Combinational Design Procedure

Overview

- Design digital circuit from specification
- Digital inputs and outputs known
  - Need to determine logic that can *transform* data
- Start in truth table form
- Create K-map for each output based on function of inputs
- Determine minimized sum-of-product representation
- Draw circuit diagram

Design Procedure (Mano)

Design a circuit from a specification.

1. **Determine number of required inputs and outputs.**
2. **Derive truth table**
3. **Obtain simplified Boolean functions**
4. **Draw logic diagram and verify correctness**

S = A + B + C
R = ABC

A	B	C	R	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Previously, we have learned…

- **Boolean algebra can be used to simplify expressions, but not obvious:**
  - **how to proceed at each step, or**
  - **if solution reached is minimal.**
- **Have seen five ways to represent a function:**
  - **Boolean expression**
  - **truth table**
  - **logic circuit**
  - **minterms/maxterms**
  - **Karnaugh map**

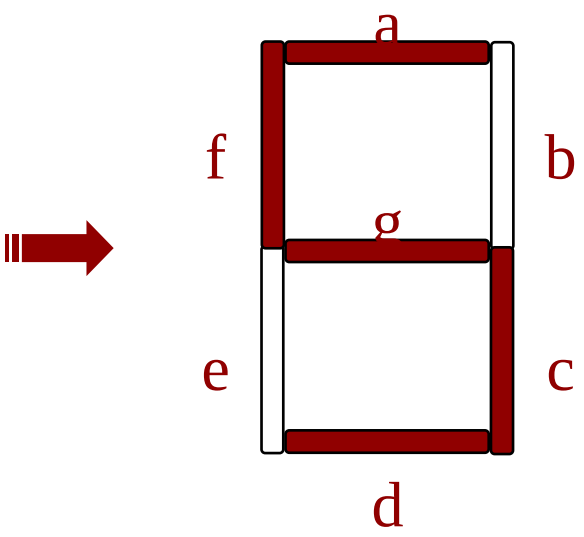
Combinational logic design

- Use multiple representations of logic functions
- Use graphical representation to assist in simplification of function.
- Use concept of “don’t care” conditions.
- Example - encoding BCD to seven segment display.
- Similar to approach used by designers in the field.

BCD to Seven Segment Display

- **Used to display binary coded decimal (BCD) numbers using seven illuminated segments.**
- **BCD uses 0's and 1's to represent decimal digits 0 - 9. Need four bits to represent required 10 digits.**
- **Binary coded decimal (BCD) represents each decimal digit with four bits**

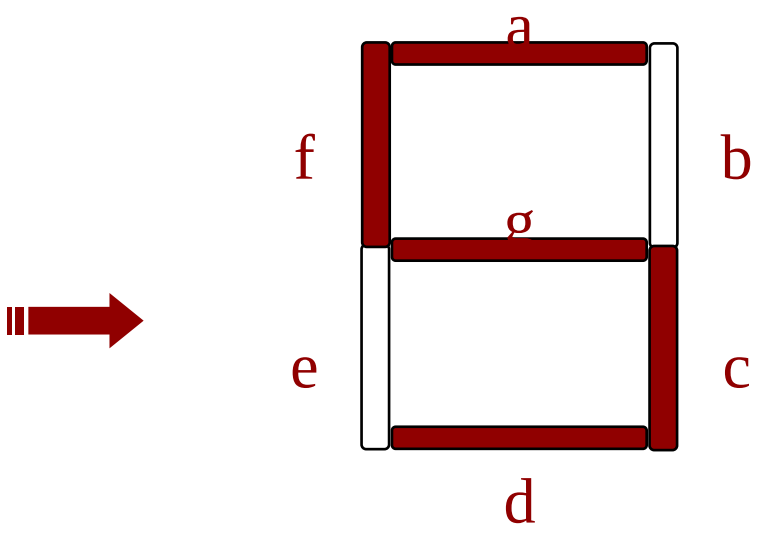
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
.	.	.	.	.
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1



BCD to seven segment display

- **List the segments that should be illuminated for each digit.**

0	a,b,c,d,e,f
1	b,c
2	a,b,d,e,g
3	a,b,c,d,g
4	b,c,f,g
5	a,c,d,f,g
6	a,c,d,e,f,g
7	a,b,c
8	a,b,c,d,e,f,g
9	a,b,c,d,f,g



BCD to seven segment display

- **Derive the truth table for the circuit.**
- **Each output column in one circuit.**

	Inputs				Outputs					
Dec	w	x	y	z	a	b	c	d	e	.
0	0	0	0	0	1	1	1	1	1	.
1	0	0	0	1	0	1	1	0	0	.
2	0	0	1	0	1	1	0	1	1	.
.	.	.	.	.	.	.	.	.	.	.
7	0	1	1	1	1	1	1	0	0	.
8	1	0	0	0	1	1	1	1	1	.
9	1	0	0	1	1	1	1	1	0	.

BCD to seven segment display

- **Find minimal sum-of-products representation for each output**

For segment “a” :

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

Note: Have only filled in ten squares, corresponding to the ten numerical digits we wish to represent.

Don’t care conditions (BCD display) ...

- **Fill in don’t cares for undefined outputs.**
  - **Note that these combinations of inputs should never happen.**
- **Leads to a reduced implementation**

For segment “a” :

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

Put in “X” (don’t care), and interpret as either 1 or 0 as desired ….

Don’t care conditions (BCD display) ...

- Circle biggest group of 1’s and Don’t Cares.
- Leads to a reduced implementation

For segment “a” :

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

$$F_{a1} = y$$

Don’t care conditions (BCD display)

- **Circle biggest group of 1’s and Don’t Cares.**
- **Leads to a reduced implementation**

For segment “a” :

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

$$F_{a2} = w$$

Don’t care conditions (BCD display) ...

- **Circle biggest group of 1’s and Don’t Cares.**
- **All 1’s should be covered by at least one implicant**

For segment “a” :

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

$$F_{a3} = \bar{x}\bar{z}$$

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

$$F_{a4} = xz$$

Don’t care conditions (BCD display) ...

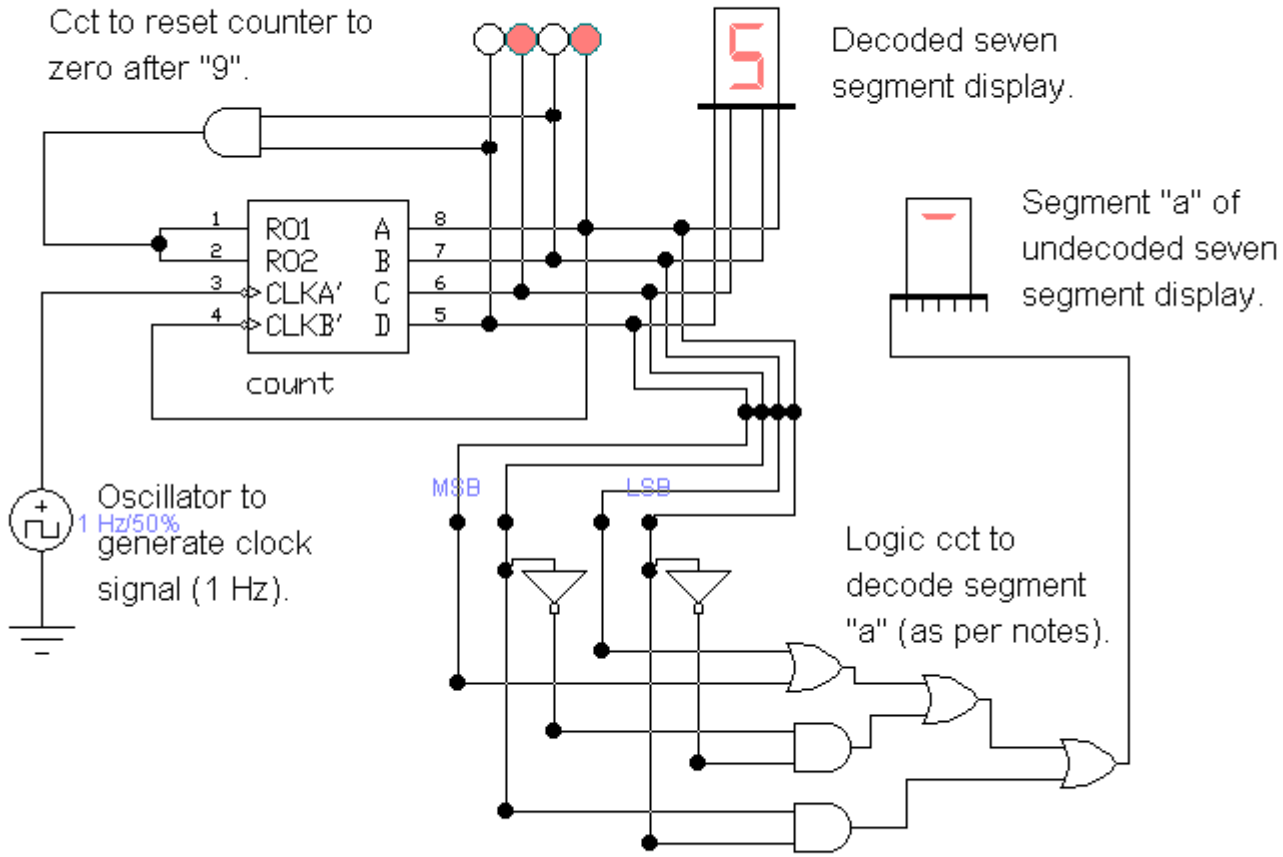
- **Put all the terms together**
- **Generate the circuit**

For segment “a” :

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

$$F = y + w + \bar{x}\bar{z} + xz$$

Example of seven segment display decoding.



Hint: Select a component and then push "?" from main menu bar to get info on what that component does and how it works.

BCD to seven segment display

- **Derive the truth table for the circuit.**
- **Each output column in one circuit.**

	Inputs				Outputs					
Dec	w	x	y	z	a	b	c	d	e	.
0	0	0	0	0	1	1	1	1	1	.
1	0	0	0	1	0	1	1	0	0	.
2	0	0	1	0	1	1	0	1	1	.
.	.	.	.	.	.	.	.	.	.	.
7	0	1	1	1	1	1	1	0	0	.
8	1	0	0	0	1	1	1	1	1	.
9	1	0	0	1	1	1	1	1	0	.

BCD to seven segment display

- **Find minimal sum-of-products representation for each output**

For segment “b” :

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

See if you complete this example.

Summary

- **Need to formulate circuits from problem descriptions**
  1. **Determine number of inputs and outputs**
  2. **Determine truth table format**
  3. **Determine K-map**
  4. **Determine minimal SOP**
- **There may be multiple outputs per design**
  - **Solve each output separately**
- **Current approach doesn't have memory.**
  - **This will be covered next week.**