Depending upon the level of communication required between the computer and hardware, any base system can be converted into another base system. In computing, the most important conversions are:

- base 10 to base 2 (decimal to binary),
- base 2 to base 10 (binary to decimal),
- base 2 to base 16 (binary to hexadecimal), and
- base 16 to base 2 (hexadecimal to binary).

Fully understanding integrated circuits, low-level programming, interfacing, inputs, and outputs requires an understanding of the three major base systems (decimal, binary, hexadecimal) and the ability to convert among the three systems.

Base 10 to Base 2

The conversion from base 10 to base 2 relies on the arithmetic operation of division. To convert between base 10 and base 2, you must continually divide the base 10 number by 2 until the quotient is zero. The binary answer is found in the remainders collected in reverse.

Here are two examples of base 10 to base 2 conversion. Note that the number appearing in subscript indicates the base.

Example 1:

To convert

$$14_{10} = X_2$$

Collect the binary remainders in reverse (see Figure 4.1).

The answer is 1110. Therefore,

$$14_{10} = 1110_2$$

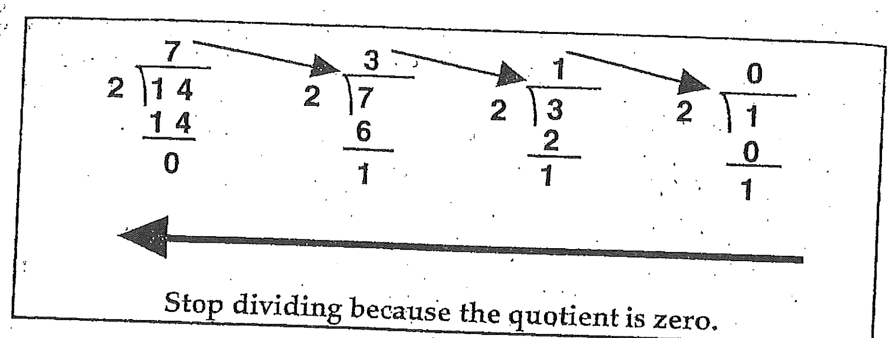

Figure 4.1 Base 10 to Base 2 (Example 1)

Example 2:

Convert

$$75_{10} = X_2$$

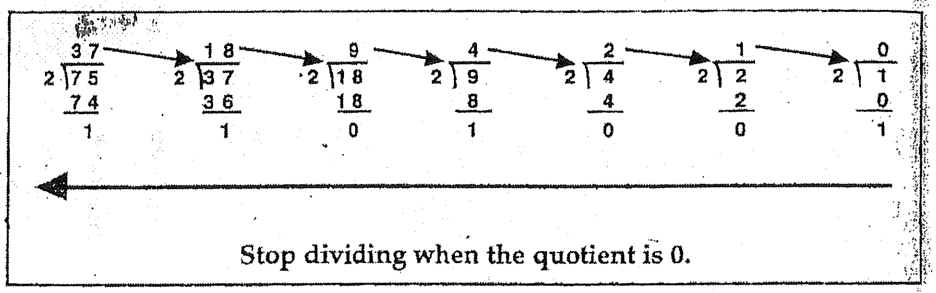

Figure 4.2 Base 10 to Base 2 (Example 2)

Collect the binary remainder in reverse.

The answer is 1001011. Therefore,

$$75_{10} = 1001011_2$$

Base 2 to Base 10

Converting from base 10 to base 2 requires many divisions. Since the conversion from base 2 (binary) to base 10 (decimal) is in the opposite direction, the arithmetic operation used to convert from binary to decimal is multiplication. To convert from base 2 to base 10, you must multiply each binary digit by a power of 2 and add the results to form the base 10 number.

Here is an example of a base 2 to base 10 conversion. Figure 4.3 shows the process for each digit.

Example 1:

Convert

$$10111_2 = X_{10}$$

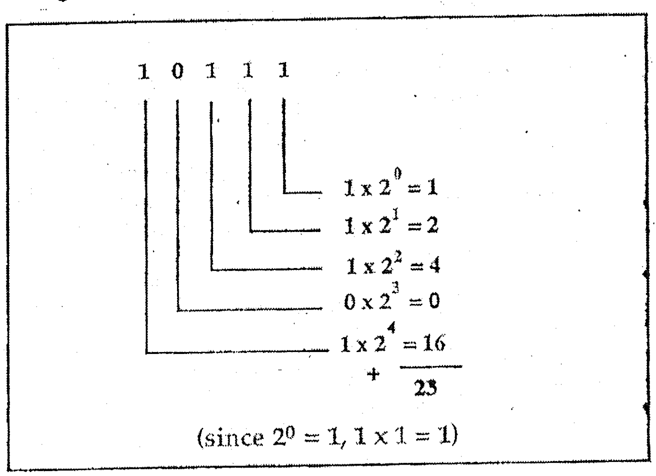

Figure 4.3 Base 2 to Base 10

Therefore

$$10111_2 = 23_{10}$$

Base 2 to Base 16

Base 16 is an important base system since binary values are often displayed in hexadecimal because hexadecimal numbers are shorter and easier to read. Each set of four bits converts into a single hexadecimal digit (see the chart in Section 4.1.1 for more information). Base 2 (binary) to base 16 (hexadecimal) is therefore called a **four-bit conversion.**

Here are two examples of base 2 to base 16 conversion.

Example 1:

Convert

$$10111000_2 = X_{16}$$

Divide the binary number in groups of four starting from the right-most digit.

$1000_2 = 8_{16}$ Therefore,

$1011_2 = B_{16}$ $10111000_2 = B8_{16}$

Example 2:

Convert

$$101111101_2 = X_{16}$$

Separate the binary number into 0001_2 | 0111_2 | 1101_2 so there are groups of four digits. Note that the leading digit is a 1. To make the four binary digit group, three leading 0s were added.

$1101_2 = D_{16}$

$0111_2 = 7_{16}$ Therefore,

$0001_2 = 1_{16}$ $1011\,1101_2 = 17D_{16}$

Base 16 to Base 2

The four-bit conversion process shown in the previous examples is also used to convert from base 16 (hexadecimal) to base 2 (binary). In these conversions, each hexadecimal digit is converted into four bits (see the chart in Section 4.1.1 for more information).

Here are two examples of base 16 to base 2.

Example 1:

Convert

$$A65_{16} = X_2$$

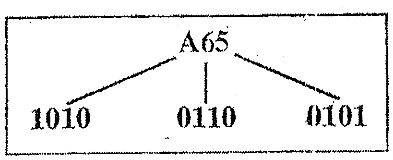

Figure 4.4 Base 16 to Base 2 (Example 1)

Therefore,

$$A65_{16} = 101001100101_2$$

Example 2:

Convert

$$13F_{16} = X_2$$

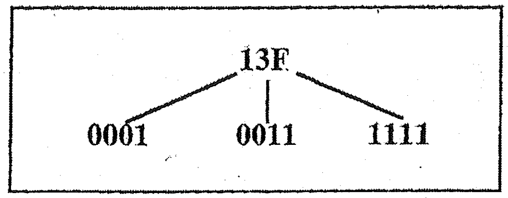

Figure 4.5 Base 16 to Base 2 (Example 2)

Therefore,

$$13F_{16} = 100111111_2$$

as the leading 0s can always be dropped.

4.1.5 Summary of Base Conversions

Conversions among base 2 (binary), base 16 (hexadecimal), and base 10 (decimal) can be accomplished by the methods described in the previous four sections. Base 10 numbers can be converted to any base using similar methods but these conversions are not as useful from a Computer Engineering point of view. The bases that are very useful are:

- base 10 - counting system used in most regular everyday transactions,
- base 2 - counting system used to represent the bits inside a computer as well as machine language programming, and
- base 16 – counting system used to display binary numbers as well as assembly language programming.

Figure 4.6 illustrates which method (multiply, divide, or a four-bit conversion) should be used to convert between the three bases.

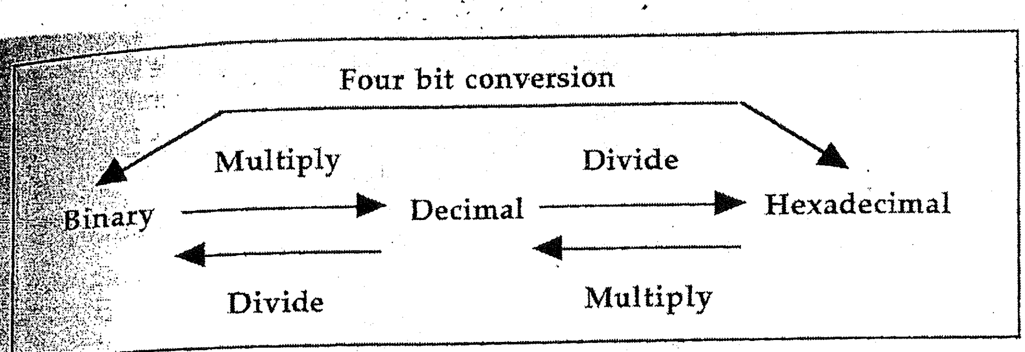

Figure 4.6 Base Conversion Summary