Week 9

Chapter 7: Integer Arithmetic

Chapter Overview

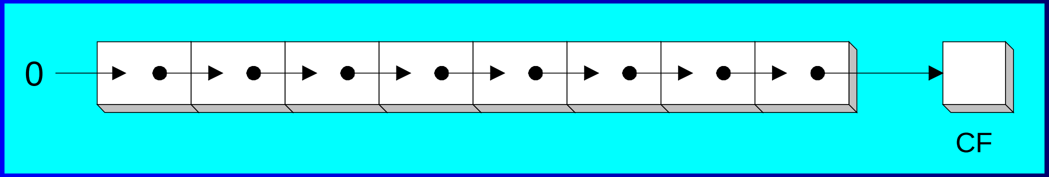
- **Shift and Rotate Instructions**
- Shift and Rotate Applications
- Multiplication and Division Instructions
- Extended Addition and Subtraction
- ASCII and Unpacked Decimal Arithmetic
- Packed Decimal Arithmetic

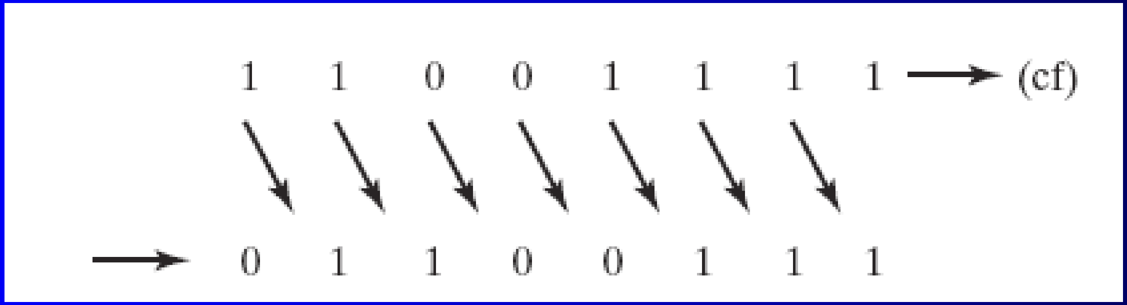
Shift and Rotate Instructions

- Logical vs Arithmetic Shifts
- SHL Instruction
- SHR Instruction
- SAL and SAR Instructions
- ROL Instruction
- ROR Instruction
- RCL and RCR Instructions
- SHLD/SHRD Instructions

Logical Shift

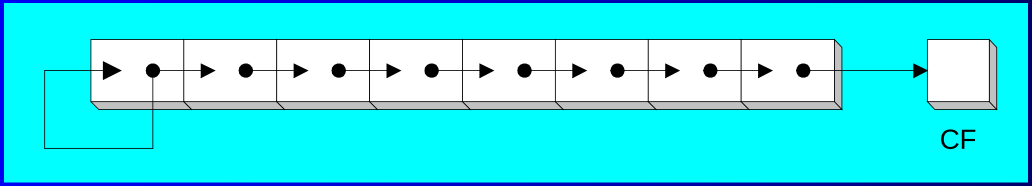
- A logical shift fills the newly created bit position with zero:

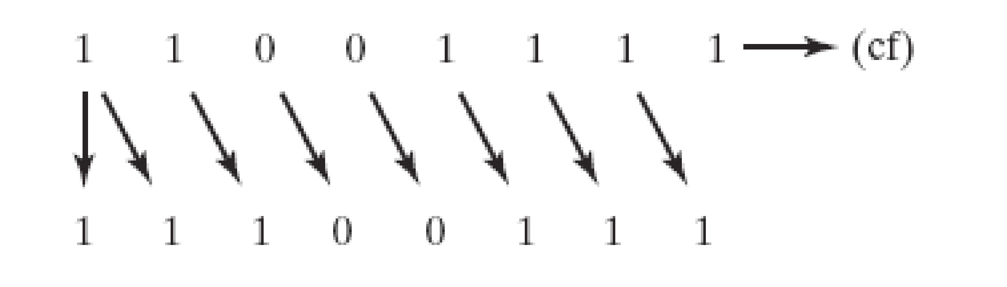




Arithmetic Shift

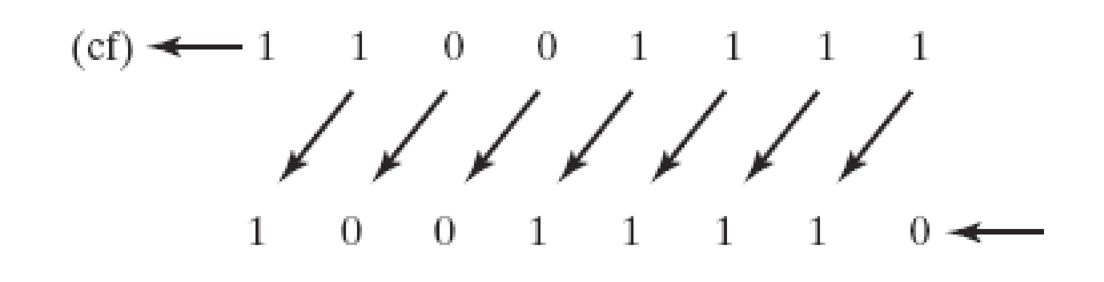
- An arithmetic shift fills the newly created bit position with a copy of the number's sign bit:





SHL Instruction

- The SHL (shift left) instruction performs a logical left shift on the destination operand, filling the lowest bit with 0.



- Operand types for SHL:

```
SHL reg,imm8
SHL mem,imm8
SHL reg,CL
SHL mem,CL
```

(Same for all shift and rotate instructions)

Fast Multiplication

Shifting left 1 bit multiplies a number by 2

```
mov dl,5
shl dl,1
```

Before:	0 0 0 0 0 1 0 1	= 5
After:	0 0 0 0 1 0 1 0	= 10

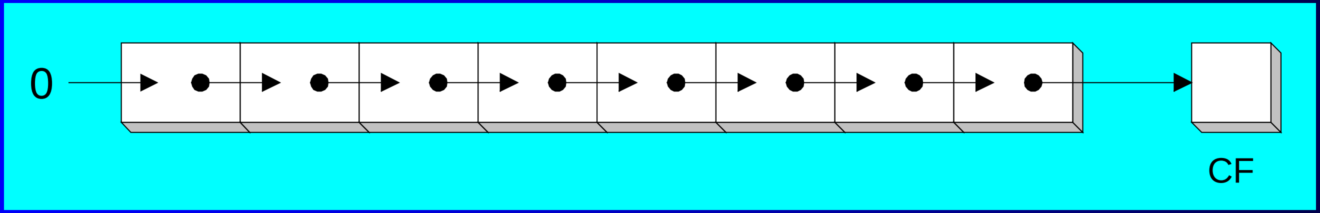
Shifting left *n* bits multiplies the operand by 2^n

For example, $5 * 2^2 = 20$

```
mov dl,5
shl dl,2                        ; DL = 20
```

SHR Instruction

- The SHR (shift right) instruction performs a logical right shift on the destination operand. The highest bit position is filled with a zero.

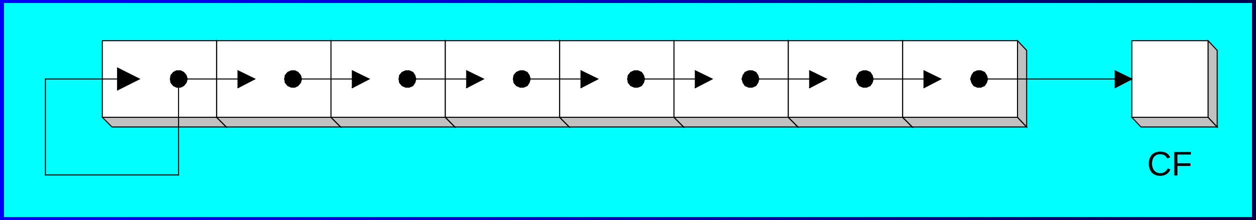


Shifting right *n* bits divides the operand by 2^n

```
mov dl,80
shr dl,1                        ; DL = 40
shr dl,2                        ; DL = 10
```

SAL and SAR Instructions

- SAL (shift arithmetic left) is identical to SHL.
- SAR (shift arithmetic right) performs a right arithmetic shift on the destination operand.



An arithmetic shift preserves the number's sign.

```
mov dl,-80
sar dl,1                          ; DL = -40
sar dl,2                          ; DL = -10
```

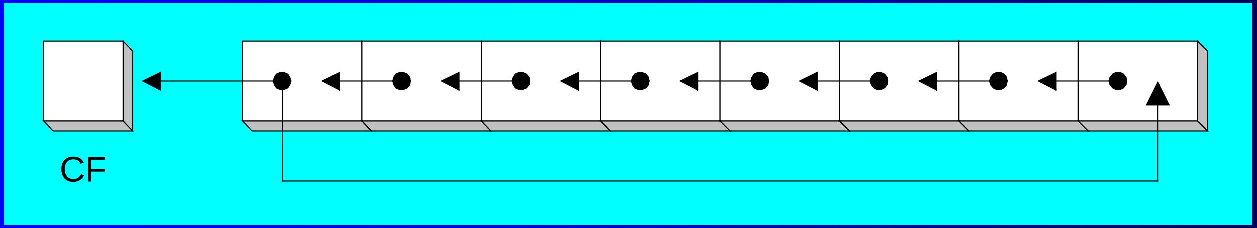
Your turn . . .

Indicate the hexadecimal value of AL after each shift:

```
mov al,6Bh
shr al,1                          a.  35h
shl al,3                          b.  A8h
mov al,8Ch
sar al,1                          c.  C6h
sar al,3                          d.  F8h
```

ROL Instruction

- ROL (rotate) shifts each bit to the left
- The highest bit is copied into both the Carry flag and into the lowest bit
- No bits are lost

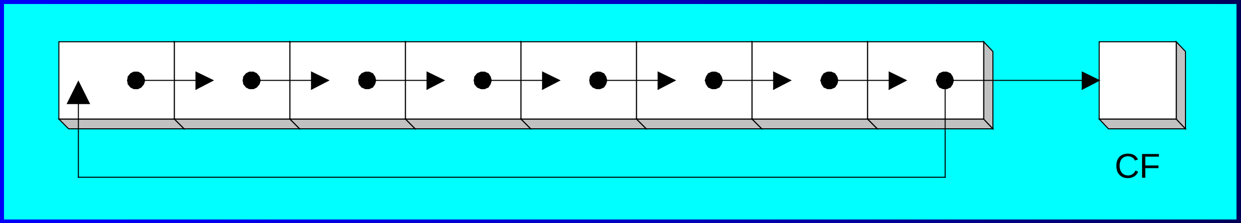


```
mov al,11110000b
rol al,1                          ; AL = 11100001b

mov dl,3Fh
rol dl,4                          ; DL = F3h
```

ROR Instruction

- ROR (rotate right) shifts each bit to the right
- The lowest bit is copied into both the Carry flag and into the highest bit
- No bits are lost



```
mov al,11110000b
ror al,1                        ; AL = 01111000b

mov dl,3Fh
ror dl,4                        ; DL = F3h
```

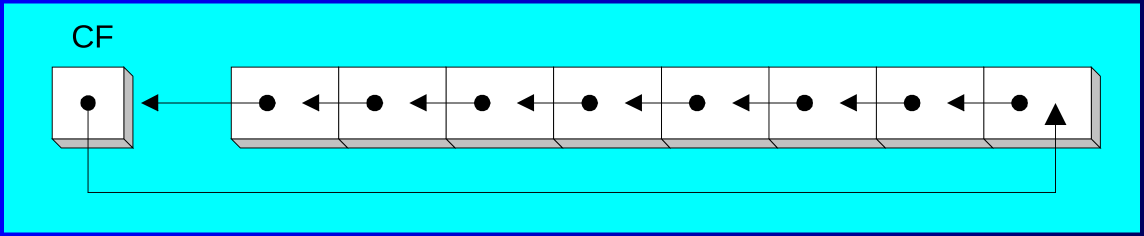
Your turn . . .

Indicate the hexadecimal value of AL after each rotation:

```
mov al,6Bh
ror al,1                          a.  B5h
rol al,3                          b.  ADh
```

RCL Instruction

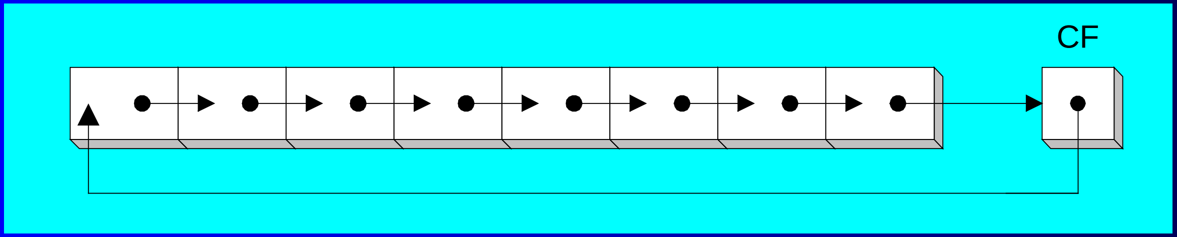
- RCL (rotate carry left) shifts each bit to the left
- Copies the Carry flag to the least significant bit
- Copies the most significant bit to the Carry flag



```
clc                        ; CF = 0
mov bl,88h                 ; CF,BL = 0 10001000b
rcl bl,1                   ; CF,BL = 1 00010000b
rcl bl,1                   ; CF,BL = 0 00100001b
```

RCR Instruction

- RCR (rotate carry right) shifts each bit to the right
- Copies the Carry flag to the most significant bit
- Copies the least significant bit to the Carry flag



```
stc                     ; CF = 1
mov ah,10h              ; CF,AH = 1 00010000b
rcr ah,1                ; CF,AH = 0 10001000b
```

Your turn . . .

Indicate the hexadecimal value of AL after each rotation:

```
stc
mov al,6Bh
rcr al,1                   a. B5h
rcl al,3                   b. AEh
```

SHLD Instruction

- Shifts a destination operand a given number of bits to the left
- The bit positions opened up by the shift are filled by the most significant bits of the source operand
- The source operand is not affected
- Syntax:

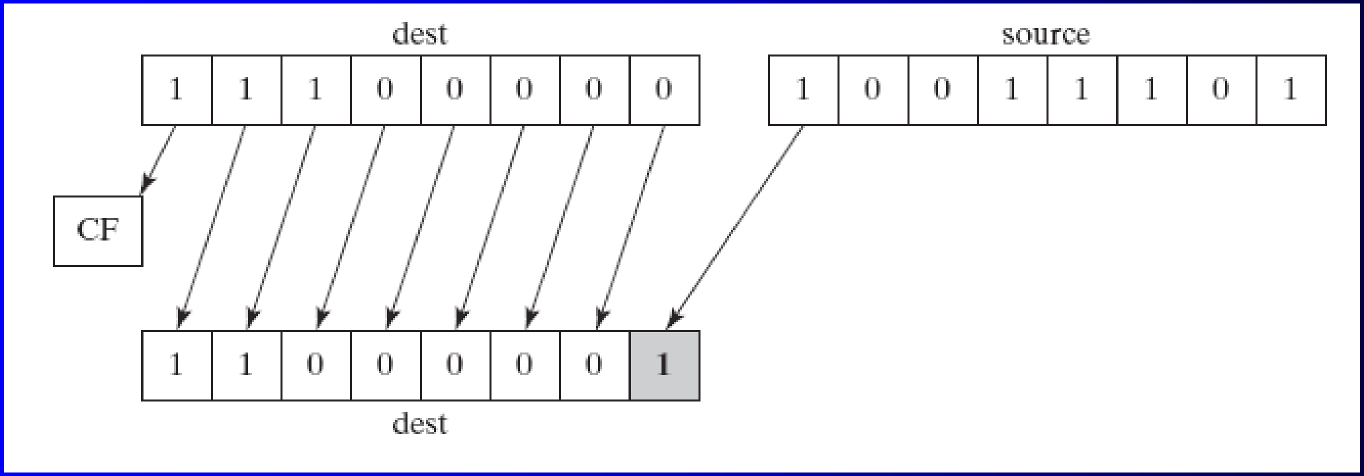
  SHLD *destination, source, count*
- Operand types:

```
SHLD reg16/32, reg16/32, imm8/CL
SHLD mem16/32, reg16/32, imm8/CL
```

SHLD Example

Shift count of 1:

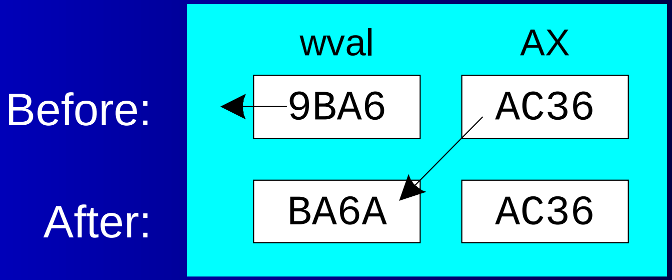
```
mov al,11100000b
mov bl,10011101b
shld al,bl,1
```



Another SHLD Example

Shift wval 4 bits to the left and replace its lowest 4 bits with the high 4 bits of AX:

```
.data
wval WORD 9BA6h
.code
mov  ax,0AC36h
shld wval,ax,4
```



SHRD Instruction

- Shifts a destination operand a given number of bits to the right
- The bit positions opened up by the shift are filled by the least significant bits of the source operand
- The source operand is not affected
- Syntax:

  SHRD *destination, source, count*

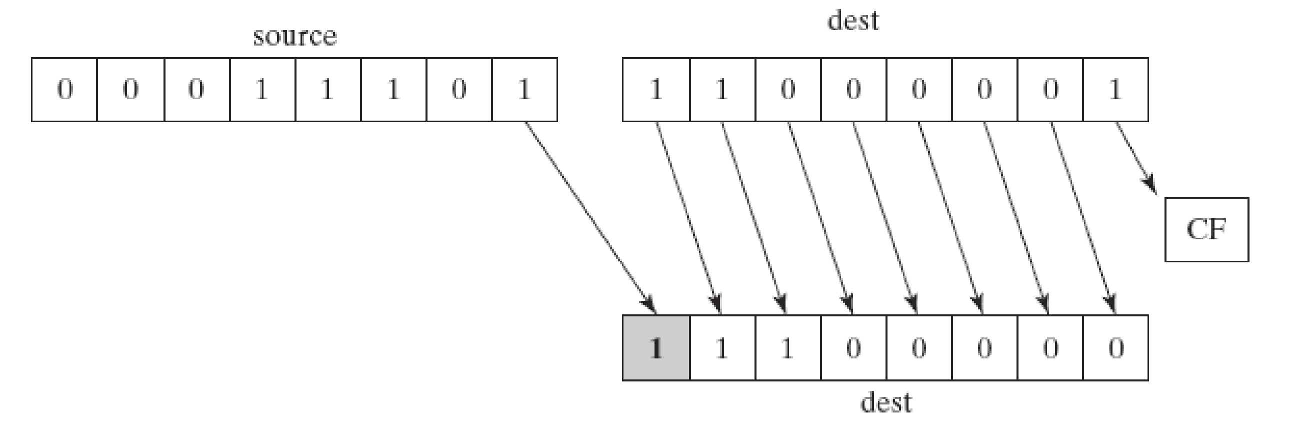
- Operand types:

```
SHRD reg16/32, reg16/32, imm8/CL
SHRD mem16/32, reg16/32, imm8/CL
```

SHRD Example

Shift count of 1:

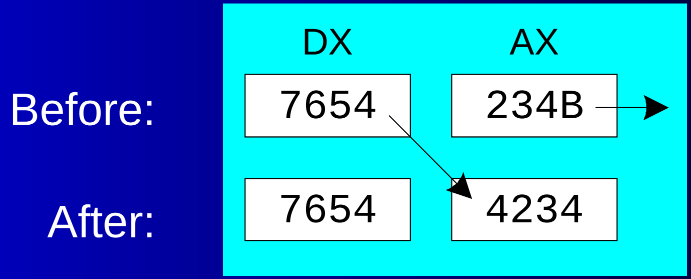
```
mov al,11000001b
mov bl,00011101b
shrd al,bl,1
```



Another SHRD Example

Shift AX 4 bits to the right and replace its highest 4 bits with the low 4 bits of DX:

```
mov  ax,234Bh
mov  dx,7654h
shrd ax,dx,4
```



	DX	AX
Before:	7654	234B
After:	7654	4234

Your turn . . .

Indicate the hexadecimal values of each destination operand:

```
mov  ax,7C36h
mov  dx,9FA6h
shld dx,ax,4          ; DX = FA67h
shrd dx,ax,8          ; DX = 36FAh
```

What's Next

- Shift and Rotate Instructions
- **Shift and Rotate Applications**
- Multiplication and Division Instructions
- Extended Addition and Subtraction
- ASCII and Unpacked Decimal Arithmetic
- Packed Decimal Arithmetic

Shift and Rotate Applications

- Shifting Multiple Doublewords
- Binary Multiplication
- Displaying Binary Bits
- Isolating a Bit String

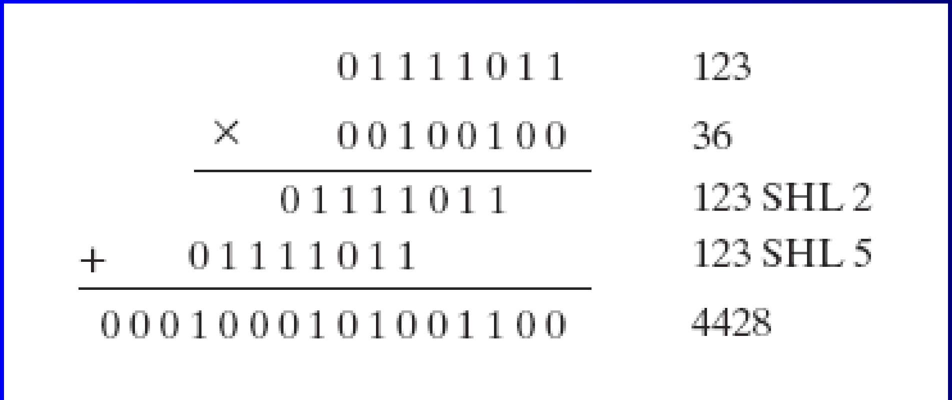
Shifting Multiple Doublewords

- Programs sometimes need to shift all bits within an array, as one might when moving a bitmapped graphic image from one screen location to another.
- The following shifts an array of 3 doublewords 1 bit to the right (view complete source code):

```
.data
ArraySize = 3
array DWORD ArraySize DUP(99999999h)      ; 1001 1001...
.code
mov esi,0
shr array[esi + 8],1          ; high dword
rcr array[esi + 4],1          ; middle dword, include Carry
rcr array[esi],1              ; low dword, include Carry
```

Binary Multiplication

- mutiply 123 * 36



```
          01111011      123
  ×       00100100      36
  ----------------
        01111011        123 SHL 2
+    01111011           123 SHL 5
------------------
  0001000101001100      4428
```

Binary Multiplication

- We already know that SHL performs unsigned multiplication efficiently when the multiplier is a power of 2.
- You can factor any binary number into powers of 2.
  - For example, to multiply EAX * 36, factor 36 into 32 + 4 and use the distributive property of multiplication to carry out the operation:

```
EAX * 36
= EAX * (32 + 4)
= (EAX * 32)+(EAX * 4)
```

```
mov eax,123
mov ebx,eax
shl eax,5                ; mult by $2^5$
shl ebx,2                ; mult by $2^2$
add eax,ebx
```

Your turn . . .

Multiply AX by 26, using shifting and addition instructions.
Hint: 26 = 16 + 8 + 2.

```
mov ax,2                          ; test value

mov dx,ax
shl dx,4                          ; AX * 16
push edx                          ; save for later
mov dx,ax
shl dx,3                          ; AX * 8
shl ax,1                          ; AX * 2
add ax,dx                         ; AX * 10
pop edx                           ; recall AX * 16
add ax,dx                         ; AX * 26
```

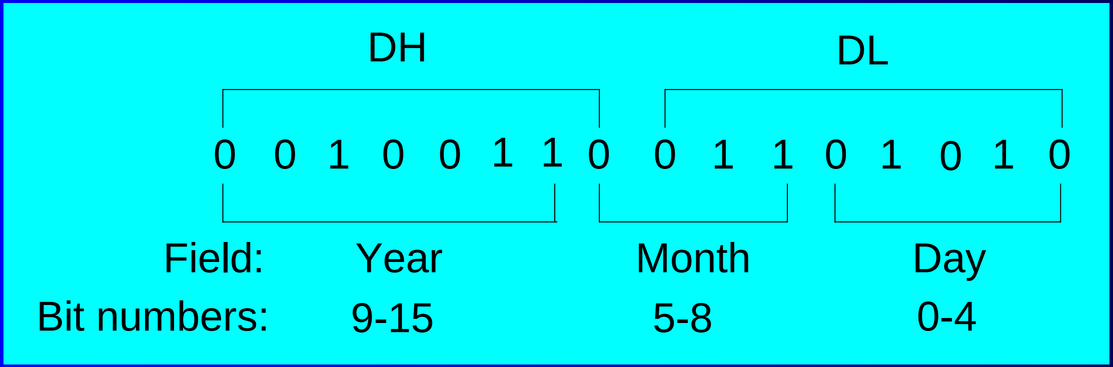
Displaying Binary Bits

Algorithm: Shift MSB into the Carry flag; If CF = 1, append a "1" character to a string; otherwise, append a "0" character. Repeat in a loop, 32 times.

```
.data
buffer BYTE 32 DUP(0),0
.code
    mov ecx,32
    mov esi,OFFSET buffer
L1: shl eax,1
    mov BYTE PTR [esi],'0'
    jnc L2
    mov BYTE PTR [esi],'1'
L2: inc esi
    loop L1
```

Isolating a Bit String

- The MS-DOS file date field packs the year, month, and day into 16 bits:



DH

DL

0 0 1 0 0 1 1 0 0 1 1 0 1 0 1 0

Field: Year Month Day

Bit numbers: 9-15 5-8 0-4

Isolate the Month field:

```
mov ax,dx                   ; make a copy of DX
shr ax,5                    ; shift right 5 bits
and al,00001111b            ; clear bits 4-7
mov month,al                ; save in month variable
```