SHIFT AND ROTATE

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Dept. of Computer Science
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Overview: ROTATE

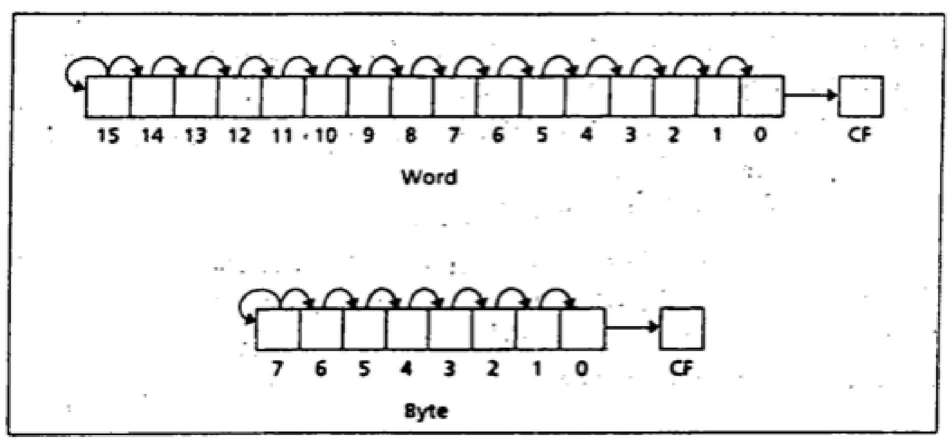
- Rotates work like the shifts, except that when a bit Is shifted out one end of an operand it is **put back in the other end**.
- These instructions can be used to **examine** and/or **change bits or groups of bits**.
- *** Logic, shift, and rotate instructions is used to do binary and hexadecimal I/O.
- The ability to read and write numbers will let us solve a great variety of problem.

Example SHR

- **Problem:** Suppose DH contains 8Ah and CL contains 2. What are the values of DH and CF after the Instruction SHR DH,CL is executed?
- **Solution:** The value of DH in binary is 10001010.
- After two right shifts, CF=1
- The new value of DH is obtained by **erasing the rightmost two bits** and adding two 0 bits to the left end, thus DH =00100010b = 22h.

SAR Instruction

- The SAR Instruction (shift arithmetic right) operates like SHR , with one difference: the **msb retains Its original value**. The syntax is:
- SAR destination,1
- SAR destination, CL



Division by Right Shift

- A Left shift doubles the destination's value,
- Similarly, it's reasonable to guess that a right shift might divide it by 2. This Is correct for **even** numbers.
- For odd numbers, a **right shift halves it and rounds down to the nearest integer**.
- For example, if BL contains 00000101 = 5, then after a right shift. BL will contain 00000010 = 2

Signed and Unsigned Division

- In case of division by right shifts, we need to make a distinction between signed and unsigned numbers.

- If an **unsigned** interpretation is being given, **SHR** should be used.

- For a **signed** interpretation, **SAR** must be used, because it preserves the sign.

- **Problem:** Use right shifts to divide the unsigned number 65143 by 4. Put the quotient in AX

- To divide by 4, two right shifts are needed. Since the dividend is unsigned, we use SHR. The code is

  - MOV AX, 65143
  - MOV CL, 2
  - SHR AX,2

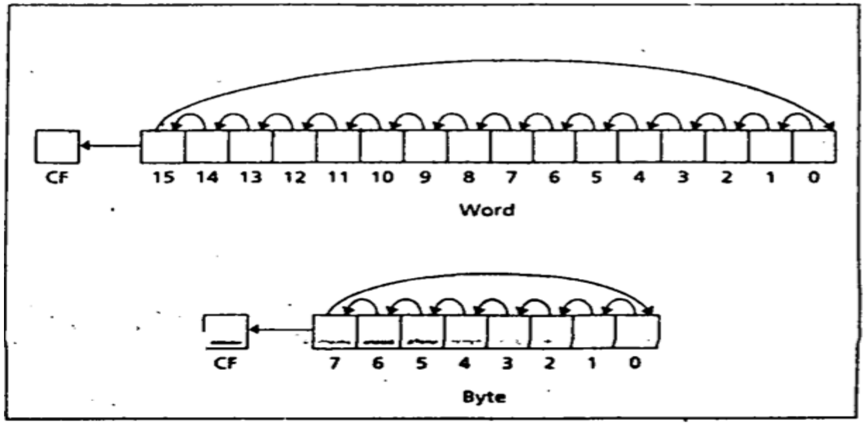
SAR

- Example: If AL contains -15, give the decimal value of AL after SAR AL,1 is performed.
- Solution: Execution of SAR AL,1 divides the number by 2 and rounds down.
  - Dividing -15 by 2 yields -7.5, and after rounding down we get -8.
  - In terms of the binary contents, we have -15=11110001b. After shifting, we have 11111000b= -8.

*** We will see some MUL and DIV for multiplication operations that are not limited to power of 2 only. However, MUL and DIV is much slower than SHIFT operation

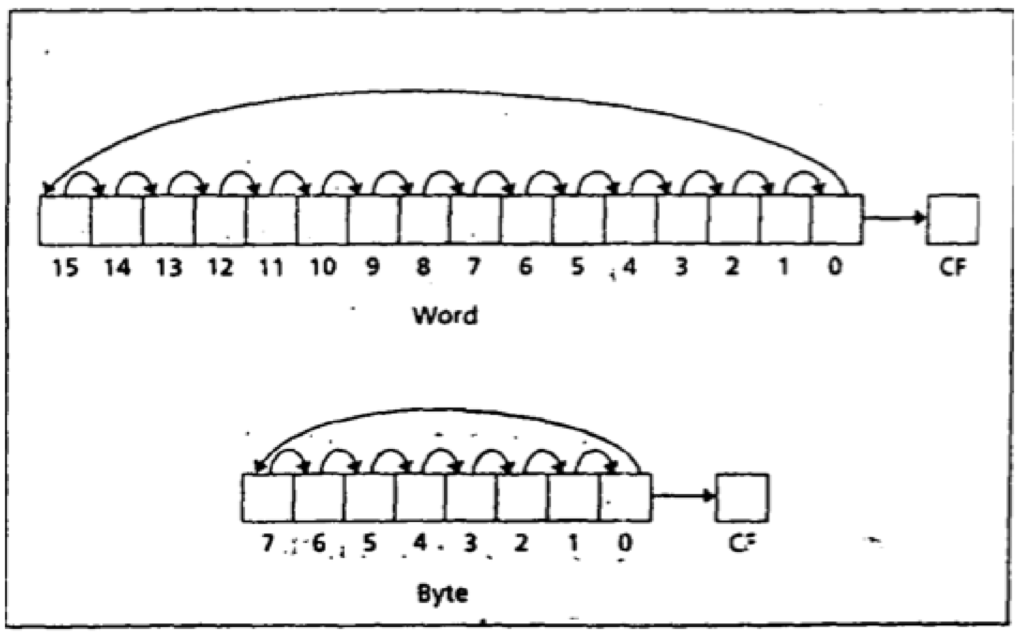
Rotate Instructions

- The instruction ROL (rotate left) shifts bits to the left. The msb shifted into the rightmost bit.
- The CF also gets the bit shifted out of the msb.
- You can think of the destination bits forming a circle, with the least significant bit following the msb in the circle.
- ROL destination, 1
- and
- ROL destination, CL



Rotate Right (ROR)

- The instruction ROR (rotate right) works just like ROL except that the bits are rotated to the right.
- The rightmost bit is shifted into the msb, and also into the CF
- ROR destination, 1
- and
- ROR destination, CL



ROL, ROR and CF

- In ROL and ROR, CF reflects the bit that is rotated out.
- ROL and ROR can be used to inspect the bits in a byte or word, without changing the contents.
- Example: Use ROL to count the number of 1 bits in BX, without changing BX. Put the answer in AX.
- Solution:

  XOR AX,AX

  MOV CX,16
- **TOP:**

  ROL BX,1

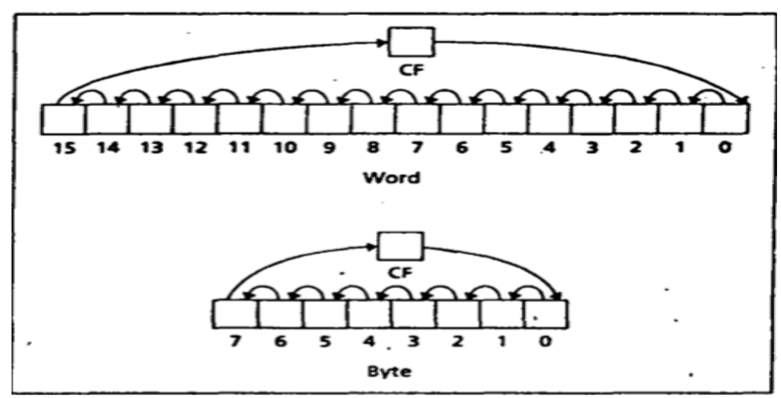
  JNC NEXT

  INC AX
- **NEXT:**

  LOOP TOP

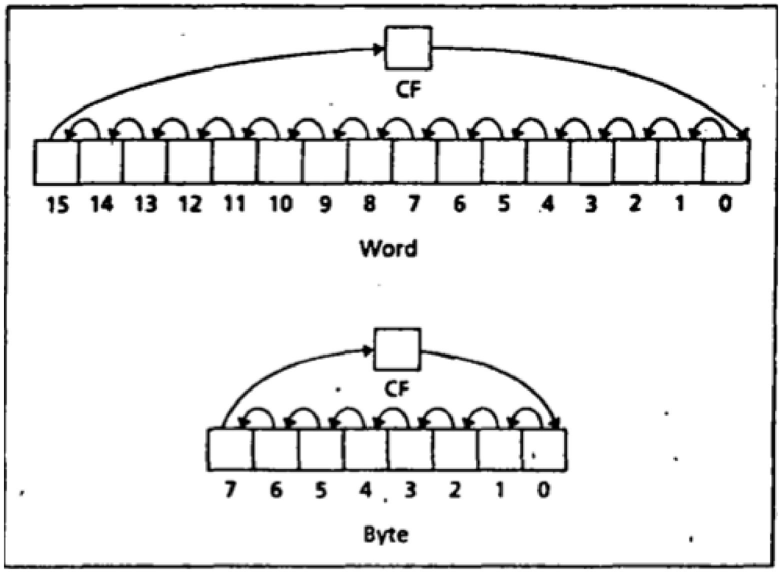
RCL (Rotate Carry Left)

- The Instruction RCL (Rotate through Carry LEFT) shifts the bits of the destination to the left.
- The msb is shifted Into the CF and the previous value of CF is shifted Into the rightmost bit.
- In other words, RCL works like Just like ROL, except that CF is part of the circle of bits being rotated. The syntax is:
- RCL destination,1
- and
- RCL destination, CL



RCR (Rotate Carry Right)

- The Instruction RCR (Rotate through Carry RIGHT) works just like RCL except the bits are rotated to the right. The syntax is:
- RCR destination,1
- and
- RCR destination, CL



Example

- Suppose DH contains 8Ah, CF= 1, and CL contains 3.
- What are the values of DH and CF after the instruction RCR DH,CL is executed?

Solution:

	CF	DH
initial values	1	10001010
after 1 right rotation	0	11000101
after 2 right rotations	1	01100010
after 3 right rotations	0	10110001 = B1h

Effect of the rotate instructions on the flags

SF, PF, ZF reflect the result

AF is undefined

CF = last bit shifted out

OF = 1 if result changes sign on the last rotation

Reversing Bit Pattern Application

- **Expectation:** If AL contains **11011100**, we want to make it **00111011**
- Use **SHL** to shift the bits out the left end of AL Into CF.
- Then use **RCR** to move them Into the left end of another register (i.e. **BL**)
- Run the above operation 8 times for 8 bits

```
         MOV    CX,8      ;number of operations to do
REVERSE:
         SHL    AL,1      ;get a bit into CF
         RCR    BL,1      ;rotate it into BL
         LOOP   REVERSE   ;loop until done
         MOV    AL,BL     ;AL gets reversed pattern
```

Binary and Hex Input & Output

- **Binary Input:** Lets assume a program reads In a binary number from the keyboard, followed by a carriage return. [i.e. string of 0's and 1's]
- Conversion in bit value needs to be done as soon as the input character is entered.
- After that collect the bits in register.
- To read a binary number from keyboard and store it in BX:

```
Clear BX      /* BX will hold binary value */
Input a character /* '0' or '1' */
WHILE character <> CR DO
  Convert character to binary value
  Left shift BX
  Insert value into lsb of BX
  Input a character
END_WHILE
```

Example: Process Input 110

```
Clear BX
   BX = 0000 0000 0000 0000
Input character '1', convert to 1
Left shift BX
   BX = 0000 0000 0000 0000
Insert value into lsb
   BX = 0000 0000 0000 0001
Input character '1', convert to 1
Left shift BX
   BX = 0000 0000 0000 0010
Insert value into lsb
   BX = 0000 0000 0000 0011

Input character '0', convert to 0
Left shift BX
   BX = 0000 0000 0000 0110
Insert value into lsb
   BX = 0000 0000 0000 0110
BX contains 110b.
```

Assembly Conversion for input processing (110)

```
        XOR  BX,BX       ;clear BX
        MOV  AH,1        ;input char function
        INT  21H         ;read a character
WHILE_:
        CMP  AL,0DH      ;CR?
        JE   END_WHILE   ;yes, done
        AND  AL,0FH      ;no, convert to binary value
        SHL  BX,1        ;make room for new value
        OR   BL,AL       ;put value into BX
        INT  21H         ;read a character
        JMP  WHILE_      ;loop back
END_WHILE:
```

Binary Output

- Outputting the contents of BX in binary also involves the shift operation.
- **Algorithm for Binary output:**

```
FOR 16 times DO
  Rotate left BX /* BX holds output value,
           put msb into CF */
  IF CF = 1
   THEN
    output '1'
   ELSE
    output '0'
  END_IF.
END_FOR
```

Write an assembly code to process the Binary output for this problem.

Hex Input

- Hex input consists of digits ("0" to "9") and letters ("A" to "F”) followed by a carriage return.
- For simplicity, we will assume that
- Only uppercase letters are used, and
- The user inputs no more than four hex characters.
- The process of converting characters to binary values is more Involved than it was for binary input, and BX must be **shifted four times** to make room for a hex value.

Algorithm for hex input

```
Clear BX      /* BX will hold input value */
input hex character
WHILE character <> CR DO
  convert character to binary value
  left shift BX 4 times
  insert value into lower 4 bits of BX
  input a character
END_WHILE
```

Example: input 6AB

```
Clear BX
   BX = 0000 0000 0000 0000
Input '6', convert to 0110
Left shift BX 4 times
   BX = 0000 0000 0000 0000
Insert value into lower 4 bits of BX
   BX = 0000 0000 0000 0110
Input 'A', convert to Ah = 1010
Left shift BX 4 times
   BX = 0000 0000 0110 0000
Insert value into lower 4 bits of BX
   BX = 0000 0000 0110 1010
Input 'B', convert to 1011
Left shift BX 4 times
   BX = 0000 0110 1010 0000
Insert value into lower 4 bits of BX
   BX = 0000 0110 1010 1011
BX contains 06ABh.
```

Assembly Code for Processing 6AB

```
        XOR   BX,BX      ;clear BX
        MOV   CL,4       ;counter for 4 shifts
        MOV   AH,1       ;input character function
        INT   21H        ;input a character
WHILE_:
        CMP   AL,0DH     ;CR?
        JE    END_WHILE  ;yes, exit
;convert character to binary value
        CMP   AL,39H     ;a digit?
        JG    LETTER     ;no, a letter
;input is a digit
        AND   AL,0FH     ;convert digit to binary value
        JMP   SHIFT      ;go to insert in BX
LETTER:
        SUB   AL,37H     ;convert letter to binary value
SHIFT:
        SHL   BX,CL      ;make room for new value
;insert value into BX
        OR    BL,AL      ;put value into low 4 bits
                         ;of BX
        INT   21H        ;input a character
        JMP   WHILE_     ;loop until CR
END_WHILE:
```

Algorithm for Hex Output

```
FOR 4 times DO
    Move BH to DL        /* BX holds output value */
    shift DL 4 times to the right
    IF DL < 10
     THEN
      convert to character in '0'..'9'
     ELSE
      convert to character in 'A'..'F'
    END_IF
    output character
    Rotate BX left 4 times
END_FOR
```

Conversion of 4CA9h to Binary

```
BX = 4CA9h = 0100 1100 1010 1001
Move BH to DL
   DL = 0100 1100
Shift DL 4 times to the right
   DL = 0000 0100
Convert to character and output
   DL = 0011 0100 = 34h = '4'
Rotate BX left 4 times
   BX = 1100 1010 1001 0100
Move BH to DL
   DL = 1100 1010
Shift DL 4 times to the right
   DL = 0000 1100
Convert to character and output
   DL = 0100 0011 = 43h = 'C'
Rotate BX left 4 times
   BX = 1010 1001 0100 1100
Move BH to DL
   DL = 1010 1001
Shift DL 4 times to the right
   DL = 0000 1010
Convert to character and output
   DL = 0100 0010 = 42h = 'B'
Rotate BX left 4 times
   BX = 1001 0100 1100 1010
Move BH to DL
   DL = 1001 0100
Shift DL 4 times to the right
   DL = 0000 1001
Convert to character and output
   DL = 0011 1001 = 39h = '9'
Rotate BX 4 times to the left
   BX = 0100 1100 1010 1001 = original contents
```

Write an assembly code to process the Binary output for this problem.

References

- Assembly Language Programming and Organization of the IBM PC, Ytha Yu and Charles Marut, McGraw Hill, 1992. (ISBN: 0-07-072692-2).
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