Jiangxi University of Science and Technology

DIGITAL DESIGN

Chapter 4 Combinational Logic_4
Design a 7-Segment Decoder

• Design Concepts

- Combinational Logic Circuits
  - Outputs are functions of (present) inputs
  - No memory
  - Can be described using Boolean expressions
- Hierarchical design
  - Used to solve large design problems
  - Break problem into smaller (sub-)problems
  - Solve each sub-problem (i.e. realize design)
  - Combine individual solutions

Design Concepts

- Specification
  - Describes the problem to be solved.
  - Describes what needs to be done, not how to do it.

- Implementation
  - Describes how the problem is solved.

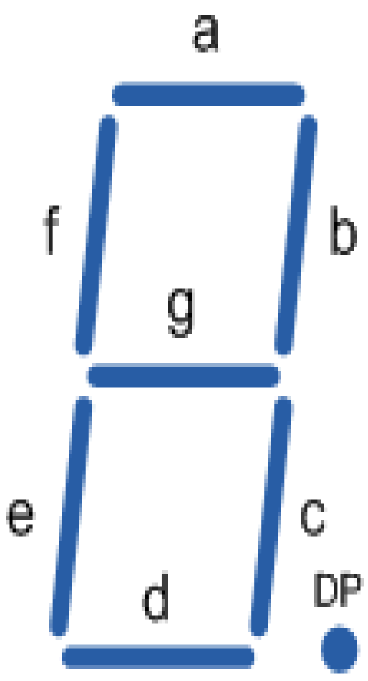
Design Concepts

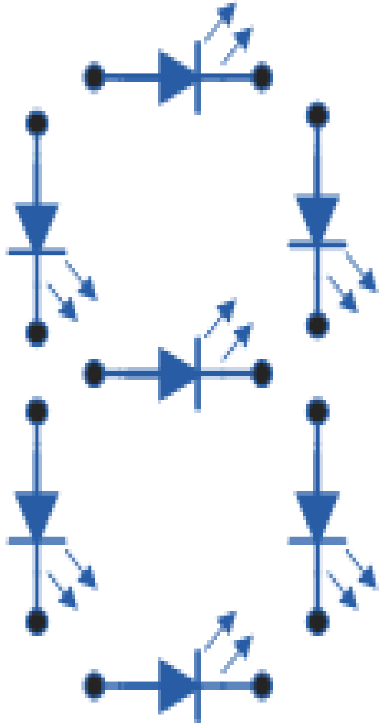
- Issues
  - Most solutions are not unique.
    - More than one solution may meet the specifications.
  - Cannot always satisfy all of the requirements.
  - Must identify (and study) design tradeoffs.
    - Cost
    - Speed
    - Power consumption
    - etc.

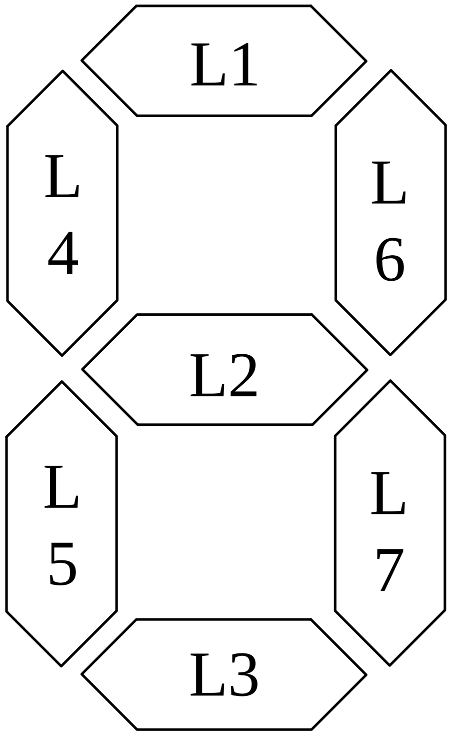
Design Process

1. Identify requirements (i.e. circuit specifications)
2. Determine the inputs and outputs.
3. Derive the Truth Table
4. Determine simplified Boolean expression(s)
5. Implement solution
6. Verify solution

Seven Segment Display

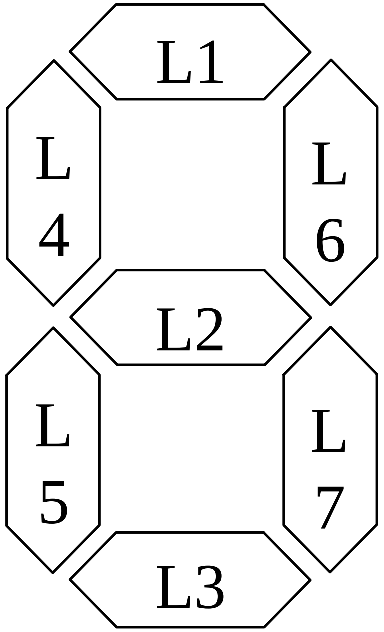




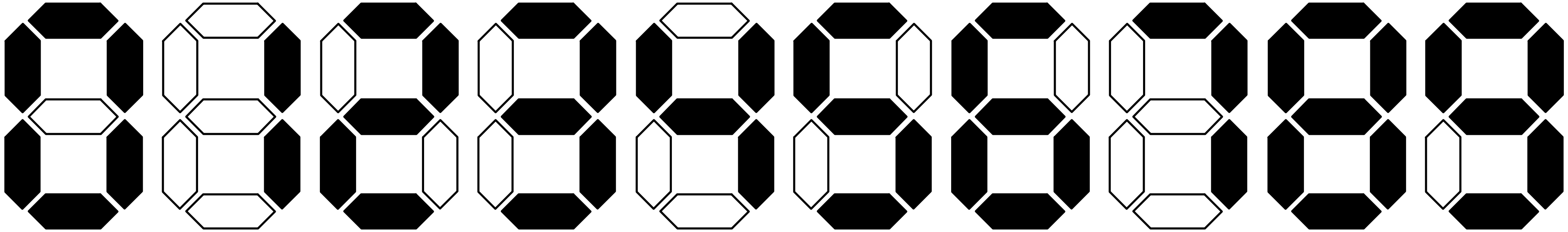


B3	B2	B1	B0	Val
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

Seven Segment Display

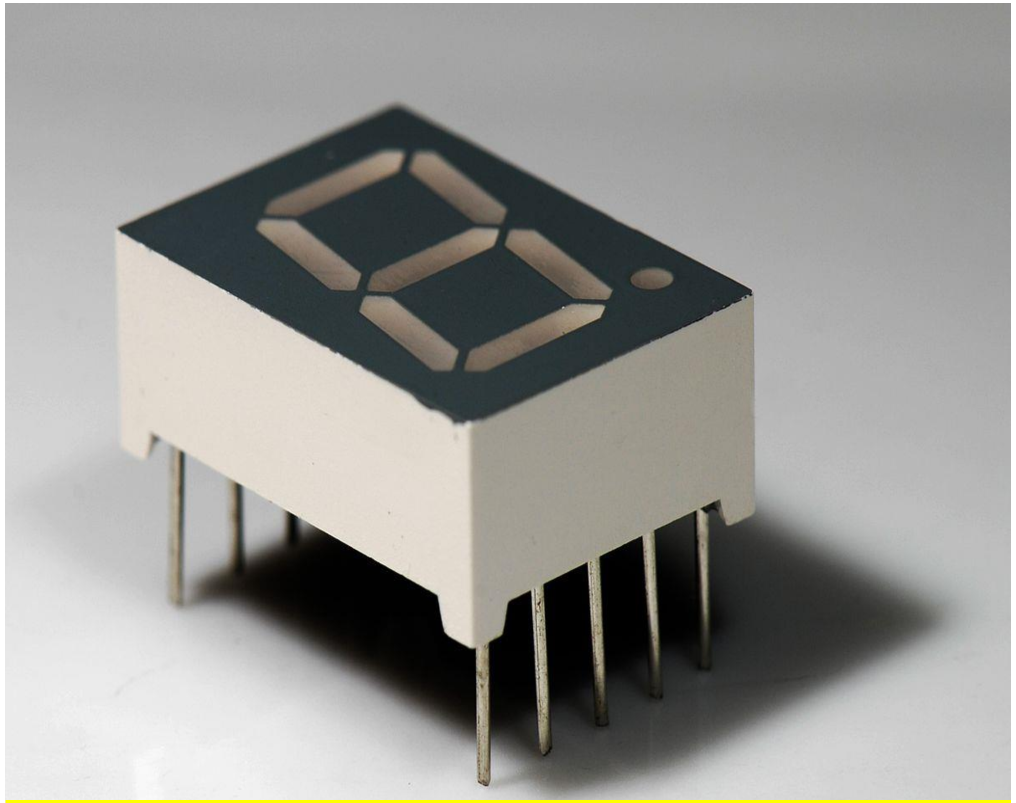


B3	B2	B1	B0	Val	L1	L2	L3	L4	L5	L6	L7
0	0	0	0	0	1	0	1	1	1	1	1
0	0	0	1	1	0	0	0	0	0	1	1
0	0	1	0	2	1	1	1	0	1	1	0
0	0	1	1	3	1	1	1	0	0	1	1
0	1	0	0	4	0	1	0	1	0	1	1
0	1	0	1	5	1	1	1	1	0	0	1
0	1	1	0	6	1	1	1	1	1	0	1
0	1	1	1	7	1	0	0	0	0	1	1
1	0	0	0	8	1	1	1	1	1	1	1
1	0	0	1	9	1	1	1	1	0	1	1



Seven Segment Display

- There are two types of LED 7-segment displays: common cathode (CC) and common anode (CA).
- The difference between the two displays is the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together.



Common Anode/Cathode 7-segment displays

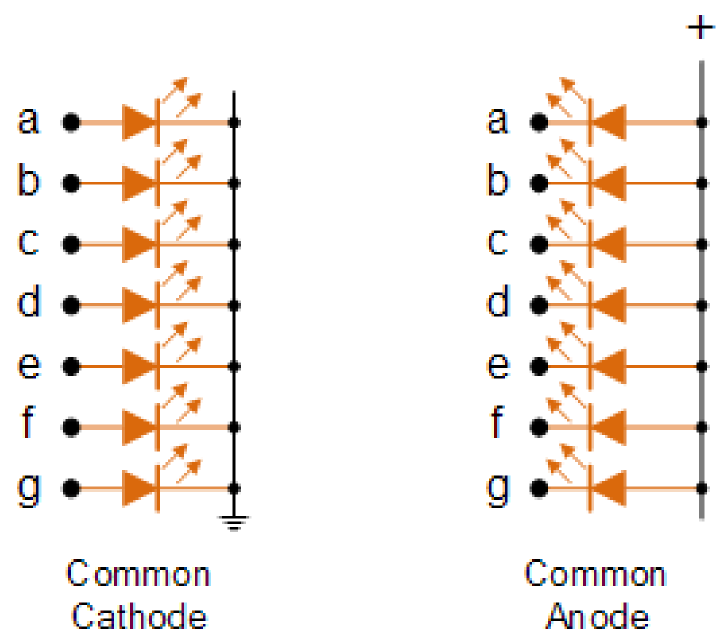
Seven Segment Display

Seven Segment Display type :

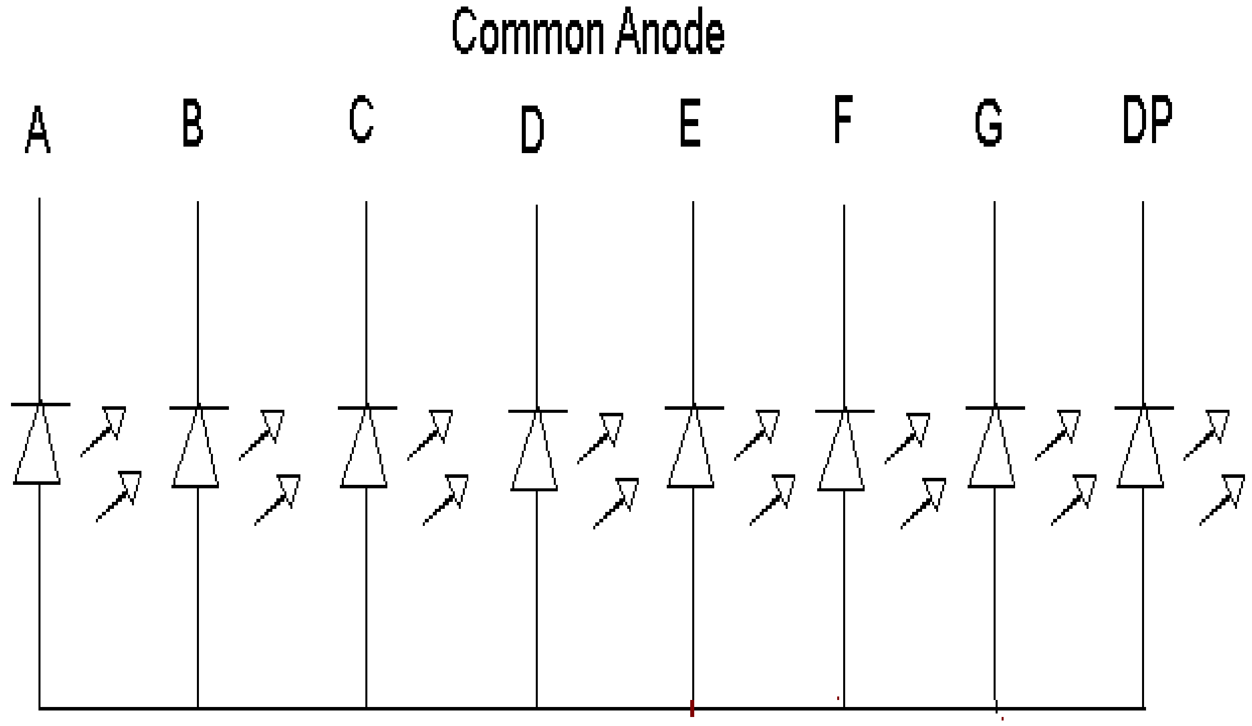
- Common Cathode
- Common Anode Format

•**1. The Common Cathode Display (CCD) –** In the common cathode display, all the cathode connections of the LED's are joined together to logic "0" or ground.
•The individual segments are illuminated by application of a "HIGH", logic "1" signal to the individual Anode terminals.

•**2. The Common Anode Display (CAD) –** In the common anode display, all the anode connections of the LED's are joined together to logic "1" and the individual segments are illuminated by connecting the individual Cathode terminals to a "LOW", logic "0" signal.



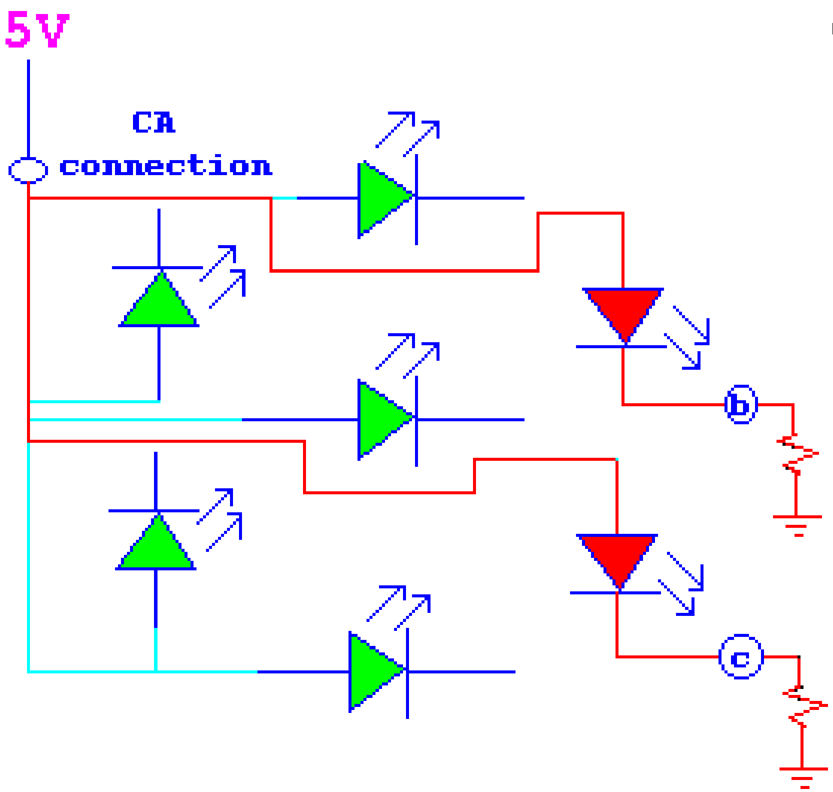
common anode seven segment.



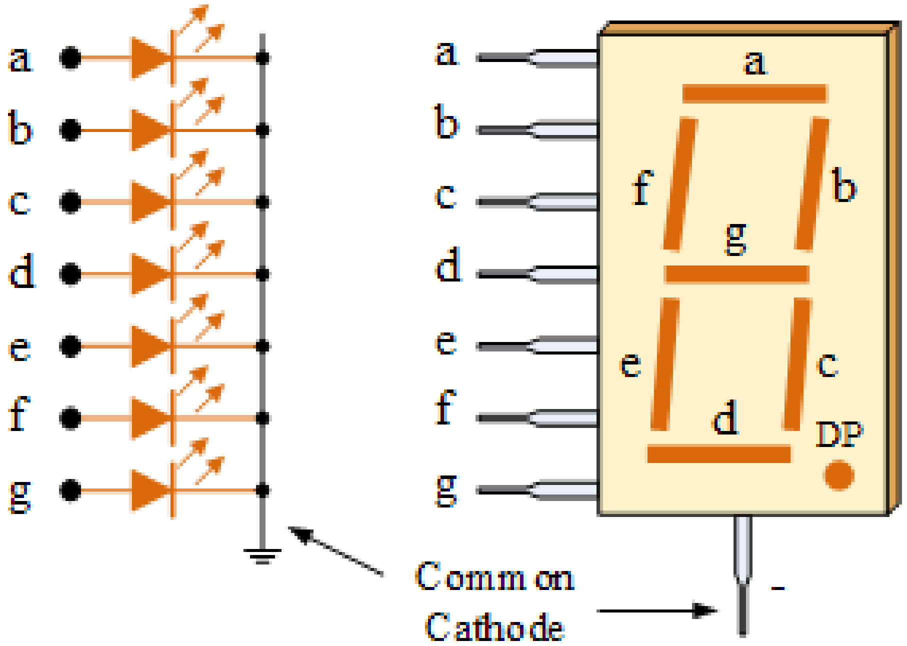
As shown all the anode segments are connected together. When working with a CA seven segment display, power must be applied externally to the the anode connection that is common to all the segments.

Then by applying a ground to a particular segment connection (a-g), the appropriate segment will light up. An additional resistor must be added to the circuit to limit the amount of current flowing thru each LED segment.

common anode seven segment.



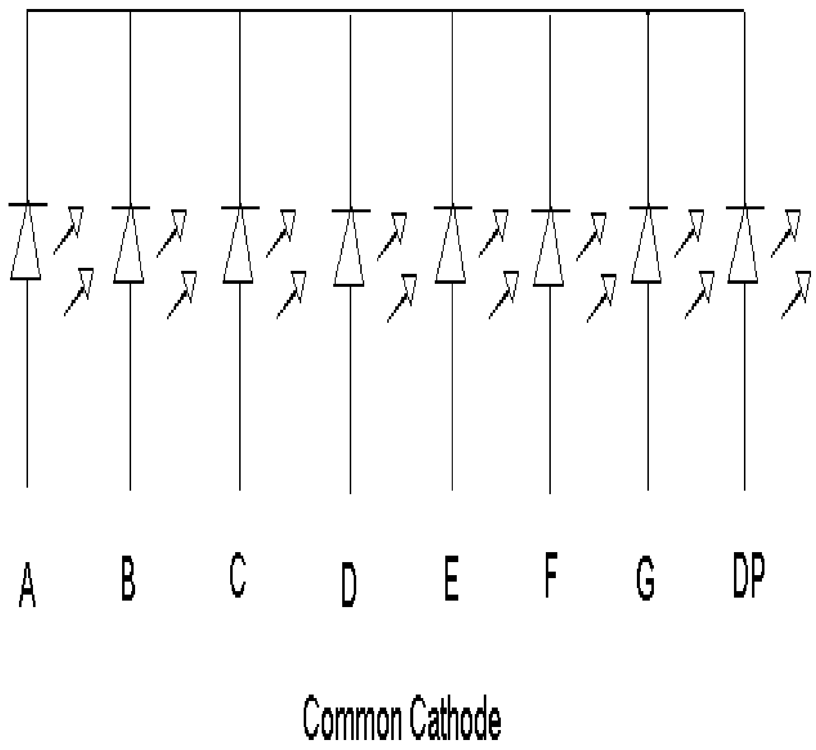
The diagram shows the instance when power is applied to the CA connection and segments b & c are grounded causing these two segments to light up.



common Cathode seven segment.

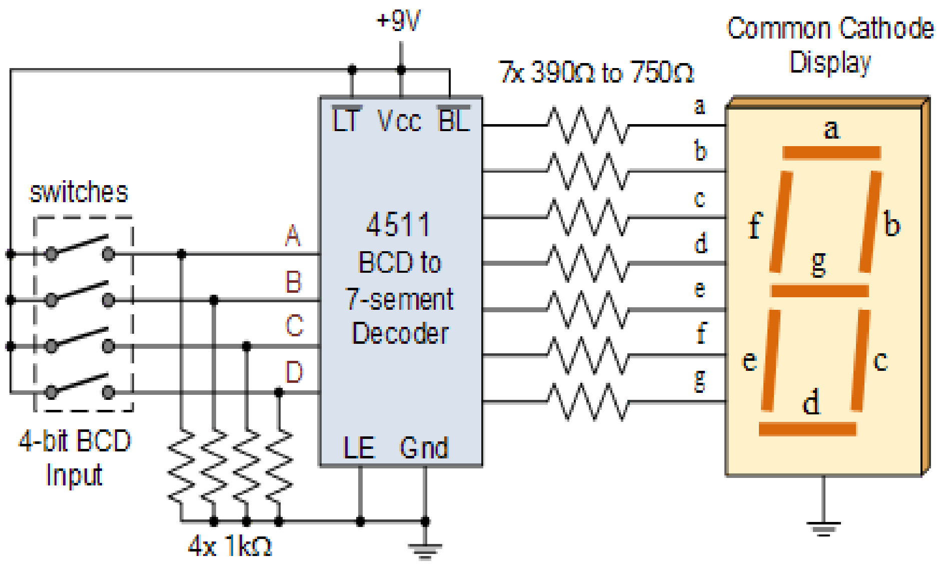
A common cathode seven segment is different from a common anode segment in that the cathodes of all the LEDs are connected together.

For the use of this seven segment the common cathode connection must be grounded and power must be applied to appropriate segment in order to illuminate that segment.



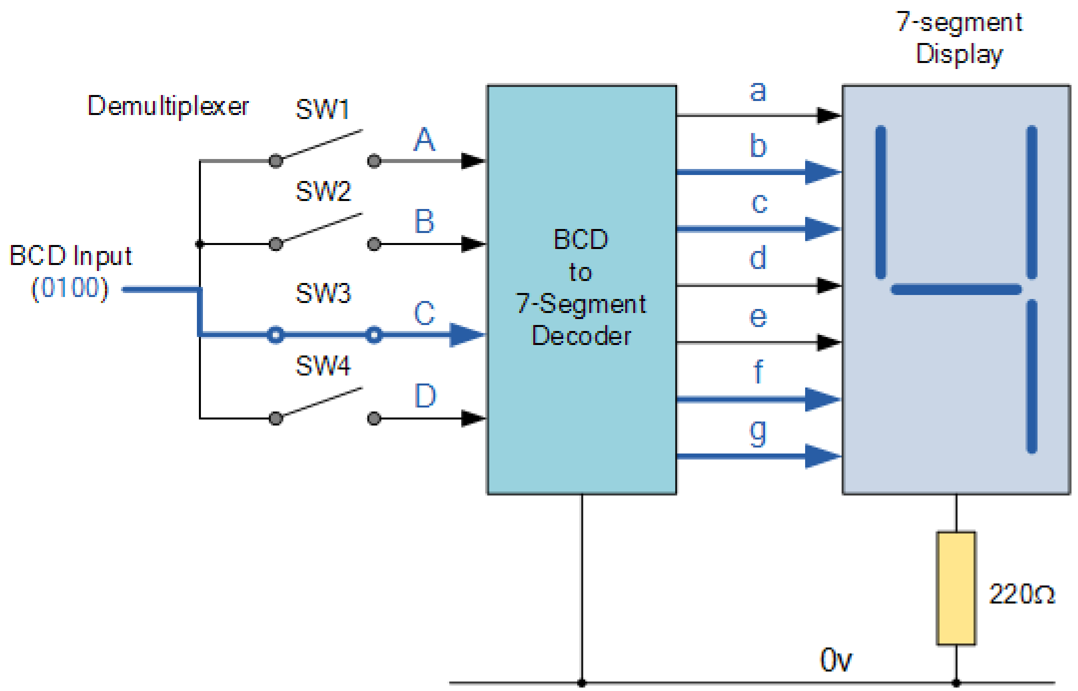
Driving a 7-segment Display

Driving a 7-segment Display using a 4511



In this simple circuit, each LED segment of the common cathode display has its own anode terminal connected directly to the 4511 driver with its cathodes connected to ground. The current from each output passes through a 1kΩ resistor that limits it to a safe amount. The binary input to the 4511 is via the four switches. Then we can see that using a BCD to 7-segment display driver such as the CMOS 4511, we can control the LED display using just four switches (instead of the previous 8) or a 4-bit binary signal allowing up to 16 different combinations.

LED based 7-segment displays are very popular amongst Electronics hobbyists as they are easy to use and easy to understand. In most practical applications, 7-segment displays are driven by a suitable decoder/driver IC such as the CMOS 4511 or TTL 7447 from a 4-bit BCD input. Today, LED based 7-segment displays have been largely replaced by *liquid crystal displays* (LCDs) which consume less current.


7-segment
Display
Demultiplexer
SW1
A
SW2
B
BCD Input
(0100)
SW3
C
SW4
D
BCD
to
7-Segment
Decoder
a
b
c
d
e
f
g
220Ω
0v

7-Segment Decoder

1. Circuit Specification
2. The 7-Segment Decoder must decode Binary Coded Decimal (BCD) digits so that they can be displayed on a 7-Segment Display
3. Determine Inputs and Outputs Input: Binary Coded Decimal digits
4. Assign a 4-bit code to each decimal digit.
    1. A 4-bit code can represent 16 values.
    2. There are only 10 digits in the decimal number system.
5. Unassigned codes are not used.
    - How do we interpret these unused codes?
        - Hint: think about K-maps.

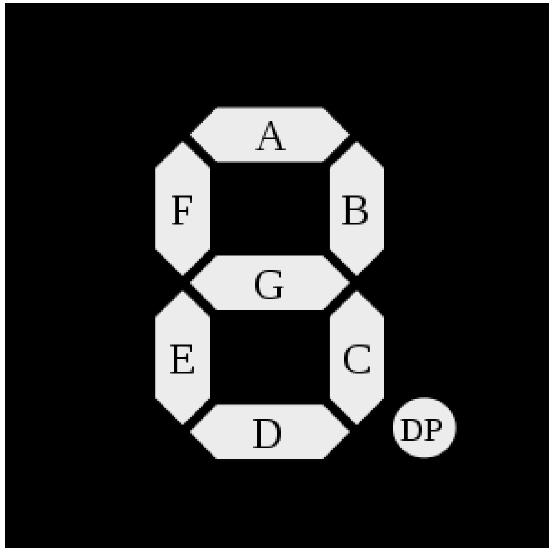
Binary Coded Decimal BCD Digits

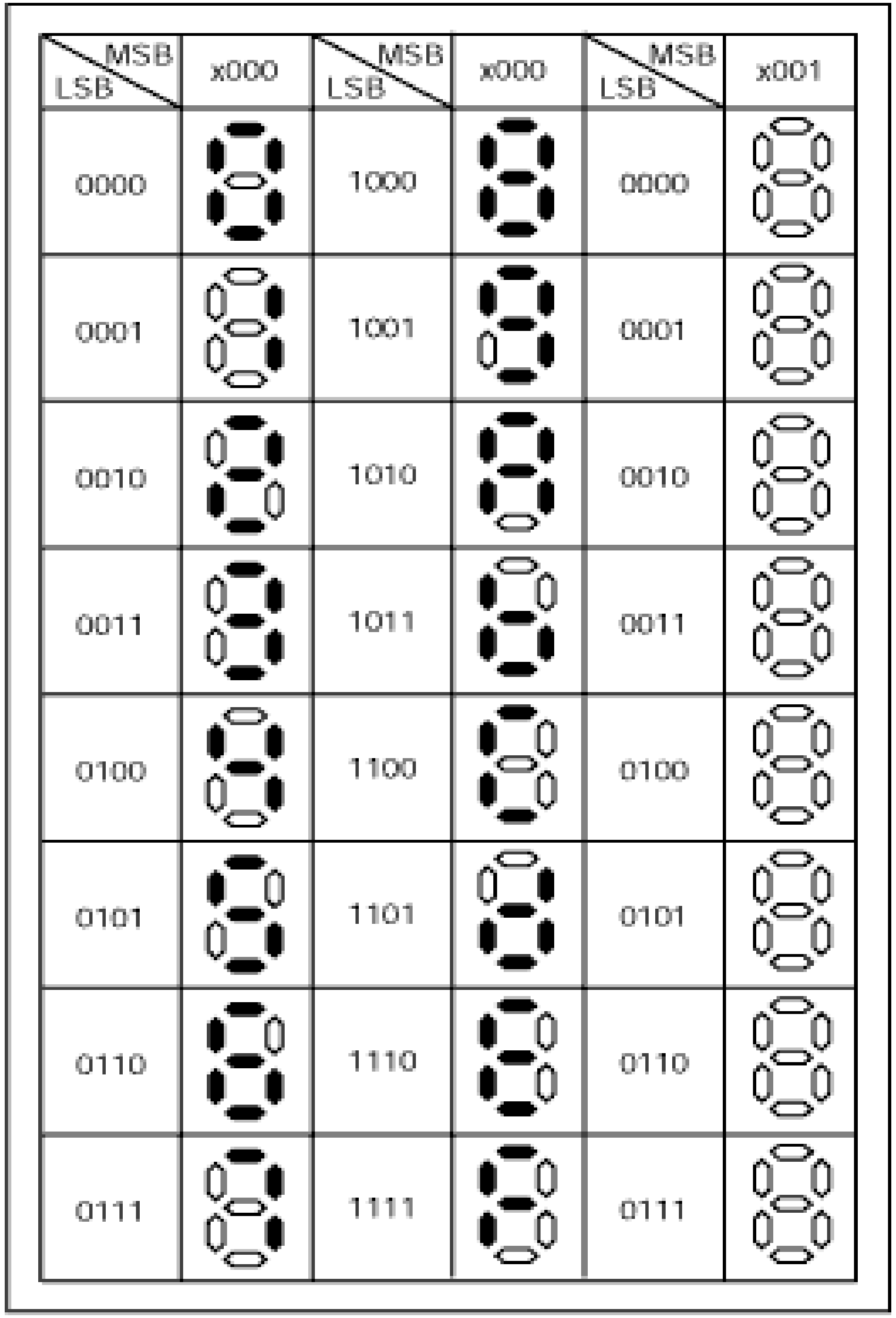
Decimal Digit	BCD Code
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

7-Segment Display

2. Determine Inputs and Outputs

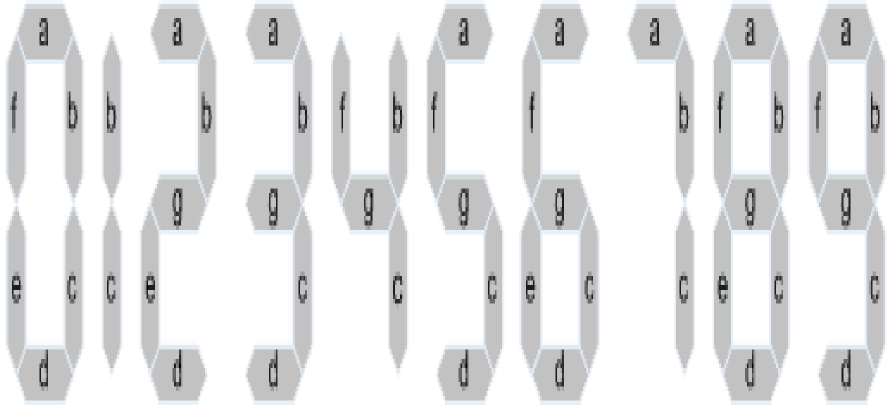
Output: 7-Segment Display





7-Segment Decoder

- 3. Derive Truth Table



w	x	y	z	A	B	C	D	E	F	G	#
0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	1	0	1	1	0	0	0	0	1
0	0	1	0	1	1	0	1	1	0	1	2
0	0	1	1	1	1						3
0	1	0	0	0	1						4
0	1	0	1	1	0						5
0	1	1	0	1	0						6
0	1	1	1	1	1						7
1	0	0	0	1	1						8
1	0	0	1	1	1						9
1	0	1	0	d	d						-
1	0	1	1	d	d						-
1	1	0	0	d	d						-
1	1	0	1	d	d						-
1	1	1	0	d	d						-
1	1	1	1	d	d						-

Other Truth Table

Individual Segments							Display
a	b	c	d	e	f	g	
×	×	×	×	×	×		0
	×	×					1
×	×		×	×		×	2
×	×	×	×			×	3
	×	×			×	×	4
×		×	×		×	×	5
×		×	×	×	×	×	6
×	×	×					7

Individual Segments							Display
a	b	c	d	e	f	g	
×	×	×	×	×	×	×	8
×	×	×	×		×	×	9
×	×	×		×	×	×	A
		×	×	×	×	×	b
×			×	×	×		C
	×	×	×	×		×	d
×			×	×	×	×	E
×				×	×	×	F

7-Segment Decoder

4. Determine simplified Boolean expression(s)

A

wx \ yz	00	01	11	10
00	1	0	1	1
01	0	1	1	1
11	d	d	d	d
10	1	1	d	d

B

wx \ yz	00	01	11	10
00	1	1	1	1
01	1	0	1	0
11	d	d	d	d
10	1	1	d	d

A = ?

B = ?

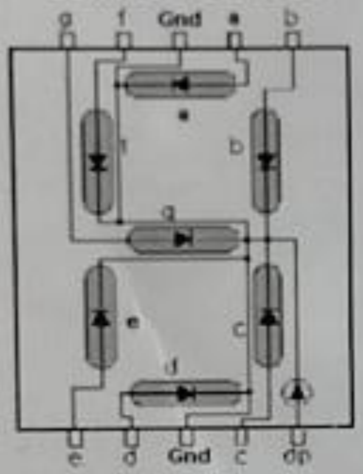
7-Segment Decoder

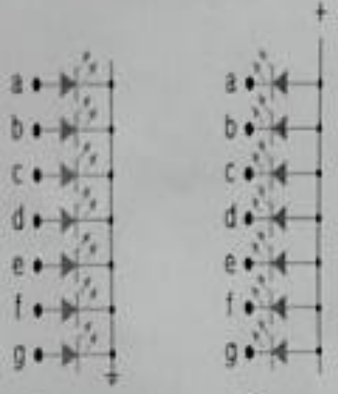
- Student Exercise:
- Determine the minimized Boolean expression for each of the segments of the 7-Segment Display.

Seven Segment Display

B3	B2	B1	B0	Val
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

Common Cathode





Common Cathode

Common Anode

$a = F1\ (A, B, C, D) = \sum m\ (0, 2, 3, 5, 7, 8, 9)$

$b = F2\ (A, B, C, D) = \sum m\ (0, 1, 2, 3, 4, 7, 8, 9)$

$c = F3\ (A, B, C, D) = \sum m\ (0, 1, 3, 4, 5, 6, 7, 8, 9)$

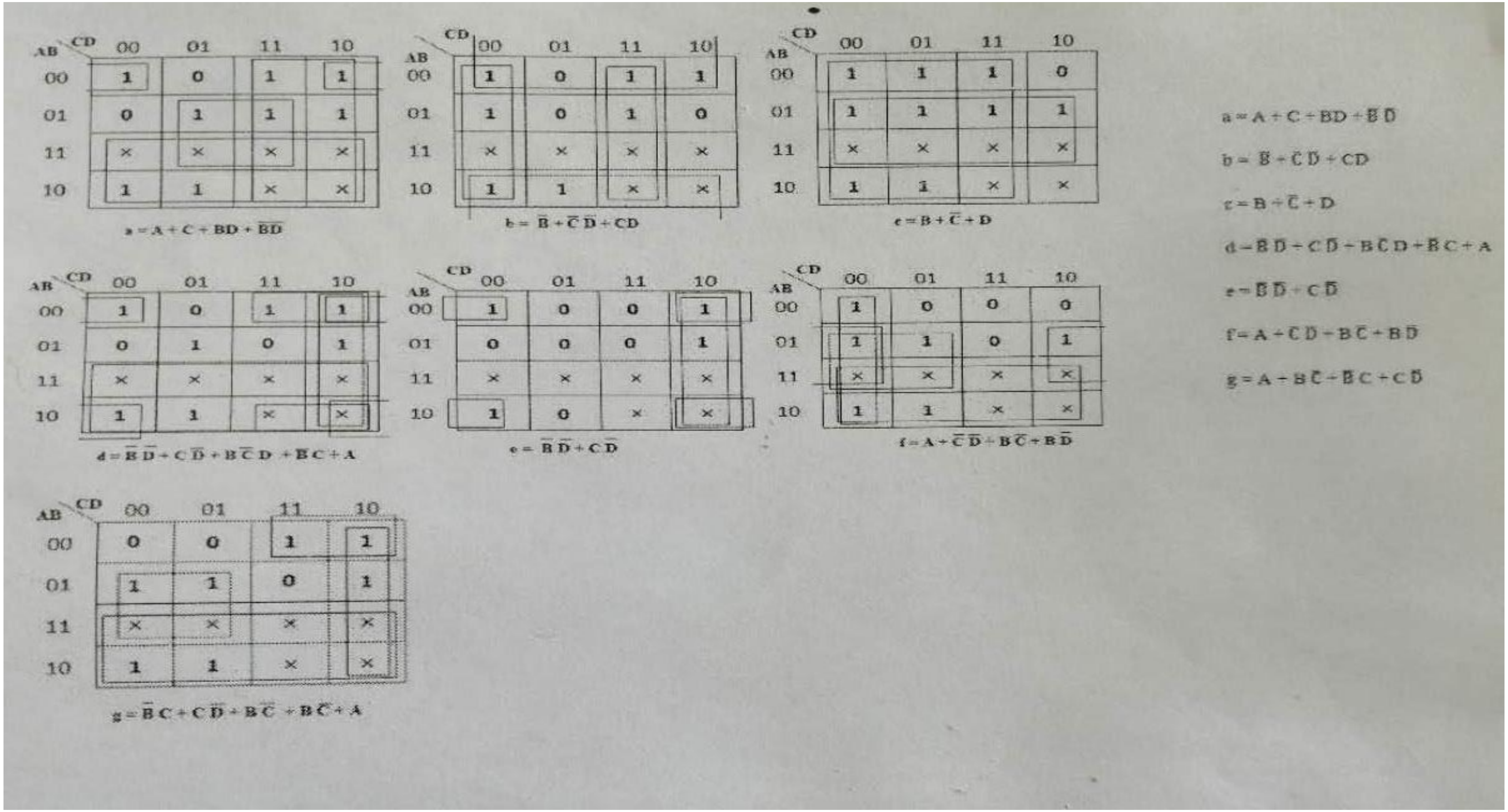
$d = F4\ (A, B, C, D) = \sum m\ (0, 2, 3, 5, 6, 8)$

$e = F5\ (A, B, C, D) = \sum m\ (0, 2, 6, 8)$

$f = F6\ (A, B, C, D) = \sum m\ (0, 4, 5, 6, 8, 9)$

$g = F7\ (A, B, C, D) = \sum m\ (2, 3, 4, 5, 6, 8, 9)$

9



AB \ CD	00	01	11	10
00	1	0	1	1
01	0	1	1	1
11	×	×	×	×
10	1	1	×	×

$a = A + C + BD + \overline{B}\overline{D}$

AB \ CD	00	01	11	10
00	1	0	1	1
01	1	0	1	0
11	×	×	×	×
10	1	1	×	×

$b = \overline{B} + \overline{C}\overline{D} + CD$

AB \ CD	00	01	11	10
00	1	1	1	0
01	1	1	1	1
11	×	×	×	×
10	1	1	×	×

$c = B + \overline{C} + D$

AB \ CD	00	01	11	10
00	1	0	1	1
01	0	1	0	1
11	×	×	×	×
10	1	1	×	×

$d = \overline{B}\overline{D} + C\overline{D} + B\overline{C}D + \overline{B}C + A$

AB \ CD	00	01	11	10
00	1	0	0	1
01	0	0	0	1
11	×	×	×	×
10	1	0	×	×

$e = \overline{B}\overline{D} + C\overline{D}$

AB \ CD	00	01	11	10
00	1	0	0	0
01	1	1	0	1
11	×	×	×	×
10	1	1	×	×

$f = A + \overline{C}\overline{D} + B\overline{C} + B\overline{D}$

AB \ CD	00	01	11	10
00	0	0	1	1
01	1	1	0	1
11	×	×	×	×
10	1	1	×	×

$g = \overline{B}C + C\overline{D} + B\overline{C} + B\overline{C} + A$

$a = A + C + BD + \overline{B}\overline{D}$

$b = \overline{B} + \overline{C}\overline{D} + CD$

$c = B + \overline{C} + D$

$d = \overline{B}\overline{D} + C\overline{D} + B\overline{C}D + \overline{B}C + A$

$e = \overline{B}\overline{D} + C\overline{D}$

$f = A + \overline{C}\overline{D} + B\overline{C} + B\overline{D}$

$g = A + B\overline{C} + \overline{B}C + C\overline{D}$

Reference

1. Mano book
2. ee.hawaii.edu/~sasaki/EE361/Fall06/Lab/7disp.html
3. https://www.tutorialspoint.com/computer_logical_organization/combinational_circuits.htm