CS 240 Lab 2
More Digital Logic
and
Combinational Circuits

- **Binary and Hex Numbers/Binary Counter**

- **Multiplexer**

- **Decoder**

- **Adder**

Binary and Hexadecimal Numbers

Hex	Binary			
	QD	QC	QB	QA
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
A	1	0	1	0
B	1	0	1	1
C	1	1	0	0
D	1	1	0	1
E	1	1	1	0
F	1	1	1	1

Hex can be converted to binary and vice versa by grouping into 4 bits.

$11110101_2 = F5_{16}$ $37_{16} = 00110111_2$

Binary Counter

NOTE: logic diagram is not the same as pin-outs! Shows information about the logical operation of the device.

- Inputs on left side of diagram
- Outputs on right
- Voltage shown on top
- Ground shown on bottom

LOGIC
DIAGRAM

input

14	A		V_{cc}	5			
1	B				QA	12	
			7493		QB	9	
2	R1				QC	8	
3	R2				QD	11	
		GND	10				
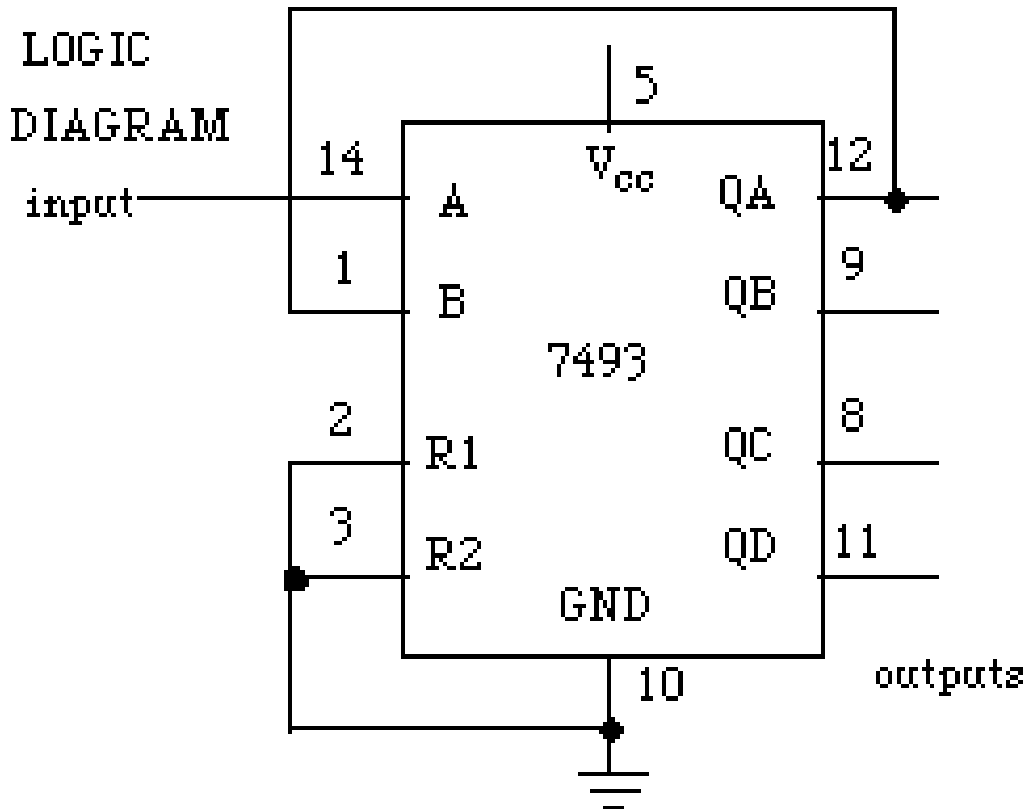
outputs

Multiplexer

A multiplexer can be thought of as a **steering circuit**, which steers a single input from a set of inputs through to the output, based on the select line.

Multiplexer
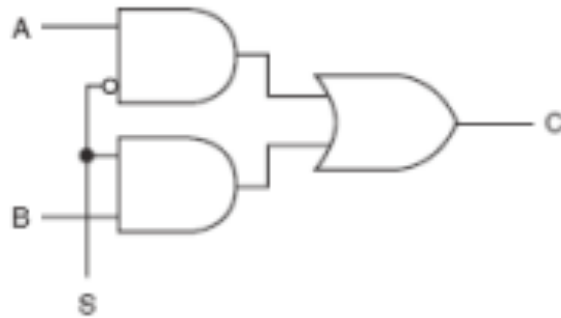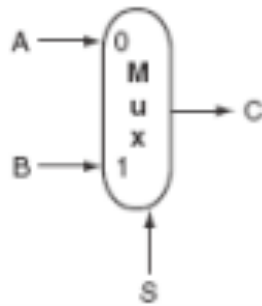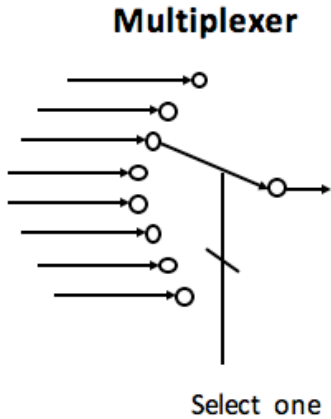
Select one

- n select lines
- 2^n input lines
- 1 output

One of the possible 2^n inputs is chosen by the n select lines, and gated through to the output of a multiplexer. The truth table for an 8x1 MUX is:
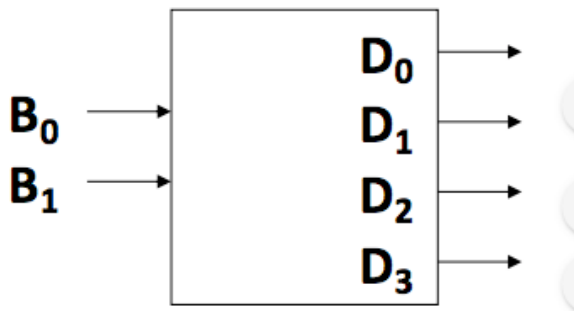
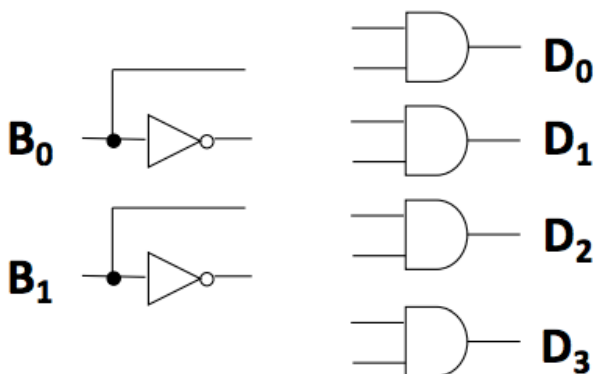| S2	S1	S0	Q
0	0	0	D0
0	0	1	D1
0	1	0	D2
0	1	1	D3
1	0	0	D4
1	0	1	D5
1	1	0	D6
1	1	1	D7

Decoder

A decoder translates an binary number input to the select lines, and asserts the corresponding numbered output.

- n input/select lines
- 2^n outputs
- only one of the outputs is active at any given time, based on the value of the n select lines.
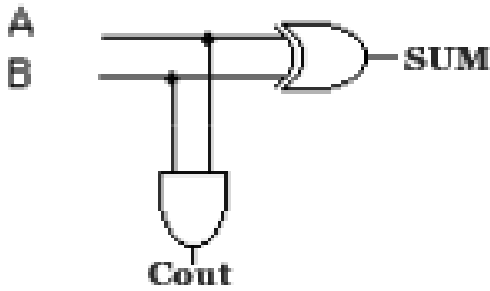
2x4 Decoder

Built with code detectors:

Truth table for an 3x8 decoder

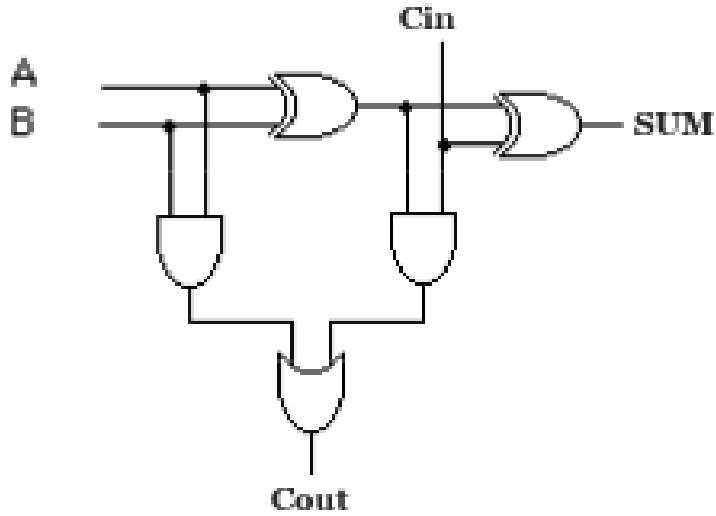| S2	S1	S0	|	Q0	Q1	Q2	Q3	Q4	Q5	Q6	Q7
0	0	0	|	1	0	0	0	0	0	0	0
0	0	1	|	0	1	0	0	0	0	0	0
0	1	0	|	0	0	1	0	0	0	0	0
0	1	1	|	0	0	0	1	0	0	0	0
1	0	0	|	0	0	0	0	1	0	0	0
1	0	1	|	0	0	0	0	0	1	0	0
1	1	0	|	0	0	0	0	0	0	1	0
1	1	1	|	0	0	0	0	0	0	0	1

Adder

Addition is a very important arithmetic operation, and uses the Exclusive OR gate!

Half-Adder — adds two one-bit values

A	B	Cout	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Full Adder — uses two half-adders and incorporates a carry-in

Cin	A	B	Cout	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

$Sum = A \oplus B \oplus Cin$

$Cout = AB + (A \oplus B)Cin$