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# Digital System Design

## B.Tech. 3rd Sem

## EC & Allied



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# DIGITAL SYSTEM DESIGN

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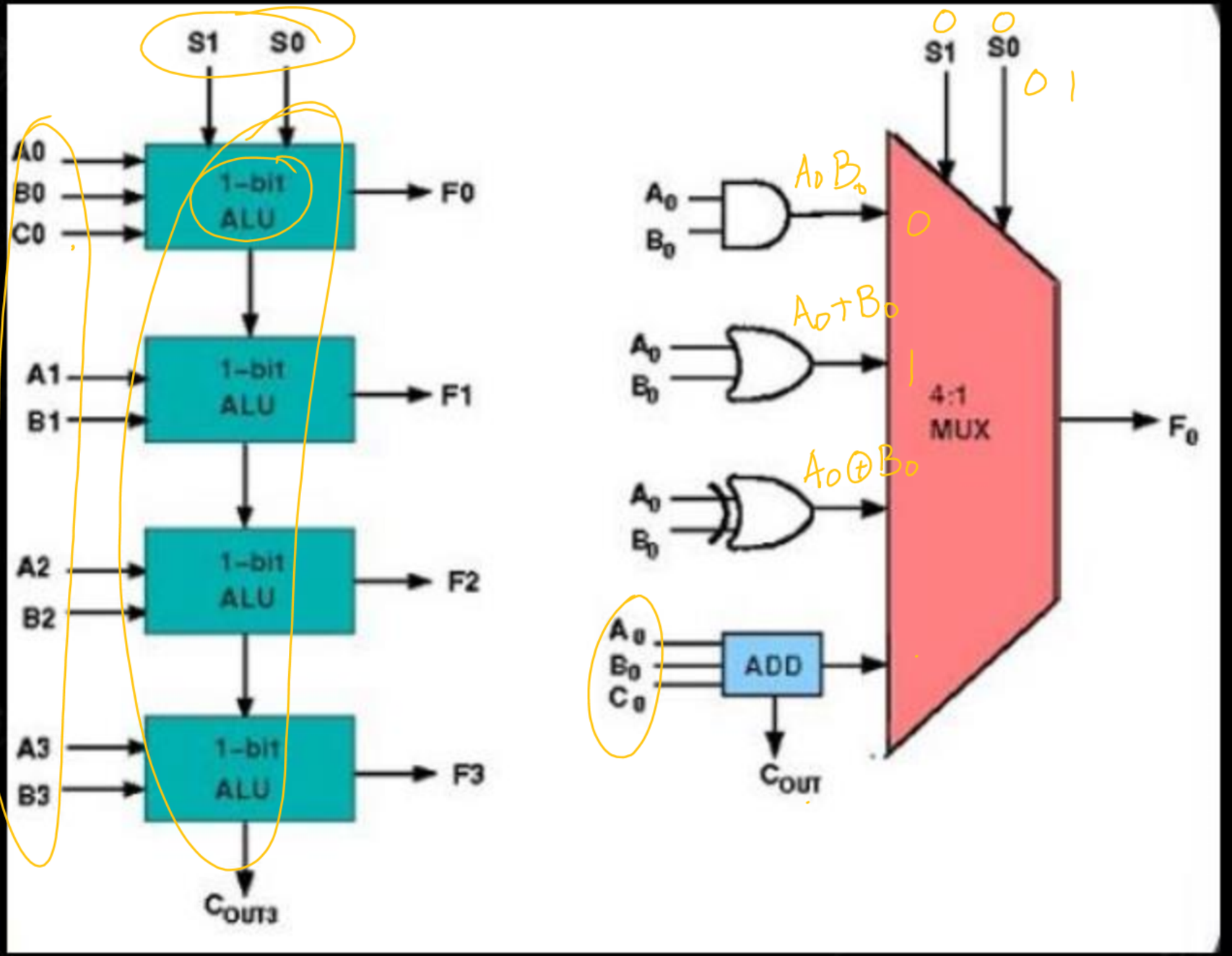
## UNIT 2 : Combinational circuits

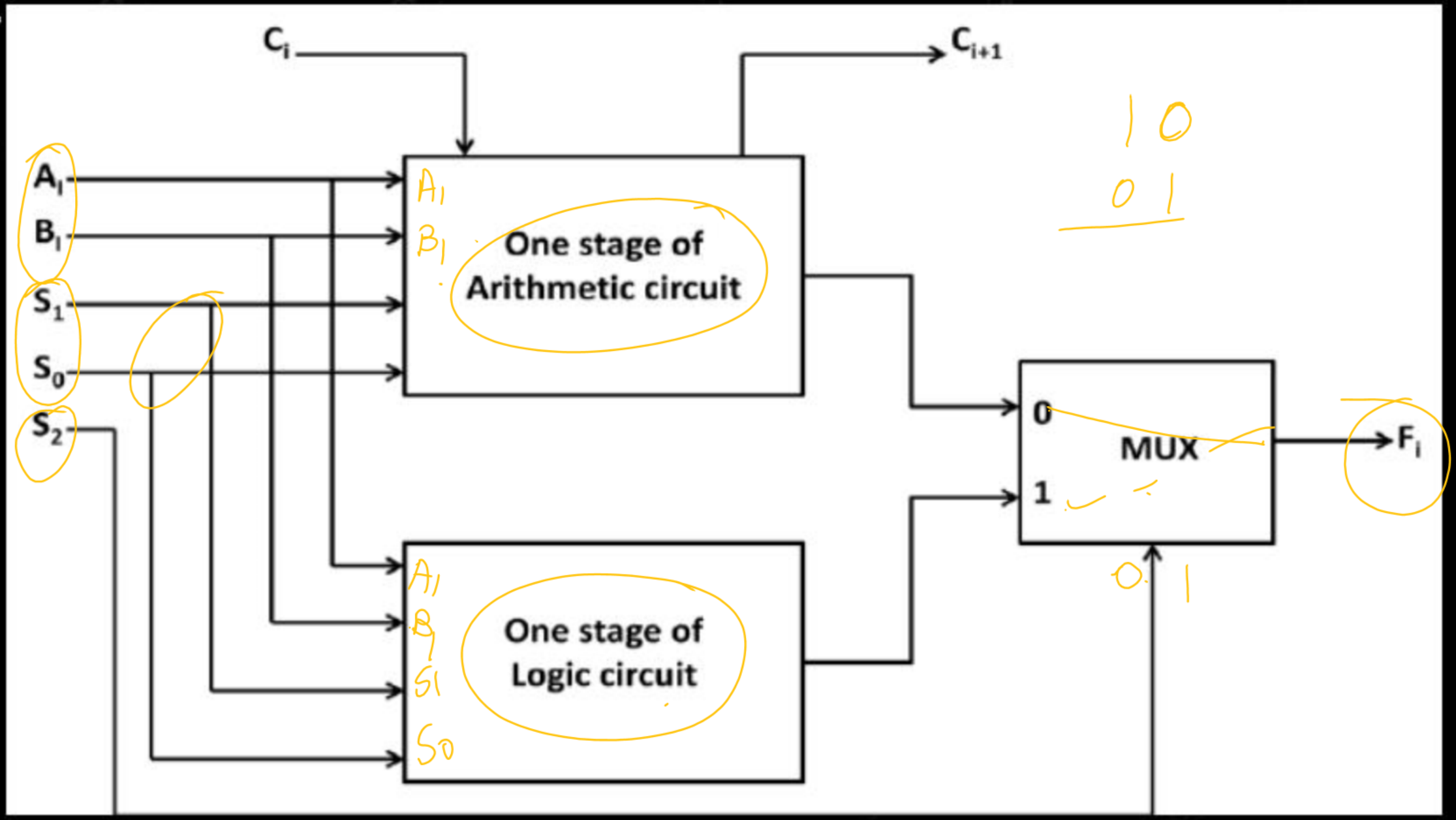
**Today's Target**

- ALU ✓ Arithmatic & Logic Unit
- How an ALU Works ✓
- Units of ALU ✓
- ALU Signals ✓
- Advantages & Disadvantages of ALU ✓

# ALU

- An arithmetic logic unit (ALU) is a digital circuit used to perform arithmetic and logic operations.
- Examples of arithmetic operations are addition, subtraction, multiplication, and division.
- Examples of logic operations are comparisons of values such as NOT, AND, and OR.
- It represents the fundamental building block of the central processing unit (CPU) of a computer.
- Modern CPUs contain very powerful and complex ALUs.
- In addition to ALUs, modern CPUs contain a control unit (CU).


S1
S0
A0
B0
C0
1-bit ALU
F0
A1
B1
1-bit ALU
F1
A2
B2
1-bit ALU
F2
A3
B3
1-bit ALU
F3
COUT3
S1
S0
A0
B0
A0 B0
A0+B0
A0⊕B0
4:1 MUX
F0
A0
B0
C0
ADD
COUT


$C_i$
$C_{i+1}$
$A_I$
$B_I$
$S_1$
$S_0$
$S_2$
One stage of Arithmetic circuit
One stage of Logic circuit
MUX
0
1
$F_i$

# How an ALU Works

- Most of the operations of a CPU are performed by one or more ALUs, which load data from input registers.
- A register is a small amount of storage available as part of a CPU.
- The control unit tells the ALU what operation to perform on that data, and the ALU stores the result in an output register.
- The control unit moves the data between these registers, the ALU, and memory.
- All information in a computer is stored and manipulated in the form of binary numbers, i.e. 0 and 1.
- Transistor switches are used to manipulate binary numbers since there are only two possible states of a switch: open or closed.
- Operations can be accomplished by connecting multiple transistors. This is referred to as a gate because the arrangement can be used to allow or stop a current.

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- When the operations become more and more complex, then the ALU will also become more and more expensive and also takes up more space in the CPU and dissipates more heat.
- That is why engineers make the ALU powerful enough to ensure that the CPU is also powerful and fast, but not so complex as to become prohibitive in terms of cost and other disadvantages.
- ALU is also known as an Integer Unit (IU).
- Different operation as carried out by ALU can be categorized as follows –
- **Logical operations** – These include operations like AND, OR, NOT, XOR, NOR, NAND, etc.
- **Bit-Shifting Operations** – This pertains to shifting the positions of the bits by a certain number of places either towards the right or left, which is considered a multiplication or division operations.
- **Arithmetic operations** – This refers to bit addition and subtraction. Although multiplication and division are sometimes used, these operations are more expensive to make. Multiplication and division can also be done by repetitive additions and subtractions respectively.

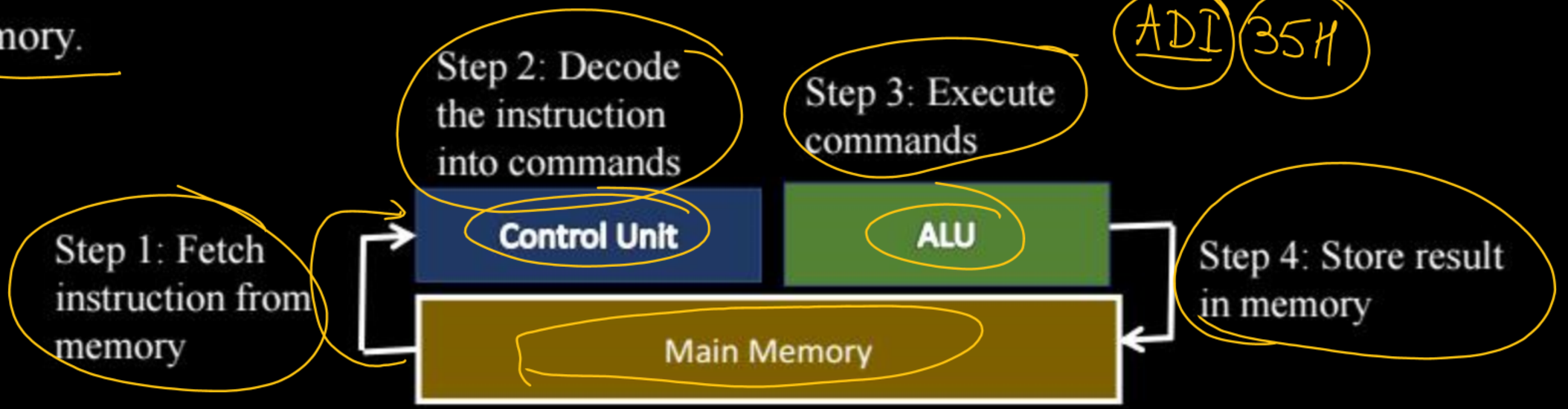
# Units of ALU

- The arithmetic logic unit is split into AU (arithmetic unit) and LU (logic unit).
- The operands and code used by the ALU tell it which operations have to perform according to input data.
- When the ALU completes the processing of input, the information is sent to the computer's memory.

opcode operand

MUL B

ADI 35H



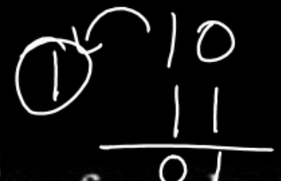
# Arithmetic Logic Unit (ALU) Signals

- A variety of input and output electrical connections are contained by the ALU, which led to casting the digital signals between the external electronics and ALU.
- ALU input gets signals from the external circuits, and in response, external electronics get outputs signals from ALU.
- **Data:** Three parallel buses are contained by the ALU, which include two input and output operand. These three buses handle the number of signals, which are the same.
- **Opcode:** When the ALU is going to perform the operation, it is described by the operation selection code what type of operation an ALU is going to perform arithmetic or logic operation.




**Status**

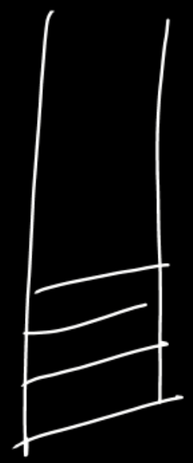



- **Output:** The results of the ALU operations are provided by the status outputs in the form of supplemental data as they are multiple signals. Usually, status signals like overflow, zero, carry out, negative, and more are contained by general ALUs. When the ALU completes each operation, the external registers contained the status output signals. These signals are stored in the external registers that led to making them available for future ALU operations.
- **Input:** When ALU once performs the operation, the status inputs allow ALU to access further information to complete the operation successfully. Furthermore, stored carry-out from a previous ALU operation is known as a single "carry-in" bit.

# Configurations of the ALU

- The description of how ALU interacts with the processor is given below.
- Every arithmetic logic unit includes the following configurations:
- Instruction Set Architecture
- Accumulator
- Stack
- Register to Register
- Register Stack
- Register Memory



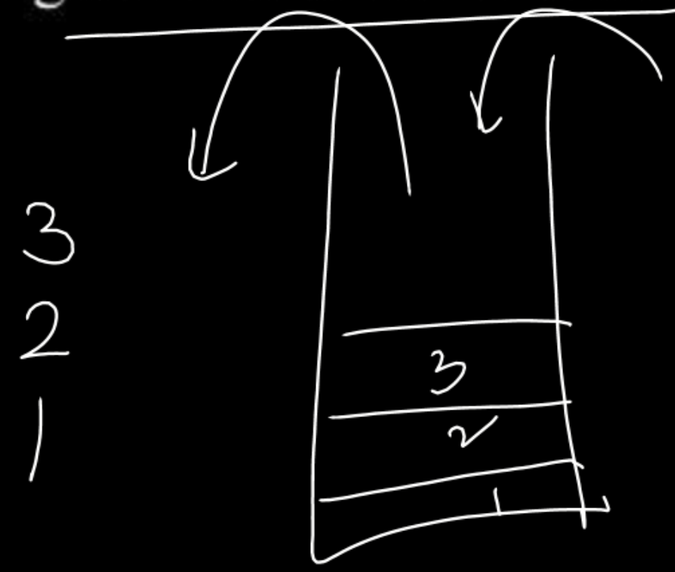
ADD B

# Accumulator

- The intermediate result of every operation is contained by the accumulator, which means Instruction Set Architecture (ISA) is not more complex because there is only required to hold one bit.
- Generally, they are much fast and less complex but to make Accumulator more stable; the additional codes need to be written to fill it with proper values.
- Unluckily, with a single processor, it is very difficult to find Accumulators to execute parallelism.
- An example of an Accumulator is the desktop calculator.

# Stack

- Whenever the latest operations are performed, these are stored on the stack that holds programs in top-down order, which is a small register.
- When the new programs are added to execute, they push to put the old programs.



# Register and Memory

- In this architecture, one operand comes from the register, and the other comes from the external memory as it is one of the most complicated architectures.
- The reason behind it is that every program might be very long as they require to be held in full memory space.
- Generally, this technology is integrated with Register-Register Register technology and practically cannot be used separately.

# Advantages of ALU

- It supports parallel architecture and applications with high performance.
- It has the ability to get the desired output simultaneously and combine integer and floating-point variables.
- It has the capability of performing instructions on a very large set and has a high range of accuracy.
- Two arithmetic operations in the same code like addition and multiplication or addition and subtraction, or any two operands can be combined by the ALU. For case, A+B*C.
- Through the whole program, they remain uniform, and they are spaced in a way that they cannot interrupt part in between.
- In general, it is very fast; hence, it provides results quickly.
- There are no sensitivity issues and no memory wastage with ALU.
- They are less expensive and minimize the logic gate requirements.

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# Disadvantages of ALU

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- With the ALU, floating variables have more delays, and the designed controller is not easy to understand.
- The bugs would occur in our result if memory space were definite.
- It is difficult to understand amateurs as their circuit is complex; also, the concept of pipelining is complex to understand.
- A proven disadvantage of ALU is that there are irregularities in latencies.
- Another demerit is rounding off, which impacts accuracy.

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# Thank You