**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= 47=32+8+4+2+1=2^5+2^3+2^2+2^1+2^0=101111(2)**

**Y= 96=64+32=2^6+2^5=1100000(2)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7 6 5 4 3 2 1 0** | | | | | | | |
| **[47] dir = [47]inv= [47]compl =** | **0** | **0** | **1** | **0** | **1** | **1** | **1** | **1** |
| **[-47]dir =** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **1** |
| **[-47]inv =** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **0** |
| **[-47]compl =** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **1** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 6 5 4 3 2 1 0** | | | | | | | |
| **[96] dir = [96]inv= [96]compl=** | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **0** |
| **[-96]dir =** | **1** | **1** | **1** | **0** | **0** | **0** | **0** | **0** |
| **[-96]inv =** | **1** | **0** | **0** | **1** | **1** | **1** | **1** | **1** |
| **[-96]compl =** | **1** | **0** | **1** | **0** | **0** | **0** | **0** | **0** |

**[47+96]compl = [47]compl  [96]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  | **Overflow because the operands are positive numbers and the result is negative(signed bit is 1)** |
| **[47]compl =** |  | **0** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **** |
| **[96]compl =** |  | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **0** |  |
|  |  | **1** | **0** | **0** | **0** | **1** | **1** | **1** | **1** |  |

**[96-47]compl = [96]compl  [-47]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  | **Correct result**  **2^0+2^4+2^5=1+16+32=49** |
| **[96]compl =** |  | **0** | **1** | **1** | **0** | **0** | **0** | **0** | **0** | **** |
| **[-47]compl =** |  | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **1** |  |
| **[49]compl** | **~~1~~** | **0** | **0** | **1** | **1** | **0** | **0** | **0** | **1** |  |

**[47-96]compl = [47]compl  [-96]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S** | | | | | | | |  | **Correct result**  **-(1+2^4+2^5)=-(1+16+32)=-49** |
| **[47]compl=** |  | **0** | **0** | **1** | **0** | **1** | **1** | **1** | **1** | **** |
| **[-96]compl =** |  | **1** | **0** | **1** | **0** | **0** | **0** | **0** | **0** |  |
| **[-49]compl** |  | **1** | **1** | **0** | **0** | **1** | **1** | **1** | **1** |  |
|  |  | **0** | **0** | **1** | **1** | **0** | **0** | **0** | **1** |  | **complement** |

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

**Example 2**

**n=8 bits**

**X= 0,31 = 0,0100111(2)**

**0,31\*2= 0,62**

**0,62 \* 2 =1,24**

**0,24 \* 2 = 0,48**

**0,48 \* 2 = 0, 96**

**0,96 \* 2 = 1,92**

**0,92 \* 2 = 1,84**

**0,84 \* 2 =1,68**

**Y= 0,73 = 0,565(8)= 0,101110101(2)**

**0,73\*8= 5,84**

**0,84 \* 8 = 6,72**

**0,72 \* 8 = 5,76**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7, 6 5 4 3 2 1 0** | | | | | | | |
| **[0,31] dir = [0,31]inv= [0,31]compl =** | **0** | **0** | **1** | **0** | **0** | **1** | **1** | **1** |
| **[-0,31]dir =** | **1** | **0** | **1** | **0** | **0** | **1** | **1** | **1** |
| **[-0,31]inv =** | **1** | **1** | **0** | **1** | **1** | **0** | **0** | **0** |
| **[-0,31]compl =** | **1** | **1** | **0** | **1** | **1** | **0** | **0** | **1** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **positions** | **S 7, 6 5 4 3 2 1 0** | | | | | | | |
| **[0,73] dir = [0,73]inv= [0,73]compl=** | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **1** |
| **[-0,73]dir =** | **1** | **1** | **0** | **1** | **1** | **1** | **0** | **1** |
| **[-0,73]inv =** | **1** | **0** | **1** | **0** | **0** | **0** | **1** | **0** |
| **[-0,73]compl =** | **1** | **0** | **1** | **0** | **0** | **0** | **1** | **1** |

**[0,31+0,73]compl = [0,31]compl  [0,73]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,31]compl =** |  | **0** | **0** | **1** | **0** | **0** | **1** | **1** | **1** | **** | **Overflow because the operands are positive and the result is negative** |
| **[0,73]compl =** |  | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **1** |  |
|  |  | **1** | **0** | **0** | **0** | **0** | **1** | **0** | **0** |  |

**[0,31-0,31]compl = [0,31]compl  [-0,31]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,31]compl =** |  | **0** | **0** | **1** | **0** | **0** | **1** | **1** | **1** | **** | **Correct result: 0** |
| **[-0,31]compl =** |  | **1** | **1** | **0** | **1** | **1** | **0** | **0** | **1** |  |
| **[0]compl** | **~~1~~** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |  |

**[0,73-0,31]compl = [0,73]compl  [-0,31]compl**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **S ,** | | | | | | | |  |  |
| **[0,73]compl** |  | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **1** | **** | **Correct result**  **2^(-2)+2^(-3)+2^(-5)+2^(-6)=¼+1/8+1/32+1/64=0,25+0,125+ 0,03125+0,015625=0,421875** |
| **[-0,31]compl =** |  | **1** | **1** | **0** | **1** | **1** | **0** | **0** | **1** |  |
|  | **~~1~~** | **0** | **0** | **1** | **1** | **0** | **1** | **1** | **0** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

**Example 3: Represent in fixed-point notation, on 32 bits, I=14 bits, the number 3456,73**

**3456,73= 110 110 000 000, 101 110 101 110 000 101(2)**

**3456=6600(8) = 110 110 000 000(2)**

**3456:8=432 r 0**

**432:8 = 54 r 0**

**54:8 = 6 r 6**

**6:8 = 0 r 6**

**0,73 = 0,565605(8)= 0,101 110 101 110 000 101(2)**

**0,73\*8= 5,84**

**0,84 \* 8 = 6,72**

**0,72 \* 8 = 5,76**

**0.76 \* 8 = 6. 08**

**0.08 \* 8 = 0.64**

**0.64 \* 8 = 5.12**

**1011(2)=2^0+2^1+2^3=13=D(16)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | I=14 bits, integer part -> , <- F=17 bits, fractional part | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | | | | | B | | | | 0 | | | | 1 | | | | 7 | | | | 5 | | | | C | | | | 2 | | | |

**Example 4: Represent in floating point notation, single precision (SP), with mantissa<1, the number: 3456,73**

**3456,73= 110 110 000 000, 101 110 101 110 000 101(2)=**

**= 0,110 110 000 000101 110 101 110 000 101(2) \*2^12**

**c = 127 + 12 = 139= 128 + 8 + 2 +1 = 2^ 7+ 2^3 + 2^1 + 2^0 = 10001011(2)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | c=e+127 (8bits) -> , <- mantissa (23bits) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 4 | | | | | 5 | | | | E | | | | C | | | | 0 | | | | 5 | | | | D | | | | 7 | | | |

**Example 5: Find the real number X having C504A800 its fixed-point representation on 32 bits with I=17 bits.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | I=17 bits, integer part -> , <- F=14 bits, fractional part | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | | | | 5 | | | | 0 | | | | 4 | | | | A | | | | 8 | | | | 0 | | | | 0 | | | |

X = -10001010000010010,10100000000000(2) = -(2^17+2^13+2^11+2^4+2^1+2^-1+2^-3)

= -(131072+8192+2048+16+2+0,5+0,125) = -141330,625

**X = -141330,625**

**Example 6:** **Find the real number X having C504A800 as its floating-point representation, SP, m>1.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | c=e+127 (8bits) -> , <- mantissa (23bits) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | | | | | 5 | | | | 0 | | | | 4 | | | | A | | | | 8 | | | | 0 | | | | 0 | | | |

c= 10001010(2) = 2^1 + 2^3 + 2^7 = 2 + 8 + 128 = 138

e= 138 – 127 = 11

X = -1,000010010101(2) \* 2 ^ 11

= -100001001010,1(2)

= -(2^1 + 2^3 + 2^6 + 2^11 + 2^(-1)) = -(2 + 8 + 64 + 2048 + 0.5) = - (74 + 2048 + 0.5) =

= -2122.5