**10 .... 0(2)=2^n**

**n**

**1... .... 1(2)= 10.....0(2) -1(2)= 2^n -1**

**n n**

**Integer numbers – codes and operations in complementary code**

**Example 1**

**n=8 bits**

**X= 60= 32+16+8+4=2^5+2^4+2^3+2^2=111100(2)**

**Y= 80 = 64+16 = 2^6+2^4=1010000(2)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7 6 5 4 3 2 1 0** | | | | | | | |
| **[60] dir = [60]inv= [60]compl =** | **0** | **0** | **1** | **1** | **1** | **1** | **0** | **0** |
| **[-60]dir =** | **1** | **0** | **1** | **1** | **1** | **1** | **0** | **0** |
| **[-60]inv =** | **1** | **1** | **0** | **0** | **0** | **0** | **1** | **1** |
| **[-60]compl =** | **1** | **1** | **0** | **0** | **0** | **1** | **0** | **0** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7 6 5 4 3 2 1 0** | | | | | | | |
| **[80] dir = [80]inv= [80]compl=** | **0** | **1** | **0** | **1** | **0** | **0** | **0** | **0** |
| **[-80]dir =** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **0** |
| **[-80]inv =** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** |
| **[-80]compl =** | **1** | **0** | **1** | **1** | **0** | **0** | **0** | **0** |

**[60+80]compl = [60]compl Å [80]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S 1** | | | | | | | |  | **Overflow, because the operands are positive and the result is negative.** |
| **[60]compl =** |  | **0** | **0** | **1** | **1** | **1** | **1** | **0** | **0** | **Å** |
| **[80]compl =** |  | **0** | **1** | **0** | **1** | **0** | **0** | **0** | **0** |  |
|  |  | **1** | **0** | **0** | **0** | **1** | **1** | **0** | **0** |  |

**[60-60]compl = [60]compl Å [-60]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  |  |
| **[60]compl =** |  | **0** | **0** | **1** | **1** | **1** | **1** | **0** | **0** | **Å** |
| **[-60]compl =** |  | **1** | **1** | **0** | **0** | **0** | **1** | **0** | **0** |  |
| **[0]compl** | **~~1~~** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |  |

**[80-60]compl = [80]compl Å [-60]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  | **2^2+2^4=20**  **Correct result** |
| **[80]compl =** |  | **0** | **1** | **0** | **1** | **0** | **0** | **0** | **0** | **Å** |
| **[-60]compl =** |  | **1** | **1** | **0** | **0** | **0** | **1** | **0** | **0** |  |
| **[20]compl** | **~~1~~** | **0** | **0** | **0** | **1** | **0** | **1** | **0** | **0** |  |

**[-80+60]compl = [-80]compl Å [60]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  | **-(2^2+2^4)=-20** |
| **[-80]compl** |  | **1** | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **Å** |
| **[60]compl =** |  | **0** | **0** | **1** | **1** | **1** | **1** | **0** | **0** |  |
| **[-20]compl** |  | **1** | **1** | **1** | **0** | **1** | **1** | **0** | **0** | **result** |
|  |  | **0** | **0** | **0** | **1** | **0** | **1** | **0** | **0** |  | **complement** |

**Subunitary numbers – codes and operations in complementary code**

**Example 2**

**n=8 bits**

**X= 0,43=0,334(8)=0,011011100(2)**

**0,43\*8=3,44**

**0,44\*8=3,52**

**0.52\*8=4,16**

**Y=**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7, 6 5 4 3 2 1 0** | | | | | | | |
| **[0,43] dir = [0,43]inv= [0,43]compl =** | **0** | **0** | **1** | **1** | **0** | **1** | **1** | **1** |
| **[-0,43]dir =** | **1** | **0** | **1** | **1** | **0** | **1** | **1** | **1** |
| **[-0,43]inv =** | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **0** |
| **[-0,43]compl =** | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **1** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7, 6 5 4 3 2 1 0** | | | | | | | |
| **[0.76] dir = [0.76]inv= [0.76]compl=** | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **1** |
| **[-0,76]dir =** | **1** | **1** | **1** | **0** | **0** | **0** | **0** | **1** |
| **[-0,76]inv =** | **1** | **0** | **0** | **1** | **1** | **1** | **1** | **0** |
| **[-0.76]compl =** | **1** | **0** | **0** | **1** | **1** | **1** | **1** | **1** |

**[0,43+0,76]compl = [0,43]compl Å [0,76]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,43]compl** |  | **0** | **0** | **1** | **1** | **0** | **1** | **1** | **1** | **Å** | **Overflow because both operands are positive nb and the result is negative** |
| **[0,76]compl** |  | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **1** |  |
|  |  | **1** | **0** | **0** | **1** | **1** | **0** | **0** | **0** |  |

**[0,43-0,43]compl = [0,43]compl Å [-0,43]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,43]compl** |  | **0** | **0** | **1** | **1** | **0** | **1** | **1** | **1** | **Å** | **Correct result** |
| **[-0,43]compl** |  | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **1** |  |
| **[0]compl** | **~~1~~** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |  |

**[0,76-0,43]compl = [0,76]compl Å [-0,43]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,76]compl** |  | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **1** | **Å** | **2^-2+2^-4+2^-6=**  **0,328125** |
| **[-0,43]compl** |  | **1** | **1** | **0** | **0** | **1** | **0** | **0** | **1** |  |
|  | **~~1~~** | **0** | **0** | **1** | **0** | **1** | **0** | **1** | **0** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

**Example 3: Represent in fixed-point notation, on 32 bits, I=14, the number 3000,76**

**3000,76 = 101110111000, 110000101000111101(2)**

**3000=5670(8)=101110111000(2)**

**3000/8 = 375 r 0**

**375/8 = 46 r 7**

**46/8 = 5 r 6**

**5/8 = 0 r 5**

**0,76=0,605075(8)=0,110000101000111101(2)**

**0,76\*8=6.08**

**0,08\*8 = 0,64**

**0,64\*8 = 5,12**

**0,12\*8= 0,98**

**0,96\*8 = 7,68**

**0,68\*8=5,44**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| s | I=14 bits, integer part -> , <- F=17 bits , fractional part | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | | | | 7 | | | | 7 | | | | 1 | | | | 8 | | | | | 5 | | | | 1 | | | | E | | | |

**Example 4: Represent in floating point notation, single precision (SP), with mantissa<1, the number: 3000,76**

**3000,76=101110111000,110000101000111101(2)=**

**= 0,1101110111000110000101000111101(2)\*2^12**

**e=12(exponent)**

**c= e+ q=12+127=139=128+8+2+1=2^7+2^3+2^1+2^0=010001011(2)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | c=e+127 (8 bits) -> , <- mantissa (23 bits) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | | 1 | 1 | 1 | 0 | | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
|  | | | |  | | | |  | | | |  | | | | |  | | | | |  | | | |  | | | |  | | | |

**Example 5: Find the real number X having C58EBF00 its fixed-point representation on 32 bits with I=15 bits.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | I=15 bits, integer part -> , <- F=16 bits , fractional part | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | | 1 | 1 | 1 | 0 | | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | | | | 5 | | | | 8 | | | | E | | | | | B | | | | | F | | | | 0 | | | | 0 | | | |

X=-100010110001110,1011111100000000 (2)

= - (2 ^ 14 + 2 ^ 10 + 2 ^ 8 + 2 ^ 7 + 2 ^ 3 + 2 ^ 2 + 2 + 2 ^ -1 + 2 ^ -3 + 2 ^ -4 + 2 ^ -5 + 2 ^ - 6 + 2 ^ -7 + 2 ^ -8) =

=-17806, 76171875

**Example 6:** **Find the real number X having C58EBF00 as its floating-point representation, SP, m>1.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | c=e+127 (8 bits) -> , <- mantissa (23 bits) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | | 1 | 1 | 1 | 0 | | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | | | | 5 | | | | 8 | | | | E | | | | | B | | | | | F | | | | 0 | | | | 0 | | | |

c= 10001011(2) = 1+2+8+128 = 139

e= 139-127 = 12

1 hidden bit

X=-1,00011101011111100000000(2)\*2^12 = -1000111010111,11100000000(2) =

= -(1+2+4+16+64+128+256+4096+0.5+0.25+0.125)= -4567.875