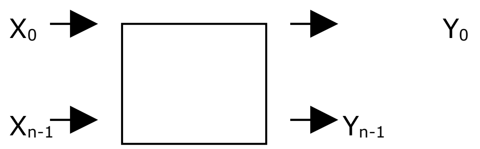
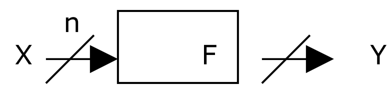
CMSC 130 – Logic Design and Digital Computer Circuits
Handout # 5: DESIGN OF COMBINATIONAL CIRCUITS

Fundamental Components of Digital Systems

1.) Combinatorial Logic Blocks (Functions)
2.) State Elements (Memory)
3.) Interconnect (wires)

Combinatorial Circuit – consists of logic gates whose outputs at a time are determined from the present combination of inputs without regards to the previous inputs.

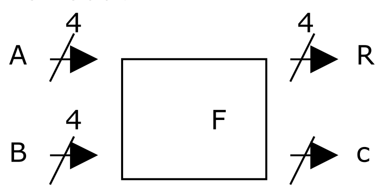




each input/output is a single bit.

$Y = F(X_1, X_2, \ldots, X_{n-1})$ where x,y are {0,1}

ex. 4-bit adder



R=A+B
c is a carry out

Truth Table Representation :

a3	a2	a1	a0	b3	b2	b1	b0	r3	r2	r1	r0	c
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1	0	0	1	0	0
0	0	1	0	0	0	1	0	0	1	0	0	0
0	0	1	1	0	0	1	1	0	1	1	0	0
…												
0	0	1	0	0	0	1	0	0	1	0	0	0
0	0	1	0	0	0	1	1	0	1	0	1	0
…												
0	0	0	0	1	1	1	1	1	1	1	1	0
0	0	0	1	1	1	1	1	0	0	0	0	1

-> 256 rows! In general, 2^n rows for n inputs.

	a3	a2	a1	a0
+	b3	b2	b1	b0
c	r3	r2	r1	r0

Add a_0 and b_0 as follows:

a	b	sum	c_{out}
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

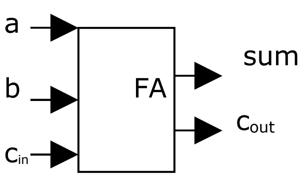
sum = a XOR b
c_{out} = a AND b
= ab

Add a_0 and b_0 as follows: carry to next column

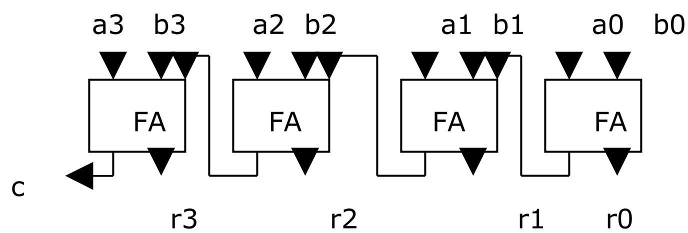
c_{in}	a_i	b_i	sum_i	c_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

sum_i = a_i XOR b_i XOR c_{in}
$c_{out} = a_ib_i + a_ic_{in} + b_ic_{in}$

Full Adder Cell



The 4-bit adder :



Example: BCD-to-Excess3 code converter

Truth Table

BCD				XS-3			
A	B	C	D	W	X	Y	Z
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
…							
1	0	0	1	1	1	0	0
1	0	1	0	X	X	X	X
…							
1	1	1	1	X	X	X	X

AB\CD	00	01	11	10
00	1			1
01	1			1
11	X	X	X	X
10	1		X	X

z = d’

AB\CD	00	01	11	10
00	1		1	
01	1		1	
11	X	X	X	X
10	1		X	X

y = cd+c’d’

AB\CD	00	01	11	10
00		1	1	1
01	1			
11	X	X	X	X
10		1	X	X

x = b’c+b’d+bc’d’

AB\CD	00	01	11	10
00				
01		1	1	1
11	X	X	X	X
10	1	1	X	X

w=a+bc+bd

Functions for the BCD-to-XS3 Converter:

z=d’ y=cd+c’d’

x=b’c+b’d+bc’d’ w=a+bc+bd

Note: The functions are algebraically manipulated for the purpose of using common gates for two or more outputs.

Logic Diagram of the BCD-to-XS3 Converter: