Color and Technology

The Beginner's Guide

A pocket guide for art, tech, print, and graphic design enthusiasts.

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Introduction

Welcome to '*Color and Technology: The Beginner's Guide*'!
By the end of this guide, even those with no knowledge whatsoever about the world of technology will be able to understand…

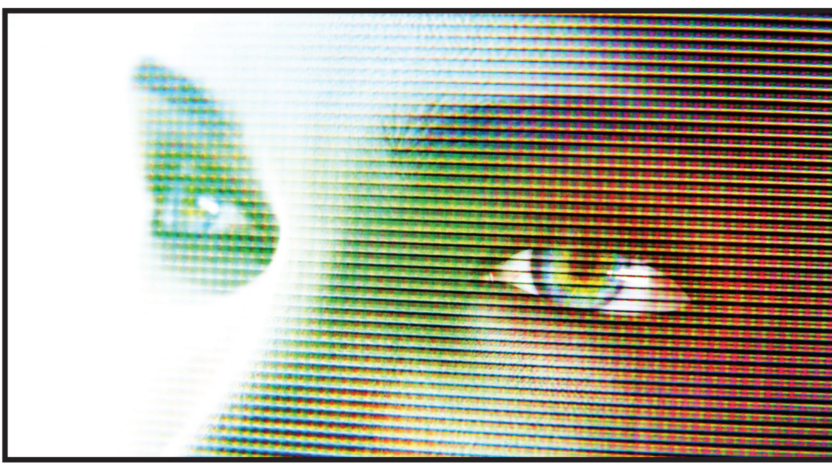
- Resolution terminology such as ‘1080p’ and ‘4k’.
- What a pixel is and how it works.
- The difference between a television and a computer monitor.
- The different types of displays, including LCD and OLEDs.
- What RGB and CMYK are, and how they are different from each other on a technical level.
- How to calibrate a screen to be more accurate.

Section 1: Basic Display Technology

1.1 Resolutions and Pixel Densities

To understand display technology, you must first understand terminology such as *‘1080p’* and *‘4k’*. On a screen, be it computer, television, or even a digital watch, anything you see is made up of tiny pixels.

Widescreen displays have an aspect ratio typically of 16:9, meaning a width of 16 compared to a height of 9 or however many pixels they might have. Though they are no longer produced, screens used to have a common aspect ratio of 4:3.
Widescreen displays these days commonly have resolutions of 720p or 1080p, although this number has grown over the years. 1080p means 1,080 rows of pixels horizontally. A resolution of 1080p is 1080x1920, meaning vertically it has 1,920 columns of pixels. Multiplied, this means the screen has 2,073,000 pixels.



1.1 Resolutions and Pixel Densities continued...

This may seem like a lot of pixels, almost an impossible amount, but remember that a computer is using electricity to power these lighted pixels, and **electricity moves at a rate of around 90% of the speed of light**, which is about **604 million miles per hour**.

Common resolutions...

Common Name	Exact Resolution (Width x Height)	Number of Pixels
240p	426 x 240	102,240
360p	480 x 360	172,800
480p	640 x 480	307,200
720p	1280 x 720	921,600
1080p	1920 x 1080	2,073,600
4k	3840 x 2160	8,294,400
8k	7860 x 4320	33,955,200

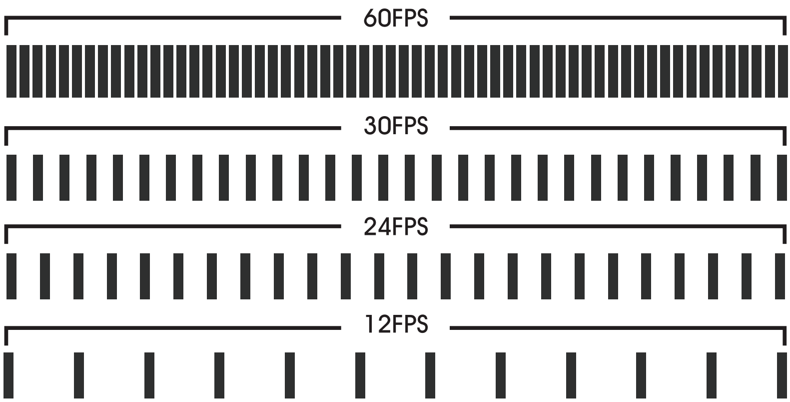
Wrist watches and calculators have far less pixels than computer or television displays.

1.2 Frames Per Second and Refresh Rates

Common screens have refresh rates of around 60 hertz, or 60hz. What is hertz? It's the same thing as frames per second, but when you are describing the maximum capability of a display you say hertz, such as a 60hz screen.

60 frames per second means that each pixel is changing color and brightness at, you guessed it, a rate of 60 times per second. Other common refresh rates are 30hz, 120hz, and 144hz. Typically, movies are filmed in around 25hz, or 25fps, on purpose as the low frame-rate gives them a more cinematic effect. Frame-rates are deliberately dropped even further during action sequences or in animated movies. In action films, the low frame-rate helps the excitement and helps to intentionally blur certain scenes like action sequences, alongside shaking the camera. In animated movies the low frame-rate adds a sort of effect as if the viewer were reading a comic book or watching an old cartoon.

1 SECOND OF ANIMATION



Each bar represents 1 frame of a moving image.

Section 2: Pixels

2.1: RGB – Red, Green, & Blue

Each individual pixel in a full-color screen is made up of three separate lights: a red, a green, and a blue light. These are called sub-pixels. Each of these three lights is capable of 255 levels of brightness. There are 256 x 256 x 256 = **16,777,216** total possible colors a pixel can output in a screen.

The reason there are 256 (with 0 being counted as off or black) total levels each is because of the binary signals used in a computer. A byte uses just 8 signals, or bits, to compose a message, with each of those 8 signals being either a 0 or a 1 (on or off- electricity being sent or not).

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

0	1	0	1	1	0	0	1

01011001

For each 1, add the corresponding number from above. In a computer this would be a sequential electrical signal. The result is..

0 + 64 + 0 + 16 + 8 + 0 + 0 + 1

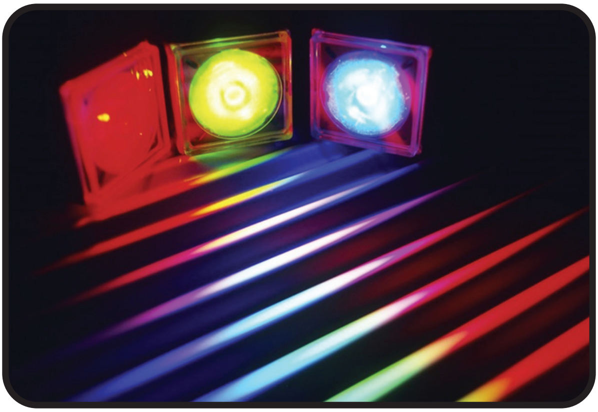
= 89

In a pixel, this 89 (out of 255) would be assigned to the red, green, or blue sub-pixel, and ultimately each pixel has its 3 numbers being updated every second; i.e. at a rate of 60 frames per second, even if it's just the same color over and over again until the image on the screen changes.

Hex codes work in a similar way, but instead of being a base 8 number they are a base 16 number in which numbers 0 through 9 are normal numbers but 10 is represented as an *'A'* up to 15 which is *'F'*. A hex number, such as B6, can be translated to a byte. B is 11 which as a byte is 1011. 6 is 0110 so that sub-pixel's byte is 10110110, or the number 182.

2.1: RGB – Red, Green, & Blue continued...

A color's hex codes, such as #FFFFFF (All white: each pixel is maxed at 255) or #000000 (all black- each pixel has 0 signal and is off), are easier to read and organize than other methods. The graphic design community tends to prefer them due to the convenience of copying just one string of text as opposed to three separate RGB codes.
When you mix red, green, and blue lights, the resulting output is capable of all colors in the visible human spectrum. The screen you view an image on, however, will be limited to the capability of its hardware. Just like everything else in the world of computers, better screen technology becomes more affordable over time.

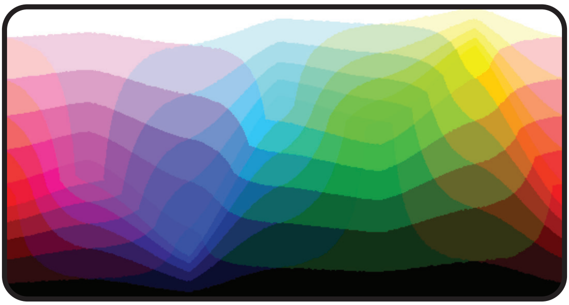


Have you ever wondered what the difference is between a monitor and a TV? It really has to do with how fast an image can appear on your screen between when a signal is sent (i.e. from a mouse) and when it's displayed. Monitors tend to be specifically designed to have faster response times, such as under a few milliseconds as opposed to 1/4th of a millisecond. Nowadays, TVs are so advanced that the differences are indiscernible and there aren't really any special differences between the two.

2.1: RGB – Red, Green, & Blue continued...

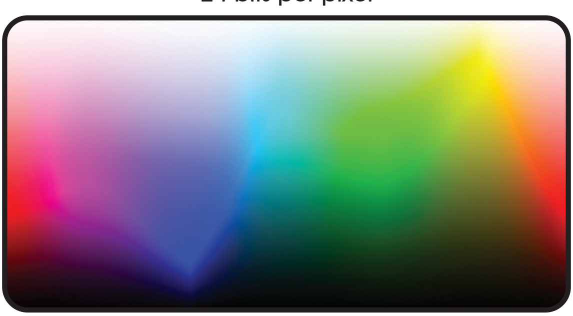
These diagrams from Cambridge in Color show what color outputs are possible with a limited number of bits per pixel. The usual amount these days is 24bpp with an extra 8 (32 total) for transparency. The pixel on the screen isn't actually transparent; the computer calculates what color it's supposed to be by using the RGB color values of the virtual pixel behind it to create a physical pixel on the screen.

8 bits per pixel



10 bits per pixel

24 bits per pixel



2.2: Hue, Saturation, & Brightness

Colors have three variables for adjusting in a graphic design scenario beyond just levels of red, green, and blue: hue, saturation, and brightness.

Hue: What color specifically is chosen; such as green or yellow.

Saturation: How black and white a color is; completely desaturated colors are black, a shade of gray, or white.

Brightness: Also called 'Light' or 'Value', this is how bright a color is. A brighter gray is light gray, and a darker gray is dark gray.

Notice how combining...

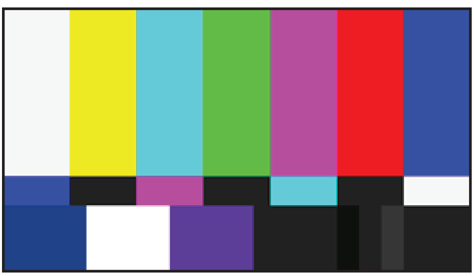
- Blue and green makes cyan.
- Green and red makes yellow.
- Red and blue makes magenta.

On a screen it's important to note that the three sub-pixels (red, green, and blue) making up a pixel only appear as different colors because of how small they are in your field of vision. An individual pixel up close will appear as red, green, and blue in individual blocks no matter how bright they are set to in the display- i.e., even if each sub-pixel is maxed to 255 each.

Section 3: Screen Calibration

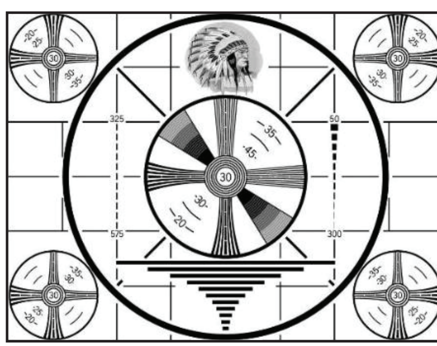
3.1: What is Screen Calibration?

Believe it or not, most screens sold out of the box do not accurately display colors as the parts and materials used in the factory are sourced from varying places and assembled with varying machines. They usually aren't quality checked beyond a certain point before being shipped; typically they are only checked for a standard amount of color accuracy and for defects such as 'dead pixels' in which one or more pixels (sometimes a column or row of them) are off and will not light up. Even high-end monitors and televisions costing thousands require calibrations.



SMPTE (The Society of Motion Picture and Television Engineers) color bars were an old standard in the 1970s used to ensure colors, widths, and heights of a display's images were being shown accurately.

Before color television was introduced, this black and white image introduced in 1939 by RCA, the Radio Corporation of America, was used to calibrate brightness and contrast in screens.



3.1: What is Screen Calibration? Continued...

It’s up to the user to calibrate the screen using its on-board settings. It's recommended to use a colorimeter (see page 16), a small device that helps identify color accuracy, but calibrating by eye can be done without one. The next section will show you the Windows operating system's built-in software for calibrating a screen, however the best practice is to use what's built into your monitor or television as it will be defined before loading up your computer's operating system and it will be consistently calibrated if you are using other devices such as a DVD player or game console, which themselves likely will not have color calibration settings. Using the Windows color calibrator is a good starting point for familiarizing yourself with calibrating screens.

The most common color inaccuracy in displays is an overabundance of blue. This is due to displays relying on backlights that are naturally tinted blue, though they are installed with the intent of being completely white.

This issue is largely responsible for products such as blue-light filtering glasses and “warm” screen filters built into operating systems like Windows and Android, which are less necessary after manually calibrating a display.