ELECTRONIC PRINCIPLES AND DEVICES

Unit 4 –DIGITAL ELECTRONICS

ELECTRONIC PRINCIPLES AND DEVICES

Number Systems – binary and hexadecimal, Binary Addition and Subtraction, 2’s complement subtraction.

Department of Electronics and Communication.

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Introduction

Digital electronics is a branch that deals with circuits and systems using digital signals.

Works with discrete signals represented by binary values— 0 and 1.

These binary values correspond to two voltage levels, typically representing "low" (0) and "high" (1).

Number System

Each number system is characterized by its **base** or **radix**, which determines the number of symbols used.

Base (or **Radix**) refers to the number of unique digits or symbols used in a number system.

For example: The **decimal system** has a base of 10, using digits 0 to 9.
The **binary system** has a base of 2, using digits 0 and 1.
The **hexadecimal system** has a base of 16, using digits 0 to 9 and letters A to F.

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Binary Number System

Key features

- The **binary number system** is a base-2 system that uses only two digits: **0** and **1**.

- Each digit in a binary number is called a **bit** (short for "binary digit").

- **Place Value:** Each bit in a binary number represents a specific power of 2, starting from 2^0 (rightmost bit) and increasing to 2^1 ,2^2,2^3, etc., as you move leftward.

- **Representation of Numbers:**
  Any numerical value can be represented in binary form using combinations of 0s and 1s.

The number of **bits** in a binary number determines the total number of unique combinations or values that can be represented.

If n is the number of bits, the maximum number values that can be represented using n bits equals 2^n

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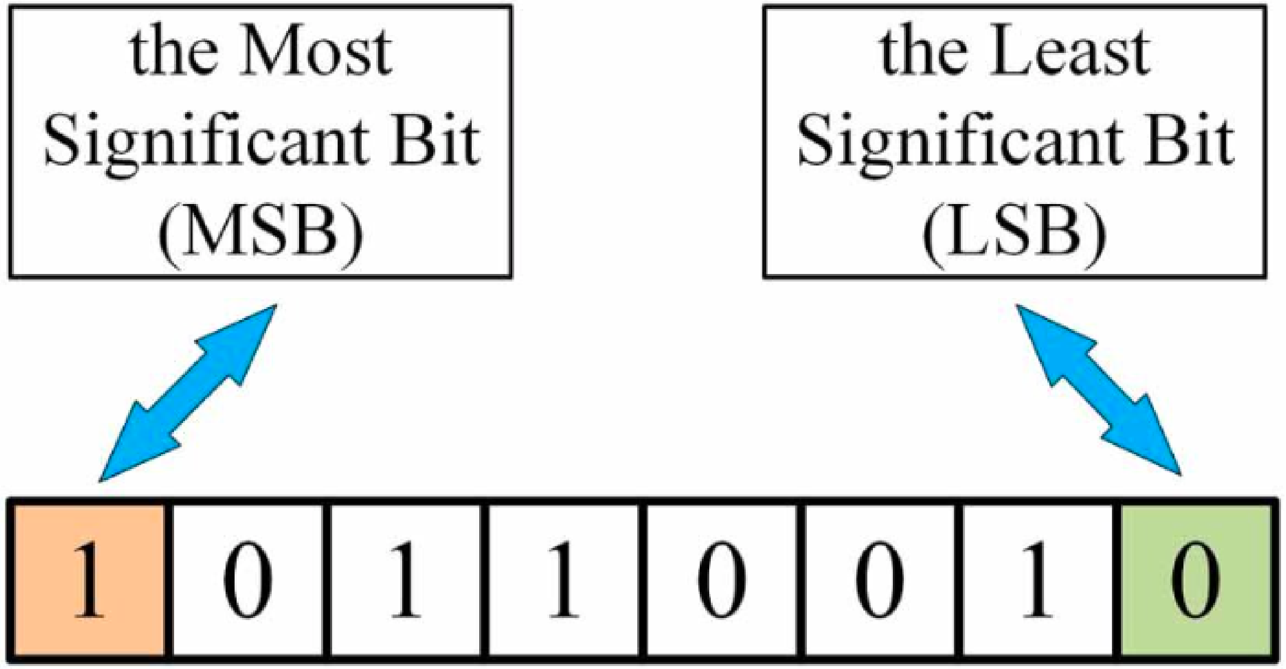
- In a binary number, the rightmost bit is called the **Least Significant Bit (LSB)** and the left most bit is the **Most Significant Bit (MSB).**



The place value of the LSB is 2^0 and the next digits to the left gets the place value in terms of increasing powers of 2. In the above number, the place value of MSB is 2^7.

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- Range of Values for Unsigned Binary Numbers
  In **unsigned binary**, all values are non-negative, starting from 0.

  Range= 0 to (2^n-1)

  For ex: With n=1 bit: no of values is 2^1=2 values (0,1)
  With n=2 bits: no of values is 2^2=4 values (00,01,10,11), 0 to 3 in decimal.
  With n= 3 bits: 2^3=8 values (000-111), 0 to 7 in decimal

- Range of Values for Signed Binary Numbers:
  In **signed binary**, one bit is reserved as the **sign bit** (0 for positive, 1 for negative).

  Range= -2^{n-1} to ($2^{n-1}-1$)

  For ex: With 2 bits: 2^2=4 values (−2 to 1), −2,−1,0,1,2
  With 3 bits: 2^3=8 values (−4 to 3), −4,−3,−2,−1,0,1,2,3

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2 bit binary

Representation	Range
00	0
01	1
10	2
11	3

3 bit binary

Representation	Range
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

4 bit binary

Representation	Range
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

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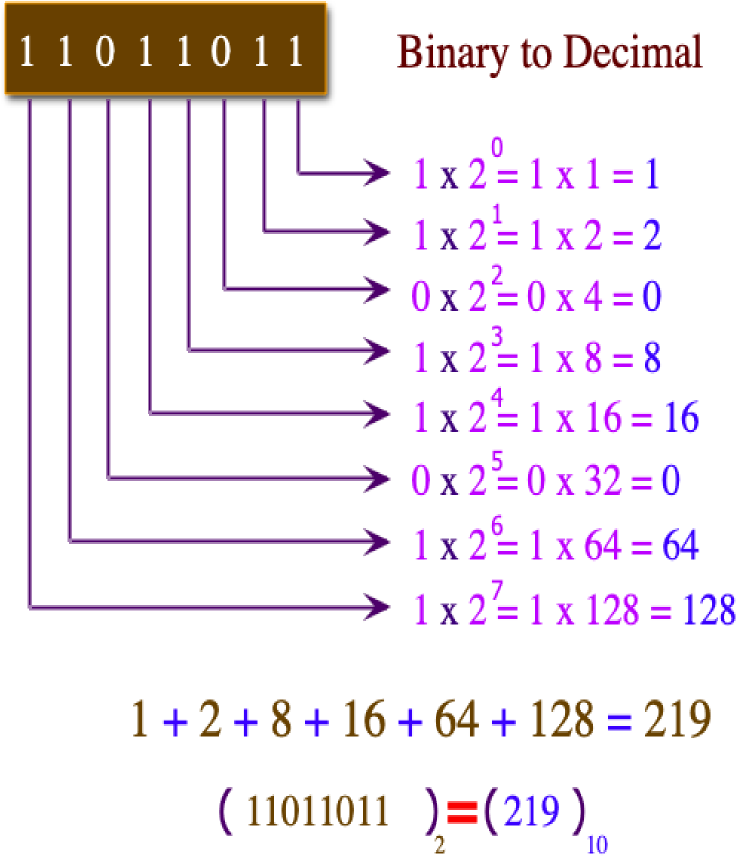
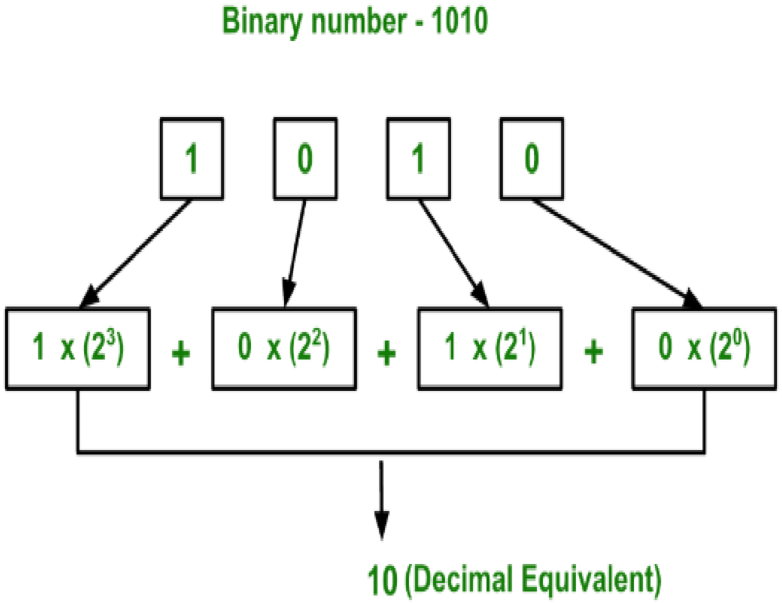
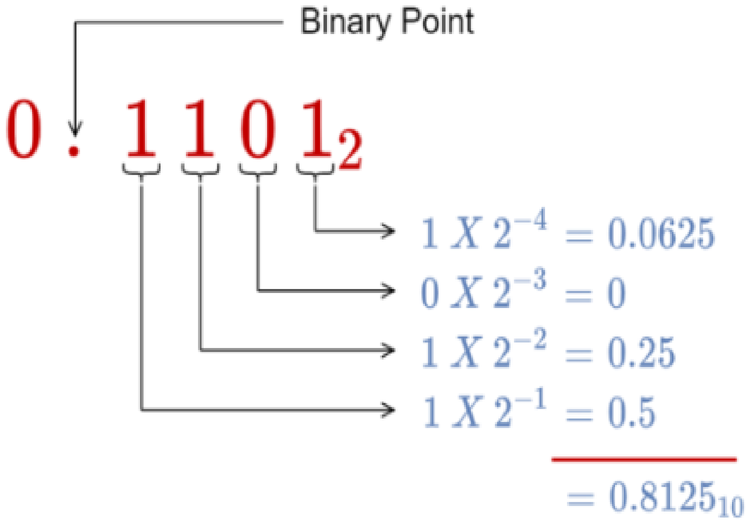
Binary to Decimal Conversion:

- Multiply each binary digit by the value of its position or place value (power of 2).
- Add all the products together to get the decimal equivalent







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Convert the following binary numbers to its decimal equivalent

a) 1011

Starting from LSB,

$1\times 2^0 + 1\times 2^1 + 0 \times 2^2 + 1 \times 2^3$

$=1+2+0+8 = 11$

$(1011)_2 = (11)_{10}$

b) 11010

$(11010)_2 = (26)_{10}$

c) 1111101

$(1111101)_2 = (127)_{10}$

d) 101.01011

$$101_2 = (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$

$$= (1 \times 4) + (0 \times 2) + (1 \times 1)$$

$$= 4 + 0 + 1 = 5$$

$$.01011_2 = (0 \times 2^{-1}) + (1 \times 2^{-2}) + (0 \times 2^{-3}) + (1 \times 2^{-4}) + (1 \times 2^{-5})$$

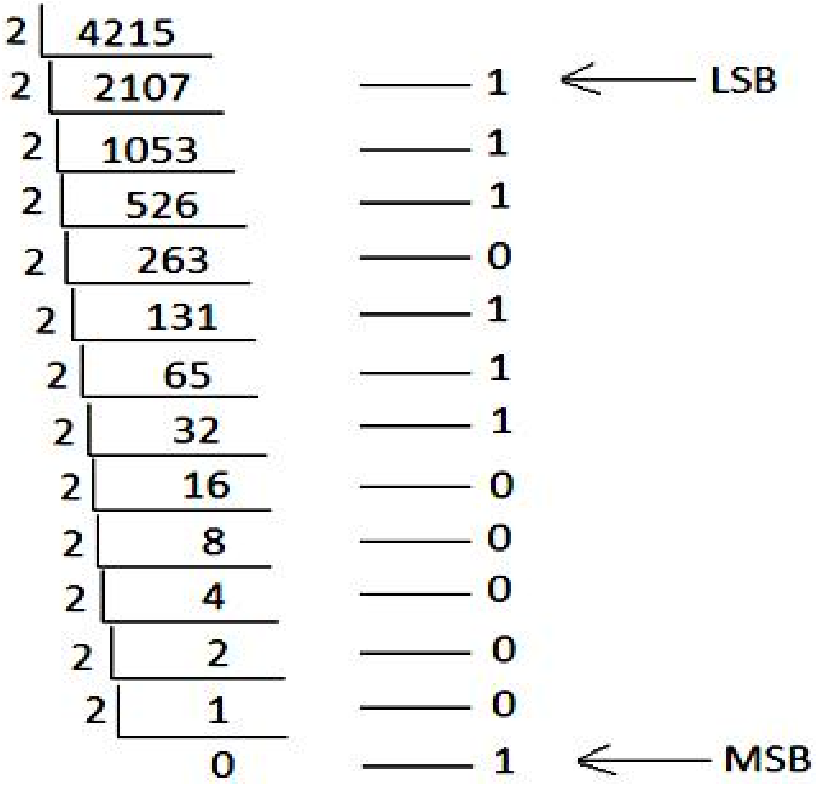
$$= 0 + \frac{1}{4} + 0 + \frac{1}{16} + \frac{1}{32}$$

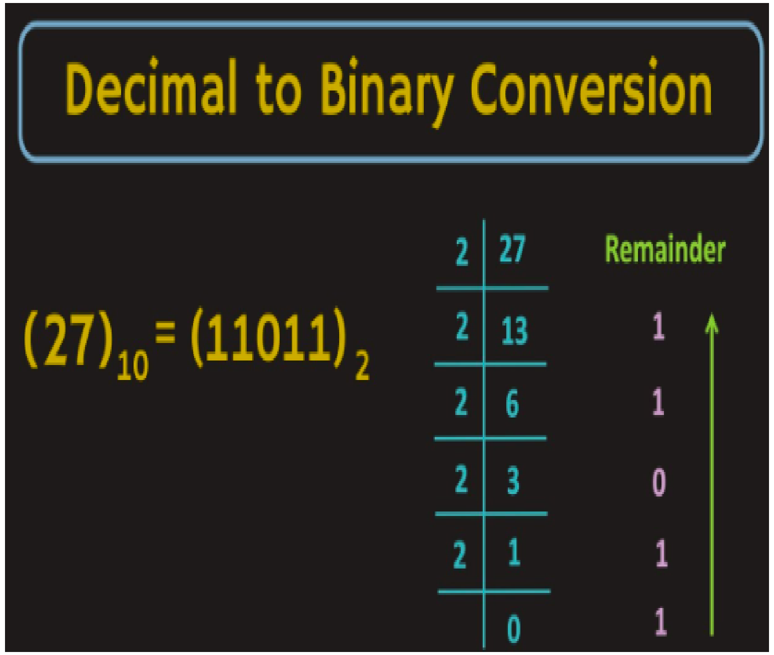
$$= 0 + 0.25 + 0 + 0.0625 + 0.03125 = 0.34375$$

$$101.01011_2 = 5.34375_{10}$$

Decimal to Binary Conversion

- Divide the Decimal Number by 2.
- Record the quotient and the remainder.
- Repeat the division by 2 until the quotient is 0.
- The last remainder represents the MSB and the first remainder represents the LSB. The remainders represent the equivalent binary number





Convert $(0.6875)_{10}$ to binary.

	Integer		Fraction
$0.6875 \times 2 =$	1	+	0.3750
$0.3750 \times 2 =$	0	+	0.7500
$0.7500 \times 2 =$	1	+	0.5000
$0.5000 \times 2 =$	1	+	0.0000

$(0.6875)_{10} = (0.1011)_2$

Convert the decimal number 41 to binary.

	Integer Quotient		Remainder	Coefficient
$41/2 =$	20	+	$\frac{1}{2}$	$a_0 = 1$
$20/2 =$	10	+	0	$a_1 = 0$
$10/2 =$	5	+	0	$a_2 = 0$
$5/2 =$	2	+	$\frac{1}{2}$	$a_3 = 1$
$2/2 =$	1	+	0	$a_4 = 0$
$1/2 =$	0	+	$\frac{1}{2}$	$a_5 = 1$

$(41)_{10} = (101001)_2$

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Hexadecimal Number System

The **hexadecimal (base-16)** number system is a positional numeral system that uses **16 distinct symbols** to represent values.

Symbols Used:

- **Digits:** 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- **Letters:** A, B, C, D, E, F
  (where A = 10, B = 11, C = 12, D = 13, E = 14, F = 15 in decimal).

•**Place Values:**
Each digit in a hexadecimal number represents a power of 16, starting from 16^0 at the rightmost position

Ex: 1A316, 2AC

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

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Hexadecimal to Decimal Conversion

- Convert each hexadecimal bit into its decimal equivalent.
- Multiply each bit by the value of its position or place value (power of 16).
- Add all the products together to get the decimal equivalent

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

2F36

$6\times 16^0 + 3\times 16^1 + 15 \times 16^2 + 2 \times 16^3$

= 8192+3840+48+6

=12086

$(B65F)_{16}$

$$(B65F)_{16} = 11 \times 16^3 + 6 \times 16^2 + 5 \times 16^1 + 15 \times 16^0 = (46{,}687)_{10}$$

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Decimal to Hexadecimal Conversion

Divide the Decimal Number by 16

Divide the decimal number by 16. The quotient will be used for the next division, and the remainder will be one of the hexadecimal digits.

Record the Remainder

The remainder of each division corresponds to a hexadecimal digit. If the remainder is between 10 and 15, use the hexadecimal letters:

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Repeat the Division

Divide the quotient by 16 again, and continue recording the remainders until the quotient is 0.

Read the Remainders in Reverse Order

The remainders, when read from last to first, form the hexadecimal representation of the decimal number.

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Example 1: Convert 255 (Decimal) to Hexadecimal
Step 1: Divide 255 by 16:

$$255 \div 16 = 15 \text{ (quotient)} \quad \text{remainder} = 15$$

Step 2: Divide the quotient (15) by 16:

$$15 \div 16 = 0 \text{ (quotient)} \quad \text{remainder} = 15$$

Step 3: The quotient is now 0, so stop dividing.

Step 4: Read the remainders in reverse order: The remainders, from last to first, are F and F.
Thus, **255 (decimal) = FF (hexadecimal)**.

1’s Complement

One’s Complement

If all bits in a byte are inverted by changing each 1 to 0 and each 0 to 1, we have formed the one’s complement of the number.

```
Original      One's Complement
------------------------------
10011001  -->  01100110
10000001  -->  01111110
11110000  -->  00001111
11111111  -->  00000000
00000000  -->  11111111
```

1’s Complement Representation in Signed Magnitude :

In sign-magnitude, 6 is a positive number, its binary representation is 0000 0110, and it will be represented as it is, i.e. 0000 0110.

Whereas a negative number suppose -6 will be represented as 1111 1001

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2’s Complement

To form the two’s complement, add 1 to the one’s complement.

Step 1: Begin with the original binary value

```
    10011001  Original byte
```

Step 2: Find the one's complement

```
    01100110  One's complement
```

Step 3: Add 1 to the one's complement

```
    01100110  One's complement
  +        1  Add 1
    -----------
    01100111  <---  Two's complement
```

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2's Complement

2's Complement Representation in Signed Magnitude :

For signed binary numbers the most significant bit (MSB) is used as the sign bit.
If the sign bit is "0", this means the number is positive in value.
If the sign bit is "1", then the number is negative in value.

Positive Signed Binary Number

2's complement representation of 5 = 00000101

Negative Signed Binary Number

For -5
First take 5 into binary= 00000101
take 1's Complement = 11111 010
add 1 to it + 1

11111011 → 2's Complement of -5

Binary Addition using 2’s Complement

(1): 8 + 5 = ?
2’s complement representation of 8 = 00001000
2’s complement representation of 5 = 00000101
Since 8 and 5 are positive, so their 2’complement representation will be the same as its true (uncomplemented) form.

```
   0 0 0 0 1 0 0 0
+  0 0 0 0 0 1 0 1
-----------------
   0 0 0 0 1 1 0 1
```

Sum: 0 0 0 0 1 1 0 1

Sign bit is zero, so the result is a positive number

```
   8
+  5
-----
  13
```

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13 => 00001101

Binary Addition using 2's Complement

(2) 8 + (-5) = ?

This example can also be read as 8 – 5 = ?

2's complement representation of 8 = 00001000

2's complement representation of -5 = 11111011

```
                 0 0 0 0 1 0 0 0
              +  1 1 1 1 1 0 1 1
              ------------------
Discard Carry  1 0 0 0 0 0 0 1 1

Sum: 0 0 0 0 0 0 1 1
```

Sign bit is zero, so the result is a positive number

```
   8
+ -5
----
   3
```

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3 => 00000011

Binary Subtraction using 2’s Complement

(1) Subtract (1010)2 from (1111)2 using 2’s complement method.

Solution:

Step-1: 2’s complement of (1010)2 is (0110)2.

Step-2: Add (0110)2 to (1111)2. This is shown below.

method of 2s complement subtraction of smaller number from a larger number

$$
\begin{array}{rcccc}
 & 1 & 1 & 1 & 1 \\
+ & & & & \\
 & 0 & 1 & 1 & 0 \\
\hline
\text{Omit this carry } 1 & 0 & 1 & 0 & 1
\end{array}
$$

$$\boxed{0\ 1\ 0\ 1}\ \textit{Answer}$$

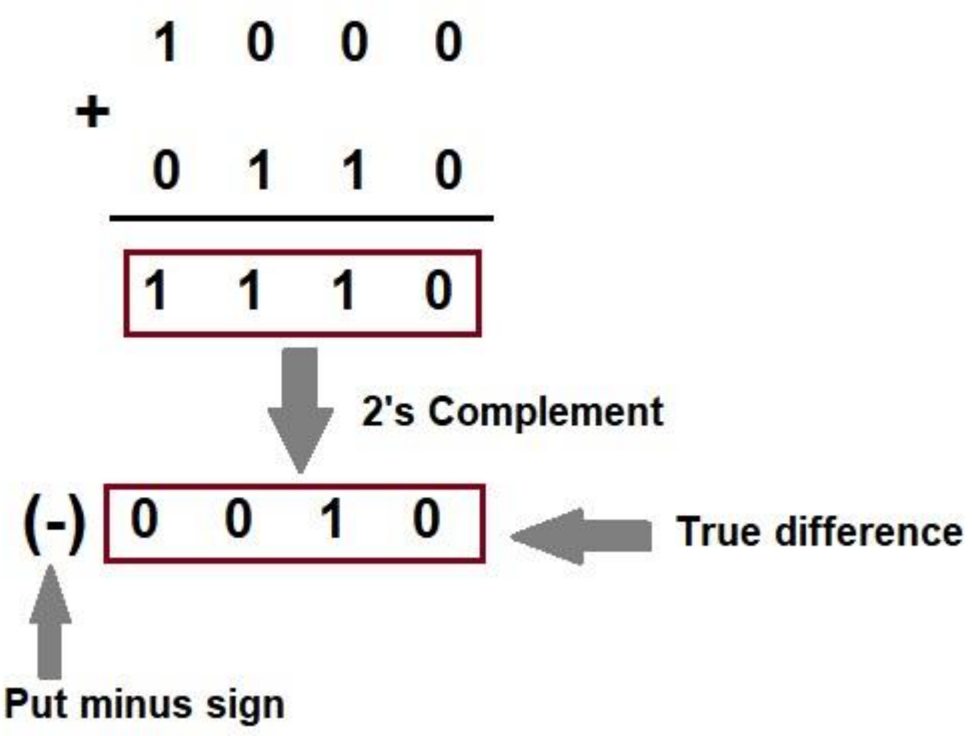
Binary Subtraction using 2's Complement

(1) ***Example-2:*** Subtract $(1010)_2$ from $(1000)_2$ using 2's complement.

Solution:

Step-1: Find the 2's complement of $(1010)_2$. It is $(0110)_2$.

Step-2: Add $(0110)_2$ to $(1000)_2$.



THANK YOU

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