EC-310 Microprocessor and Microcontroller Based Design

Chapter - 5

Arithmetic (Signed)

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Outline

1. Arithmetic Instructions
2. Signed Number Concepts and Arithmetic

Concept of Signed Numbers

- For signed numbers, the MSB has been reserved as the sign bit
- If MSB is 0, then it represents a positive number
- If MSB is 1, then it represents a negative number
- The rest of the seven bits are used for magnitude

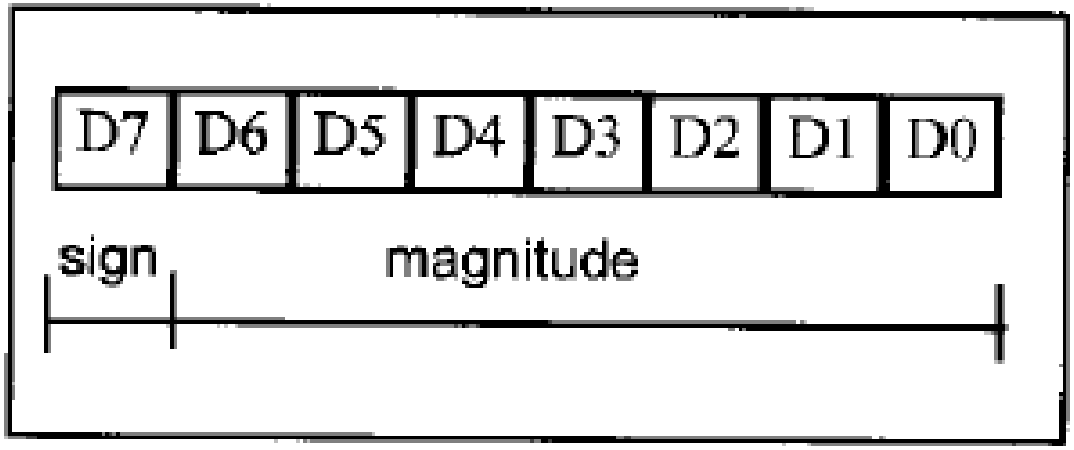
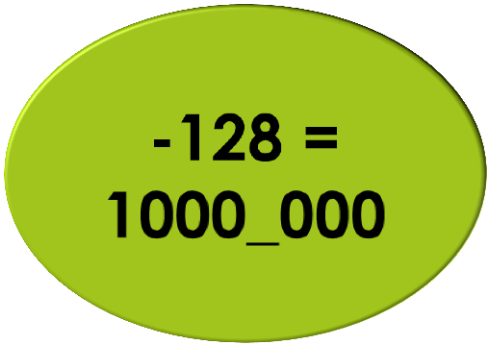


Figure 5-2. 8-Bit Signed Operand

Concept of Signed Numbers

- **Positive Numbers**
  - For positive numbers, MSB = 0.
  - The maximum positive number possible in seven bit representation is 127.
  - The minimum positive number possible is 0.
- **Negative Numbers**
  - For negative numbers, MSB = 1
  - The maximum number possible is -1
  - The minimum number possible is ?



Concept of Signed Numbers

Decimal	Binary	Hex
-128	1000 0000	80
-127	1000 0001	81
-126	1000 0010	82
...	.....	..
-2	1111 1110	FE
-1	1111 1111	FF
0	0000 0000	00
+1	0000 0001	01
+2	0000 0010	02
..	.....	..
+127	0111 1111	7F

Concept of Signed Numbers

Example 5-10

Show how the PIC would represent –5.

Solution:

Observe the following steps.

```
1.     0000 0101          5 in 8-bit binary
2.     1111 1010          invert each bit
3      1111 1011          add 1 (which becomes FB in hex)
```

Therefore, –5 = FBH, the signed number representation in 2's complement for –5. The D7 = N = 1 indicates that the number is negative.

Concept of Signed Numbers

Example 5-11

Show how the PIC would represent –34H.

Solution:

Observe the following steps.

```
1.     0011 0100          34H given in binary
2.     1100 1011          invert each bit
3      1100 1100          add 1 (which is CC in hex)
```

Therefore, –34 = CCH, the signed number representation in 2's complement for 34H. The D7 = N = 1 indicates that the number is negative.

Concept of Signed Numbers

Example 5-12

Show how the PIC would represent –128.

Solution:

Observe the following steps.

```
1.     1000 0000          128 in 8-bit binary
2.     0111 1111          invert each bit
3      1000 0000          add 1 (which becomes 80 in hex)
```

Therefore, –128 = 80H, the signed number representation in 2's complement for –128. The D7 = N = 1 indicates that the number is negative. Notice that 128 (binary 10000000) in unsigned representation is the same as signed –128 (binary 10000000).

Overflow problem is signed numbers

- PIC indicates the existence of an error by raising the OV flag.
- But it is up to the programmer to take care of the erroneous result.
- If the result of an operation on signed numbers is too large for the register, an overflow has occurred and the programmer is notified.

Overflow problem is signed numbers

Example 5-13

Examine the following code and analyze the result, including the N and OV flags.

```
MOVLW +D'96'        ;WREG = 0110 0000
ADDLW +D'70'        ;WREG = (+96) + (+70) = 1010 0110
                    ;WREG = A6H = -90 decimal, INVALID!!
```

Solution:

```
   +96    0110 0000
+  +70    0100 0110
+ 166    1010 0110   N = 1 (negative) and OV = 1. Sum = -90
```

According to the CPU, the result is negative (N = 1), which is wrong. The CPU sets OV = 1 to indicate the overflow error. Remember that the N flag is the D7 bit. If N = 0, the sum is positive, but if N = 1, the sum is negative.

When is the OV flag set?

- In 8-bit signed number operations, OV is set to 1 if either of the following two conditions occurs:
  - There is a carry from D6 to D7 but no carry out of D7 (C=0)
  - There is a carry from D7 out (C=1) but no carry from D6 to D7
  - If there is a carry both from D6 to D7 and from D7 out, OV=0.

When is the OV flag set?

Example 5-14

Observe the following, noting the role of the OV and N flags:

```
MOVLW -D'128'      ;WREG = 1000 0000 (WREG = 80H)
ADDLW -D'2'        ;W = (-128) + (-2)
                   ;W = 1000000 + 11111110 = 0111 1110,
                   ;N = 0, W = 7EH = +126, invalid
```

Solution:

```
  -128          1000 0000
+ - 2           1111 1110
- 130           0111 1110   N = 0 (positive) and OV = 1
```

According to the CPU, the result is +126, which is wrong, and OV = 1 indicates that.

When is the OV flag set?

Example 5-15

Observe the following, noting the OV and N flags:

```
MOVLW -D'2'          ;WREG = 1111 1110 (WREG = FEH)
ADDLW -D'5'          ;WREG = (-2) + (-5) = -7 or F9H
                     ;correct, since OV = 0
```

Solution:

```
   -2     1111 1110
 + -5     1111 1011
  - 7     1111 1001   and OV = 0 and N = 1. Sum is negative
```

According to the CPU, the result is –7, which is correct, and the OV flag indicates that. (OV = 0).

When is the OV flag set?

Example 5-16

Examine the following, noting the role of the OV and N flags:

```
MOVLW +D'7'          ;WREG = 0000 0111
ADDLW +D'18'         ;W = (+7) + (+18)
                     ;W = 00000111 + 00010010 = 0001 1001
                     ;W = (+7) + (+18) = +25, N = 0, positive and
                     ;correct, OV = 0
```

Solution:

```
   + 7 0000 0111
+ +18 0001 0010
  +25 0001 1001   N = 0 (positive 25) and OV = 0
```

According to the CPU, this is +25, which is correct and OV = 0 indicates that.