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Sequential and Combinational ALU

Computer Architecture and Organization

Topics To be covered

- Introduction to ALU
- Introduction to Combinational Circuits
- Design Procedure of Combinational Circuits
- Analysis Procedure of Combinational Circuits
- Introduction to Sequential Circuits
- Types of Sequential Circuits

Introduction to ALU

- ALU stands for: Arithmetic Logic Unit
- ALU is a digital circuit that performs Arithmetic (Add, Sub, . . .) and Logical (AND, OR, NOT) operations.
- John Von Neumann proposed the ALU in 1945 when he was working on EDVAC.

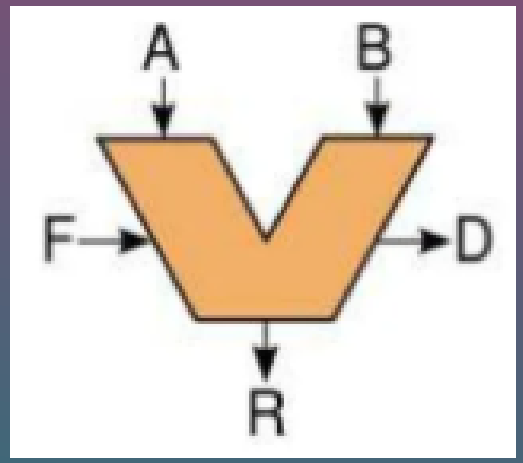
Introduction to ALU: Cont…

- An ALU is the fundamental unit of any computing system.
- Understanding how an ALU is designed and how it works is essential to building any advanced logic circuits.
- Using this knowledge and experience, we can move on to designing more complex integrated circuits.
- The ALU is the "heart" of a processor—you could say that everything else in the CPU is there to support the ALU.

Typical Schematic Symbol of an ALU

A and B: the inputs to the ALU (aka operands)
R: Output or Result
F: Code or Instruction from the Control Unit
D: Output status; it indicates cases such as:

- carry-in
- carry-out,
- overflow,
- division-by-zero
- And . . .



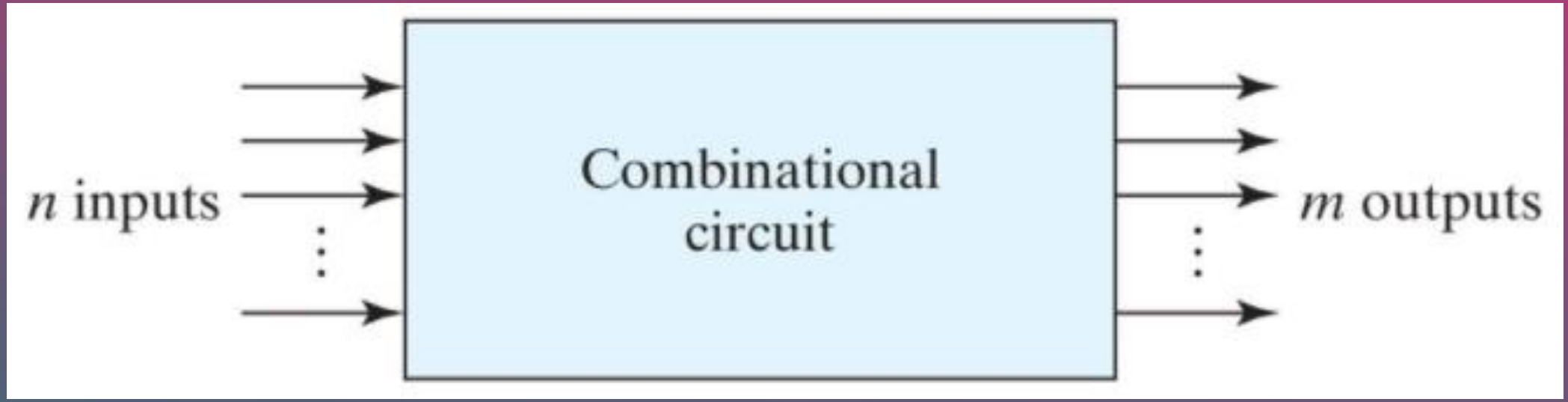
Types of Digital Logic Circuits in ALU

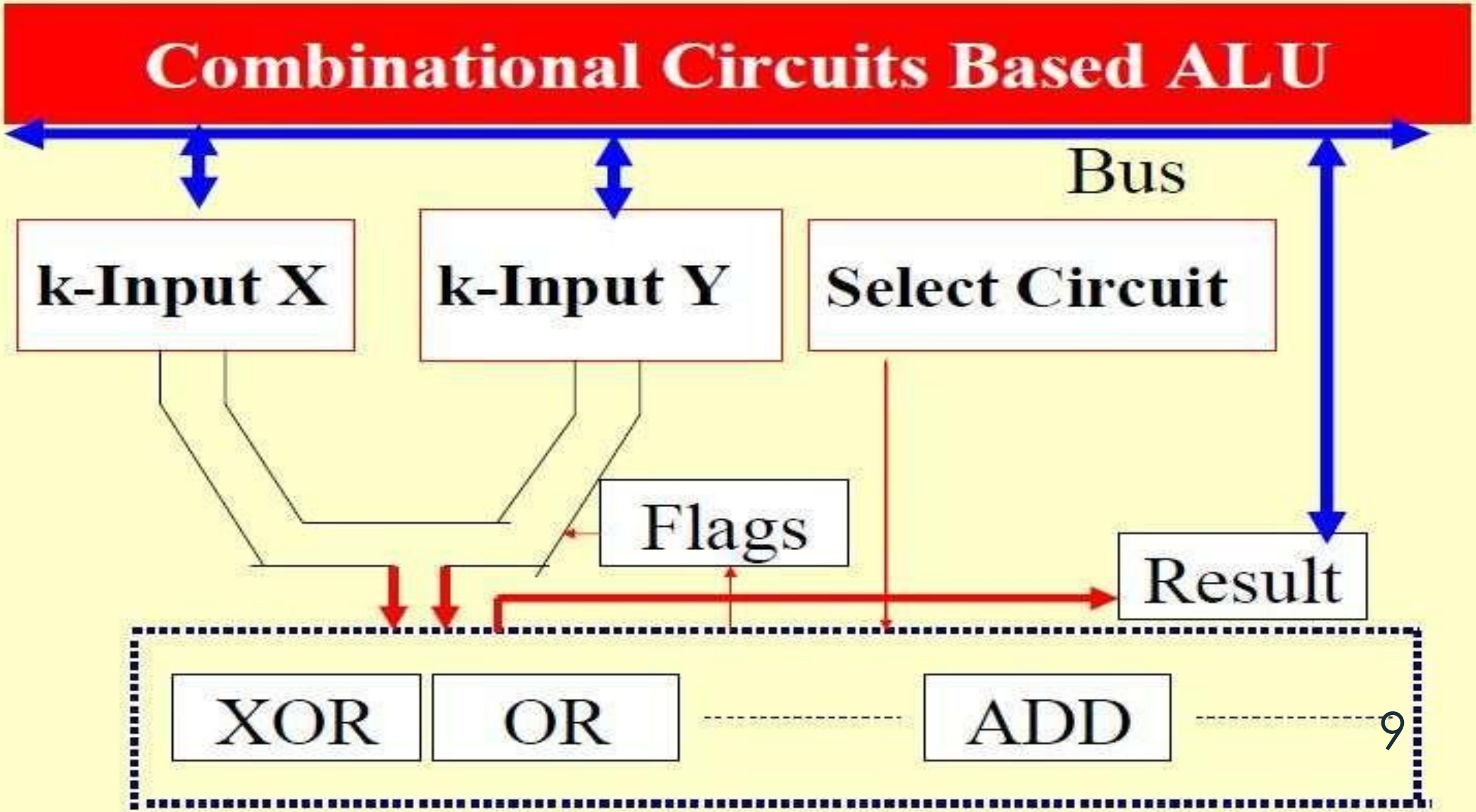
- COMBINATIONAL CIRCUITS
- SEQUENTIAL CIRCUITS

Introduction to Combinational Circuits

- Combinational Circuits are made of logic gates.
- Doesn't contain memory element , that's why they cant store any information.
- Value of present output is determined by present input.
- Examples of combinational circuits are half adders, full adders, sub tractors etc.

Block Diagram of a Combinational Circuit



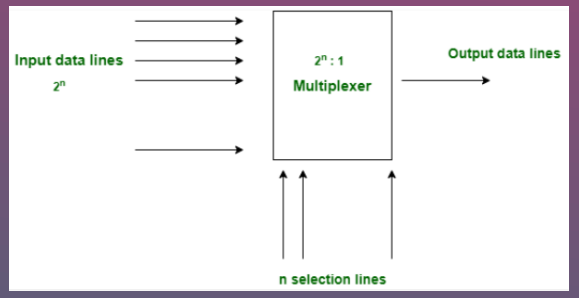

Combinational Circuits Based ALU
Bus
k-Input X
k-Input Y
Select Circuit
Flags
Result
XOR
OR
ADD

Examples of Combinational Circuits

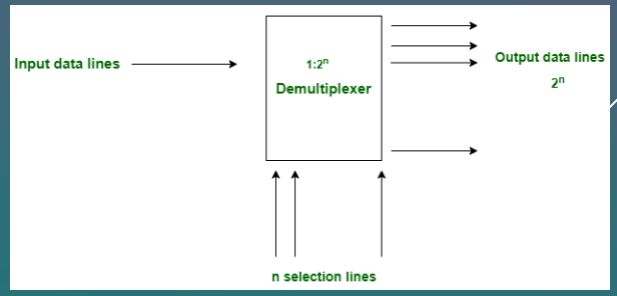
- Multiplexer
- Demultiplexer
- Encoder
- Decoder
- Half Adder
- Full Adder

Multiplexer and Demultiplexer

- Multiplexer-
  - A multiplexer is a combinational circuit where binary information from one of many input lines is selected and directs it to a single output line.

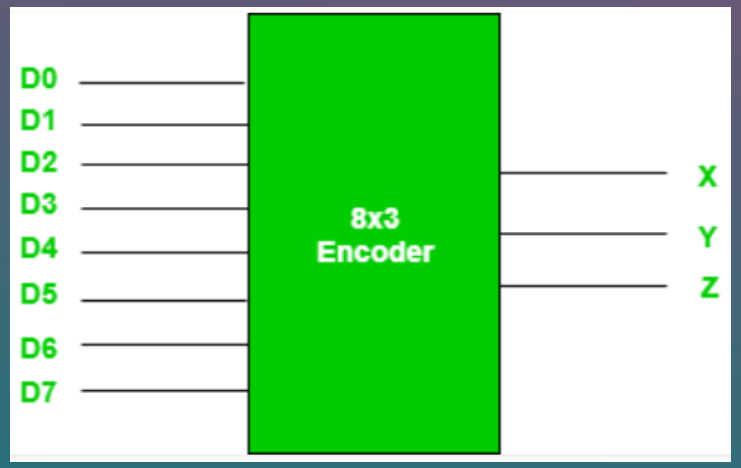


- Demultiplexer-
  - Demultiplexing is the reverse process of multiplexing; i.e., a demultiplexer is a combinational circuit that receives information on a single line and transmits this information on one of 2^n possible output lines.

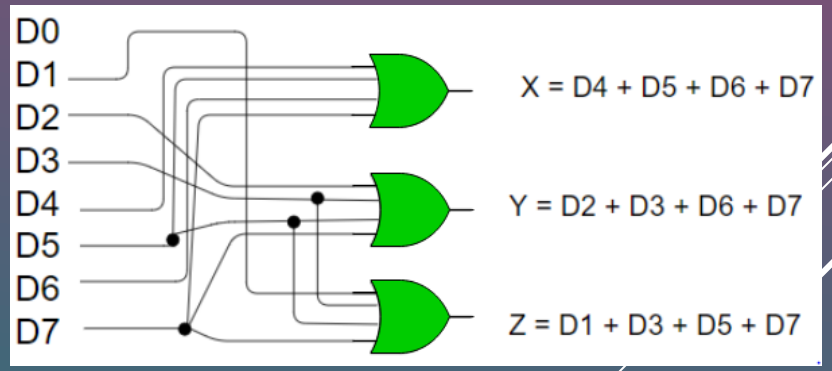


Encoder and Decoder

- Encoder-
  - An encoder is a combinational circuit that converts binary information in the form of a 2^n input lines into n output lines, which represent N bit code for the input. For simple encoders, it is assumed that only one input line is active at a time

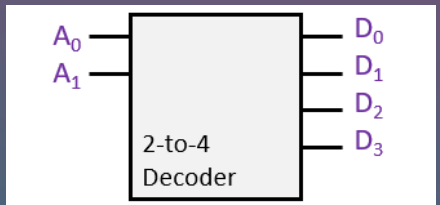


D7	D6	D5	D4	D3	D2	D1	D0	X	Y	Z
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

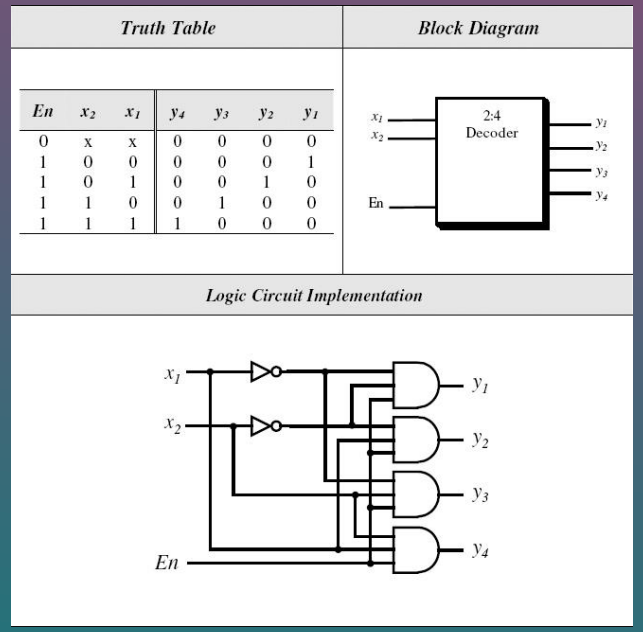


Encoder and Decoder: Cont…

- Decoder-
  - A decoder is a combinational logic circuit that receives coded information on n input lines and feeds them to maximum of 2^n unique output lines after conversion.



INPUT A_1A_0	OUTPUT $D_3D_2D_1D_0$
00	0001
01	0010
10	0100
11	1000

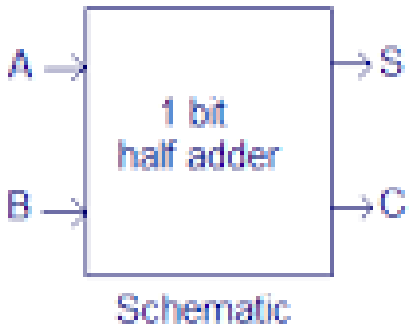


Half-Adder and Full-Adder

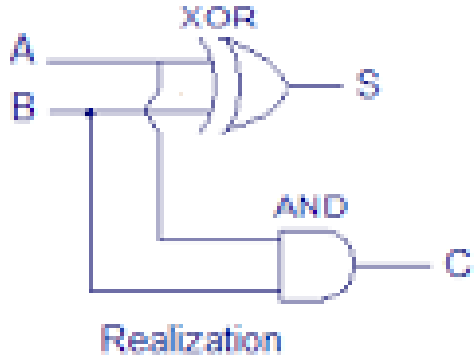
- Half-Adder :
  - A half-adder is a combinational circuit that performs the addition of two bits.

Inputs		Outputs	
A	B	S	C
0	0	0	0
1	0	1	0
0	1	1	0
1	1	0	1

Truth table



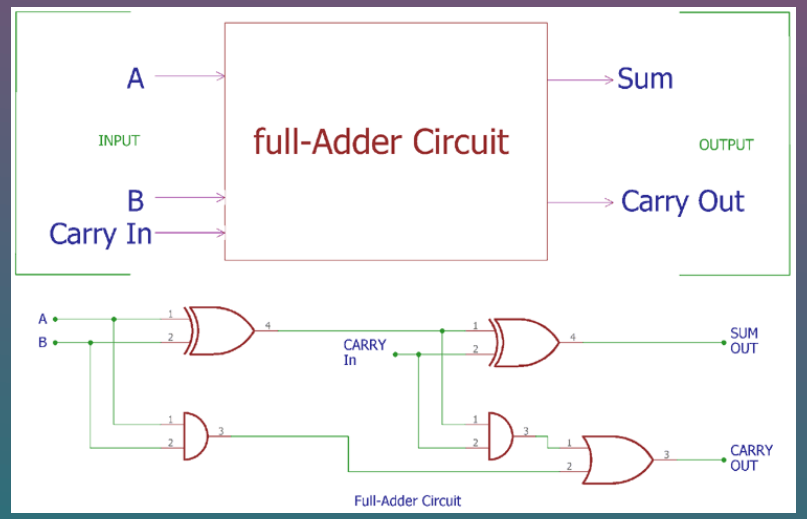
Schematic



Realization

Half-Adder and Full-Adder: Cont…

- Full Adder :
  - This type of adder is a little more difficult to implement than a half-adder.
  - The main difference between a half-adder and a full-adder is that the full-adder has three inputs and two outputs.



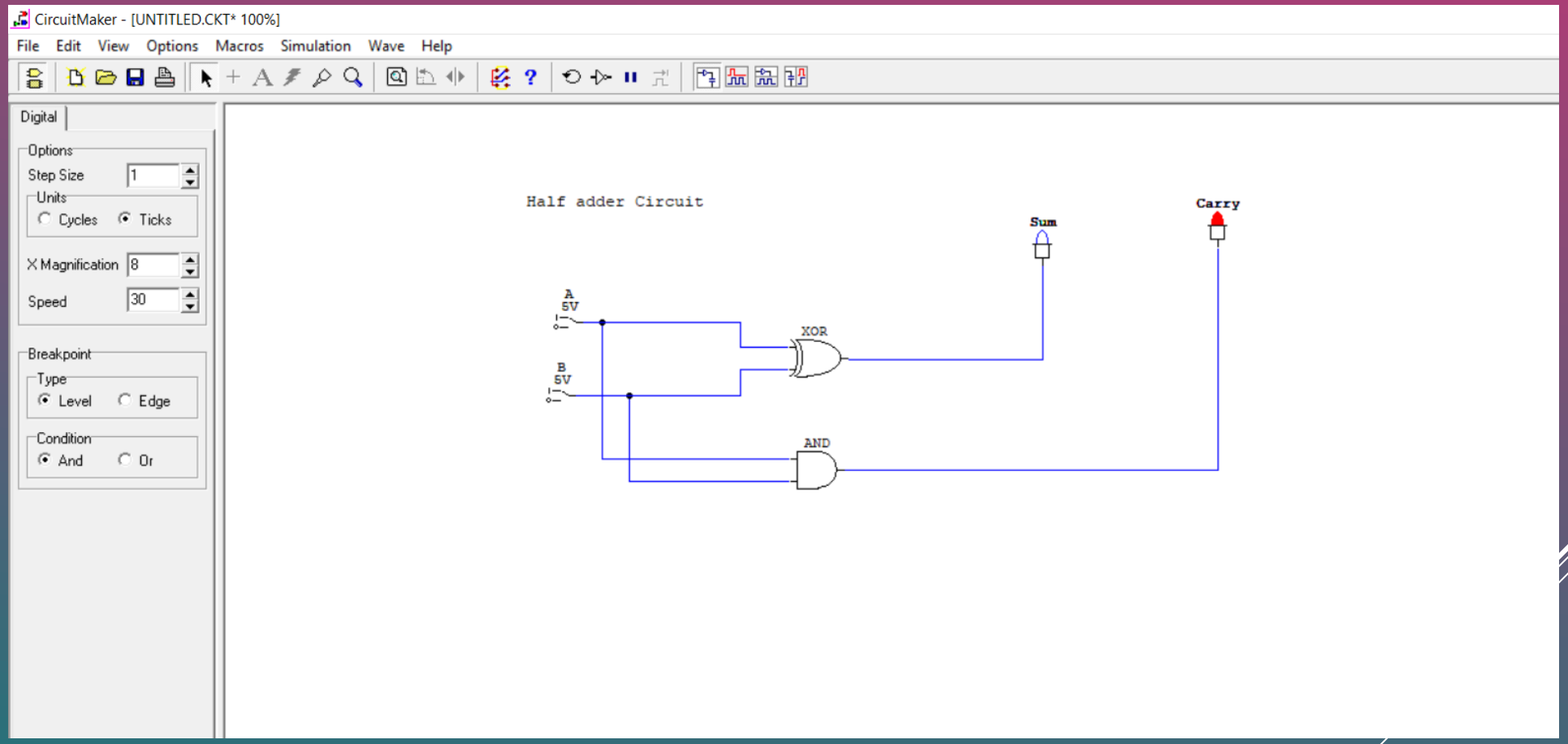
Inputs			Outputs	
A	B	C_{in}	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Design Procedure of Combinational Circuits

This procedure involves the following steps:

- The problem is stated.
- The number of available input variables and output variables is determined.
- The input and output variables are assigned letter symbols.
- Truth table is drawn.
- Boolean function for output is obtained.
- The logic diagram is drawn.

Design Procedure of Combinational Circuits



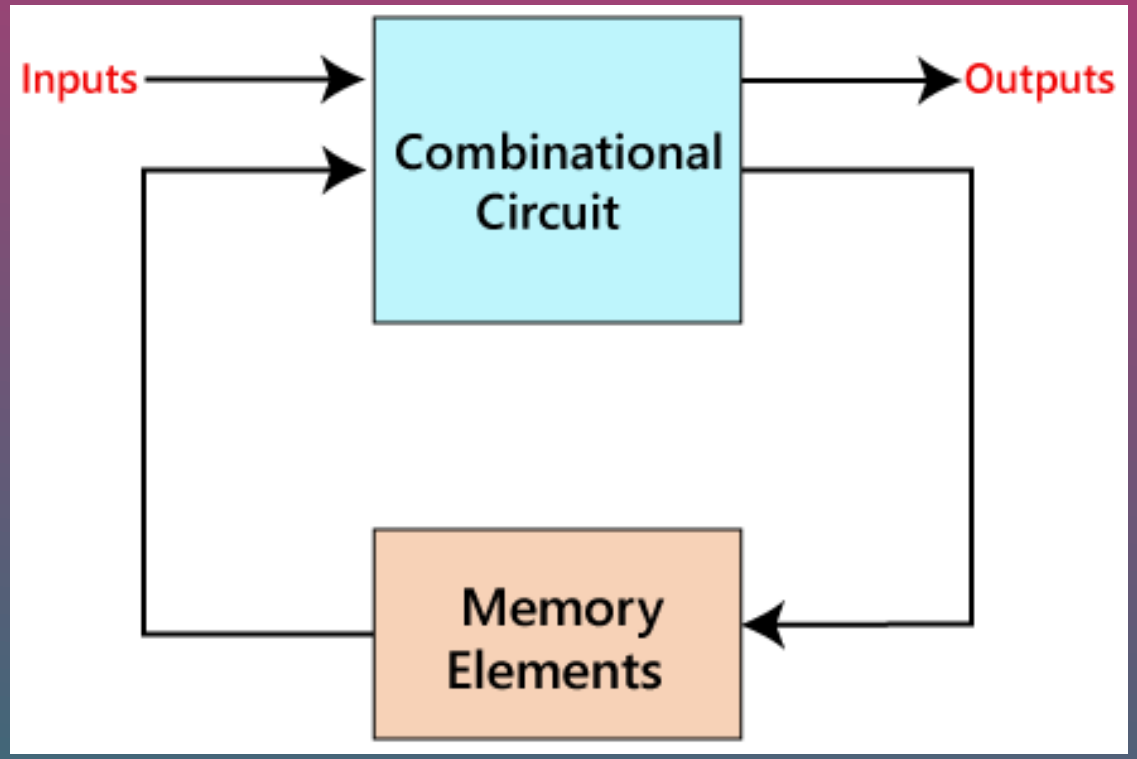
Analysis Procedure of Combinational Circuit

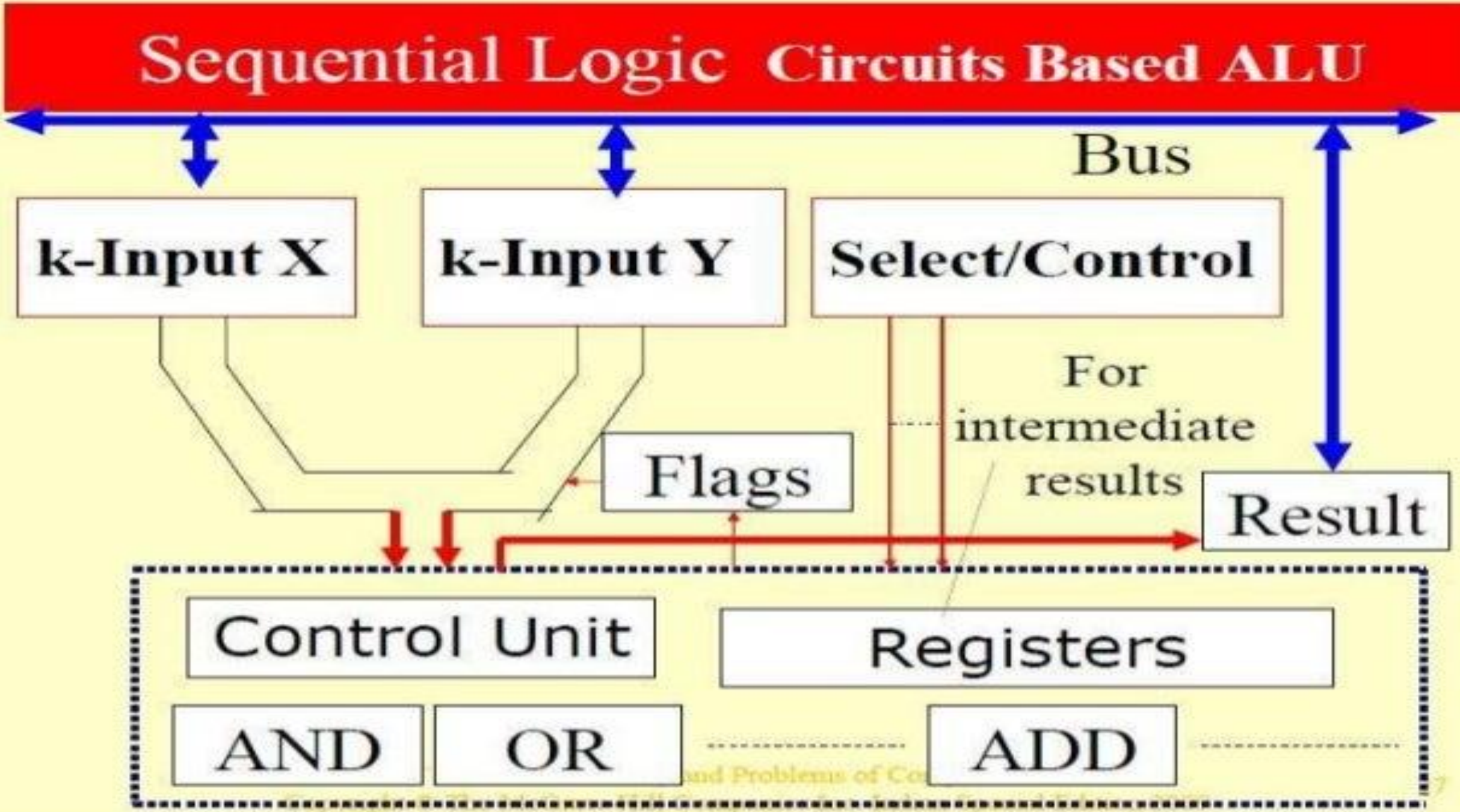
- TO DETERMINE THE OUTPUT FUNCTIONS AS ALGEBRAIC EXPRESSIONS.
- It is the reverse process of design procedure.
- Logic diagram of the circuit is given.
- Obtain the truth table from the diagram.
- Obtain Boolean function from the Truth Table for output.

Sequential Logic Circuits

- Made up of combinational circuits and memory elements.
- These memory elements are devices capable of storing ONE-BIT information.
- Output depends on input and previous state.
- Examples of sequential circuits are flip flops, counters, shift registers

Block Diagram of a Sequential Circuit



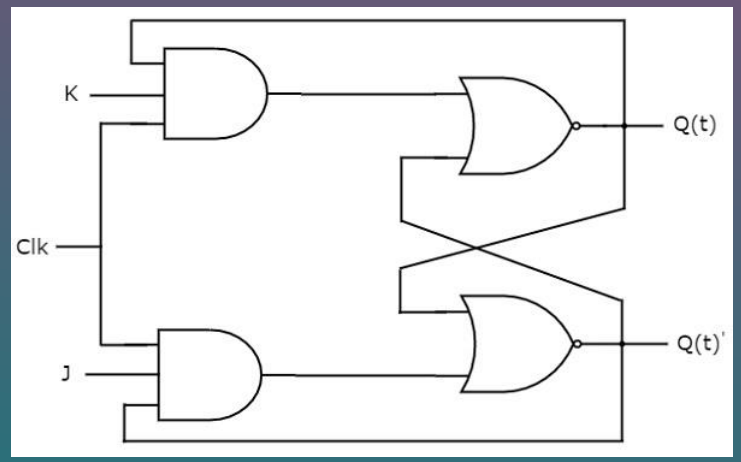

Sequential Logic Circuits Based ALU
Bus
k-Input X
k-Input Y
Select/Control
For intermediate results
Flags
Result
Control Unit
Registers
AND
OR
ADD

Examples of Sequential Circuits

- Flip-Flops
  - JK Flip-Flop
  - RS Flip-Flop
  - T Flip-Flop
  - D Flip-Flop
- Registers
- Counters

Flip-Flops

- Flip-Flops are the basic building blocks of sequential circuits.
- A flip-flop is a binary cell which can store a bit of information.
- A basic function of flip-flop is storage, which means memory. A flip-flop (FF) is capable of storing 1 (one) bit of binary data.
- It has two stable states either '1' or '0'. A flip-flop maintains any one of the two stable states which can be treated as zero or one depending on presence and absence of output signals.



Registers and Counters

- A circuit with flip-flops is considered a sequential circuit even in the absence of combinational logic.
- Circuits that include flip-flops are usually classified by the function they perform.
- Two such circuits are registers and counters:
- **Registers-**
  - It is a group of flip-flops.
  - Its basic function is to hold information within a digital system so as to make it available to the logic units during the computing process.
- **Counters-**
  - It is essentially a register that goes through a predetermined sequence of states.

Types of Sequential Circuits

- *SYNCHRONOUS SEQUENTIAL CIRCUITS*
- *ASYNCHRONOUS SEQUENTIAL CIRCUITS*

Synchronous Circuits

- In synchronous sequential circuits, the state of the device changes only at discrete times in response to a clock Pulse.

- In a synchronous circuit, an electronic oscillator called a *clock* generates a sequence of repetitive pulses called the *clock signal* which is distributed to all the memory elements in the circuit.

Asynchronous Circuits

- Asynchronous circuit is not synchronized by a clock signal; the outputs of the circuit change directly in response to changes in Inputs.
- The advantage of asynchronous logic is that it can be faster than synchronous logic, because the circuit doesn't have to wait for a clock signal to process inputs.
- The speed of the device is potentially limited only by the propagation delays of the logic gates used.

Thanks to All