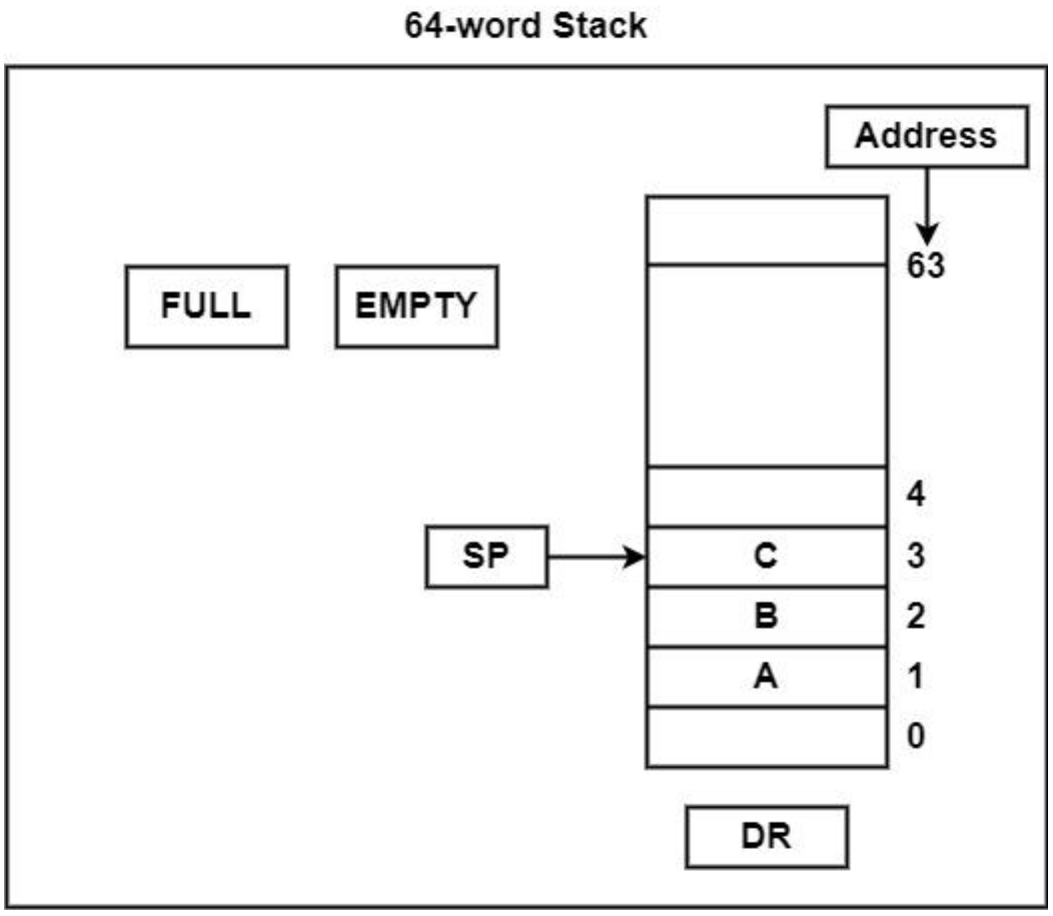
What is Stack Organization?

- Stack is also known as the Last In First Out (LIFO) list. It is the most important feature in the CPU. It saves data such that the element stored last is retrieved first.
- A stack is a memory unit with an address register. This register influence the address for the stack, which is known as Stack Pointer (SP). The stack pointer continually influences the address of the element that is located at the top of the stack.
- It can insert an element into or delete an element from the stack. The insertion operation is known as push operation and the deletion operation is known as pop operation. In a computer stack, these operations are simulated by incrementing or decrementing the SP register.

Register Stack

- The stack can be arranged as a set of memory words or registers. Consider a 64-word register stack arranged as displayed in the figure. The stack pointer register includes a binary number, which is the address of the element present at the top of the stack. The three-element A, B, and C are located in the stack.
- The element C is at the top of the stack and the stack pointer holds the address of C that is 3. The top element is popped from the stack through reading memory word at address 3 and decrementing the stack pointer by 1. Then, B is at the top of the stack and the SP holds the address of B that is 2. It can insert a new word, the stack is pushed by incrementing the stack pointer by 1 and inserting a word in that incremented location.



- The stack pointer includes 6 bits, because $2^6 = 64$, and the SP cannot exceed 63 (111111 in binary). After all, if 63 is incremented by 1, therefore the result is 0(111111 + 1 = 1000000). SP holds only the six least significant bits. If 000000 is decremented by 1 thus the result is 111111.
- Therefore, when the stack is full, the one-bit register 'FULL' is set to 1. If the stack is null, then the one-bit register 'EMTY' is set to 1. The data register DR holds the binary information which is composed into or readout of the stack.
- First, the SP is set to 0, EMTY is set to 1, and FULL is set to 0. Now, as the stack is not full (FULL = 0), a new element is inserted using the push operation.
- The push operation is executed as follows −

SP←SP + 1	It can increment stack pointer
K[SP] ← DR	It can write element on top of the stack
If (SP = 0) then (FULL ← 1)	Check if stack is full
EMTY ← 0	Mark the stack not empty

- The stack pointer is incremented by 1 and the address of the next higher word is saved in the SP. The word from DR is inserted into the stack using the memory write operation. The first element is saved at address 1 and the final element is saved at address 0. If the stack pointer is at 0, then the stack is full and 'FULL' is set to 1. This is the condition when the SP was in location 63 and after incrementing SP, the final element is saved at address 0. During an element is saved at address 0, there are no more empty registers in the stack. The stack is full and the 'EMTY' is set to 0.

- A new element is deleted from the stack if the stack is not empty (if EMTY = 0). The pop operation includes the following sequence of micro-operations −

DR←K[SP]	It can read an element from the top of the stack
SP ← SP – 1	It can decrement the stack pointer
If (SP = 0) then (EMTY ← 1)	Check if stack is empty
FULL ← 0	Mark the stack not full

- The top element from the stack is read and transfer to DR and thus the stack pointer is decremented. If the stack pointer reaches 0, then the stack is empty and 'EMTY' is set to 1. This is the condition when the element in location 1 is read out and the SP is decremented by 1.

Addressing Modes-

- The different ways of specifying the location of an operand in an instruction are called as **addressing modes**.

Types of Addressing Modes-

- In computer architecture, there are following types of addressing modes-

1. Implied / Implicit Addressing Mode
2. Stack Addressing Mode
3. Immediate Addressing Mode
4. Direct Addressing Mode
5. Indirect Addressing Mode
6. Register Direct Addressing Mode
7. Register Indirect Addressing Mode
8. Relative Addressing Mode
9. Indexed Addressing Mode
10. Base Register Addressing Mode
11. Auto-Increment Addressing Mode
12. Auto-Decrement Addressing Mode

1. Implied Addressing Mode-

In this addressing mode,

- The definition of the instruction itself specify the operands implicitly.
- It is also called as **implicit addressing mode**.

Examples-

- The instruction "Complement Accumulator" is an implied mode instruction.
- In a stack organized computer, Zero Address Instructions are implied mode instructions. (since operands are always implied to be present on the top of the stack)

2. Stack Addressing Mode-

In this addressing mode,

- The operand is contained at the top of the stack.

Example-

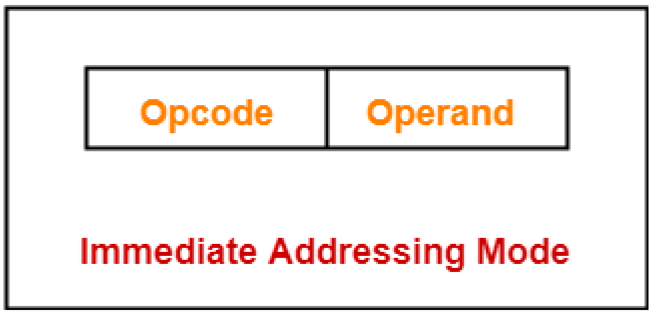
ADD

- This instruction simply pops out two symbols contained at the top of the stack.
- The addition of those two operands is performed.
- The result so obtained after addition is pushed again at the top of the stack.

3. Immediate Addressing Mode-

In this addressing mode,

- The operand is specified in the instruction explicitly.
- Instead of address field, an operand field is present that contains the operand.



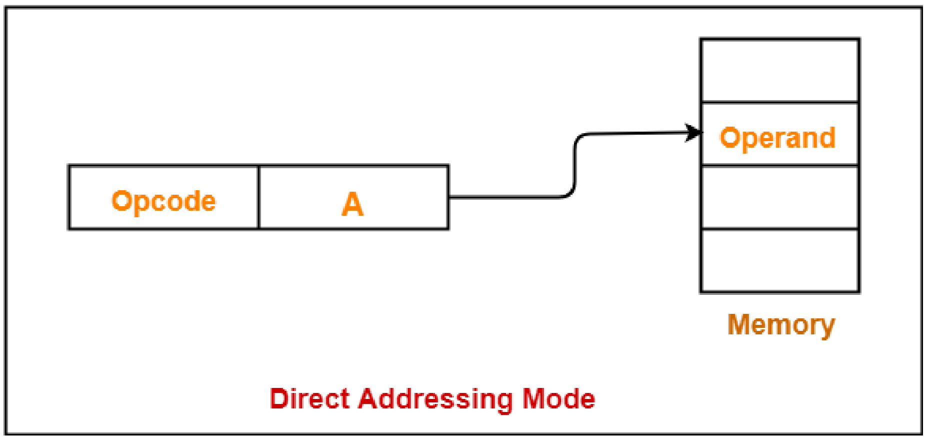
Examples-

- ADD 10 will increment the value stored in the accumulator by 10.
- MOV R #20 initializes register R to a constant value 20.

4. Direct Addressing Mode-

In this addressing mode,

- The address field of the instruction contains the effective address of the operand.
- Only one reference to memory is required to fetch the operand.
- It is also called as **absolute addressing mode**.



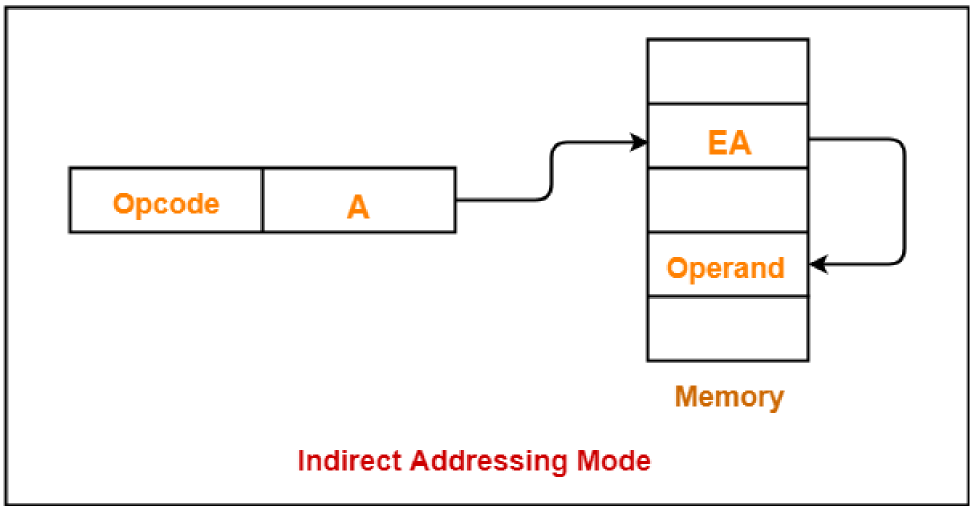
Example-

- ADD X will increment the value stored in the accumulator by the value stored at memory location X.

5. Indirect Addressing Mode-

In this addressing mode,

- The address field of the instruction specifies the address of memory location that contains the effective address of the operand.
- Two references to memory are required to fetch the operand.



Example-

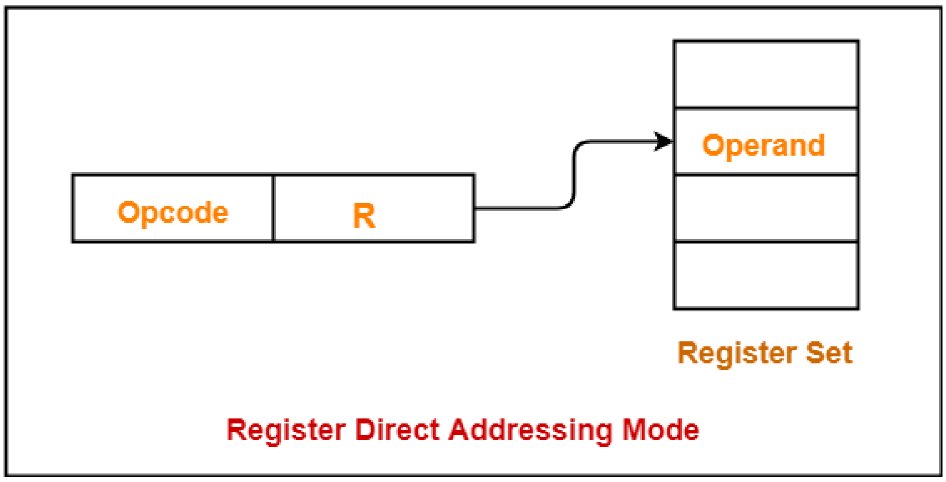
- ADD X will increment the value stored in the accumulator by the value stored at memory location specified by X.

$$AC \leftarrow AC + [[X]]$$

6. Register Direct Addressing Mode-

In this addressing mode,

- The operand is contained in a register set.
- The address field of the instruction refers to a CPU register that contains the operand.
- No reference to memory is required to fetch the operand.



Example-

- ADD R will increment the value stored in the accumulator by the content of register R.

AC ← AC + [R]

NOTE-

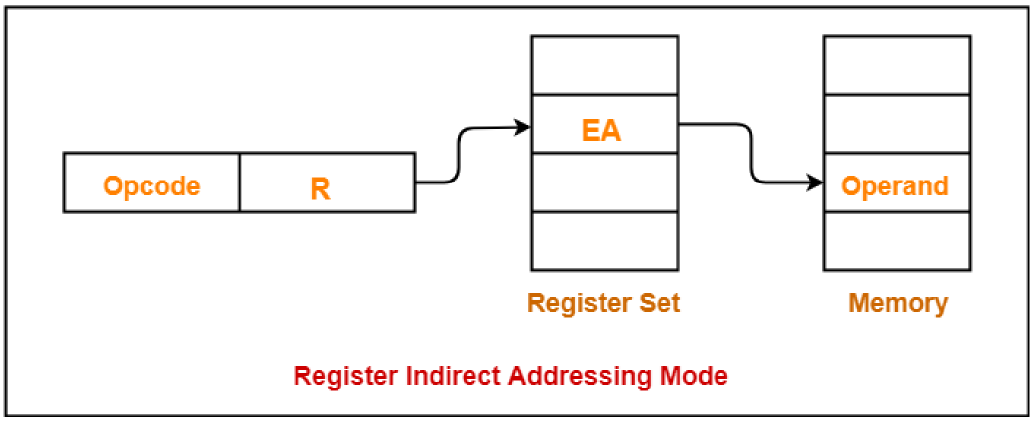
It is interesting to note-

- This addressing mode is similar to direct addressing mode.
- The only difference is address field of the instruction refers to a CPU register instead of main memory.

7. Register Indirect Addressing Mode-

In this addressing mode,

- The address field of the instruction refers to a CPU register that contains the effective address of the operand.
- Only one reference to memory is required to fetch the operand.



Example-

- ADD R will increment the value stored in the accumulator by the content of memory location specified in register R.

AC ← AC + [[R]]

NOTE-

It is interesting to note-

- This addressing mode is similar to indirect addressing mode.
- The only difference is address field of the instruction refers to a CPU register.

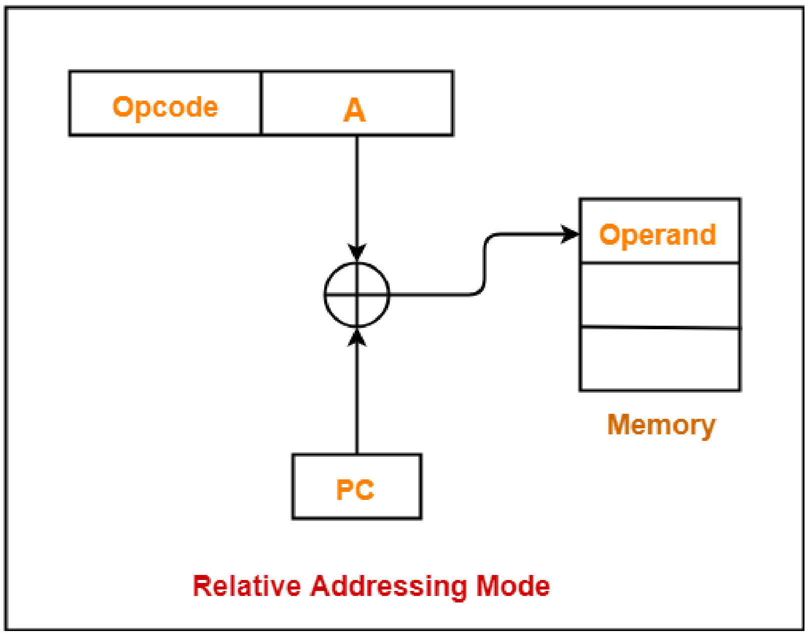
8. Relative Addressing Mode-

In this addressing mode,

- Effective address of the operand is obtained by adding the content of program counter with the address part of the instruction.

Effective Address

= Content of Program Counter + Address part of the instruction



NOTE-

- **Program counter** (PC) always contains the address of the next instruction to be executed.
- After fetching the address of the instruction, the value of program counter immediately increases.
- The value increases irrespective of whether the fetched instruction has completely executed or not.

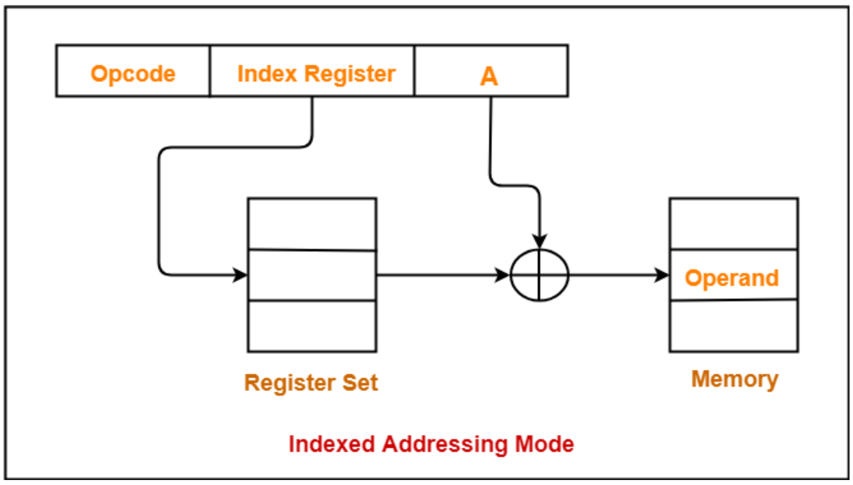
9. Indexed Addressing Mode-

In this addressing mode,

- Effective address of the operand is obtained by adding the content of index register with the address part of the instruction.

Effective Address

= Content of Index Register + Address part of the instruction



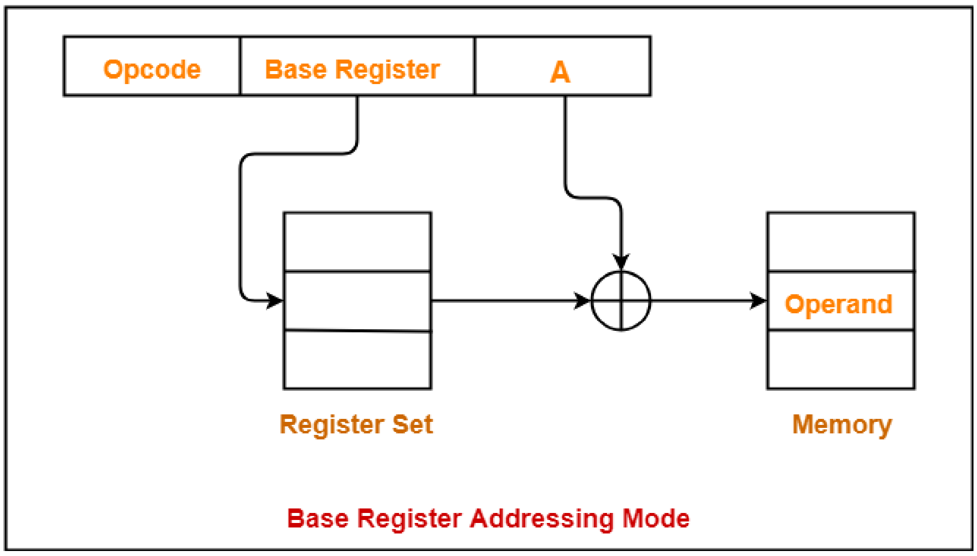
10. Base Register Addressing Mode-

In this addressing mode,

- Effective address of the operand is obtained by adding the content of base register with the address part of the instruction.

Effective Address

= Content of Base Register + Address part of the instruction



11. Auto-Increment Addressing Mode-

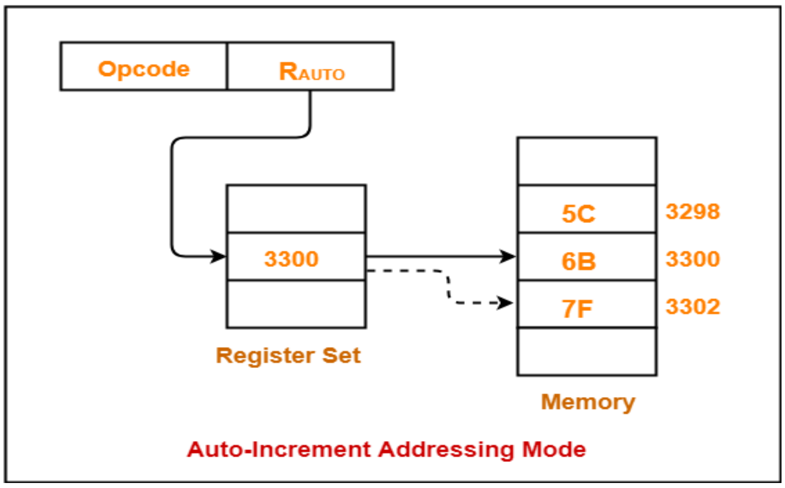
- This addressing mode is a special case of Register Indirect Addressing Mode where-

Effective Address of the Operand = Content of Register

In this addressing mode,

- After accessing the operand, the content of the register is automatically incremented by step size 'd'.
- Step size 'd' depends on the size of operand accessed.
- Only one reference to memory is required to fetch the operand.

Example-



Assume operand size = 2 bytes.

Here,

- After fetching the operand 6B, the instruction register R_{AUTO} will be automatically incremented by 2.
- Then, updated value of R_{AUTO} will be 3300 + 2 = 3302.
- At memory address 3302, the next operand will be found.

NOTE-

In auto-increment addressing mode,

- First, the operand value is fetched.
- Then, the instruction register R_{AUTO} value is incremented by step size 'd'.

13. Auto-Decrement Addressing Mode-

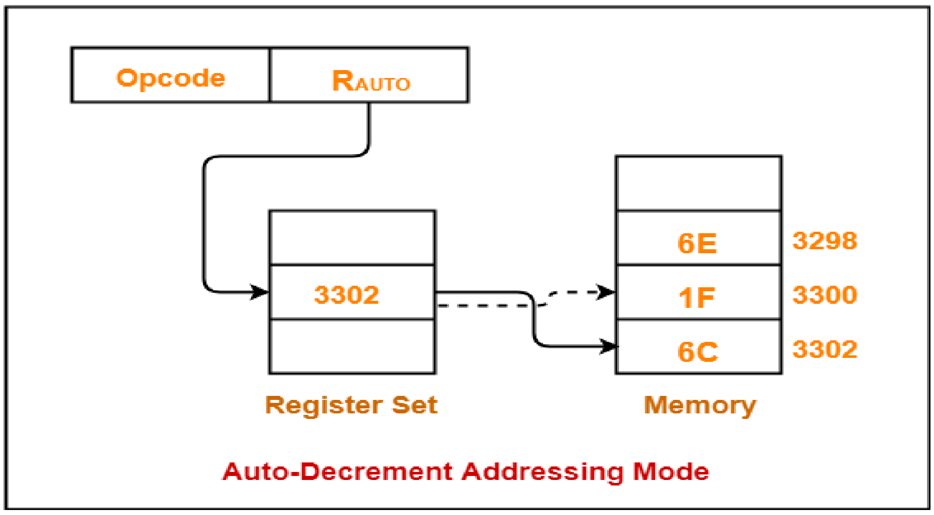
- This addressing mode is again a special case of Register Indirect Addressing Mode where-

Effective Address of the Operand = Content of Register – Step Size

In this addressing mode,

- First, the content of the register is decremented by step size ‘d’.
- Step size ‘d’ depends on the size of operand accessed.
- After decrementing, the operand is read.
- Only one reference to memory is required to fetch the operand.

Example-



Assume operand size = 2 bytes.

Here,

- First, the instruction register R_{AUTO} will be decremented by 2.
- Then, updated value of R_{AUTO} will be 3302 – 2 = 3300.
- At memory address 3300, the operand will be found.

NOTE-

In auto-decrement addressing mode,

- First, the instruction register R_{AUTO} value is decremented by step size ‘d’.
- Then, the operand value is fetched.

Applications of Addressing Modes-

Addressing Modes	Applications
Immediate Addressing Mode	• To initialize registers to a constant value
Direct Addressing Mode and Register Direct Addressing Mode	• To access static data • To implement variables
Indirect Addressing Mode and Register Indirect Addressing Mode	• To implement pointers because pointers are memory locations that store the address of another variable • To pass array as a parameter because array name is the base address and pointer is needed to point the address
Relative Addressing Mode	• For program relocation at run time i.e. for position independent code • To change the normal sequence of execution of instructions • For branch type instructions since it directly updates the program counter
Index Addressing Mode	• For array implementation or array addressing • For records implementation
Base Register Addressing Mode	• For writing relocatable code i.e. for relocation of program in memory even at run time • For handling recursive procedures
Auto-increment Addressing Mode and Auto-decrement Addressing Mode	• For implementing loops • For stepping through arrays in a loop • For implementing a stack as push and pop