

Combinatorial Logic Review

Last updated 7/13/23

Combinatorial Logic Review

- Logical world
 - Basic Signal Values
 - 1, 0
 - High Low
 - True False
 - Set Reset
 - Additional values
 - X, x = don't care
 - U, u = unknown

Combinatorial Logic Review

- Physical world

- Voltage levels

- System/Circuit dependent (V_{DD} , Gnd)

- Ideal:

3.3v System

'1' = 3.3v

'0' = 0.0v

1.8v System

'1' = 1.8v

'0' = 0.0v

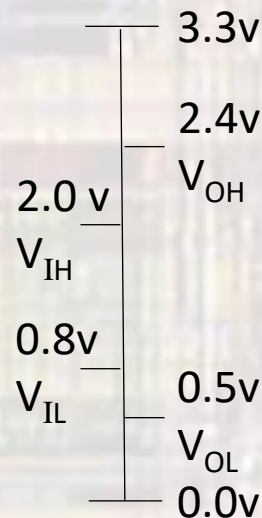
1.2v System

'1' = 1.2v

'0' = 0.0v

- Real world:

3.3v System



Combinatorial Logic Review

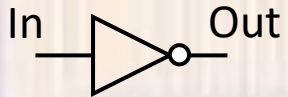
- Buffers

non-Inverting



In	Out
0	0
1	1

Inverting



In	Out
0	1
1	0

notA $\sim A$ A'

Tri-State



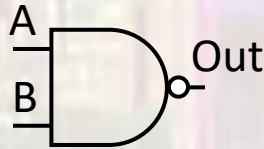
Tri	In	OUT
0	0	1
0	1	0
1	0	Z
1	1	Z

In	Tri	OUT
A	0	$\sim A$
X	1	Z

Combinatorial Logic Review

- Simple Gates

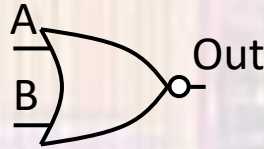
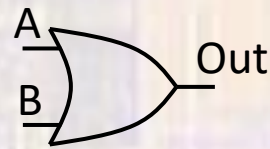
AND/NAND



A	B	AND OUT	NAND OUT
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

A and B A nand B
 $A \wedge B$ $(A \wedge B)'$
 A & B A & B
 AB A*B

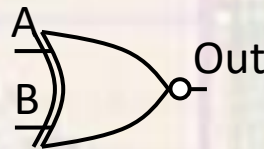
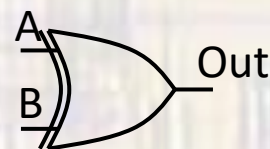
OR/NOR



A	B	OR OUT	NOR OUT
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

A or B A nor B
 $A \vee B$ $(A \vee B)'$
 A | B A | B
 A + B

XOR/XNOR



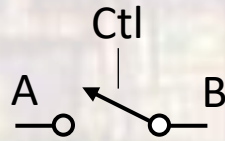
A	B	XOR OUT	XNOR OUT
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

A xor B A xnor B
 $A \oplus B$ $(A \oplus B)'$

Combinatorial Logic Review

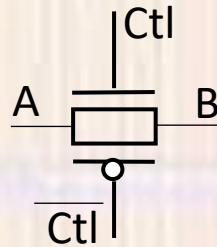
- Switches

Switch



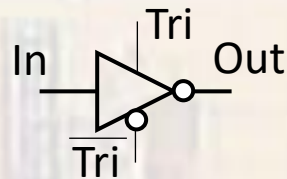
Ctl	State
0	X
1	A = B

Switch



Ctl	State
0	X
1	A = B

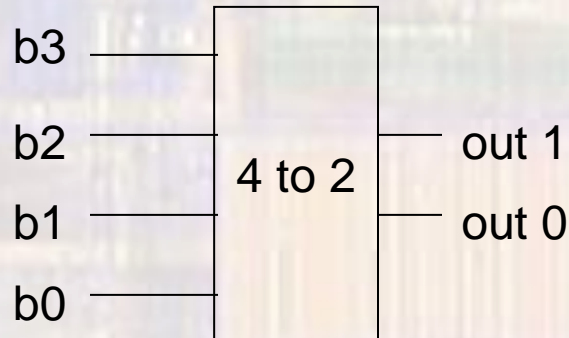
Tristate



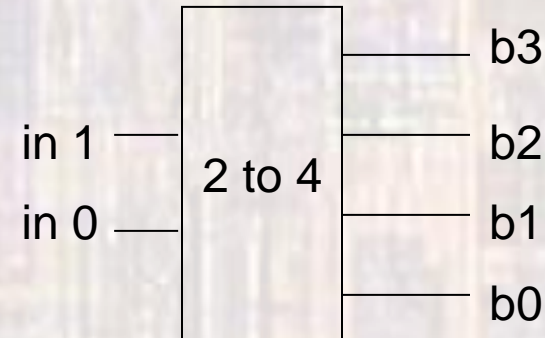
In	Tri	Tri bar	Out
A	0	0	U
A	0	1	A'
A	1	0	Z
A	1	1	U

Combinatorial Logic Review

- Coder / Decoder



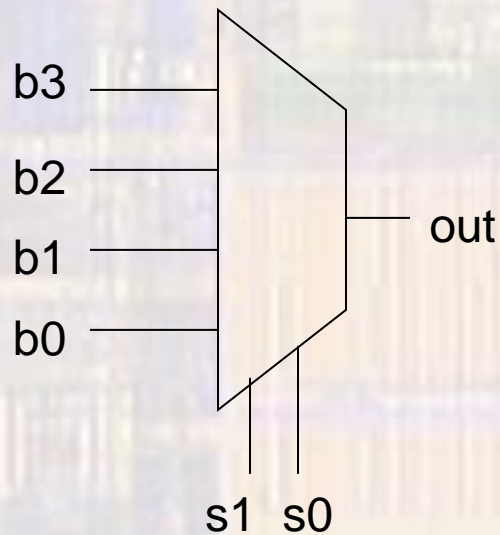
b3	b2	b1	b0	out 1	out 0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1



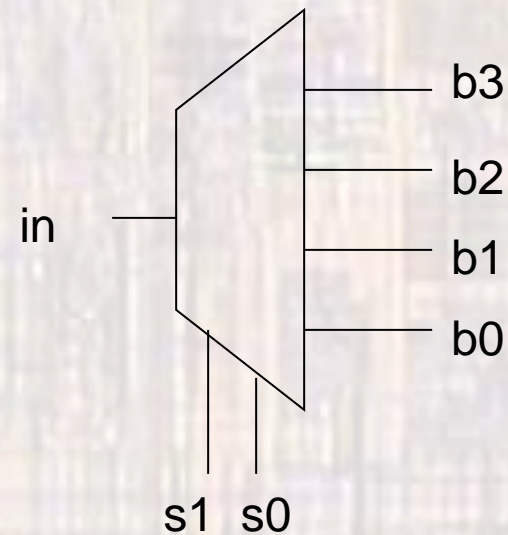
In 1	In 2	b3	b2	b1	b0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	1	0	0
1	1	1	0	0	0

Combinatorial Logic Review

- Multiplexer/ Demultiplexer



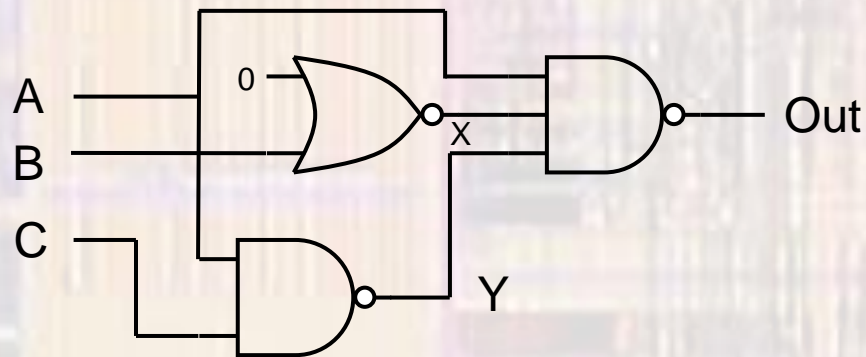
s1	s0	out
0	0	b0
0	1	b1
1	0	b2
1	1	b3



s1	s0	b3	b2	b1	b0
0	0	0	0	0	in
0	1	0	0	in	0
1	0	0	in	0	0
1	1	in	0	0	0

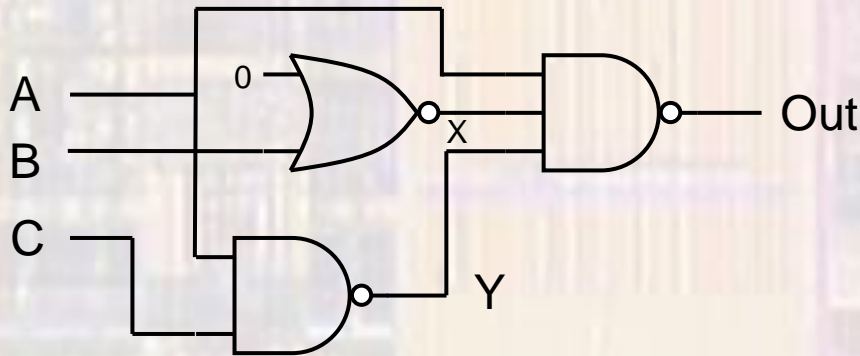
Combinatorial Logic Review

- Logic Analysis



Combinatorial Logic Review

- Logic Analysis



A	B	C	X	Y	Out
			$(B+0)'$	$(AC)'$	$(AXY)'$
0	0	0	1	1	1
0	0	1	1	1	1
0	1	0	0	1	1
0	1	1	0	1	1
1	0	0	1	1	0
1	0	1	1	0	1
1	1	0	0	1	1
1	1	1	0	0	1

Combinatorial Logic Review

- de Morgan's Laws

$$(A \cup B)' = A' \cap B'$$

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$$(A')' = A$$

$$\overline{(A + B)} = \overline{A} \overline{B}$$

$$\overline{(AB)} = \overline{A} + \overline{B}$$

$$\overline{\overline{A}} = A$$

Combinatorial Logic Review

- de Morgan's Laws

$$(A \cup B)' = A' \cap B'$$

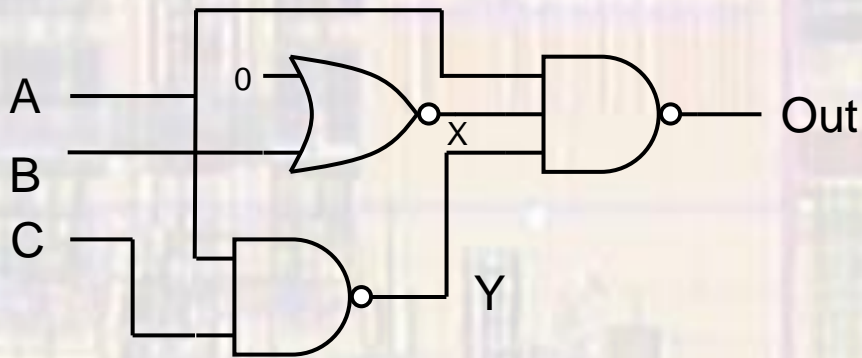
$$(A \cap B)' = A' \cup B'$$

$$(A')' = A$$

$$\overline{(A + B)} = \bar{A}\bar{B}$$

$$\overline{(AB)} = \bar{A} + \bar{B}$$

$$\overline{\bar{A}} = A$$



$$\begin{aligned} \text{Out} &= \overline{\overline{AXY}} \\ &= \overline{A(\overline{B+0})(\overline{AC})} \\ &= \bar{A} + (B+0) + (AC) \\ &= \bar{A} + B + AC \end{aligned}$$

Combinatorial Logic Review

- Sum-of-Products, Product-of-Sums

Sum-of-Products

$$(A \cap B) \cup (C \cap D) \cup (E \cap F)$$

$$AB + CD + EF$$

Product-of-Sums

$$(A \cup B) \cap (C \cup D) \cap (E \cup F)$$

$$(A + B)(C + D)(E + F)$$

Why ???

Combinatorial Logic Review

- minterm / maxterm

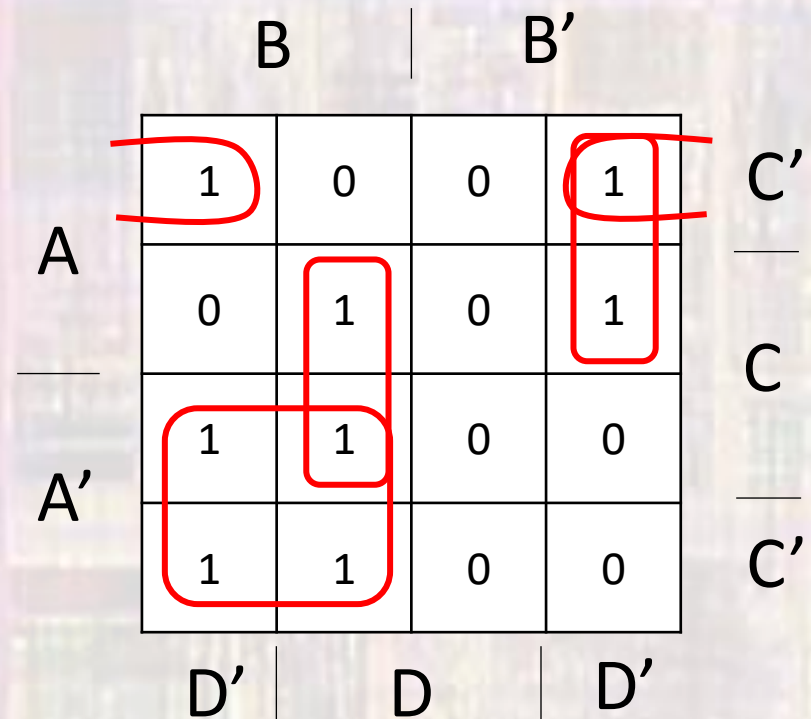
A	B	Y	minterm	maxterm
0	0	0	$A'B'$	$A + B$
0	1	1	$A'B$	$A + B'$
1	0	0	AB'	$A' + B$
1	1	1	AB	$A' + B'$

- SOP: $Y = A'B + AB$
- POS: $Y = (A + B)(A' + B)$

Combinatorial Logic Review

- Karnaugh Maps

A	B	C	D	Y
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	0
1	1	1	0	0
1	1	1	1	1



$$A'B + BCD + AB'D' + AC'D'$$

Combinatorial Logic Review

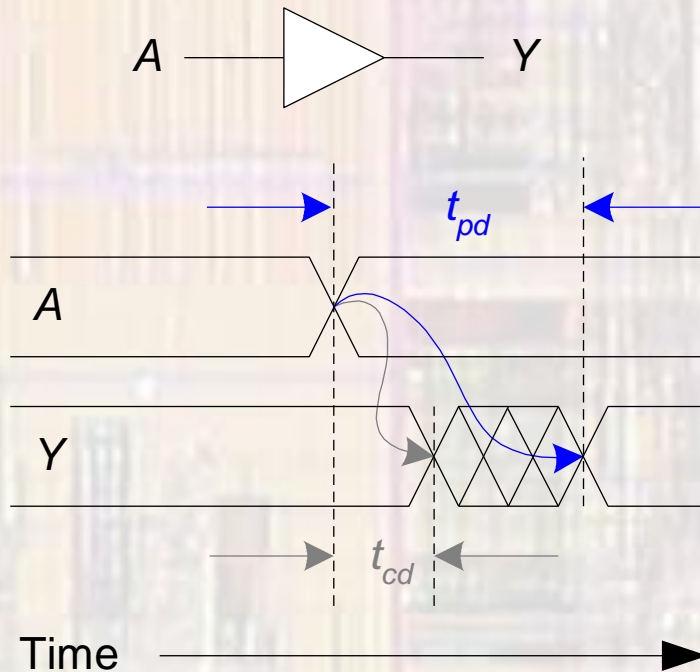
- Delays

- t_{pd} = propagation delay

- delay from input to valid output (max delay)

- t_{cd} = contamination delay

- delay from input to first movement on output (min delay)



Combinatorial Logic Review

- Shortcuts

