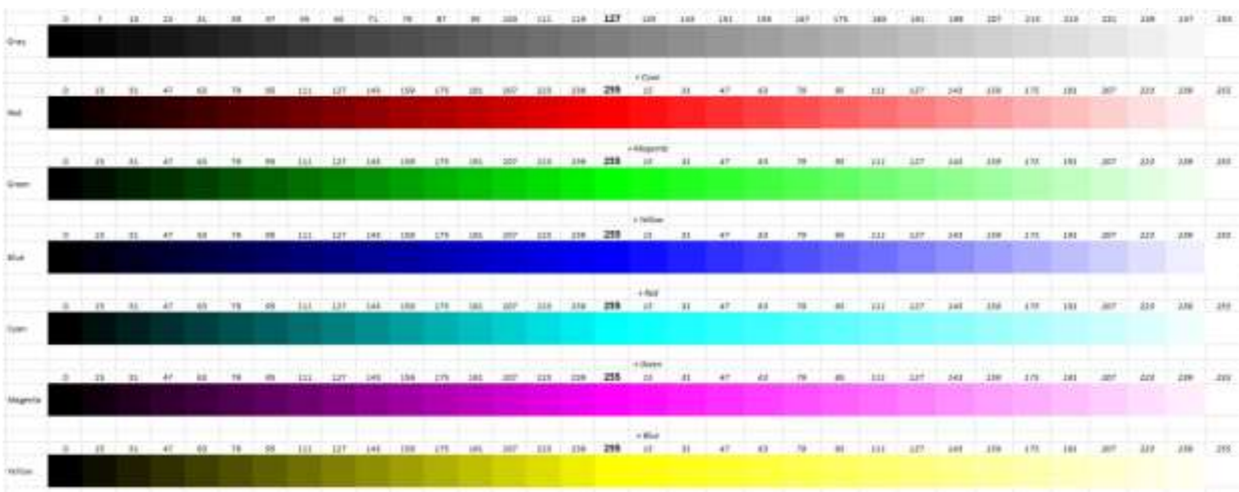
Color Saturation and Brightness

2024

A color is seen whenever the red, green and blue values are unequal in a group of pixels. It can be desaturated (converted to gray scale) by making them equal, preferably at about the same apparent brightness value.

The following table shows the primary (red, green, blue) and complementary (cyan, magenta, yellow) as their JPEG values are increased from 0 through 255.



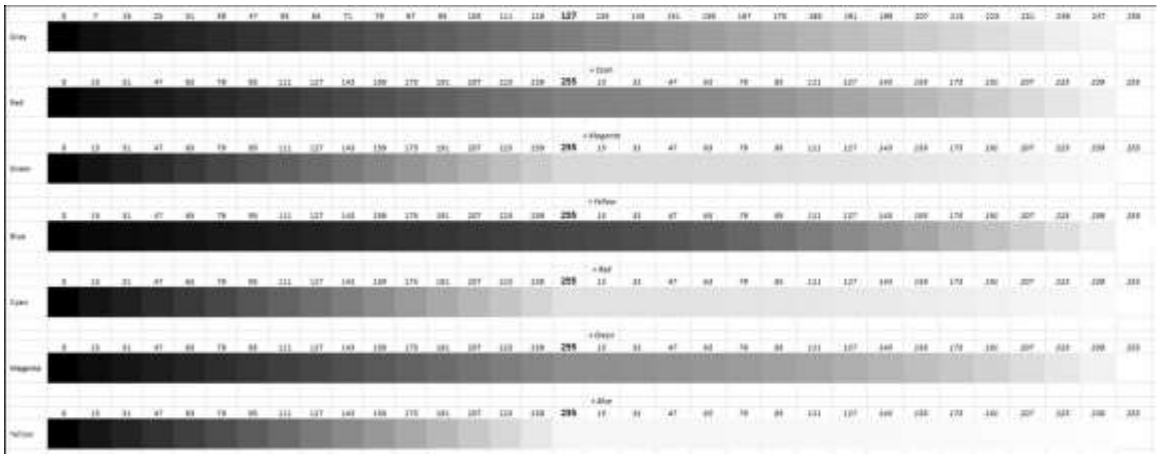
The first row shows a progression for gray (where red=green=blue) from 0 through 255 as the values increase by 8 at each step (except for the first). The value of the first square is 0 (black). In the middle of the 17 values, the ninth square is 127, middle gray. The last square is 255 (white).

In the next six rows, each step represents a change of 16 bringing the ninth value to 255, the maximum pure and saturated value for that color. In the first nine squares, the opposite color (red/cyan, green/magenta, blue/yellow) remains at 0. For the remaining eight squares, the opposite color is added gradually until it also reaches 255. The last square is white.

As you look down the ninth color you will notice that green appears slightly brighter than red which is slightly brighter than blue. Conversely, magenta appears to be slightly darker than cyan which is slightly darker than yellow. If you use a color editor to convert this table to monochrome, it would be useful to start with similar apparent brightness relationships in the monochrome version. But the expected change in brightness is sometimes very hard to see – the contrast may be weak.

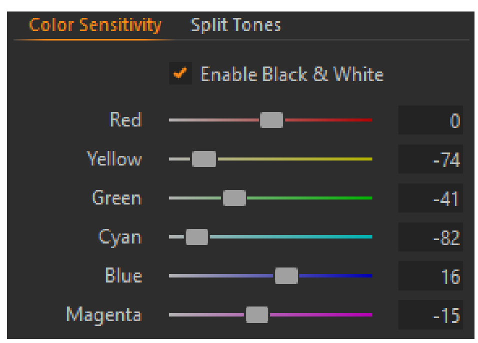
The gray row covers 256 brightness levels including black and white. But each of the color rows actually could contain a sequence of 509 brightness levels (255+254) plus black and white. The six color sequences account for over 3,000 unique colors. But they are artificially generated – they do not occur naturally among the 16.7 million possible colors that can be represented in an 8-bit JPEG. More on this later.

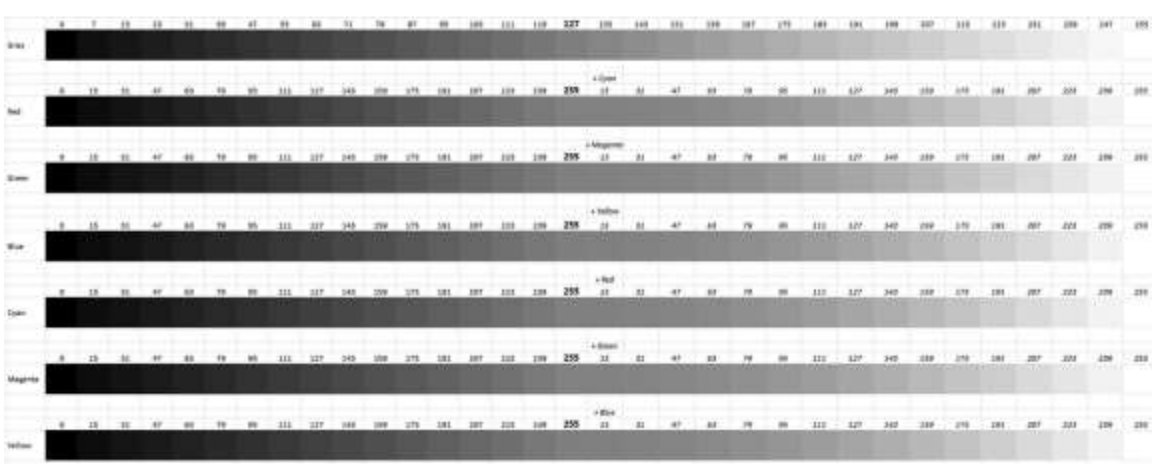
The default monochrome conversion of the original image using Capture One comes close to the apparent brightness of the color version.



The default Capture One change in apparent brightness is inconsistent. Red and magenta seem to show the steps more clearly. Green, cyan and yellow appear too light and have very little contrast to the right of the ninth square. Blue remains very dark from the start, even darker than the color version.

These adjustments make it possible to come up with a more satisfactory distribution of tones. The objective is to get the brightness of the ninth square at 255 for each color to match the brightness of the ninth square in the gray scale at 127.





We might find similar settings for Affinity Photo 2.

Both Capture One and Affinity Photo 2 let you save the settings as presets.

These settings were found by trial-and-error. The same can be done in Lightroom, ACR and other programs based on the color table on page one.

The individual colors now respond more faithfully to the changes in brightness in the monochrome version.

But these settings are only a starting point. When doing a monochrome conversion for a particular image, the image content will have more bearing on the adjustment of the color sliders than this artificial example.

If you find that you need to make significant adjustments to the sliders during the B&W conversion you might want to reconsider whether the image might actually be left in color, not converted to B&W.

But your goal may be to exaggerate the effect that colors can make on the B&W conversion. Occasionally an image can be as effective in B&W as in color.

Reality Check

So far we have been looking at artificially generated colors that represent less than about 0.02% of the 16.7 million possible 8-bit JPEG colors. But color photography is primarily made up from the other 99.98%.

We might not actually be able to distinguish that many different colors. We may be discarding some of the information by not exposing the full brightness range in a scene. Maybe we can only see about 8 million colors, maybe less, but the concept of saturation still means something.

If we ever achieved absolute saturation in an image it would look as artificial as the opening illustration. Nevertheless, that illustration contains the highest possible saturation.

The left half of the table is a reminder that there can only be six possible simple saturated colors – primary colors red, green and blue, and their complementary (opposite, counterpart) colors cyan, magenta and yellow. We can only arrive at these six colors by leaving out their counterpart. Once we start to add the opposite color we begin to desaturate the result until we reach white.

Colors like amber, aqua, brown, chartreuse, fuchsia, orange, purple, salmon – all of these have different mixtures of colors, different shades. The red, green and blue values in the JPEG are each different and none of them is zero until we approach black. Likewise, none of them is 255 unless we approach white and they begin to wash out. They can be made darker or lighter but to make them more saturated would fundamentally alter their color. But that's exactly what the saturation control in our editor tries to do. It may not be clear what goal it is trying to achieve other than to please our eye. The only clear goal that we can all see is complete desaturation, conversion to B&W, monochrome.

The color of the light falling on the subject might be controllable and we might be able to coax it in the right direction by adjusting the white balance during the conversion from raw data to an image. But if the incident light is not reasonably close to white, white balance adjustments may not work.

Our objectives can also be frustrated by the presence of two or more light sources like the sun and a blue sky, indoor and outdoor lighting or a strongly colored reflector bouncing light onto the subject. We might go to great lengths to disguise the difference in light sources but that can take a lot of effort. Surface texture can cause the color of an object to change when viewed from different directions when two or more light surfaces are present.

Our eyesight is continually compensating for the color of incident light but the camera's sensor is not. The camera's white balance setting does not change the raw data.

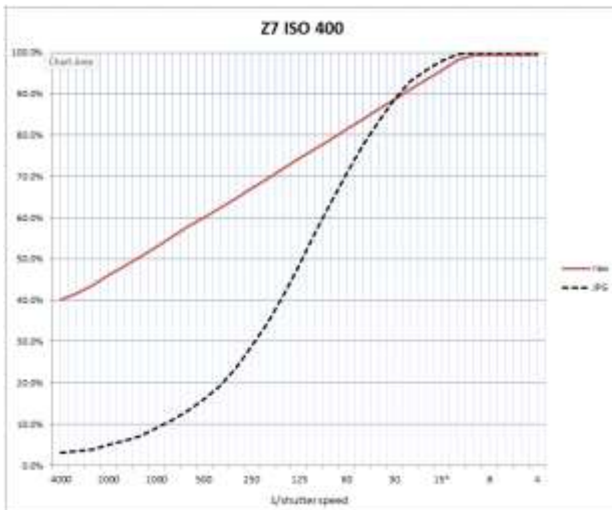
What we cannot control are the reflective properties of the subject including its color and the way it reflects light from a range of matte to glossy surface that provide a mixture of diffuse and specular reflections. A shiny leaf or flower petal can look different depending on the direction of the light falling on its surface in relation to the camera's viewpoint.

And translucent objects let light pass through them in addition to reflecting incident light.

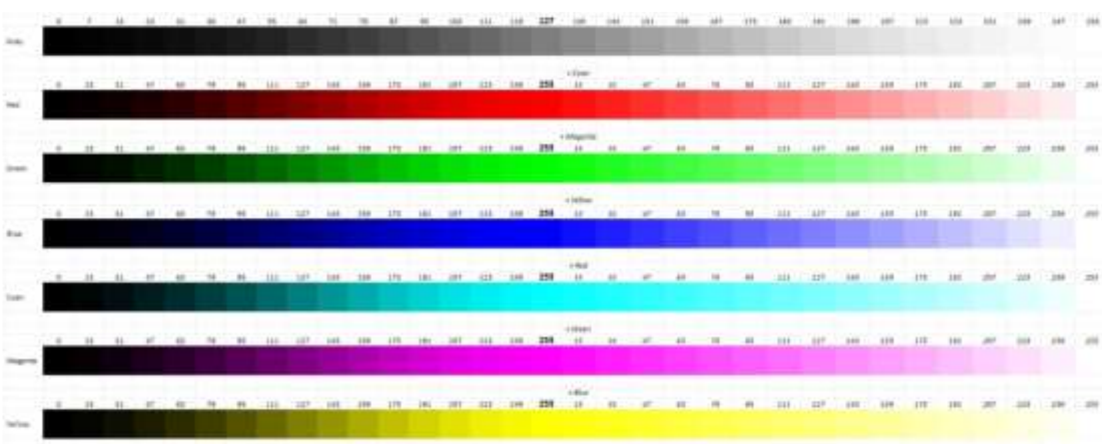
The JPEG Is Not Linear

The JPEG values in the table on the first page match the labels directly above them. They are a perfectly linear progression of values from black to white.

The values recorded in a raw file are linear in proportion to the brightness of the subject. But if you plot the normal JPEG on the same scale the JPEG response is clearly not linear. Here is a comparison linear of a sequence of raw values to the non-linear behavior of the JPEG.



A raw linear progression of subject brightness ends up in a JPEG with a higher contrast in the middle range than at the darker or lighter end. By bending the image from page one using an “S” shaped response without changing the brightness for middle gray we can get:



The JPEG curves still range from black to white. The value for the square under the 127 label on the gray scale is still 127. Black is still 0 and white is still 255. But the square under the 63 label the is now 44 (darker) and under the 191 label it is 210 (lighter). This adjustment applies to the color as well as the monochrome series. The result is that the contrast and saturation is emphasized in the middle at the expense of the dark and light tones. The change is substantial but you may need to view the two versions together to see the difference.