Lab 7: *Shift & Rotate, Multiplication & division, Extended Addition*	**Session:** Fall 2019
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Shift and Rotate Instructions

Shift

Shift instructions move bits a specified number of places to the right or left. The last in the direction of the shift goes into the carry flag, and the first bit is filled with 0 or with the previous value of the first bit. There are two different sets of shift instructions

I. One set for doubling and halving unsigned binary numbers
- SHL (Shift Left)
- SHR (Shift Right)

II. The other for doubling and halving signed
- SAL (Arithmetic Shift Left)
- SAR (Arithmetic Shift Right)

Instruction	CL	Initial Contents		Final Contents		
		Decimal	Binary	Decimal	Binary	CF
SHR AL,1		250	11111010	125	01111101	0
SHR AL,CL	3	250	11111010	31	00011111	0
SHL AL,1		23	00010111	46	00101110	0
SHL BL,CL	2	23	00010111	92	01011100	0
SAL BL,1		+23	00010111	+46	00101110	0
SAL DL,CL	4	+3	00000011	+48	00110000	0
SAR AL,1		-126	10000010	-63	11000001	0
SAR AL,CL	2	-126	10000010	-32	11100000	1

SHL (Shift Left)

Syntax:

SHL destination,count

```
mov bl,8Fh                  ;BL=10001111b
SHL bl,1                    ;CF=1,  BL=00011110b

mov al,10000000b            ;AL=10000000b
SHL al,2                    ;CF=0,  AL=00000000b

mov dl,5                    ;DL=00000101b=5
SHL dl,1                    ;CF=0, DL=00001010b=10
```

SHR (Shift Right)

Syntax:

SHR destination,count

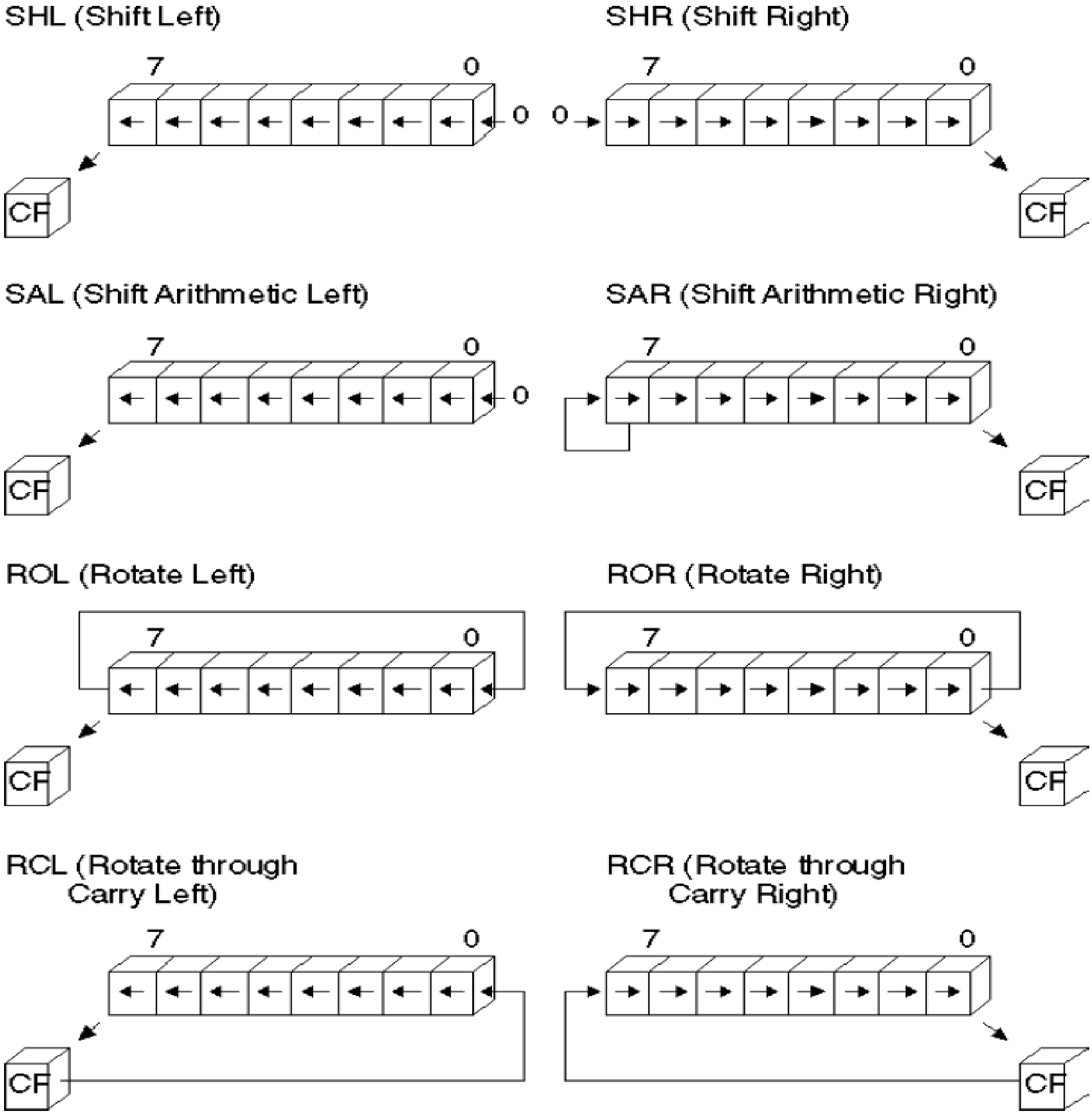
```
mov dl,32                   ;DL=00100000b=32
SHR dl,1                    ;DL=00010000b, CF=0=16
```

SAL & SAR (Shift Arithmetic Left) & (Shift Arithmetic Right)

Syntax:

SAL destination,count
SAR destination,count

mov ax,-128 *;EAX=????FF80h*
SHL eax,16 *;EAX=FF800000h*
SAR eax,16 *;EAX=FFFFFF80h*



ROTATE

Rotate instructions also move bits a specified number of places to the right or left. For each bit rotated the last bit in the direction of the rotate operation moves into the first bit position at the other end of the operand. With some variations, the carry bit is used as an additional bit of the operand.

ROR (Rotate Right)

Syntax:

ROR destination,count

mov al,0000100b
ROR al,3 *;DL=10000000b, CF=1*

ROL (Rotate Left)

Syntax:

ROL destination,count

```
mov ax,6A4Bhh                ;AX=A4B6h
ROL ax,4                     ;AX=4B6Ah
ROL ax,4                     ;AX=B6A4h
ROL ax,4                     ;AX=6A4Bh
ROL ax,4

mov al,26h
ROL al,4                     ;AL=62h
```

Instruction	CL	Initial Contents		Final Contents	
		CF	Binary	Binary	CF
ROR AL,1		0	11111010	01111101	0
ROR AL,CL	3	1	11111010	01011111	0
ROL AL,1		0	00010111	00101110	0
ROL BL,CL	2	1	00010111	01011100	0
RCL BL,1		0	00010111	00101110	0
RCL DL,CL	4	1	00000011	00111000	0
RCR AL,1		1	10000010	11000001	0
RCR AL,CL	2	0	10000010	00100000	1

RCL & RCR (Rotate Carry Right) & (Rotate Carry Left)

RCR and RCL instructions carry values from the first register to the second by passing the leftmost or rightmost bit through the carry flag.

Syntax:

RCL destination, count
RCR destination, count

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

STC                          ;CF=1
mov ah,10h                   ;AH,CF=00010000 1
RCR ah,1                     ;AH,CF=10001000 0
```

SHLD/SHRD

Syntax:

SHLD destination, source, count

Example 1:

```
.data
        a WORD 9BA6h
.code
        mov  ax,0AC36h
        shld a,ax,4                  ;a=BA6Ah
```

Example 2:

```
. .code
        mov  ax,234Bh
        mov dx,7654h
        shrd ax,dx,4                 ;ax=4234h
```

Multiplication and Division Instructions

MUL

The **MUL** instruction is for unsigned multiplication. Operands are treated as unsigned numbers.

Multiplicand	Multiplier	Product
AL	reg/mem8	AX
AX	reg/mem16	DX:AX
EAX	reg/mem32	EDX:EAX

Syntax: *MUL source*

Example 3:

```
mov eax,12345h
mov ebx,1000h
mul ebx                ; EDX:EAX = 0000000012345000h, CF = 0
```

IMUL

The IMUL instruction is for signed multiplication. Operands are treated as signed numbers and result is positive or negative depending on the signs of the operands.

Syntax: *IMUL source*

Example 4:

The following instructions multiply -4 by 4, producing -16 in AX. AH is a sign extension of AL so the Overflow flag is clear:

```
mov al,-4
mov bl,4
imul bl                ; AX = FFF0h, OF = 0
```

Example 5:

The following instructions perform 32-bit signed multiplication (4,823,424 *-423), producing -2,040,308,352 in EDX:EAX. The Overflow flag is clear because EDX is a sign extension of EAX:

```
mov eax,+4823424
mov ebx,-423
imul ebx               ; EDX:EAX = FFFFFFFF86635D80h, OF = 0
```

Example 6:

The following instructions demonstrate two-operand formats:

```
.data
    word1 SWORD 4
    dword1 SDWORD 4
.code
    mov ax,-16          ; AX = -16
    mov bx,2            ; BX = 2
    imul bx,ax          ; BX = -32
    imul bx,2           ; BX = -64
    imul bx,word1       ; BX = -256
    mov eax,-16         ; EAX = -16
    mov ebx,2           ; EBX = 2
    imul ebx,eax        ; EBX = -32
    imul ebx,2          ; EBX = -64
    imul ebx,dword1     ; EBX = -256
```

Example 7:
The following instructions demonstrate three-operand formats, including an example of signed overflow:

```
.data
        word1 SWORD 4
        dword1 SDWORD 4
.code
        imul bx,word1,-16                    ; BX = -64
        imul ebx,dword1,-16                  ; EBX = -64
        imul ebx,dword1,-2000000000          ; OF = 1
```

DIV Instructions:

The DIV (unsigned divide) instruction performs 8-bit, 16-bit, and 32-bit unsigned integer division. The single register or memory operand is the divisor.

Dividend	Divisor	Quotient	Remainder
AX	reg/mem8	AL	AH
DX:AX	reg/mem16	AX	DX
EDX:EAX	reg/mem32	EAX	EDX

Syntax: *DIV source*

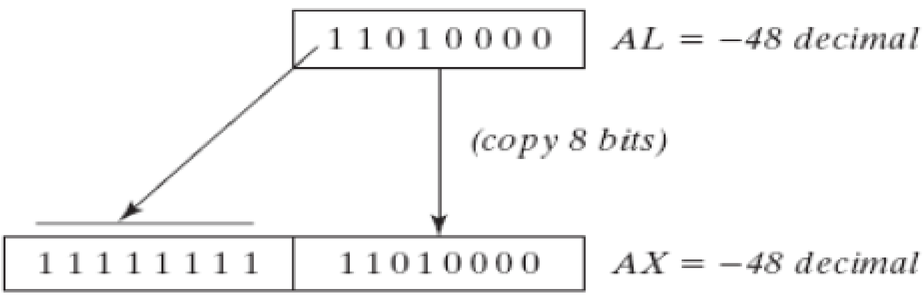
```
mov dx,0              ; clear dividend, high
mov ax,8003h          ; dividend, low
mov cx,100h           ; divisor
div cx                ; AX = 0080h, DX = 0003h
```

IDIV

Syntax: *IDIV source*

Example 8:

```
.data
        byteVal SBYTE -48            ; D0 hexadecimal
.code
        mov al,byteVal               ; lower half of dividend
        cbw                          ; extend AL into AH
        mov bl,+5                    ; divisor
        idiv bl                      ;AL = -9, AH = -3
```



Sign Extension Instructions(CBW,CWD,CDQ)

Dividends of signed integer division instructions must often be sign-extended before the division takes place. Intel provides three useful sign extension instructions: CBW, CWD, and CDQ.

Example 9:
The CBW instruction (convert byte to word) extends the sign bit of AL into AH, preserving the number's sign. In the next example, 9Bh (in AL) and FF9Bh (in AX) both equal −101 decimal:

```
.data
        byteVal SBYTE -101              ; 9Bh
.code
        mov al,byteVal                  ; AL = 9Bh
        cbw                             ; AX = FF9Bh
```

Example 10:
The CWD (convert word to doubleword) instruction extends the sign bit of AX into DX:

```
.data
        wordVal SWORD -101              ; FF9Bh
.code
        mov ax,wordVal                  ; AX = FF9Bh
        cwd                             ; DX:AX = FFFFFF9Bh
```

Example 11:
The CDQ (convert doubleword to quadword) instruction extends the sign bit of EAX into EDX:

```
.data
        dwordVal SDWORD -101            ; FFFFFF9Bh
.code
        mov eax,dwordVal
        cdq                             ; EDX:EAX = FFFFFFFFFFFFFF9Bh
```

Extended Addition and Subtraction

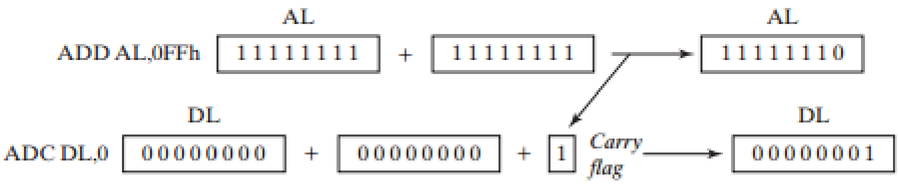
ADC

The ADC (add with carry) instruction adds both a source operand and the contents of the Carry flag to a destination operand.

Syntax: *ADC Destination,source*

Example 12:

```
.code
        mov dl,0
        mov al,0FFh
        add al,0FFh                             ; AL = FEh
        adc dl,0                                ; DL/AL = 01FEh
```



SBB

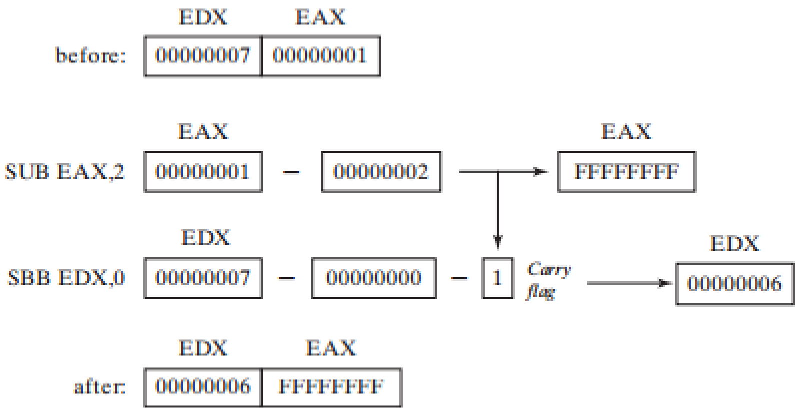
The SBB (subtract with borrow) instruction subtracts both a source operand and the value of the Carry flag from a destination operand.

Syntax: *SBB Destination,source*

Example 13:

```
.code
        mov edx,7                               ; upper half
        mov eax,1                               ; lower half
        sub eax,2                               ; subtract 2
```

sbb edx,0 *; subtract upper half*



Activity:

Implement the following C++ statement, using unsigned 32-bit integers:
var4 = (var1 * 5) / (var2 - 3);

Implement the following C++ expression in assembly language, using 32-bit signed operands:
val1 = (val2 / val3) * (val1 % val2);
var4 = (var1 * -5) / (-var2 % var3);

Write ASM instructions that calculate EAX * 21 using binary multiplication. Hint: 21 = 24 + 22 + 20.

Give an assembly language program to move -128 in ax and expend eax. Using shift and rotate instruction.

Create a procedure Extended_Sbb procedure to subtract two 64-bit (8-byte) integers.

Using the following table as a guide, write a program that asks the user to enter an integer test score between 0 and 100. The program should display the appropriate letter grade:

Score Range	Letter Grade
90 to 100	A
80 to 89	B
70 to 79	C
60 to 69	D
0 to 59	F

Write a program that performs simple encryption by rotating each plaintext byte a varying number of positions in different directions. For example, in the following array that represents the encryption key, a negative value indicates a rotation to the left and a positive value indicates a rotation to the right. The integer in each position indicates the magnitude of the rotation:

key BYTE -2, 4, 1, 0, -3, 5, 2, -4, -4, 6

Your program should loop through a plaintext message and align the key to the first 10 bytes of the message. Rotate each plaintext byte by the amount indicated by its matching key array value.
Then, align the key to the next 10 bytes of the message and repeat the process.