Logic, Shift, and Rotate Instructions

Reference: Assembly Language Programming and Organization of the IBM PC by Ytha Yu and Charles Marut (Chapter 7)

Topics Covered in This Chapter

- Logical Operations: AND, OR, XOR, NOT
- Shift Operations: SHL, SHR, SAL, SAR
- Rotation Operations: ROL, ROR, RCL, RCR

Logical Operations: AND, OR & XOR

AND	destination, source
OR	destination, source
XOR	destination, source

Effect on flags:

SF, ZF, PF reflect the result

AF is undefined

CF, OF = 0

Logical Operations: AND, OR & XOR

Rules

- The destination must be a register or memory location.
- The source may be a constant, register, or memory location.
- The memory-to-memory operations are not allowed.

Logical Operations: AND, OR & XOR

Use of AND, OR, and XOR Instructions

- Selectively modify the bits in the destination
- Construct a source bit pattern, **mask**
- Only desired destination bits are modified

Logical Operations: AND, OR & XOR

```
    10101010
AND 11110000
= 10100000
```

```
   10101010
OR 11110000
= 11111010
```

a	b	a AND b	a OR b	a XOR b
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

```
    10101010
XOR 11110000
= 01011010
```

```
NOT 10101010
  = 01010101
```

a	NOT a
0	1
1	0

Logical Operations

b AND 1 = b	b OR 0 = b	b XOR 0 = b
b AND 0 = 0	b OR 1 = 1	b XOR 1 = ~b (complement of b)

1. The AND instruction can be used to **clear** specific destination bits while preserving the others. A 0 mask bit clears the corresponding destination bit; a 1 mask bit preserves the corresponding destination bit.
2. The OR instruction can be used to **set** specific destination bits while preserving the others. A 1 mask bit sets the corresponding destination bit; a 0 mask bit preserves the corresponding destination bit.
3. The XOR instruction can be used to **complement** specific destination bits while preserving the others. A 1 mask bit complements the corresponding destination bit; a 0 mask bit preserves the corresponding destination bit.

Examples on Logical Operations

Clear the sign bit of AL while leaving the other bits unchanged.

Use AND with 0111 1111b = 7Fh as the mask.
Thus,

AND AL, 7Fh

Examples on Logical Operations

Set msb and lsb of AL while preserving the other bits.

Use OR with 1000 0001b = 81h as the mask.

Thus,

OR AL, 81h

Examples on Logical Operations

Change the sign bit of DX.

Use XOR with a mask of 8000h. Thus,

```
XOR DX, 8000h
```

Examples on Logical Operations

Converting an ASCII Digit to a Number

If the “5” key is pressed, AL gets 35h instead of 5. To get 5 in AL, we could do this:

SUB AL, 30h

Another method is to use AND to clear the high nibble (high four bits) of AL:

AND AL, 0FH

Because the codes “0” to “9” are 30h to 39h.

Examples on Logical Operations

Converting a Lowercase Letter to Upper Case

The ASCII codes of “a” to “z” range from 61h to 7Ah; the codes “A” to “Z” go from 41h to 5Ah.

Thus for example, if DL contains the code of a lowercase letter, we could convert to upper case by executing

SUB DL, 20h

Examples on Logical Operations

Converting
a Lowercase Letter to Upper Case

Character	Code	Character	Code
a	01**1**0 0001	A	01**0**0 0001
b	01**1**0 0010	B	01**0**0 0010
.	.	.	.
.	.	.	.
.	.	.	.
z	01**1**1 1010	Z	01**0**1 1010

Examples on Logical Operations

Converting a Lowercase Letter to Upper Case

We need only clear bit 5 by using AND with 1101 1111b or 0DFh.

So if the lowercase character to be converted is in DL, execute

```
AND DL, 0DFh
```

Examples on Logical Operations

Clearing a Register

To clear AX, we could execute

MOV AX, 0

SUB AX, AX

Using the fact that **1 XOR 1 = 0** and **0 XOR 0 = 0**, a third way is

XOR AX, AX

Examples on Logical Operations

Testing a Register for Zero

OR CX, CX

Because **1 OR 1 = 1** and **0 OR 0 = 0**, it leaves the content of CX unchanged; however, it affects ZF and SF, and in particular if CX contains 0 then ZF = 1.

So it can be used as an alternative to

CMP CX, 0

NOT Instruction

NOT destination

There is no effect on the status flags

Complement the bits in AX.

```
NOT    AX
```

TEST Instruction

TEST destination, source

Effect on flags:

SF, ZF, PF reflect the result

AF is undefined

CF, OF = 0

- performs an AND operation but does not change the destination content.
- The purpose of TEST is to set the status flags.

TEST Instruction

Examining Bits

TEST destination, mask

Because **1 AND b = b** and **0 AND b = 0**, the result will have 1’s in the tested bit positions if and only if the destination has 1’s in these positions; it will have 0’s elsewhere.

If destination has 0’s in all the tested position, the result will be 0 and so ZF = 1.

Example of Test Instruction

Jump to label BELOW
if AL contains an even number

Even numbers have a 0 in bit 0. Thus, the mask is 0000 0001b = 1.

```
TEST    AL, 1       ; is AL even?
JZ      BELOW       ; yes, go to BELOW
```

Shift & Rotate Instructions

For a single shift or rotate, the form is

Opcode destination, 1

For a shift or rotate of N positions, the form is

Opcode destination, CL

Where CL contains N.

In both cases, destination is an 8- or 16-bit register or memory location.

Shift Left

SHL shifts the bits in the destination to the left.

Effect on flags:

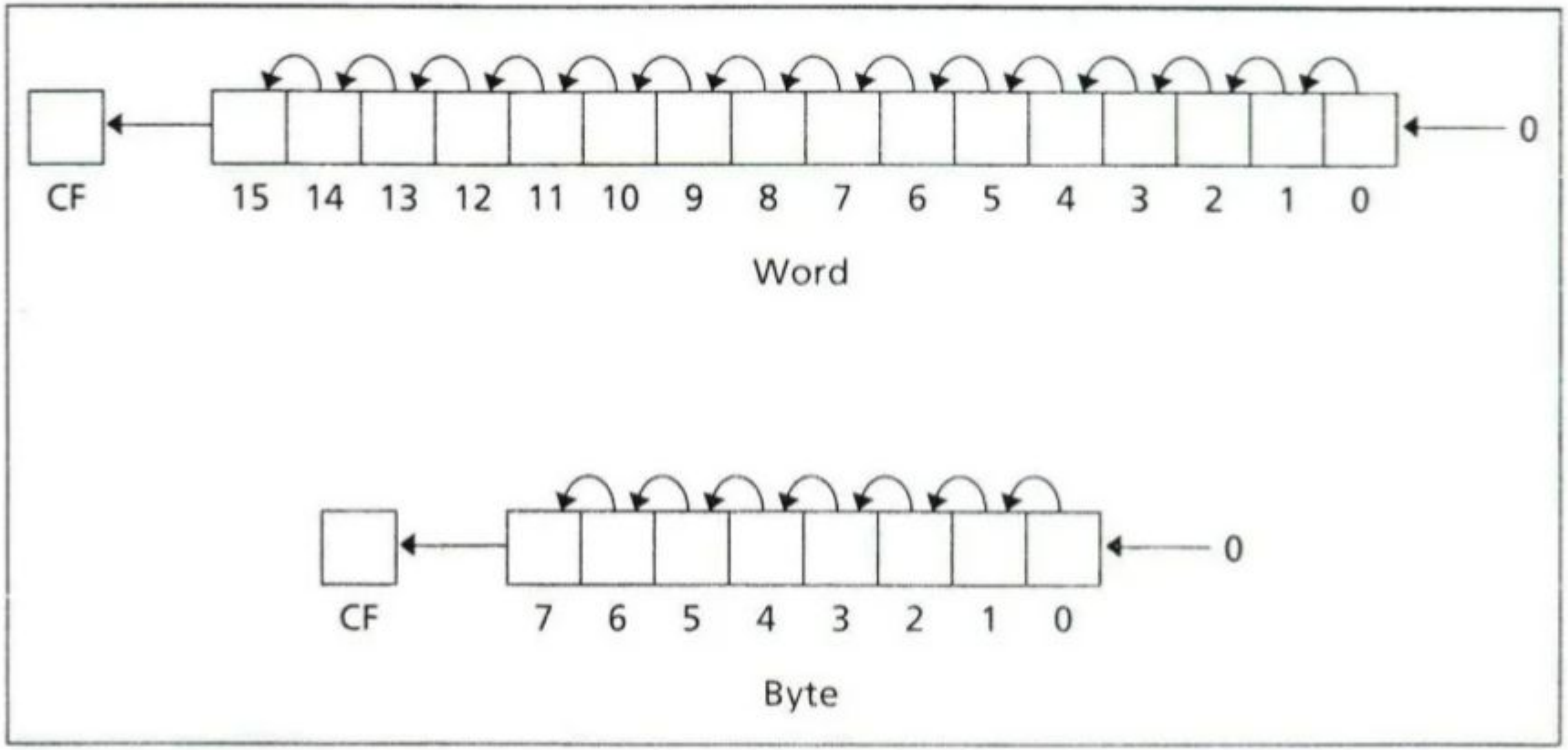
SF, ZF, PF reflect the result

AF is undefined

CF = last bit shifted out

OF = 1 if result changes sign on last shift

SHL & SAL



Example of SHL Instruction

Example 7.7 Suppose DH contains 8Ah and CL contains 3. What are the values of DH and of CF after the instruction SHL DH,CL is executed?

Solution: The binary value of DH is 10001010. After 3 left shifts, CF will contain 0. The new contents of DH may be obtained by erasing the leftmost three bits and adding three zero bits to the right end, thus 01010000b = 50h.

Multiplication by Left Shift

A left shift on a binary number multiplies it by 2.

Suppose that AL contains 5 = 00000101b. A left shift gives 00001010b = 10d, thus doubling its value.

If AX is FFFFh (–1), then shifting three times will yield AX = FFF8h (–8).

Shift Arithmetic Left

SAL is often used in instances where numeric multiplication is intended.

Both instructions generate the same machine code.

Overflow

The overflow flags are not reliable indicators for a multiple left shift because it is really a series of single shifts, and CF, OF only reflect the result of the last shift.

If BL contains 80h, CL contains 2and we execute SHL BL, CL, then CF = OF = 0 even though both signed and unsigned overflow occur.

Multiplication by Left Shift

Write some code to multiply the value of AX by 8.
Assume that overflow will not occur.

```
MOV     CL, 3       ; number of shifts to do
SAL     AX, CL      ; multiply by 8
```

Shift Right

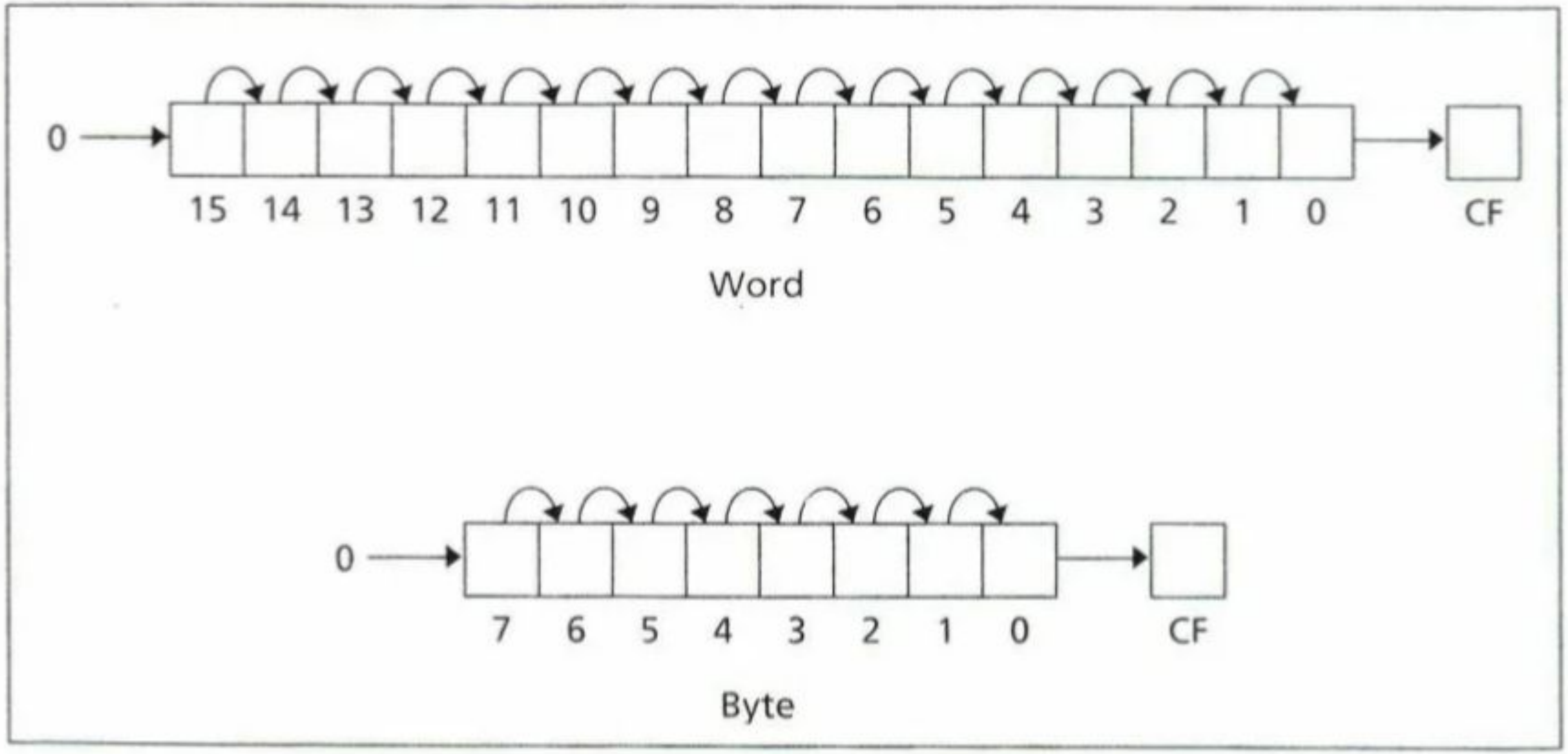
SHR performs right shifts on the destination operand.

A 0 is shifted into the msb position, and the rightmost bit is shifted into CF.

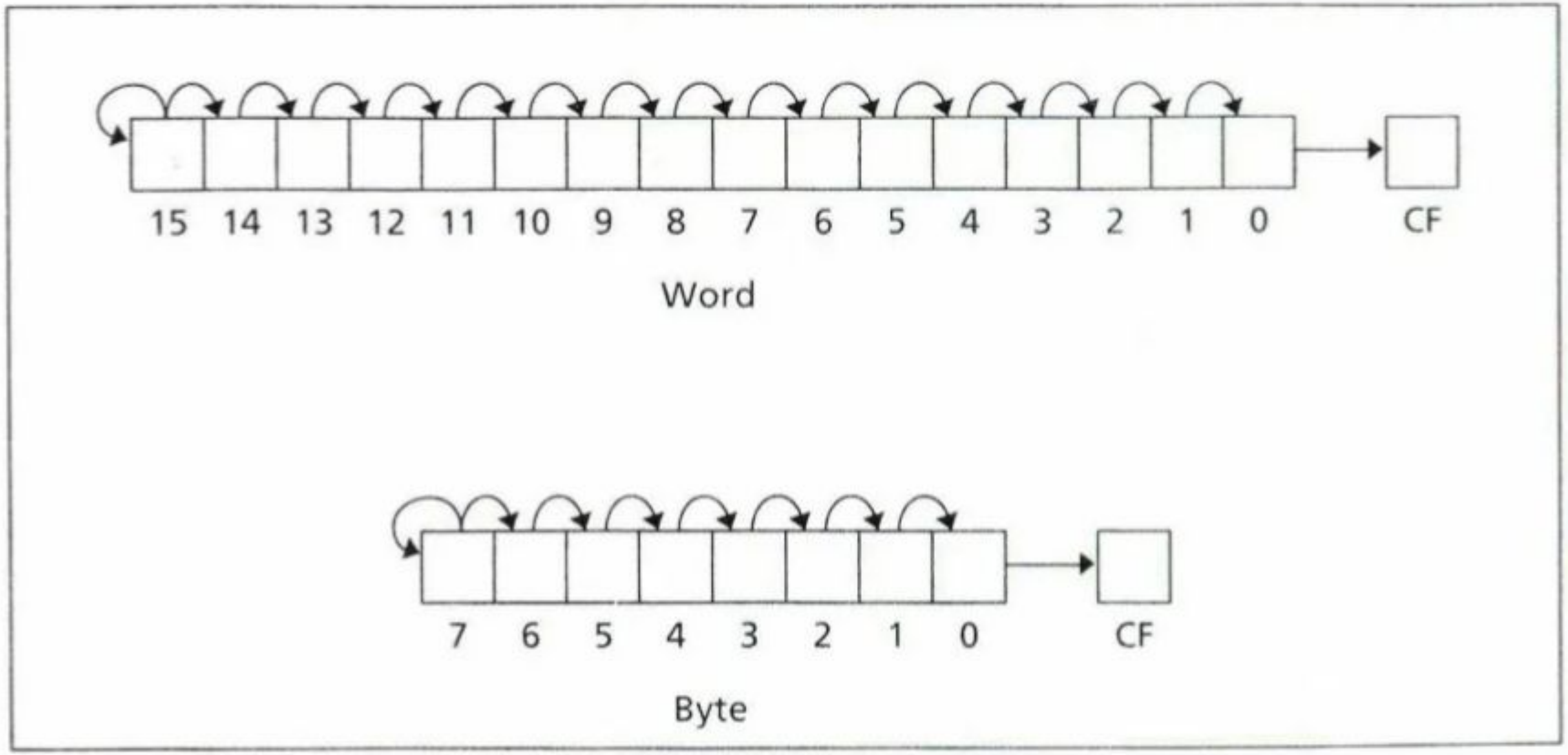
Shift Arithmetic Right

SAR operates like SHR, with one difference: the msb retains its original value.

SHR



SAR



Examples of SHR Instruction

Example 7.9 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.

Division by Right Shift

For even numbers, a right shift divides the destination's value by 2.

For odd numbers, a right shift halves the destination's value and round down to the nearest integer.

If BL contains 00000101b = 5, then after a right shift BL will contain 00000010b = 2.

Signed and Unsigned Division

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

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

Division by Right Shift

Example 7.10 Use right shifts to divide the unsigned number 65143 by 4. Put the quotient in AX.

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

```
MOV  AX,65143          ;AX has number
MOV  CL,2              ;CL has number of right shifts
SHR  AX,CL             ;divide by 4
```

Division by Right Shift

Example 7.11 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.

Rotate Left

ROL shifts bits to the left.

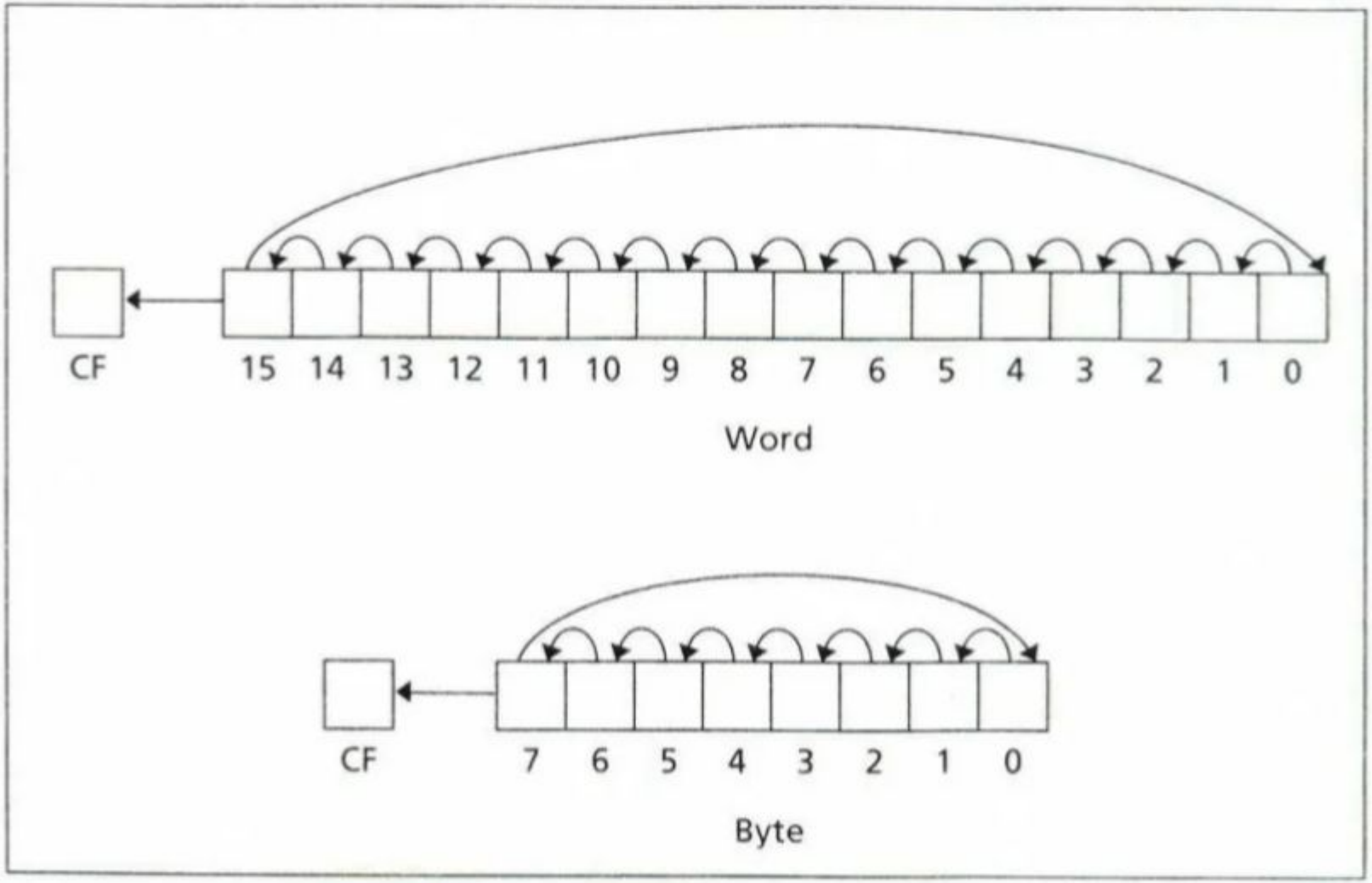
The msb is shifted into the rightmost bit.

The CF also gets the bit shifted out of the msb.

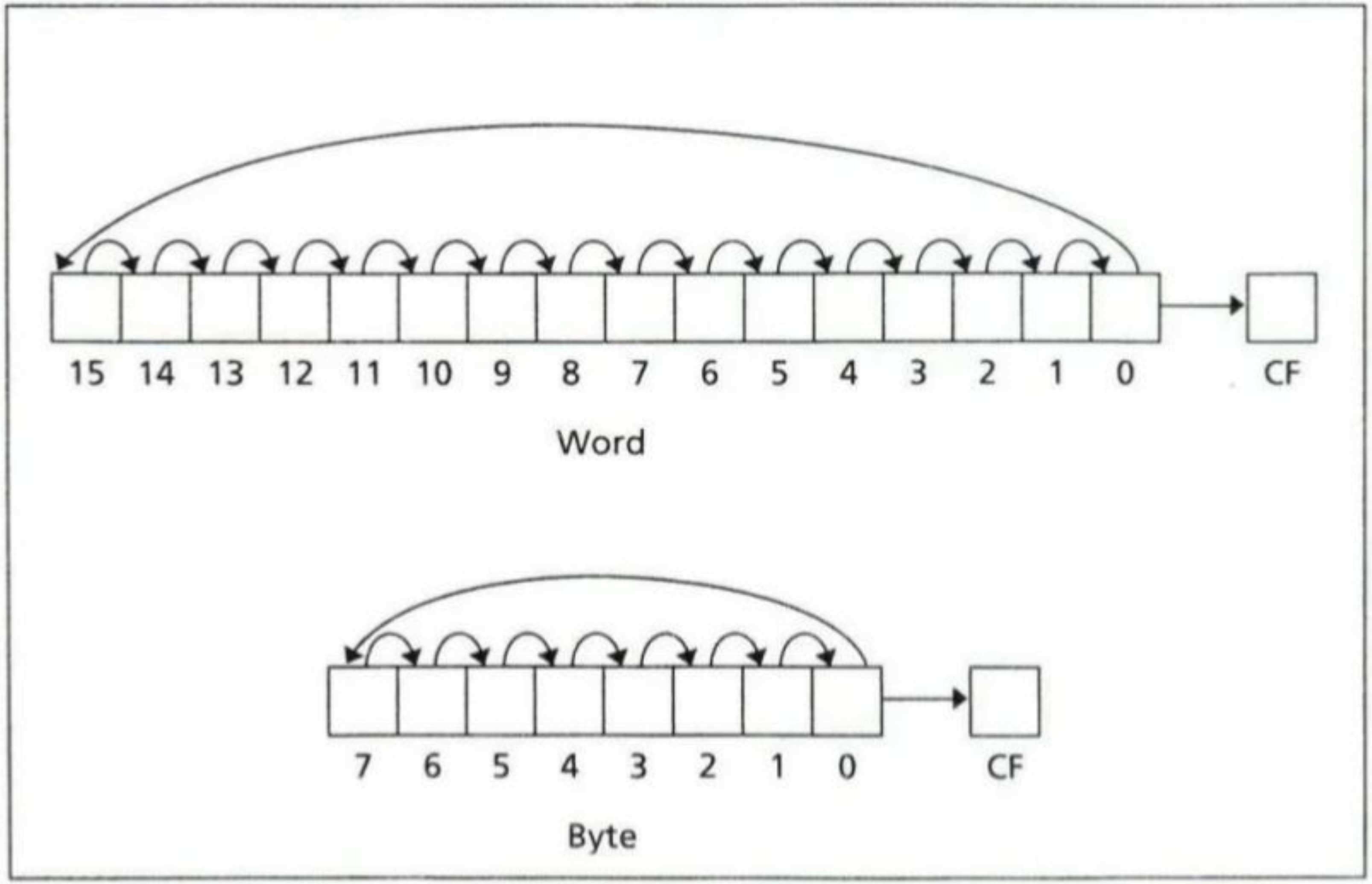
Rotate Right

ROR works just like ROL, except that the bits are rotated to the right.

ROL



ROR



Use ROL to count the number of 1 bits in BX, without changing BX. Put the answer in AX.

```
        XOR  AX, AX       ; AX counts bits
        MOV  CX, 16       ; loop counter
TOP:
        ROL  BX, 1        ; CF = bit rotated out
        JNC  NEXT         ; 0 bit
        INC  AX           ; 1 bit, increment total
NEXT:
        LOOP TOP          ; loop until done
```

Use ROL to count the number of 1 bits in BX, without changing BX. Put the answer in AX.

In this example, we used **JNC** (jump if no carry), which causes a jump if CF = 0.

Rotate Carry Left

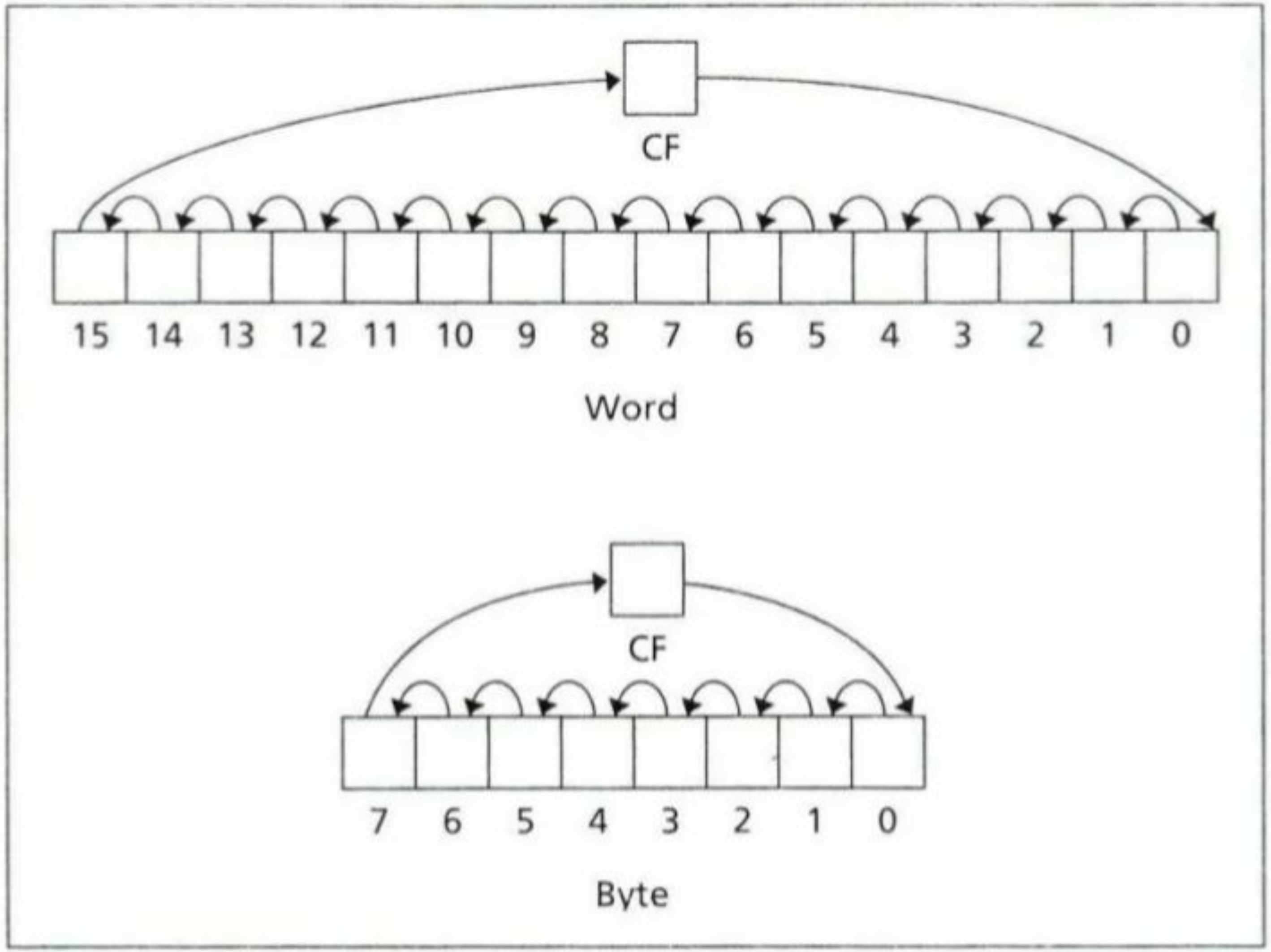
RCL shifts bits of the destination to the left.

The msb is shifted into the CF, and the previous value of CF is shifted into the rightmost bit.

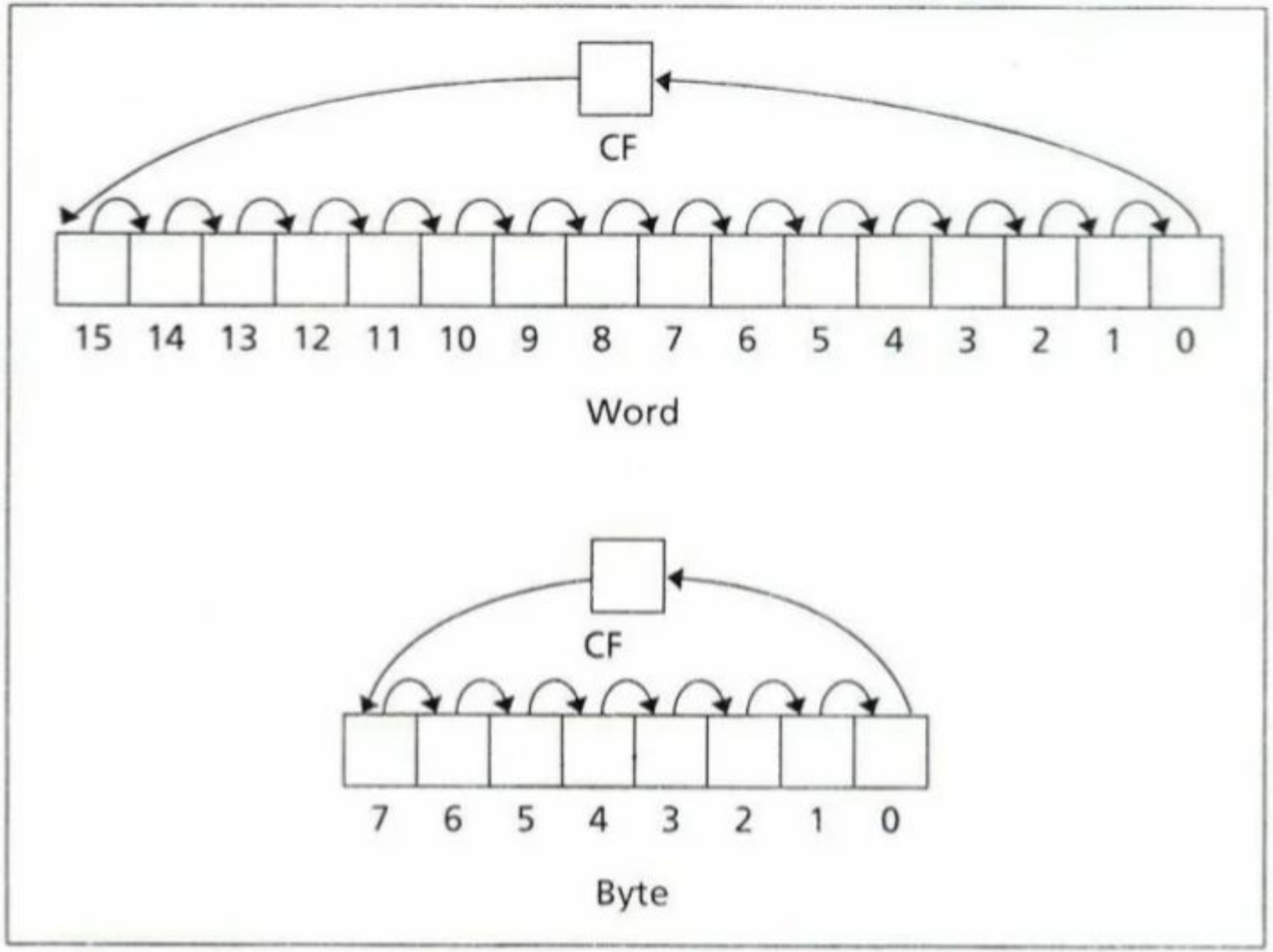
Rotate Carry Right

RCR works just like RCL, except that the bits are rotated to the right.

RCL



RCR



Example 7.13 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

An application: Reversing a Bit Pattern

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

Still have trouble understanding?
Try visiting this link:

http://mptuter.blogspot.com/2013/07/shift-and-rotate-instructions_821.html

***Solve the Exercise Problems from Textbook! ☺
(Exercise No: 1,2,3,4,5,6,7)