Microprocessors & Interfacing

INSTRUCTION SET

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Number Systems

- Negative numbers are stored as 2's complement format
- Subtraction in 8086 is done using 2's complement

E.g.

MOV CH,22H

SUB CH,44H

22H 00100010

44H + 10111100

11011110

- AF is set if there is a borrow from bit 3 to bit 4 during the subtraction, the AF flag is set.

A reverse engineered approach

http://www.righto.com/2020/08/reverse-engineering-8086s.html

AAA Instruction

- The AAA instruction adjusts the contents of the AL (accumulator low) register based on the result of a previous addition. Specifically, it performs the following steps:

1. Checks if the low nibble (bits 0-3) of AL contains a decimal value between 0 and 9 or if the Auxiliary Carry Flag (AF) is set.
2. If the low nibble is within the range of 0 to 9 or the AF is set, no adjustment is needed, and the instruction proceeds to step 5.
3. If the low nibble is in the range 10 to 15, or the AF is not set, the following adjustments are made:
   - AL is incremented by 6.
   - AH (accumulator high) is incremented by 1.
   - The Carry Flag (CF) and AF are set.
4. OR The AF and CF are cleared.
5. The contents of the high nibble (bits 4-7) of AL are cleared

Example

E.g.

MOV AX,31H

ADD AL, 39H

AAA

ADD AX,3030H

The AAA instruction clears AH if the result is less than 10, and adds 1 to AH if the result is greater than 10.

```
AX=0031 BX=0000 CX=0000 DX=0000 SP=FFFE BP=0000 SI=0000 DI=0000
DS=0859 ES=0859 SS=0859 CS=0859 IP=0103 NV UP EI NG NZ NA PE NC
0859:0103 0439              ADD     AL,39
-
AX=006A BX=0000 CX=0000 DX=0000 SP=FFFE BP=0000 SI=0000 DI=0000
DS=0859 ES=0859 SS=0859 CS=0859 IP=0105 NV UP EI PL NZ NA PE NC
0859:0105 37                AAA
-
AX=0100 BX=0000 CX=0000 DX=0000 SP=FFFE BP=0000 SI=0000 DI=0000
DS=0859 ES=0859 SS=0859 CS=0859 IP=0106 NV UP EI PL NZ AC PO CY
0859:0106 053030            ADD     AX,3030
-
AX=3130 BX=0000 CX=0000 DX=0000 SP=FFFE BP=0000 SI=0000 DI=0000
DS=0859 ES=0859 SS=0859 CS=0859 IP=0109 NV UP EI PL NZ NA PE NC
0859:0109 0000              ADD     [BX+SI],AL
-
```

Example

```
if low nibble of AL > 9 or AF = 1 then:
    AL = AL + 6
    AH = AH + 1
    AF = 1
    CF = 1
else
    AF = 0
    CF = 0
in both cases:
    clear the high nibble of AL.
```

```
MOV AX,31H
ADD AL, 39H
AAA
ADD AX,3030H
```

```
  0011 0001
+ 0011 1001
-----------
  0110 1010
     6    A
```

AL=6A+6
AH=0+1
AF=1 CF=1

What about AAA after 39H + 39H ?

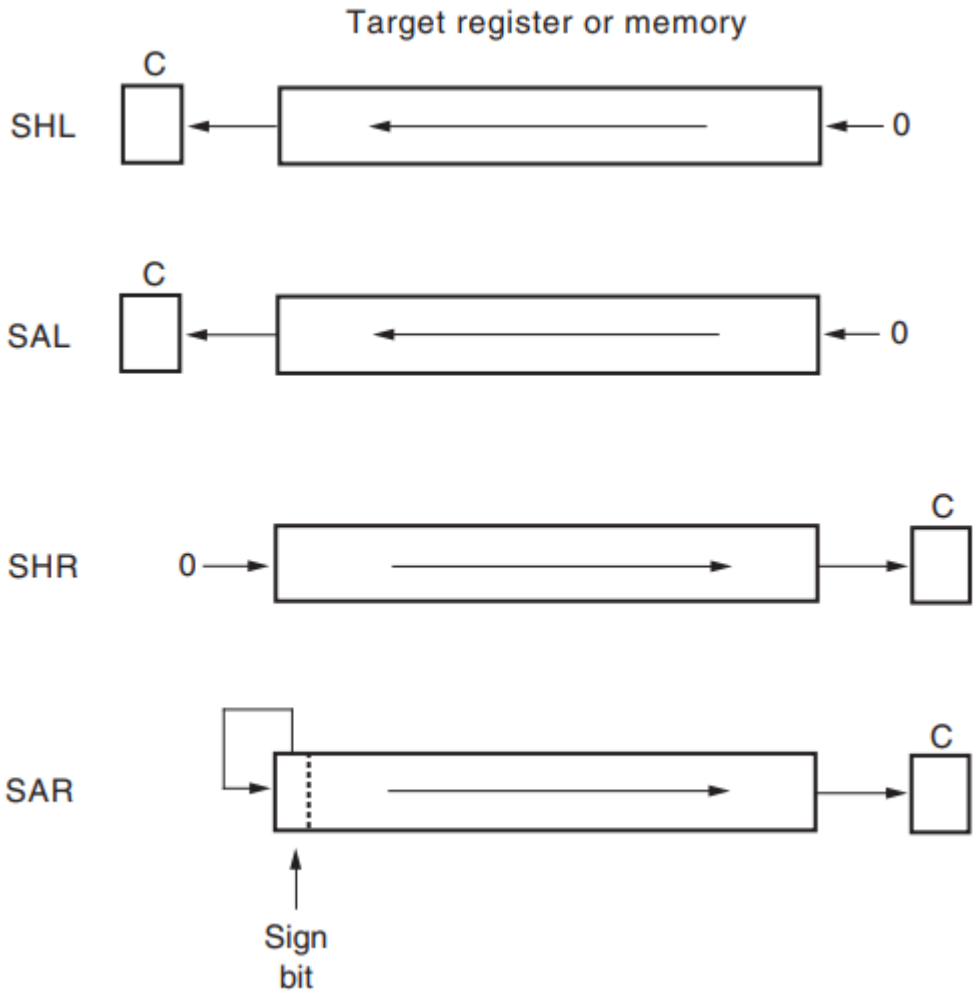
SHIFT AND ROTATE

- Shift and rotate instructions manipulate binary numbers at the binary bit level, as did the AND, OR, Exclusive-OR, and NOT instructions.
- Shifts and rotates find their most common applications in low-level software used to control I/O devices.
- The microprocessor contains a complete complement of shift and rotate instructions that are used to shift or rotate any memory data or register

Shift

- Shift instructions position or move numbers to the left or right within a register or memory location.
- They also perform simple arithmetic such as multiplication by powers of (left shift) and division by powers of 2^{-n} (right shift).
- The microprocessor's instruction set contains four different shift instructions:
  - Two are logical shifts and two are arithmetic shifts

Shift



Shift Instruction

- Logical shift operations function with unsigned numbers, and arithmetic shifts function with signed numbers.
- Logical shifts multiply or divide unsigned data, and arithmetic shifts multiply or divide signed data.
- A shift left always multiplies by 2 for each bit position shifted, and a shift right always divides by 2 for each bit position shifted.
- Shifting a number two places, to the left or right, multiplies or divides by 4.

Shift Instruction

- Shift the DX register left 14 places in two different ways.

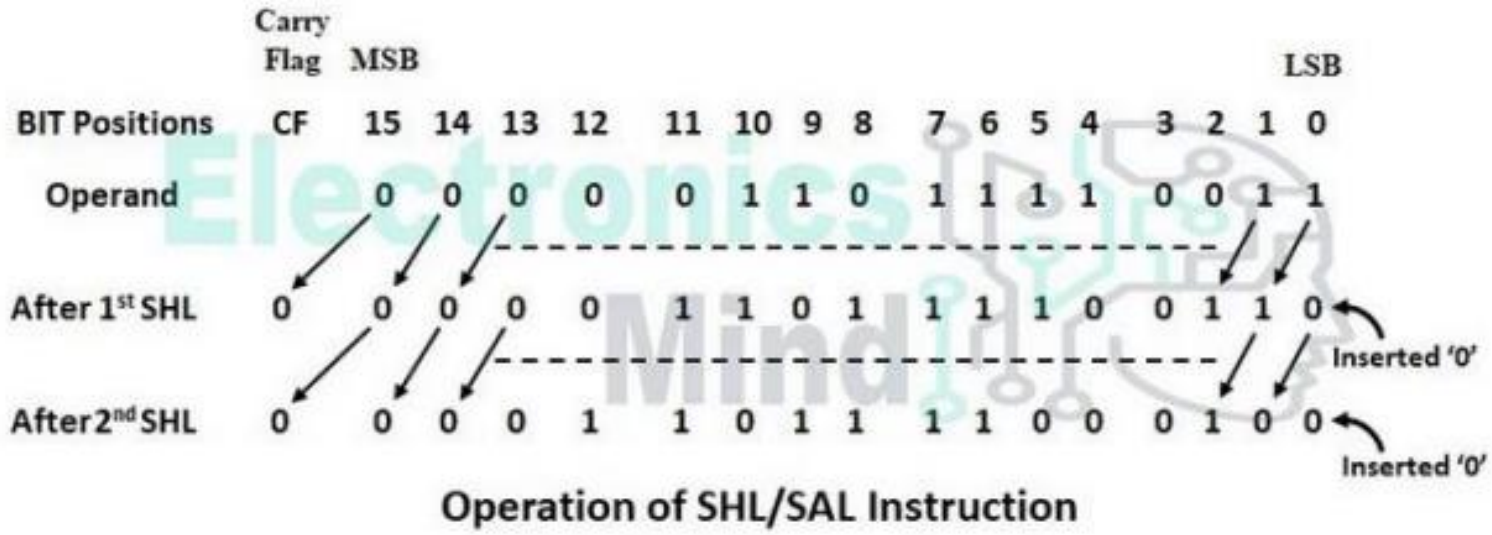
```
SHL DX,14
```

or

```
MOV CL,14
SHL DX,CL
```

SHL/SAL Instruction

- SHL/SAL instruction performs shifting of each bit in the operand (register or memory location) to the left side and fills the least significant bit (LSB) with zero and obtain the result in the destination operand.
- The MSB is shifted into the carry flag (CF).

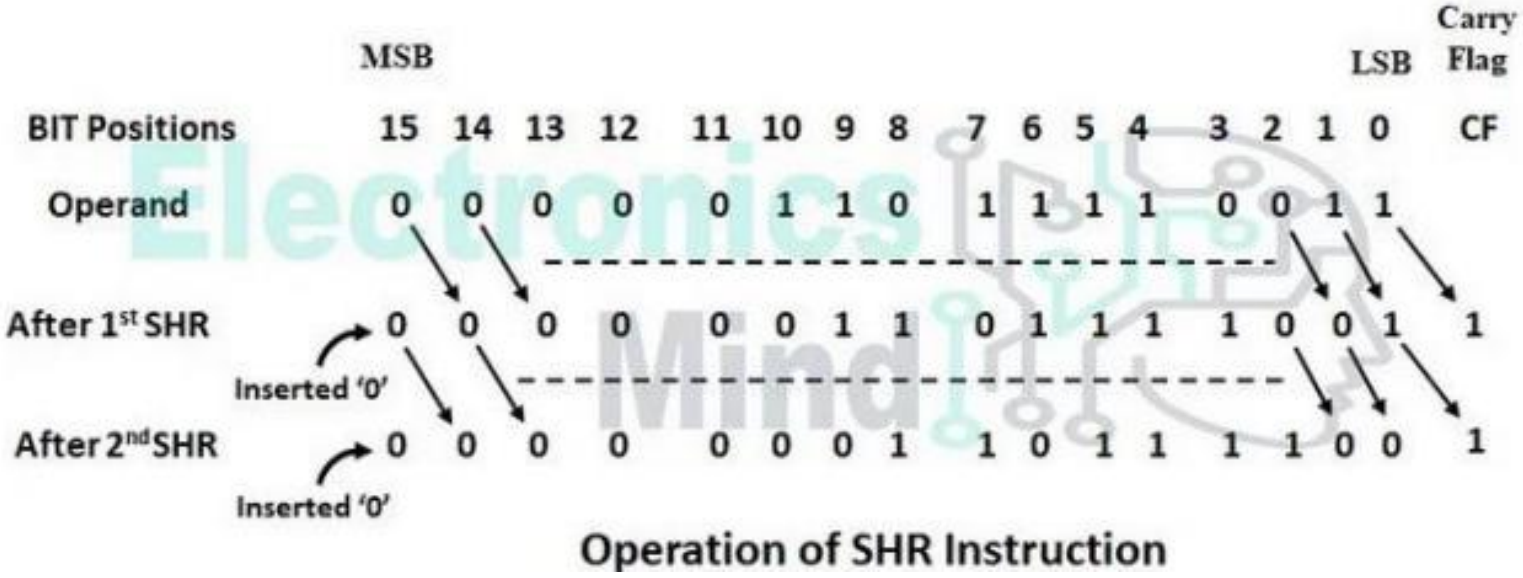


Operation of SHL/SAL Instruction

Reference: https://www.electronicsmind.com/shift-instructions-in-8086-microprocessor/

SHR Instruction

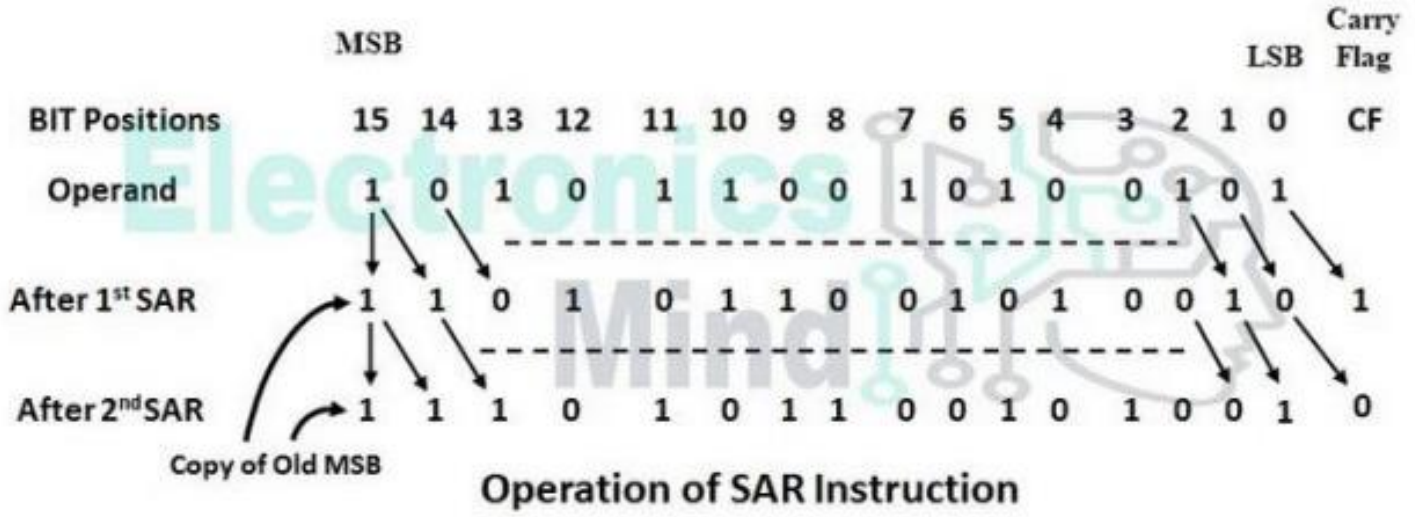
- The SHR instruction performs shifting of each bit in the operand (register or memory location) to the right side and fills the most significant bit (MSB) with zero.
- The LSB is shifted into the carry flag (CF).



Operation of SHR Instruction

SAR Instruction

- It does the same operation as SHR except it fills the bit portion shifted right from the MSB with a copy of old MSB i.e., the SAR instruction performs the right shift on each bit and fills the MSB portion with the copy of old MSB.



Operation of SAR Instruction

Rotate

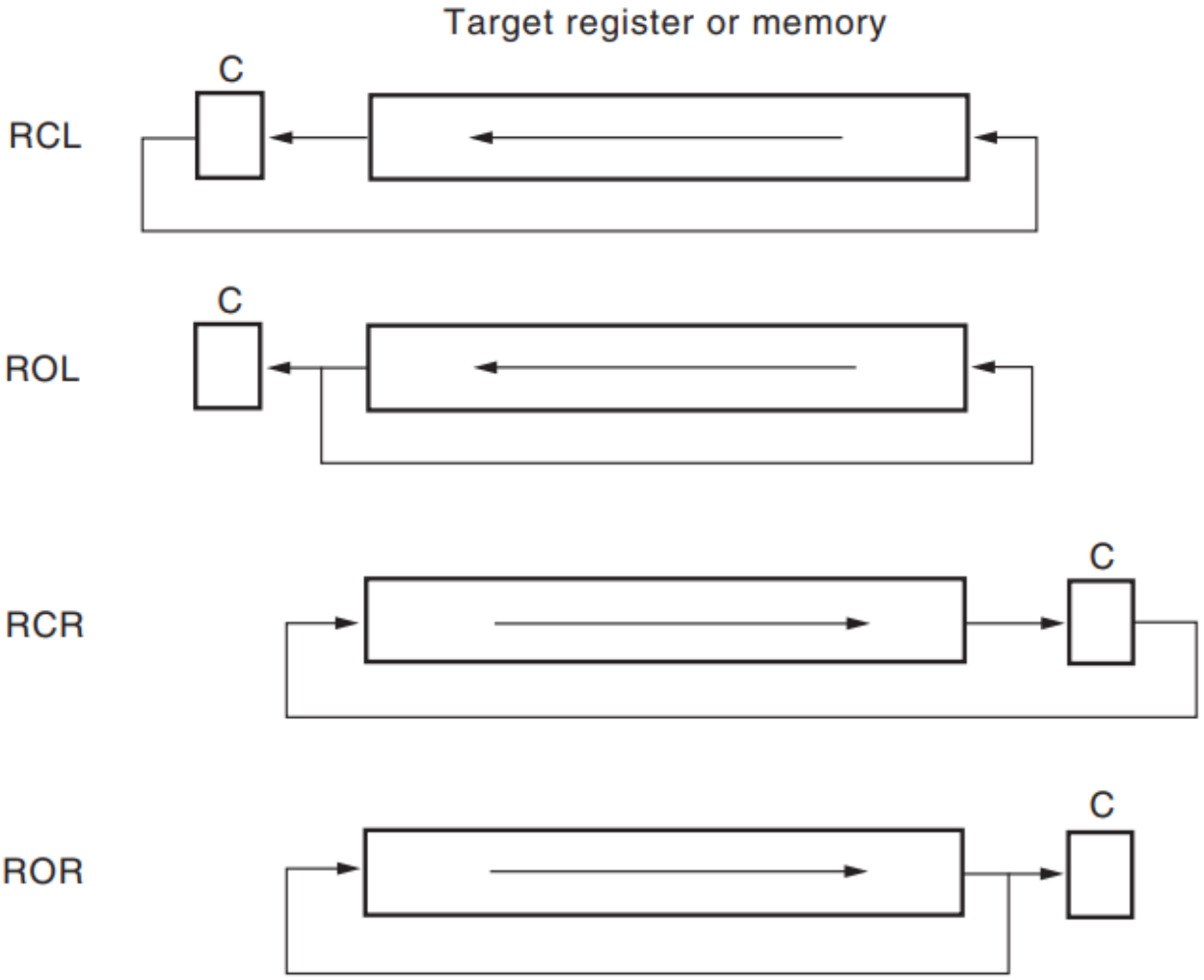
- Rotate instructions position binary data by rotating the information in a register or memory location, either from one end to another or through the carry flag.
- Numbers rotate through a register or memory location, through the C flag (carry), or through a register or memory location only.
- With either type of rotate instruction, the programmer can select either a left or a right rotate.
- A rotate count can be immediate or located in register CL.
- If CL is used for a rotate count, it does not change.

Example

- Shifts the 48-bit number in registers DX, BX, and AX left one binary place.

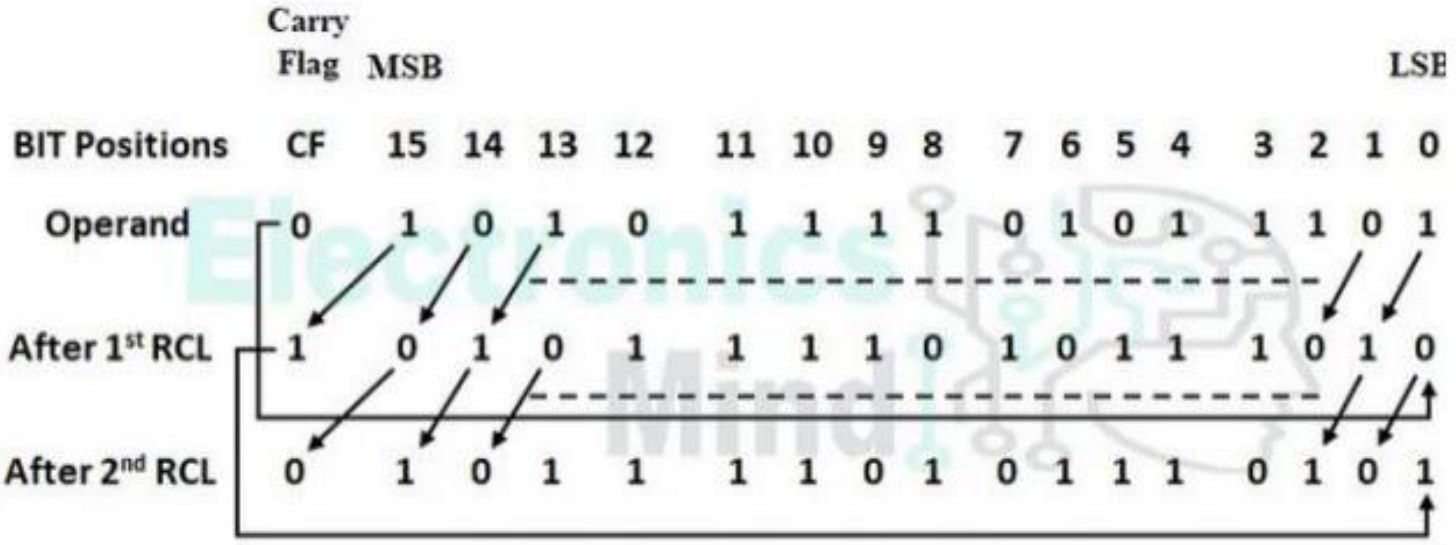
```
SHL AX,1
RCL BX,1
RCL DX,1
```

Rotate Instruction



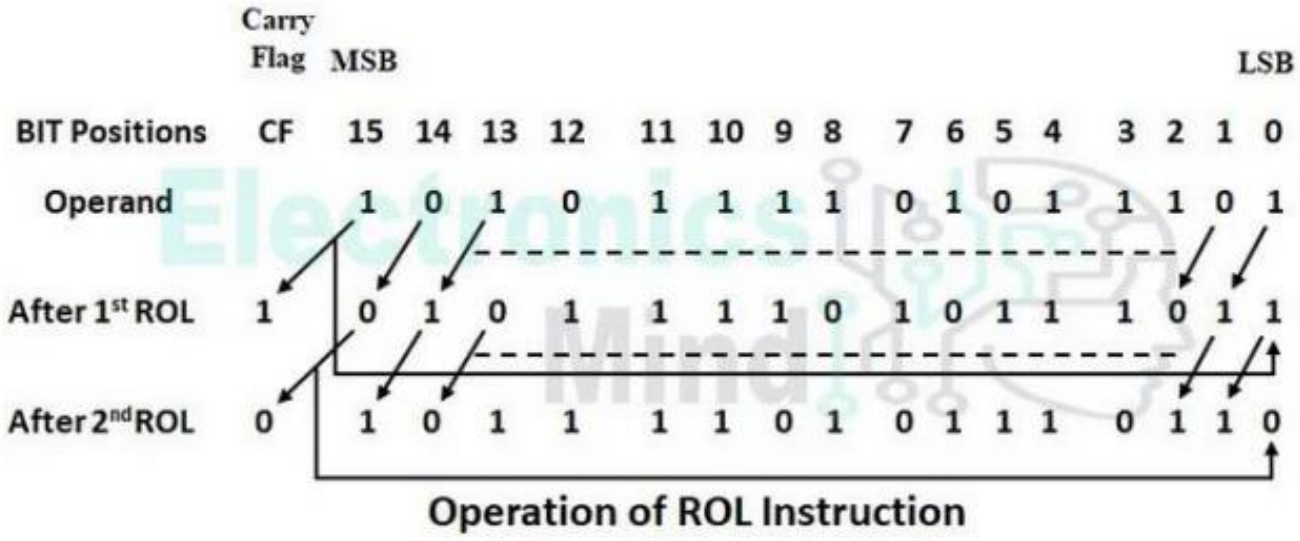
RCL Instruction

- The contents of the operand will be rotated bit-wise left with the carry flag involved in the rotation.



ROL Instruction

- The contents of the operand (register or memory location) are rotated left bit-wise by some number of positions depending on the count value.
- During this rotation, the most significant bit (MSB) is moved into the carry flag (CF) as well as into the least significant bit (LSB) position.

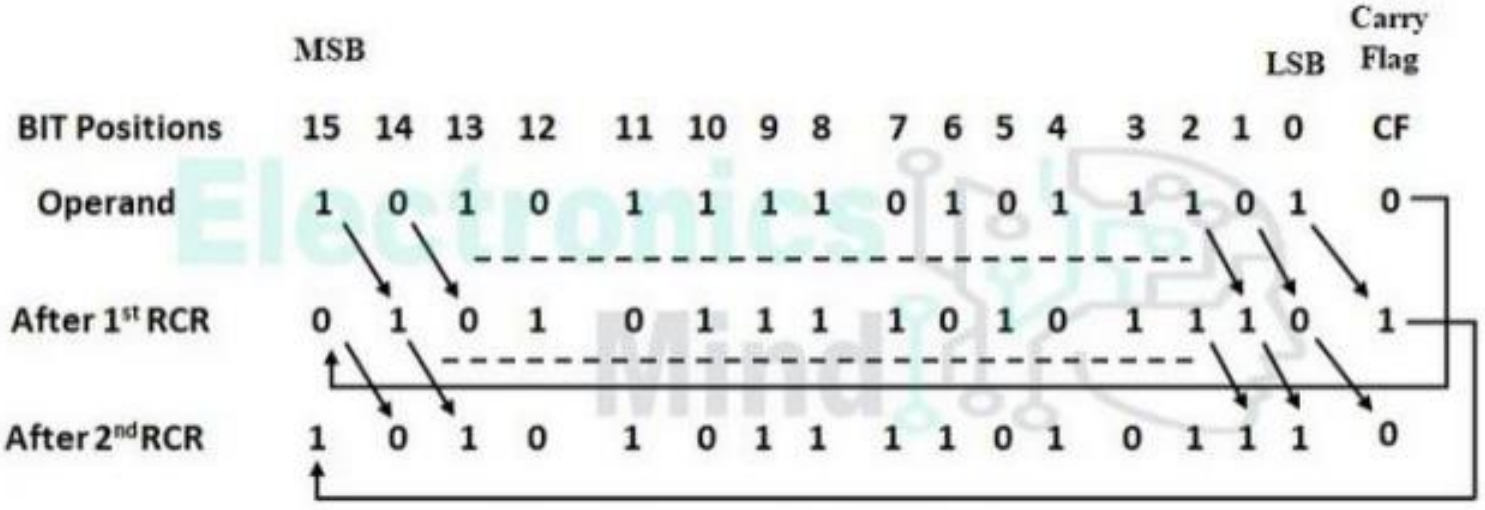


Operation of ROL Instruction

Reference: https://www.electronicsmind.com/shift-instructions-in-8086-microprocessor/

RCR Instruction

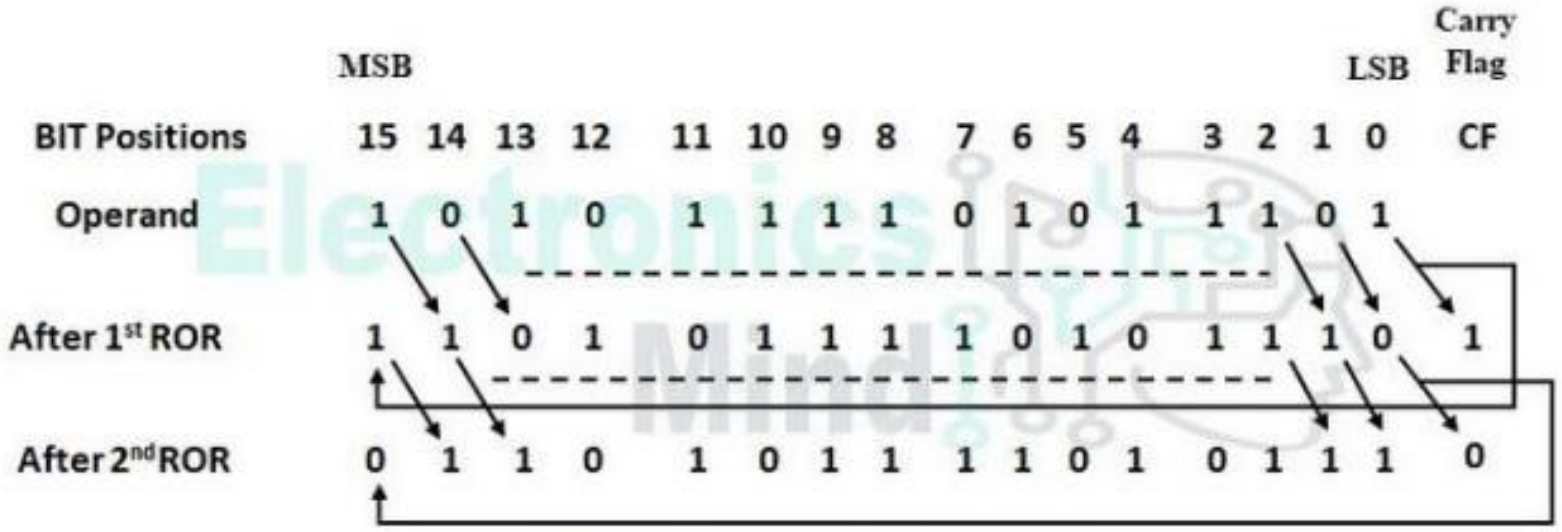
- In this instruction, the contents of the operand (register or memory location) are rotated right bit-wise by some number of positions along with the carry flag.
- During the rotation the least significant bit (LSB) is moved to carry flag, and the carry flag is moved into the most significant bit (MSB).



Operation of RCR Instruction

ROR Instruction

- The contents of the operand are rotated right bit-wise by some number of positions depending on the count value.
- The ROL instruction seen above rotates the bits towards the left side, whereas the ROR instruction rotates the bits towards the right side.
- Since this instruction rotates the bits right, the least significant bit (LSB) is moved into the carry flag (CF) as well as into the most significant bit (MSB) position.



Operation of ROR Instruction

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Thank You

Decimal Numbers	4-bit Binary Number	Hexadecimal Number
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F