

Bits, Bytes, Computers and Digital Graphics

The Base-2 System and the 8-bit Byte

Sources:

<http://computer.howstuffworks.com/bytes1.htm>
<http://en.wikipedia.org/wiki/DVD>
<http://www.osta.org/technology/dvdqa/dvdqa6.htm>
http://en.wikipedia.org/wiki/RGB_color_model
http://en.wikipedia.org/wiki/Color_depth
<http://www.siriusweb.com/tutorials/gifvsjpg/>
<http://www.sitepoint.com/gif-jpg-png-whats-difference/>

Compiled by G.C. Herman 2011-12

The Base-2 System and the 8-bit Byte

Computers use the base-2 system is because it makes it easy to correlate electronic on/off pulses with two digits, 0 and 1.

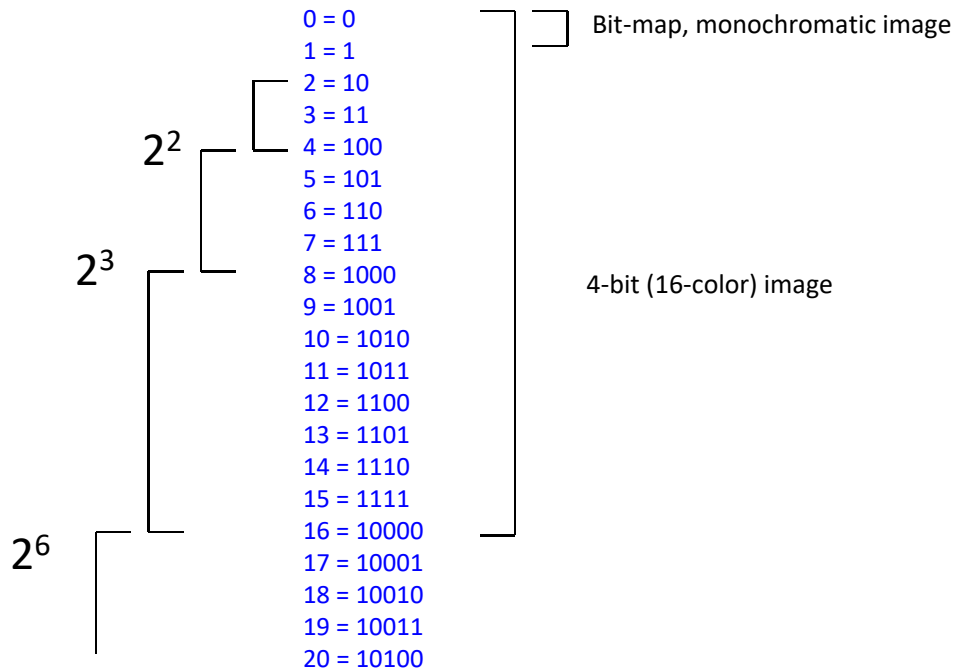
Computers use binary numbers, and therefore use **binary digits** in place of decimal digits.

The word **bit** is a shortening of the words "Binary digIT."

Whereas decimal digits have 10 possible values ranging from 0 to 9, bits have only two possible values:

0 and 1 and each bit holds the value of increasing powers of 2. That makes counting in binary easy.

Starting at zero and going through 20, counting in decimal and binary looks like this:



When you look at this sequence, 0 and 1 are the same for decimal and binary number systems. At the number 2, you see carrying first take place in the binary system.

If a bit is 1, and you add 1 to it, the bit becomes 0 and the next bit becomes 1. In the transition from 15 to 16 this effect rolls over through 4 bits, turning 1111 into 10000.

Bits are rarely seen alone in computers. They are almost always bundled together into 8-bit collections, and these collections are called **bytes**. Having 8 bits in a byte is an arbitrary arrangement that people determined through trial and error over the past 50 years.

With 8 bits in a byte, you can represent 256 values ranging from 0 to 255, as shown here:

```
0 = 00000000
1 = 00000001
2 = 00000010
   to
254 = 11111110
255 = 11111111
```

A CD uses 2 bytes, or 16 bits, per sample. That gives each sample a range from 0 to 65,535, like this:

```
0 = 0000000000000000
1 = 0000000000000001
2 = 0000000000000010
   to
65534 = 1111111111111110
65535 = 1111111111111111
```

Next, we'll look at one way that bytes are used.

Name Abbr. Size

Kilo K $2^{10} = 1,024$

Mega M $2^{20} = 1,048,576$

Giga G $2^{30} = 1,073,741,824$

Tera T $2^{40} = 1,099,511,627,776$

Peta P $2^{50} = 1,125,899,906,842,624$

Exa E $2^{60} = 1,152,921,504,606,846,976$

Zetta Z $2^{70} = 1,180,591,620,717,411,303,424$

Yotta Y $2^{80} = 1,208,925,819,614,629,174,706,176$

DVD, also known as **Digital Versatile Disc** or **Digital Video Disc**, is an optical disc storage media format, and was invented and developed by Sony, and Philips in 1995.

The capacity of a 3.95" (12 cm) DVD-R/RW (version 1.0) can vary slightly among discs from different media manufacturers although many have informally settled on 2,298,496 sectors (4,707,319,808 bytes) for a

DVD-R

(General) 4.7 GB disc.

Bits, Bytes, and Digital Graphics

RGB colors

The RGB color model is an additive color model in which red, green, and blue light is added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers, though it has also been used in conventional photography. Before the electronic age, the RGB color model already had a solid theory behind it, based in human perception of colors.

RGB is a device-dependent color model: different devices detect or reproduce a given RGB value differently, since the color elements (such as phosphors or dyes) and their response to the individual R, G, and B levels vary from manufacturer to manufacturer, or even in the same device over time. Thus an RGB value does not define the same color across devices without some kind of color management.

Typical RGB input devices are color TV and video cameras, image scanners, and digital cameras. Typical RGB output devices are TV sets of various technologies (CRT, LCD, plasma, etc.), computer and mobile phone displays, video projectors, multicolor LED displays, and large screens such as JumboTron, etc. Color printers, on the other hand, are not RGB devices, but subtractive color devices (typically CMYK color model).

Personal computers

Early personal computers of the late 1970s and early 1980s, such as those from Apple, Atari and Commodore, did not use RGB as their main method to manage colors, but rather composite video. IBM introduced a 16-color scheme (one bit each for RGB and Intensity) with the Color Graphics Adapter (CGA) for its first IBM PC (1981), later improved with the Enhanced Graphics Adapter (EGA) in 1984. The first manufacturer of a truecolor graphic card for PCs (the TARGA) was Truevision in 1987, but it was not until the arrival of the Video Graphics Array (VGA) in 1987 that RGB became popular, mainly due to the analog signals in the connection between the adapter and the monitor which allowed a very wide range of RGB colors.



A representation of additive color mixing. Projection of primary color lights on a screen shows secondary colors where two overlap; the combination of all three of red, green, and blue in appropriate intensities makes white.

Indexed colors and Palette Images

With relatively low color depth, the stored value is typically a number representing the index into a color map or palette. The colors available in the palette itself may be fixed by the hardware or modifiable within the limits of the hardware (for instance, both color Macintosh systems and VGA-equipped IBM-PCs typically ran at 8-bit due to limited VRAM, but while the best VGA systems only offered an 18-bit (262,144 color) palette from which colors could be chosen, all color Macintosh video hardware offered a 24-bit (16 million color) palette). Modifiable palettes are sometimes referred to as pseudo color palettes.

1-bit (2 colors) monochrome, often black and white

2-bit (4 colors) CGA

3-bit ($2^3 = 8$ colors) many early home computers with TV displays

4 bit ($2^4 = 16$ colors) as used by EGA and by the least common denominator VGA standard at higher resolution

8 bit ($2^8 = 256$ colors) most early color Unix workstations, VGA at low resolution, Super VGA

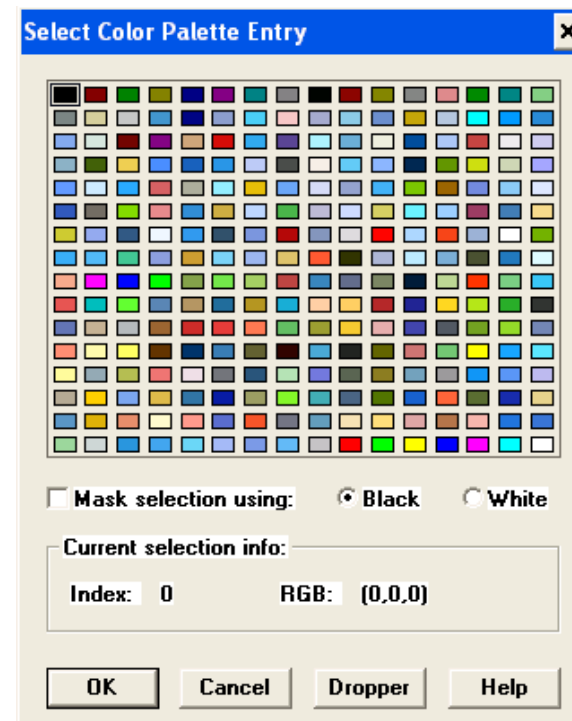
12-bit color ($2^{12} = 4096$ colors) some Silicon Graphics systems (thousands of colors)

16-bit color ($2^{16} = 65536$ colors) tens of thousands

18-bit ($2^{18} = 262,144$ color) hundreds of thousands

24-bit ($2^{24} = 16,777,216$ colors) millions

32-bit ($2^{32} = 4,294,967,296$ colors) billions



8 bit Palette ($2^8 = 256$ colors = 16 x 16 array)

Direct color (including True Color)

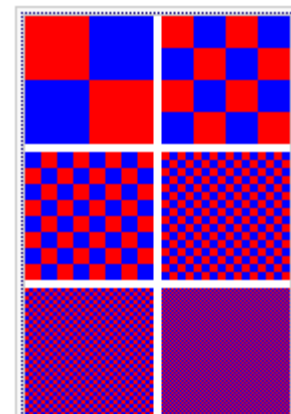
As the number of bits increases, the number of possible colors becomes impractically large for a color map. So in higher color depths, the color value typically directly encodes relative brightness's of red, green, and blue to specify a color in the **RGB color model**.

A typical computer monitor and video card may offer 8 bits of resolution (256 output levels) per R/G/B color channel, for an overall 24-bit color space (or 32-bit space, with alpha transparency bits, which have no bearing on the output resolution).

LCD displays Almost all cheap LCD displays use dithered 18-bit color ($2^8 = 262,144$ combinations) to achieve faster transition times, but they must use either dithering or Frame Rate Control to fake 24-bit-per-pixel truecolor, or throw away 6 bits of color information away entirely. The best LCD displays can display 24-bit or greater color depth.

Dithering is a technique used in computer graphics to create the illusion of color depth in images with a limited color palette (color quantization). In a dithered image, colors not available in the palette are approximated by a diffusion of colored pixels from within the available palette. The human eye perceives the diffusion as a mixture of the colors within it. Dithering is analogous to the halftone technique used in printing. Dithered images, particularly those with relatively few colors, can often be distinguished by a characteristic graininess, or speckled appearance.

Truecolor is a method of representing and storing graphical image information (especially in computer processing) in an RGB color space such that a very large number of colors, shades, and hues can be displayed in an image, such as in high quality photographic images or complex graphics. Usually, truecolor is defined to mean at least 256 shades of red, green, and blue, for a total of at least 16,777,216 (2^{24}) color variations. The human eye is popularly believed to be capable of discriminating among as many as ten million colors. On Macintosh systems, 24-bit color is referred to as "millions of colors."



An illustration of dithering. Red and blue are the only colors used but, as the red and blue squares are made smaller, the patch appears violet.

GIF vs. JPG--Which Is Best?

There are two important factors to consider: ***file size and image quality***. Currently there are only 2 widely supported formats [GIF and JPG] that will display on the web. There is another up-and-coming format [PNG] which is only supported by the leading browsers in version 4 and above

Graphics

Although the term "Graphic" can refer to all types of images in print and web layout, it generally refers to images that are non-photorealistic. Graphics and Line Art are generally simpler in composition than photos and have large areas of solid color. In the "graphic" examples below you can see compression artifacts on both JPG versions. The more compression employed, the worse the artifacts become and the quality of the whole image deteriorates.

GIF graphics of line art can be clean and crisp. This is the type of image that GIF does best because GIF employs a different type of compression than JPG. GIF's compression is called "lossless" literally meaning "doesn't lose quality" when compressed. JPG employs "lossy" compression which literally means the image "loses" quality during the compression process. Even though the file size is slightly smaller in one of the JPG versions than the GIF, the image's quality is sadly lacking.

GIF files

Generally, GIF files should be used for logos, line drawings and icons. Avoid using it for photographic images, and graphics which have long stretches of continuous-tone in them. When you're designing GIF files, avoid using gradients and turn off anti-aliasing where possible to minimize the file size.

JPEG files

The JPEG format, with its support for 16.7 million colors, is primarily intended for photographic images. The internal compression algorithm of the JPEG format, unlike the GIF format, actually throws out information. Depending on what settings you use, the thrown out data may or may not be visible to the eye. Once you lower the quality of an image, and save it, the extra data cannot be regained so be sure to save the original.

Numeric representations

A typical RGB color selector in graphic software. Each slider ranges from 0 to 255.

A color in the RGB color model is described by indicating how much of each of the red, green, and blue is included. The color is expressed as an RGB triplet (r, g, b) , each component of which can vary from zero to a defined maximum value. If all the components are at zero the result is black; if all are at maximum, the result is the brightest representable white.

These ranges may be quantified in several different ways:

- From 0 to 1, with any fractional value in between. This representation is used in theoretical analyses, and in systems that use floating-point representations.
- Each color component value can also be written as a percentage, from 0% to 100%.
- In computing, the component values are often stored as integer numbers in the range 0 to 255, the range that a single 8-bit byte can offer (by encoding 256 distinct values). These may be represented as either decimal or hexadecimal numbers.
- High-end digital image equipment can deal with the integer range 0 to 65,535 for each primary color, by employing 16-bit words instead of 8-bit bytes.

For example, brightest saturated **red** is written in the different RGB notations as:

Notation	RGB triplet
Arithmetic	(1.0, 0.0, 0.0)
Percentage	(100%, 0%, 0%)
Digital 8-bit per channel	(255, 0, 0) or sometimes #FF0000 (hexadecimal)
Digital 16-bit per channel	(65535, 0, 0)