Hexadecimal

Hexadecimal (or **hex**) is a **base 16** system used to simplify how **binary**is represented. A hex digit can be any of the following 16 digits: **0 1 2 3 4 5 6 7 8 9 A B C D E F**.
Each hex digit reflects a 4-**bit** binary sequence.

This table shows each hex digit with the equivalent values in binary and denary.

Denary	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

This means an 8-bit binary number can be written using only two different hex digits - one hex digit for each nibble (or group of 4-bits). It is much easier to write numbers as hex than to write them as binary numbers.

For example:

- **11010100** in binary would be **D4** in hex
- **FFFF3** in hex would be **11111111111111110011** in binary

Using hexadecimal

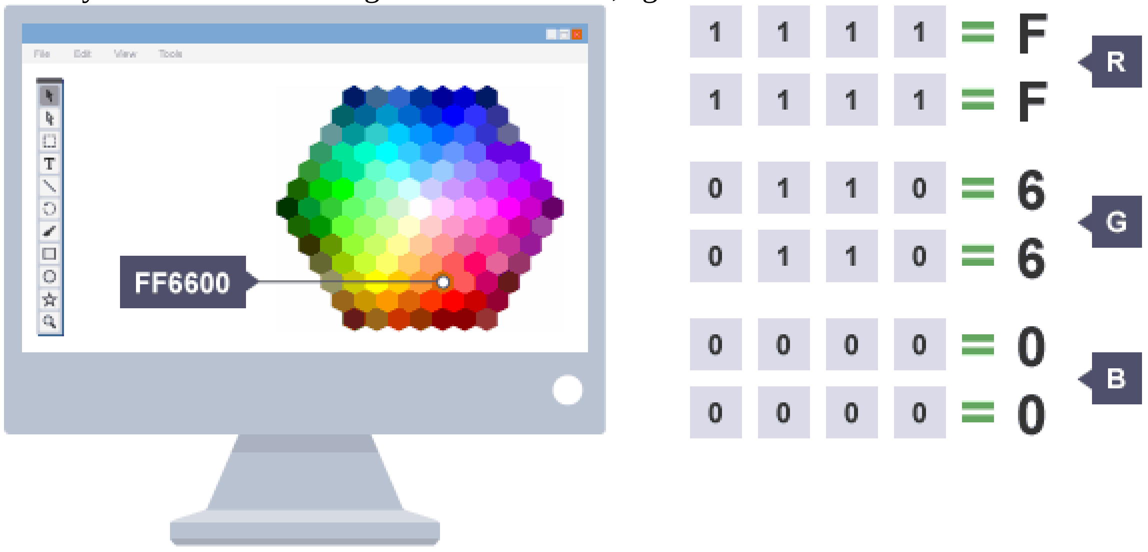
Hex codes are used in many areas of computing to simplify **binary**codes. It is important to note that computers do not use hexadecimal - it is used by humans to shorten binary to a more easily understandable form. Hexadecimal is translated into binary for computer use. Some examples of where hex is used include:

- colour references
- **assembly language** programs
- error messages

Colours

Hex can be used to represent **colours** on web pages and image-editing programs using the format **#RRGGBB** (RR = reds, GG = greens, BB = blues). The # symbol indicates that the number has been written in hex format.

This system uses two hex digits for each colour, eg #FF6600.



As one hex digit represents 4 **bits**, two hex digits together make 8 bits (1 **byte**). The values for each colour run between 00 and FF. In binary, 00 is 0000 0000 and FF is 1111 1111. That provides 256 possible values for each of the three colours.
That gives a total **spectrum** of 256 reds x 256 greens x 256 blues - which is over 16 million colours in total.
#FF0000 will be the purest red - red only, no green or blue.
Black is **#000000** - no red, no green and no blue.
White is **#FFFFFF.**

An orange colour can be represented by the code #FF6600. The hex code is much easier to read than the binary equivalent 1111 1111 0110 0110 0000 0000.
If you are making a web page with **HTML** or **CSS** you can use hex codes to choose the colours.

RGB colour model

Hex values have equivalents in the **RGB colour model**. The RGB model is very similar to the hex colour model, but instead of combining hex values you use a value between 0 and 255 for each colour. So an orange colour that is #FF6600 in hex would be 255, 102, 0 in RGB.

Errors

Hex is often used in error messages on your computer. The hex number refers to the **memory location** of the error. This helps programmers to find and then fix problems.

Converting hexadecimal

To convert **denary** numbers to **hex**, you need to remember the equivalent **binary** numbers for the first 16 hex digits.
To represent the denary number **12** in a computer system, you could use binary **1100** or hex value **C**.

To convert a 4-bit binary number to hex:

Binary	Denary	Hex
1100	(1x8) + (1x4) + (0x2) + (0x1) = **12**	**C**

A **byte** is made of eight binary digits. To convert an 8-bit binary number to hex, separate it into two **nibbles** or two half-bytes.

Binary	Denary	Hex

Binary	Denary	Hex
1011 1001	**11 and 9**	**B9**

There are two methods of converting hex to denary:

Method 1: Converting from hex to denary via binary

Separate the hex digits to find each equivalent in binary, and then piece them back together.

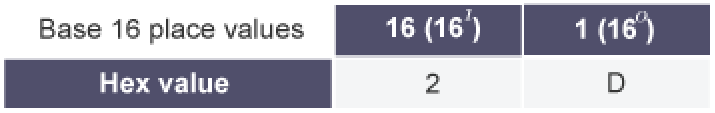
Worked example - What is the denary value of hex value 2D?

1. Separate the hex digits into **2** and **D** and find the equivalent binary numbers (**2 = 0010; D = 1101**).
2. Piece them together to get **00101101** (0x128 + 0x64 + 1x32 + 0x16 + 1x8 + 1x4 + 0x2 + 1x1 = **45 in denary**).

Method 2: Using base 16 place-value columns

Another method is to create base 16 place-value columns, and add the hex value to the appropriate columns. You would then need to work out what the hex digits represent in denary, and multiply this figure with the place-value. Finally, add all the values together.
The base 16 columns would be (16^1=16), (16^2=256), (16^3=4096), etc.

Worked example - What is the denary value of hex value 2D?

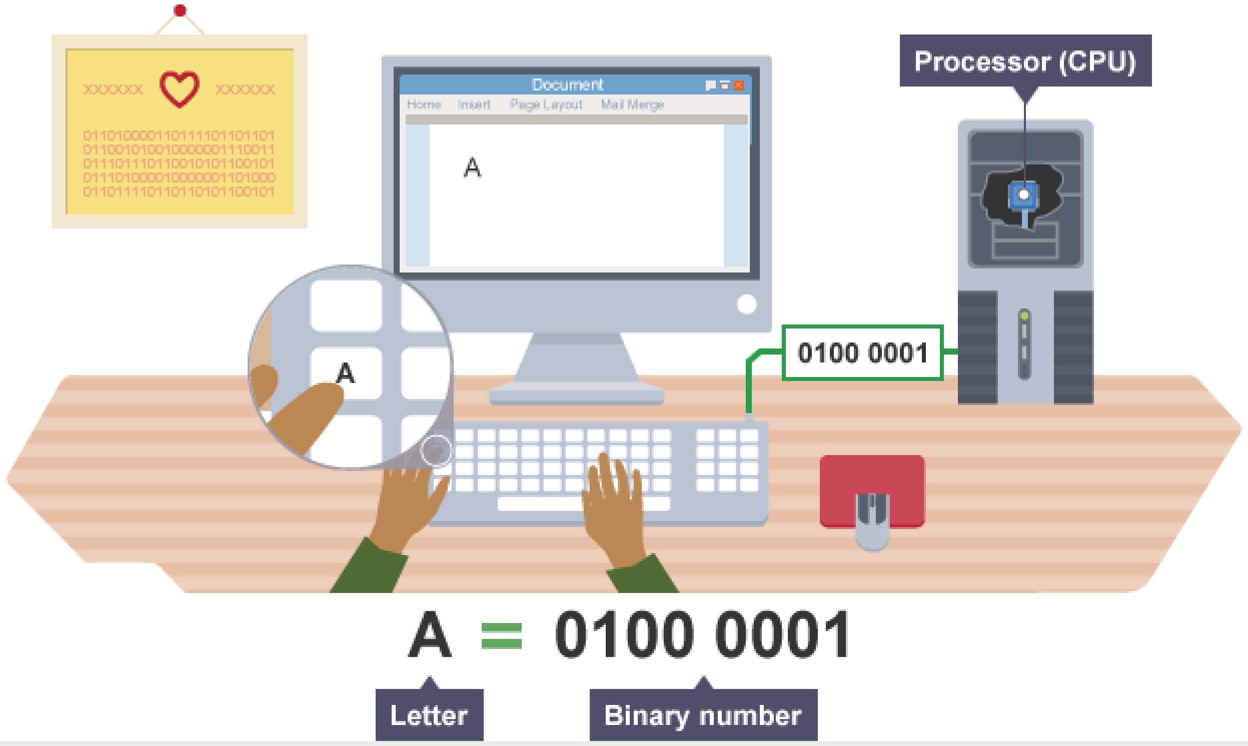


Base 16 place values	16 (16^1)	1 (16^0)
Hex value	2	D

1. Add the hex value to the appropriate base 16 place-value column: **2** in the 16 column; **D** in the 1 column.
2. Work out what the hex digits represent in denary: **2** = 2 in denary; **D** = 13 in denary.
3. Multiply this figure with the place value: 2 x 16 = 32; 13 x 1 = 13.
4. Add the values together: 32 + 13 = **45 in denary**.

Character sets

Every word is made up of symbols or characters. When you press a key on a keyboard, a number is generated that represents the symbol for that key. This is called a **character code**. A complete collection of characters is a **character set**.



Numbers are generated that represent keyboard symbols

A keyboard with Japanese characters

Different languages use different keyboard layouts. For example, a French keyboard has an **é**. If we were writing in Japanese or Arabic, we would need even more choices of characters.

A standard QWERTY keyboard

In theory, anyone can create a **character set**. But it is important that computers can communicate so we use global **standards** for character sets.
You can check what character encoding your **web browser** is using by looking in your browser settings:

- Mozilla Firefox > Tools > Page Info: Encoding
- Microsoft Internet Explorer > View > Encoding
- Google Chrome > Tools > Encoding

ASCII and Unicode

Two standard character sets are ASCII and Unicode.

ASCII

The **ASCII** character set is a 7-**bit** set of codes that allows **128 different characters**. That is enough for every upper-case letter, lower-case letter, digit and punctuation mark on most keyboards. ASCII is only used for the English language.

This table shows some examples of letters represented using the ASCII character set:

Character	Denary value	Binary value	Hex
N	78	1001110	4E
O	79	1001111	4F

Character	Denary value	Binary value	Hex
P	80	1010000	50
Q	81	1010001	51
R	82	1010010	52

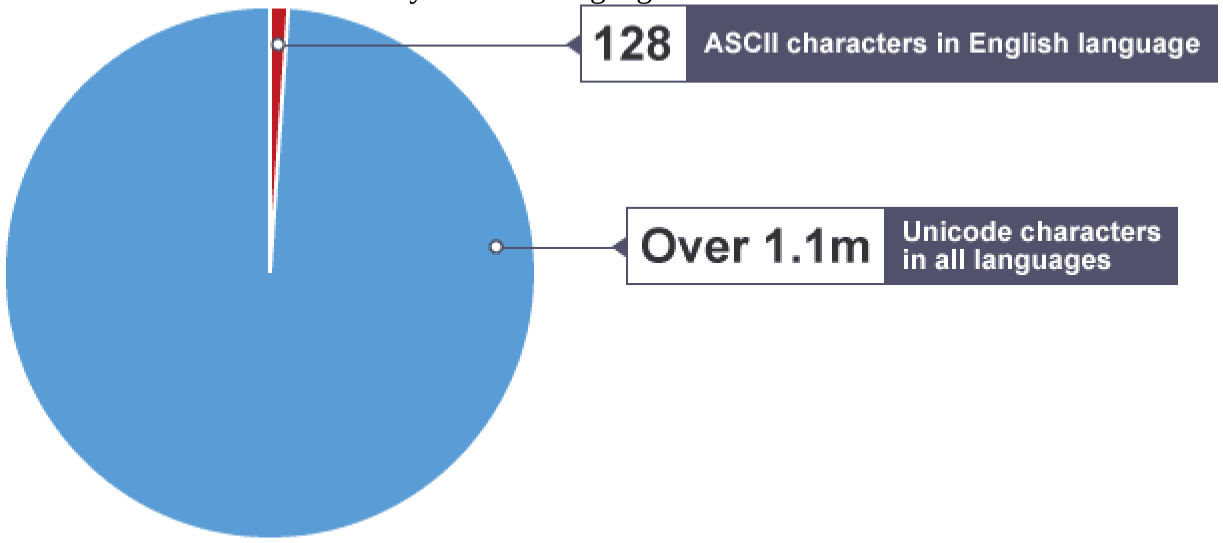
Extended ASCII

Extended ASCII code is an 8-bit character set that represents **256 different characters**, making it possible to use characters such as é or ©. Extended ASCII is useful for European languages.

Unicode

Unicode uses between 8 and 32 bits per character, so it can represent characters from languages from all around the world. It is commonly used across the internet. As it is larger than ASCII, it might take up more **storage** space when saving documents.

Global companies, like Facebook and Google, would not use the ASCII character set because their users communicate in many different languages.


ASCII characters in English language
Over 1.1m
Unicode characters in all languages