Gates and Circuits

(Part B)

By

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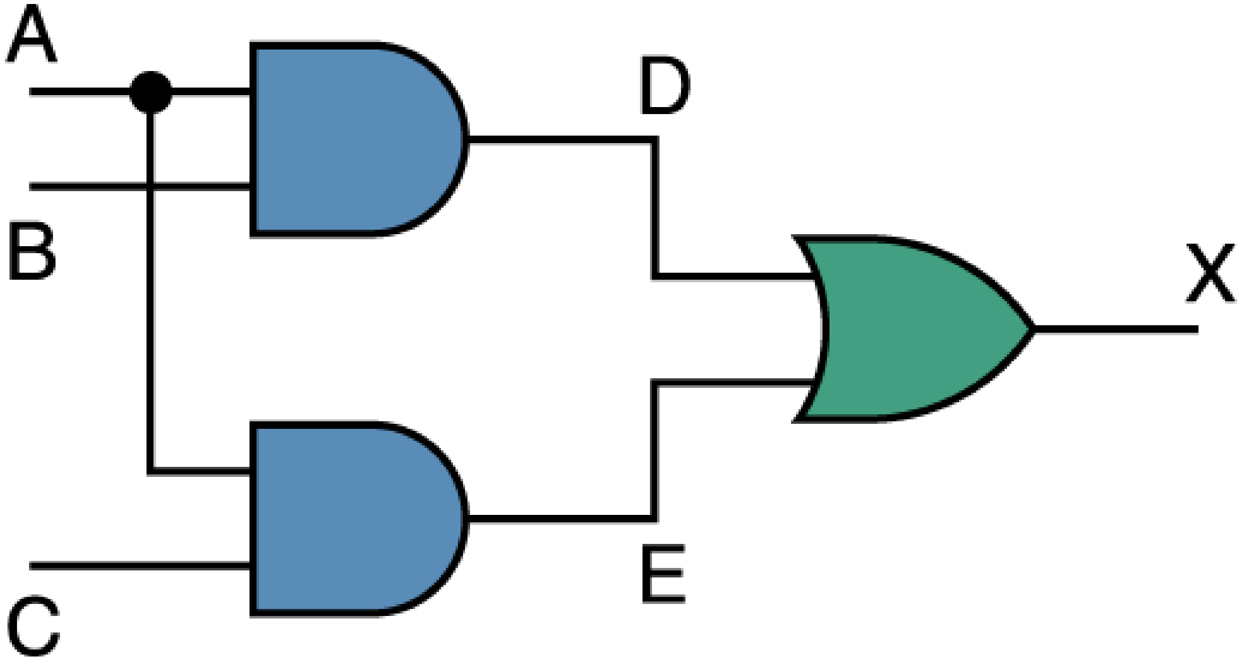
Goals

- Combine basic gates into circuits
- Describe the behavior of a gate or circuit using Boolean expressions, truth tables, and logic diagrams

Combinational Circuits

- Gates are combined into circuits by using the output of one gate as the input for another



Combinational Circuits

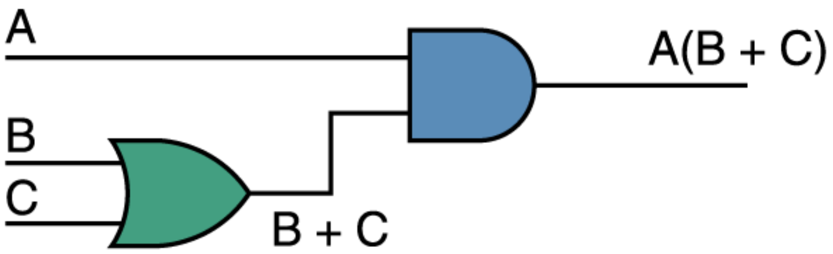
A	B	C	D	E	X
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	0
1	0	0	0	0	0
1	0	1	0	1	1
1	1	0	1	0	1
1	1	1	1	1	1

- Because there are three inputs to this circuit, eight rows are required to describe all possible input combinations
- This same circuit using Boolean algebra:

(AB + AC)

Now let's go the other way; let's take a Boolean expression and draw

- Consider the following Boolean expression: $A(B + C)$



A	B	C	B + C	A(B+C)
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

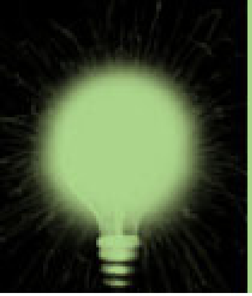
- Now compare the final result column in this truth table to the truth table for the previous example
  - They are identical

Now let’s go the other way; let’s take a Boolean expression and draw

- We have therefore just demonstrated **circuit equivalence**
  - That is, both circuits produce the exact same output for each input value combination
- Boolean algebra allows us to apply provable mathematical principles to help us design logical circuits

Multiplexers

- **Multiplexer** is a general circuit that produces a single output signal
  - The output is equal to one of several input signals to the circuit
  - The multiplexer selects which input signal is used as an output signal based on the value represented by a few more input signals, called *select signals* or *select control lines*



Multiplexers

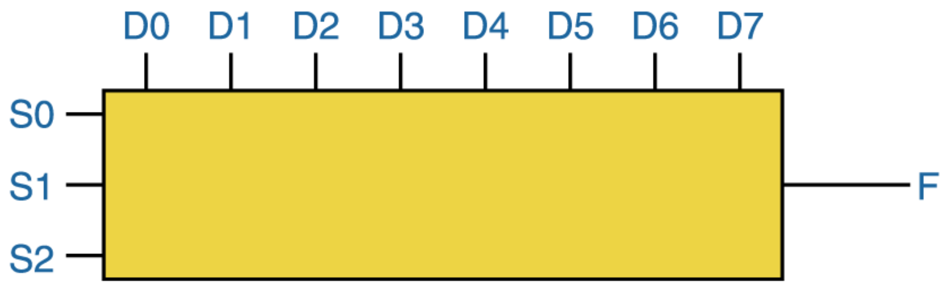


Figure A block diagram of a multiplexer with three select control lines

S0	S1	S2	F
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

- The control lines S0, S1, and S2 determine which of eight other input lines (D0 through D7) are routed to the output (F)

Circuits as Memory

- Digital circuits can be used to store information
- These circuits form a sequential circuit, because the output of the circuit is also used as input to the circuit

Circuits as Memory

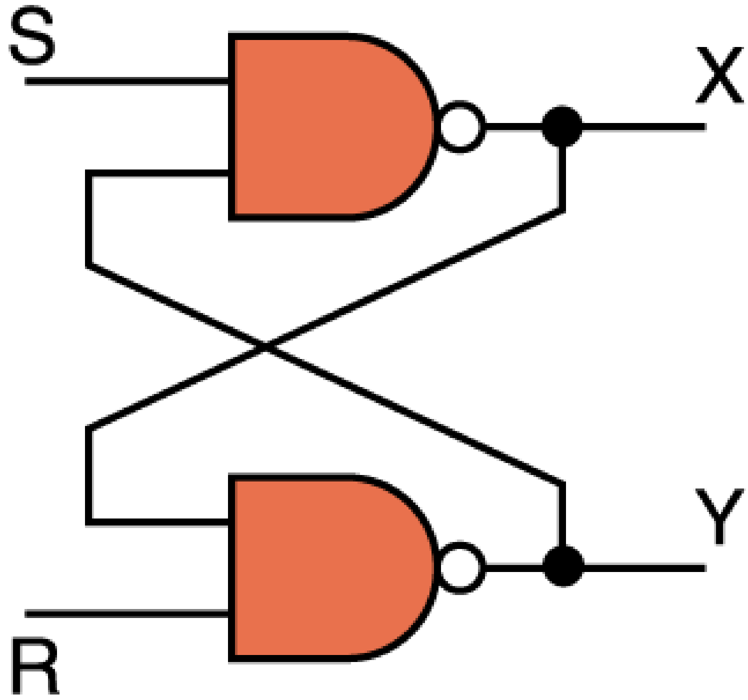


Figure: **An S-R latch**

- An S-R latch stores a single binary digit (1 or 0)
- There are several ways an S-R latch circuit could be designed using various kinds of gates

Circuits as Memory

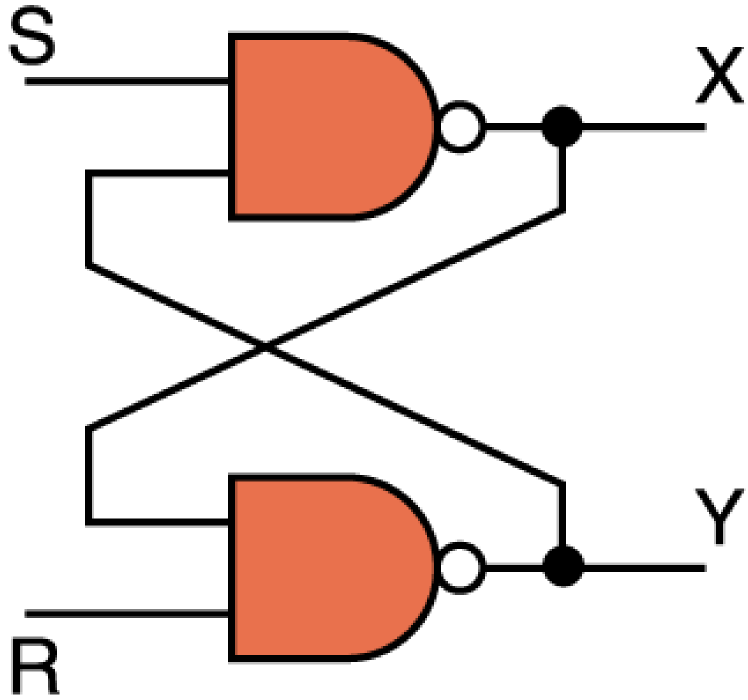


Figure An S-R latch

- The design of this circuit guarantees that the two outputs X and Y are always complements of each other
- The value of X at any point in time is considered to be the current state of the circuit
- Therefore, if X is 1, the circuit is storing a 1; if X is 0, the circuit is storing a 0

Integrated Circuits

- An **integrated circuit** (also called a *chip*) is a piece of silicon on which multiple gates have been embedded
- These silicon pieces are mounted on a plastic or ceramic package with pins along the edges that can be soldered onto circuit boards or inserted into appropriate sockets

Integrated Circuits

- Integrated circuits (IC) are classified by the number of gates contained in them

Abbreviation	Name	Number of Gates
SSI	Small-Scale Integration	1 to 10
MSI	Medium-Scale Integration	10 to 100
LSI	Large-Scale Integration	100 to 100,000
VLSI	Very-Large-Scale Integration	more than 100,000

Integrated Circuits

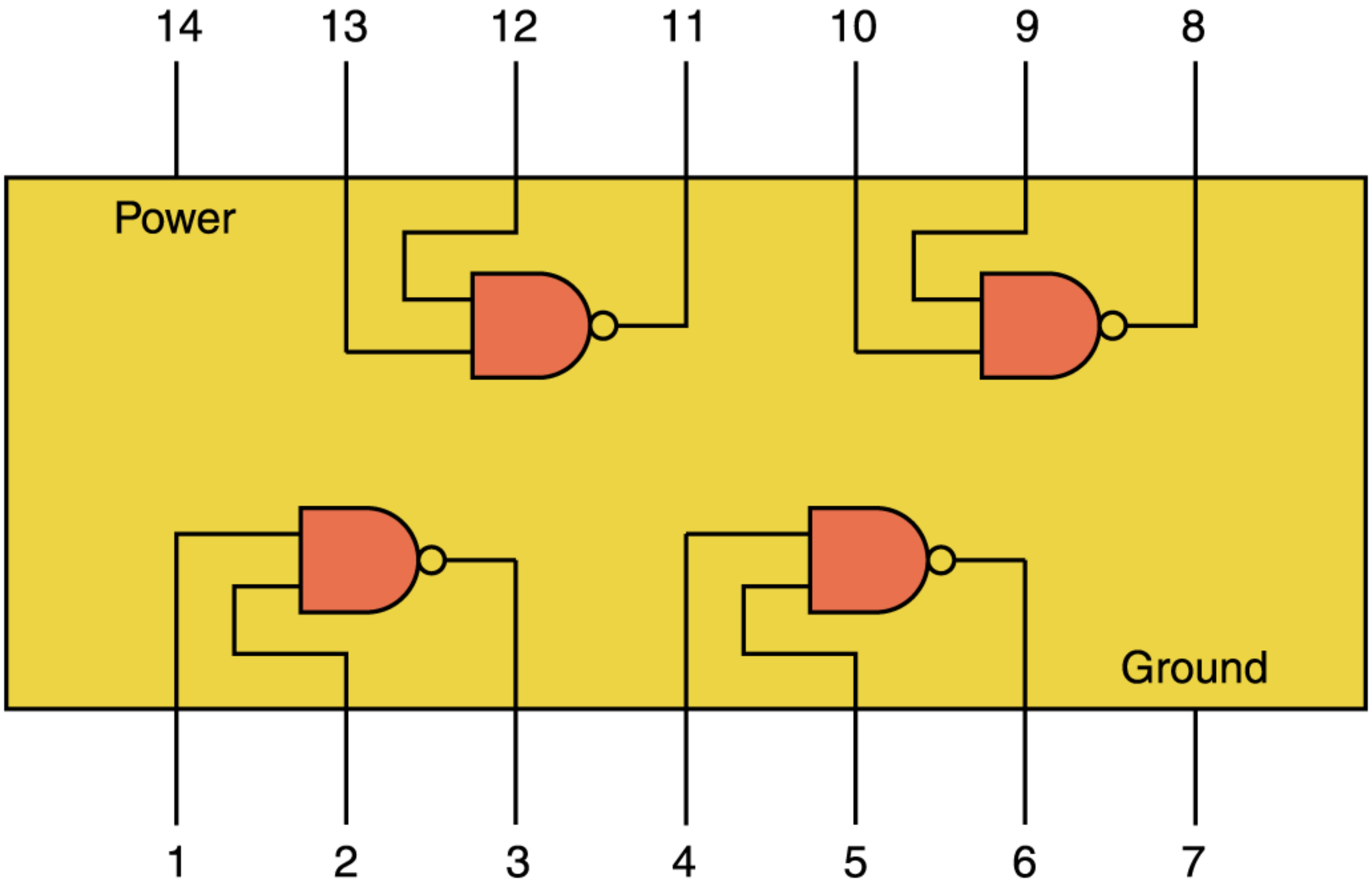


Figure An SSI chip contains independent NAND gates

CPU Chips

- The most important integrated circuit in any computer is the Central Processing Unit, or CPU
- Each CPU chip has a large number of pins through which essentially all communication in a computer system occurs