

# Base Conversion

When converting between bases we're primarily concerned with four bases used for numbers:  
2 (binary), 8 (octal), 10 (decimal), and 16 (hex).

As we'll show in a minute, converting between bases 2, 8, and 16 is fairly simple and painless. The only real work involves converting to or from decimal. Here's how that's done:

Suppose you have a decimal number, say,  $245_{10}$ . To convert to any other base from decimal (*and only from decimal!*) we use the **Div/Mod** technique. In this technique, you are determining what the coefficients are for the powers of the base – these coefficients are the digits of the number for that base.

Let's convert from decimal to octal:

**Note the desired base is used here**

$245_{10}$ :	$245 \text{ DIV } 8$	$= 30$	
	$245 \text{ MOD } 8$	$= 5$	Div = Division result as a whole number Mod = Remainder after division
	$30 \text{ DIV } 8$	$= 3$	
	$30 \text{ MOD } 8$	$= 6$	
	$3 \text{ DIV } 8$	$= 0$	
	$3 \text{ MOD } 8$	$= 3$	

Answer is:                      **3      6      5**

Answer:  $365_8$

Start at bottom of column and write the MOD results from left to right

Similarly, convert from decimal to hex (*note the conversion to hex digits*):

$245_{10}$ :	$245 \text{ DIV } 16$	$= 15$	
	$245 \text{ MOD } 16$	$= 5$	(Remember: $15_{10}$ is represented as $F_{16}$ in hex)
	$15 \text{ DIV } 16$	$= 0$	
	$15 \text{ MOD } 16$	$= 15$	

Answer is:                      **F 5**

Answer:                       $F5_{16}$

Now, to convert from any base to Decimal, use the **Powers of the Base** technique:

$$F5_{16} = 15 \cdot 16^1 + 5 \cdot 16^0 = 240 + 5 = 245_{10} \quad [\text{Note that we are using powers of 16}]$$

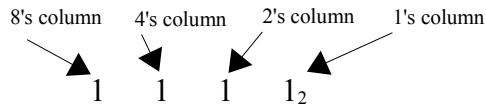
Another example:

$$AB14_{16} = 10 \cdot 16^3 + 11 \cdot 16^2 + 1 \cdot 16^1 + 4 \cdot 16^0 = 10 \cdot 4096 + 11 \cdot 256 + 16 + 4$$

$$= 40960 + 2816 + 20 = 43796_{10}$$

$A_{16} = 10_{10}$   
 $B_{16} = 11_{10}$

Once you have a number in hex, octal, or binary, converting between the three is a simple matter of arranging bits. Since each bit in a binary number represents a power of 2, we can simply add the values of the bits to get the value we want:



e.g.  $1\ 1\ 1\ 1 = 1 \cdot 2^3 + 1 \cdot 2^2 + 1 \cdot 2^1 + 1 \cdot 2^0 = 8 + 4 + 2 + 1 = 15_{10}$

$0\ 1\ 1\ 0 = 0 \cdot 2^3 + 1 \cdot 2^2 + 1 \cdot 2^1 + 0 \cdot 2^0 = 0 + 4 + 2 + 0 = 6_{10}$

When converting to binary, take the decimal value of each digit to be converted, and use this technique to find the bit values that will add up to the decimal value of the digit. If you have a hex number, convert it to binary by changing each digit into **four bits**:

$F\ 5_{16} = 1111\ 0101$  (because  $F_{16} = 15_{10} = 1111_2$  and  $5_{16} = 5_{10} = 0101_2$ )

So the binary equivalent is  $11110101_2$ .

More examples:

A6C<sub>16</sub> to binary:

A<sub>16</sub> is equivalent to 10<sub>10</sub> – to get the binary digits to add up to 10, we use 8 and 2 (because 8+2=10). No 4's and no 1's:

$A_{16} = 10_{10} = 1010_2$

$6_{16} = 6_{10} = 4 + 2 \rightarrow 0110_2$

$C_{16} = 12_{10} = 8 + 4 \rightarrow 1100_2$

$A6C_{16} = 1010\ 0110\ 1100_2$  Final answer.

If you have an octal number, convert it to binary by changing each digit into **3 bits** (where the columns are the 4's column, 2's column, and 1's column):

e.g.  $756_8 = 111\ 101\ 110_2$  (because  $7_8 = 111_2$  and  $5_8 = 101_2$  and  $6_8 = 110_2$ )

Starting with a binary number:

If you have a binary number, just regroup (**starting from the RIGHT**) into sets of 3 to get octal, or sets of 4 to get hex:

$11001111000101100_2 =$

$11\ 001\ 111\ 000\ 101\ 100 = 317054_8$

or

$1\ 1001\ 1110\ 0010\ 1100 = 19E2C_{16}$

Complete example:

Convert  $3290_{10}$  to bases 2, 8, and 16:

Recommended method: Decimal  $\rightarrow$  Octal  $\rightarrow$  Binary  $\rightarrow$  Hex

Decimal  $\rightarrow$  Octal: **Div Mod**

$$3290 \text{ DIV } 8 = 411$$

$$3290 \text{ MOD } 8 = 2$$

$$411 \text{ DIV } 8 = 51$$

$$411 \text{ MOD } 8 = 3$$

$$51 \text{ DIV } 8 = 6$$

$$51 \text{ MOD } 8 = 3$$

$$6 \text{ DIV } 8 = 0$$

$$6 \text{ MOD } 8 = 6$$

Answer:  $6332_8$

Octal  $\rightarrow$  Binary: **3 bits**

$6332_8 \rightarrow 110\ 011\ 011\ 010_2$       Binary answer

Binary  $\rightarrow$  Hex: **4 bits**

$110011011010_2 \rightarrow$  (Group in four bits, starting on right)  $1100\ 1101\ 1010_2 \rightarrow 12_{10}\ 13_{10}\ 10_{10} \rightarrow CDA_{16}$