Combinational Circuits

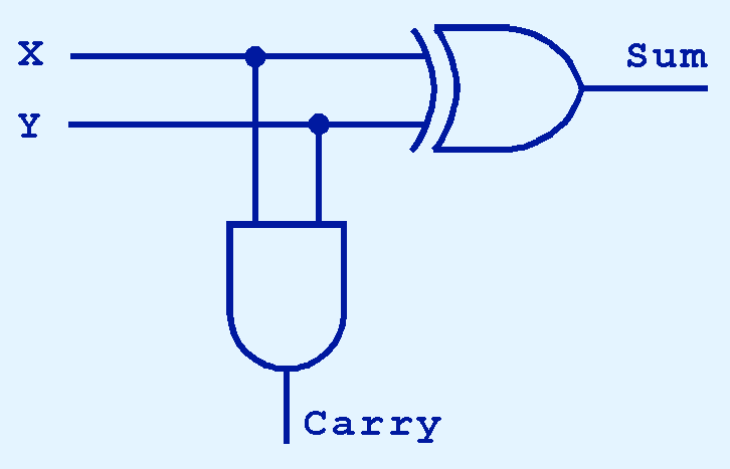
Combinational circuits are those whose output depend only on the current inputs.

As soon as the inputs change, the output changes (after a short propagational delay)

An example is a half adder :

Inputs		Outputs	
X	Y	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

- The sum matches the XOR operation and the carry matches the AND operation.



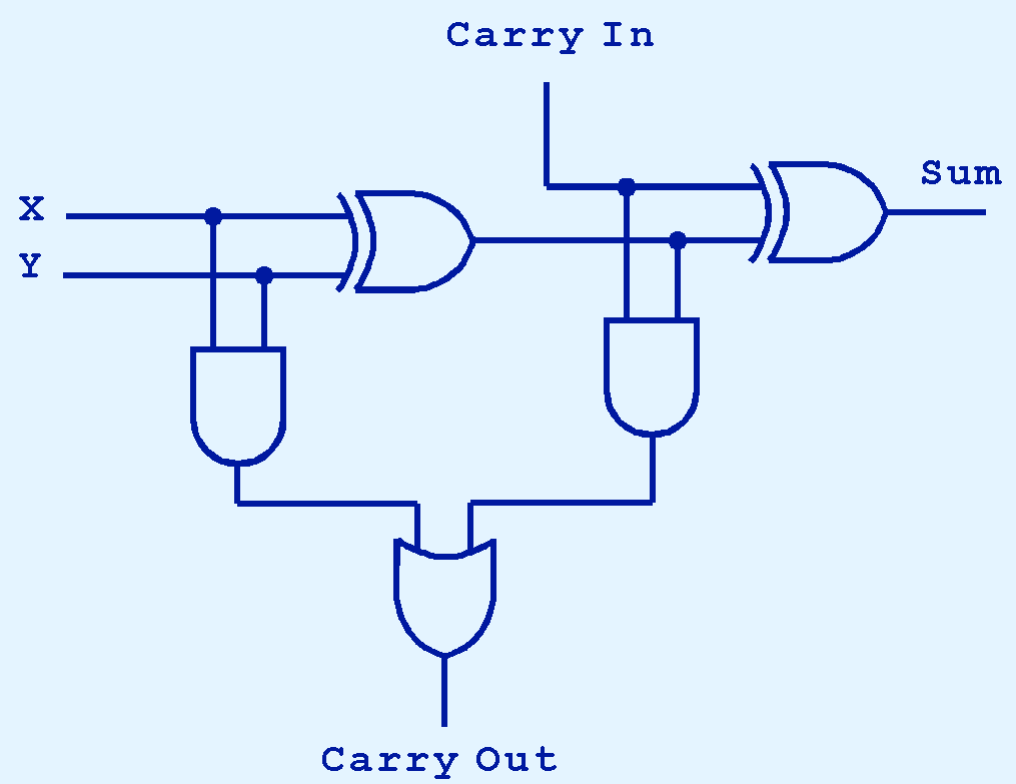
Inputs		Outputs	
X	Y	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

This only works for the LSB of the sum.

- The half adder becomes a full adder by including gates for processing the carry bit.
- The truth table for a full adder is shown at the right.

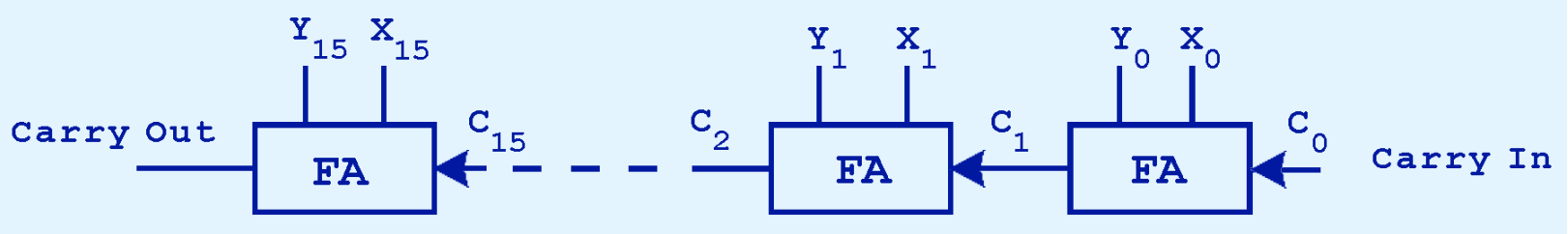
Inputs			Outputs	
X	Y	Carry In	Sum	Carry Out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Here's the completed full adder that works for any bit in the sum:



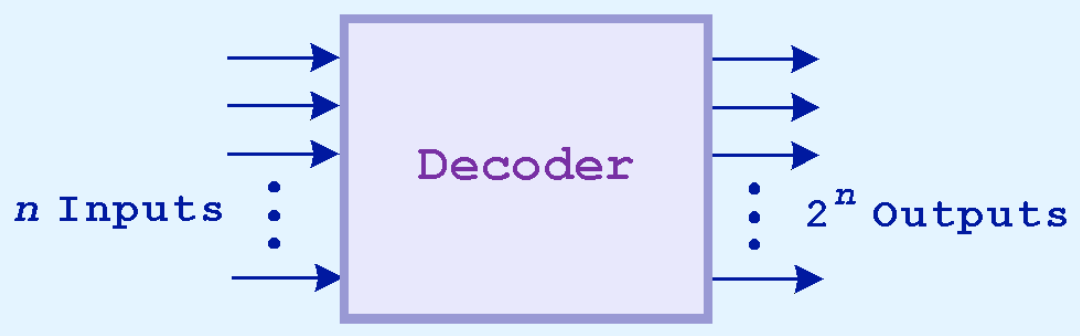
Inputs			Outputs	
X	Y	Carry In	Sum	Carry Out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

- Adders of any desired size can be produced by connecting full adders in series.
- The carry bit "ripples" from one adder to the next; hence, this configuration is called a *ripple-carry adder*.

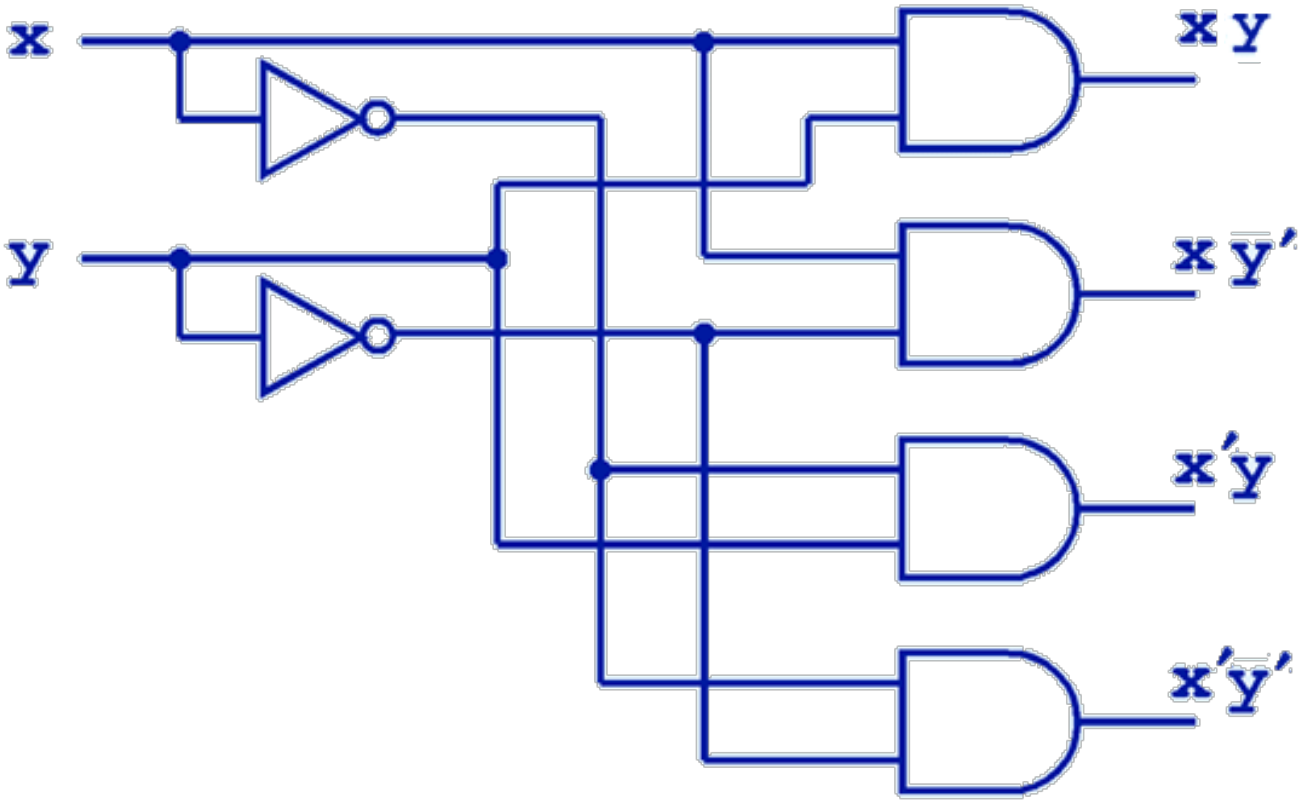


- The full adders must operate sequentially.
- A look-ahead carry adder would be more efficient because it allows the bits in the sum to be computed in parallel.

- Decoders are another important type of combinational circuit.
- Among other things, they are useful in selecting a memory location indicated by a binary value placed on the address lines of a memory bus.
- Address decoders with *n* inputs can select any of 2^n locations.

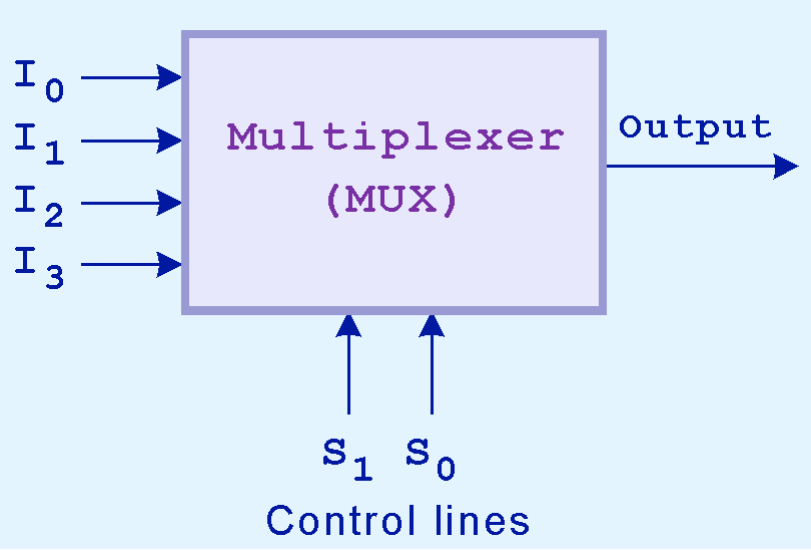


- A 2-to-4 decoder could be implemented as:



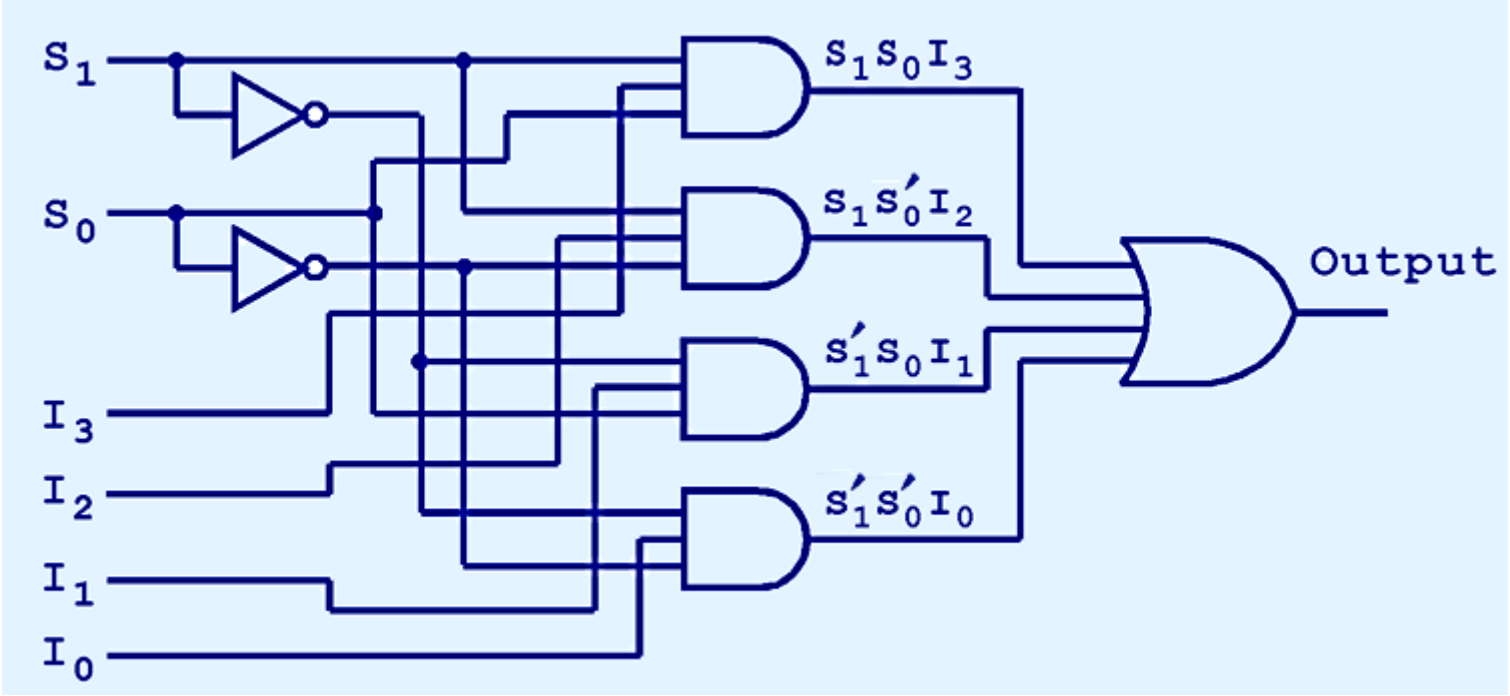
The 2-bit number xy is decoded to select one of 4 outputs.

- A multiplexer does just the opposite of a decoder.
- It selects a single output from several inputs.
- The particular input chosen for output is determined by the value of the multiplexer's control lines.
- To be able to select among *n* inputs, $\log_2 n$ control lines are needed.



Multiplexers are also called selectors.

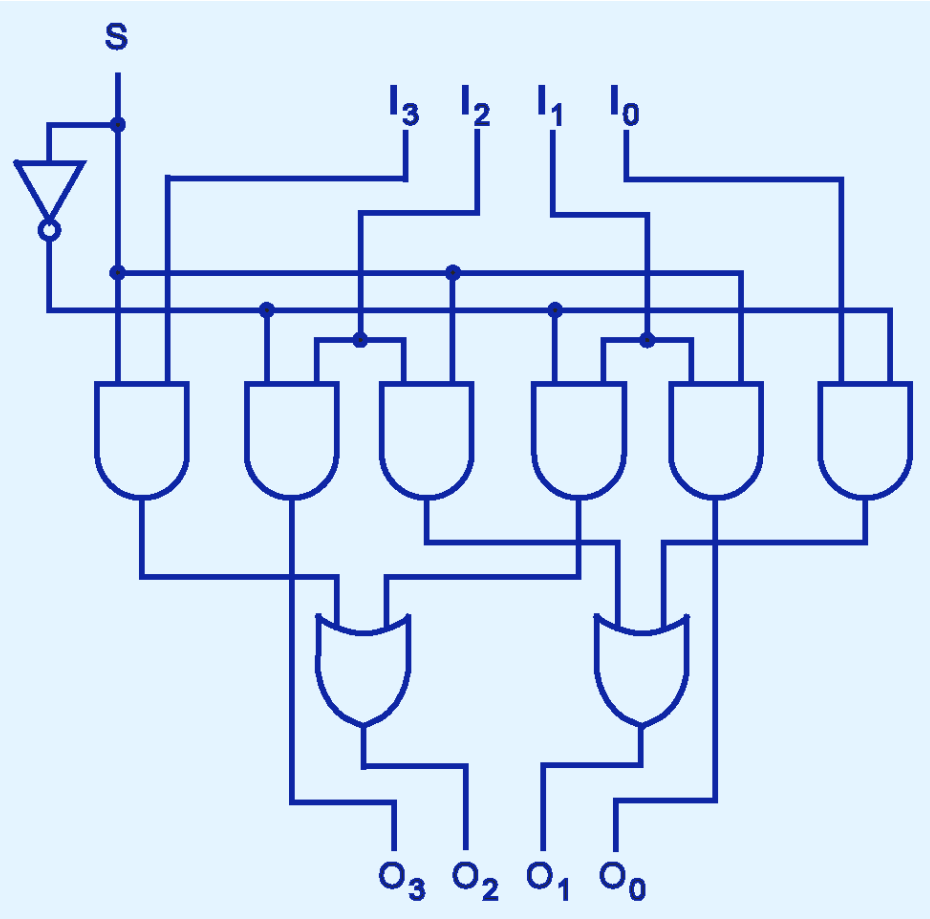
- A possible implementation of a 4-to-1 multiplexer is shown below:



S_1S_0 selects one of 4 inputs I_3, I_2 , I_1 or I_0 to pass to the output.

- Multiplication and division involve a series of additions, subtractions and shifting operations.
- We have seen how logic gates can add numbers
- Once we see how to use logic gates to perform shifing, we can then compute products, quotients and remainders.
- A shifter moves the bits within a binary pattern one position to the left or right.

One way to implement a shifter is shown below:



S = 0 shifts left, S=1 shifts right.

- Combinational logic circuits generate outputs that depend only on the current set of inputs.
- *Sequential logic circuits* generate outputs that depend on the previous history of inputs.
  - These circuits have to "remember" their current state.
- *Sequential logic circuits* are used to implement devices such as registers and memories.
- These memory-type devices will be examined later in the course.