ENGIN 112

Intro to Electrical and Computer Engineering

Lecture 13
Combinational Design Procedure

Electrical and Computer Engineering
University of Massachusetts Amherst

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

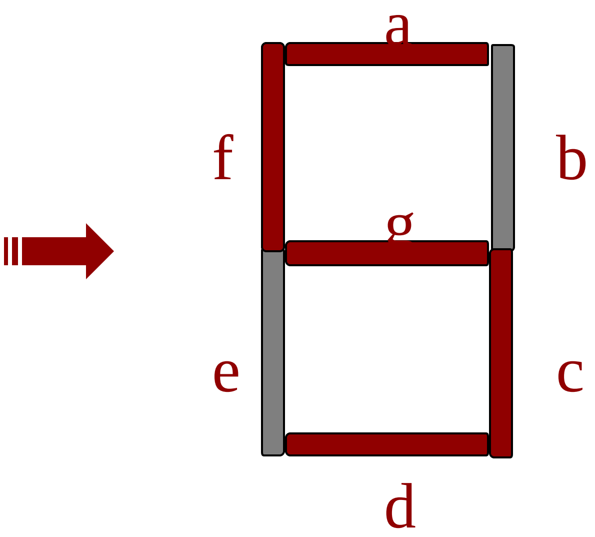
Combinational logic design

- 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

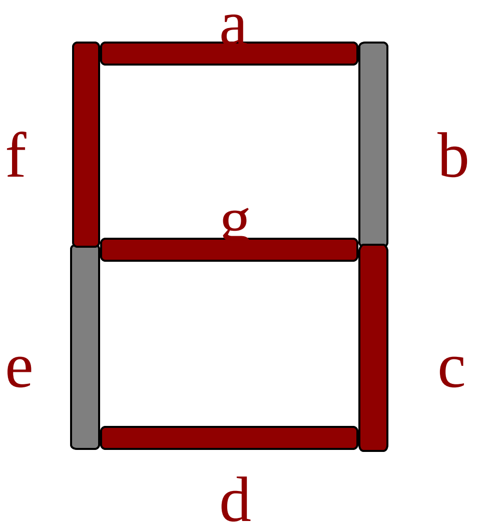
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
.	.	.	.	.
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1



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” :

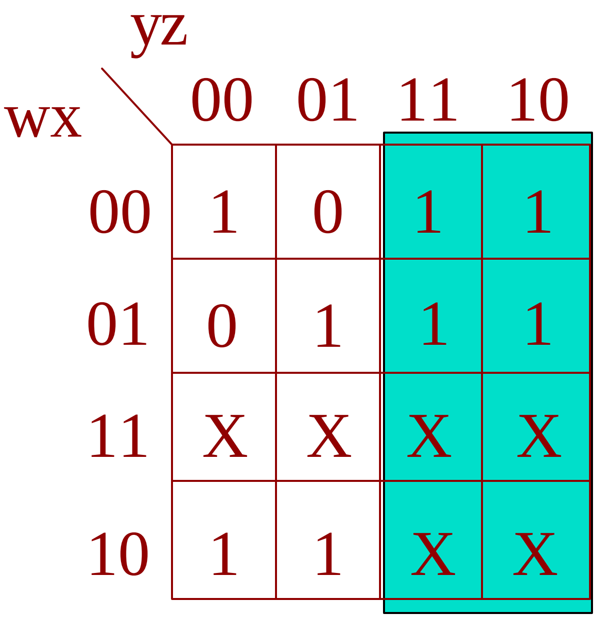
wx \ yz	00	01	11	10
00	1	0	1	1
01	0	1	1	1
11	X	X	X	X
10	1	1	X	X

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) ...

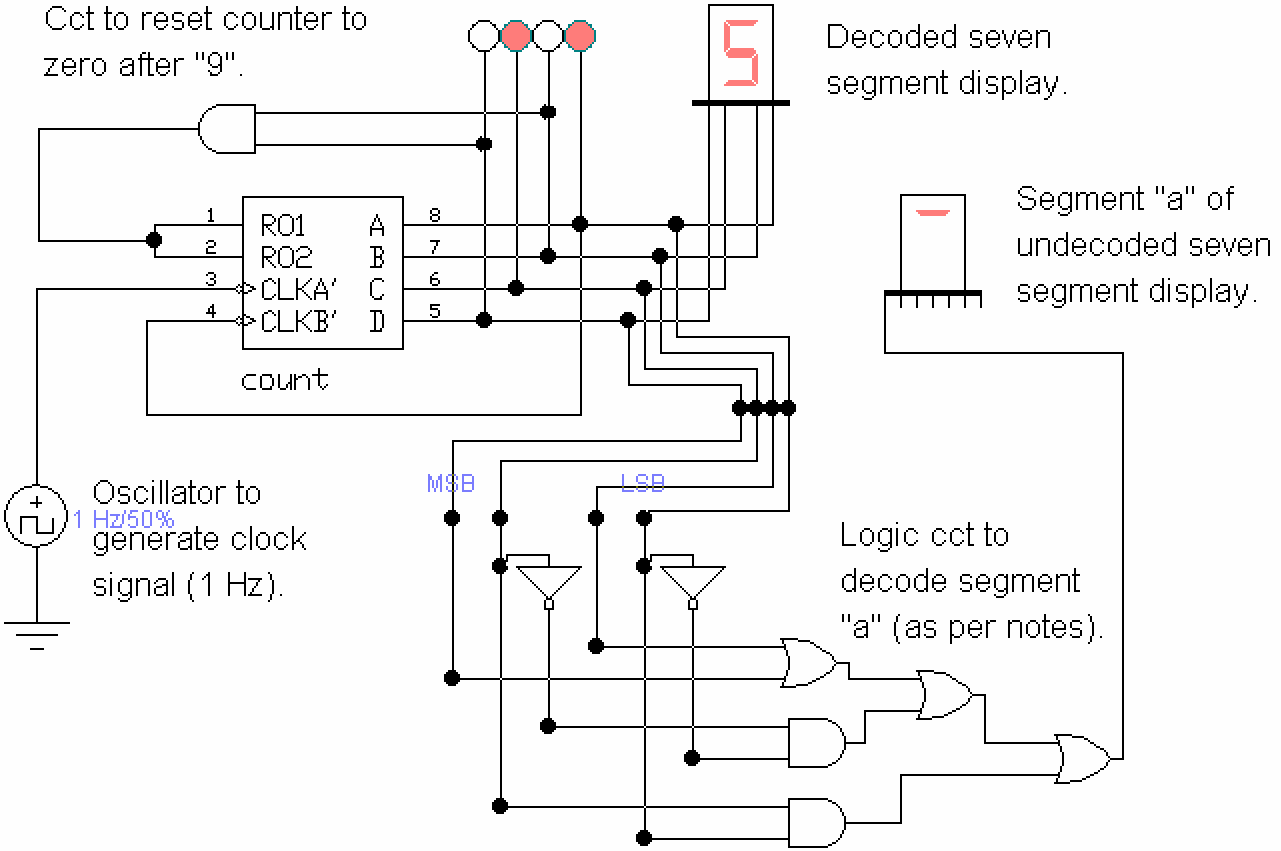
- Put all the terms together
- Generate the circuit

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

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

Example of seven segment display decoding.



Cct to reset counter to zero after "9".

Decoded seven segment display.

Segment "a" of undecoded seven segment display.

Oscillator to generate clock signal (1 Hz).

Logic cct to decode segment "a" (as per notes).

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.