How does this change the working display?

Step 6. Reverse the LED display once again, so that the dp is again at the upper left instead of at the lower right. Using the general segment identifications for the reversed display as shown at the top of the table (segment "a" is still at the top of the display), test each switch one by one, and fill in the table under the column headed "Reversed." Compare your findings for the normal and reversed display orientations. Can you think of any reason for arranging it this way? Restore the LED display to its original orientation.

Step 7. Which segments would you turn on to display the digit 2? Try it and verify your conclusion. Try generating each of the digits 0 through 9 by turning various segments on and off. Verify that all ten digits can be displayed and easily recognized.

When you have made your determinations, turn off the power to your experimental circuit and compare your results with the discussion below.

Discussion

When you tried out the various logic switches, you found that S7 controlled the decimal point and that S6 through S0 controlled segments a through g in order. This allows easy correlation between switches and segments.

When you turned on segments b and c (S5 and S4), the display responded with the digit 1. Logically, we could use either segments b and c or segments e and f for the digit 1, but standard practice is to put this digit on the right.

When you reversed the LED display and re-installed it, the digit 1 still appeared, and still on the right hand side of the display. Thus, connections to these segments must be in the same places, although we didn't determine at this point which switch controlled which of the two segments in this orientation.

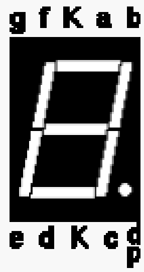
When you turned on every switch except S0, you saw a digit 8, where all seven segments were turned on. However, when you reversed the LED display unit again, you saw a digit 0 with the decimal point turned on. This indicated that the decimal point and segment g are connected to opposite but corresponding pins.

To verify this and all other connections, you reversed the LED display once more and then identified which switch controls which segment in the inverted position. You discovered that S6 through S1 still controlled segments a through f, whether the LED display is right side up or upside down. Only segment g and the decimal point are interchanged.

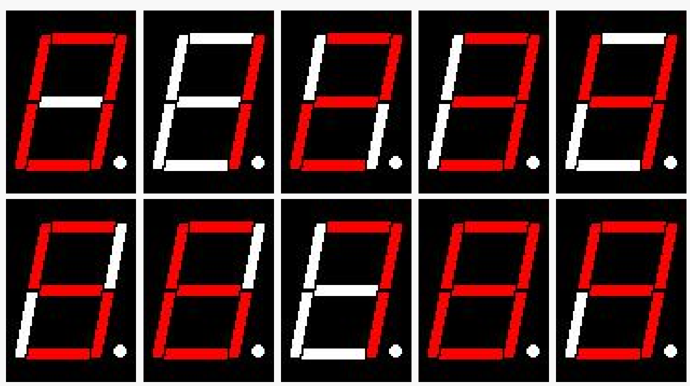
This arrangement is deliberate. It often simplifies the layout of printed circuit boards. In addition, a common technique used in digital clock displays is to turn the tens of minutes digit upside down and use its decimal point in tandem with the hours digit decimal point to form a colon.

Most single-digit 7 segment displays are set up this way, with the segment connections symmetrical.

In some cases, however, the common connection is not shared among all LEDs. Rather, multiple common connections (common cathode for this experiment) must sometimes be linked externally to enable all segments. In the case of the LED display we specified for this experiment, all LED cathodes are connected together, and to the center pins at the top and bottom of the package. The black jumper grounded the cathodes regardless of the orientation of the display. The actual pin connections to the specified display unit are ('K' represents the common cathode):



You should also have found that it's not hard to form all ten digits using the 7-segment display. Digit 2, for example, requires segments a, b, d, e, and g. Digit 3 removes segment e from that list, and adds segment c. The two digits 6 and 9 have two possibilities each. Digit 6 can be made with or without segment a, and digit 9 can be made with or without segment d. You can choose either method, but for consistency you should treat both digits the same way. Except for that possible variation, your ten digits should have looked like this:



When you have completed this experiment, make sure power to your experimental circuit is turned off. Remove all of the orange jumpers from your breadboard socket and put them aside for later use. Leave the 7-segment LED display and its black jumper in place for the next experiment.

Prev: The Bicolor LED

Next: The Seven-Segment LED Driver