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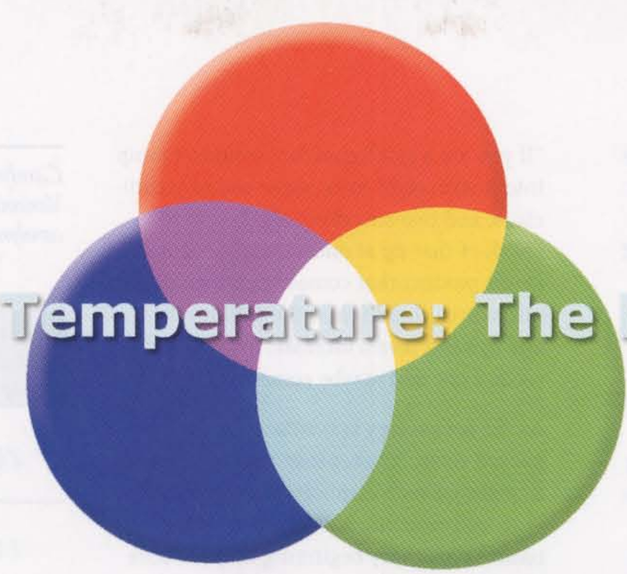


Color Temperature: The Basics

By Greg Persinger

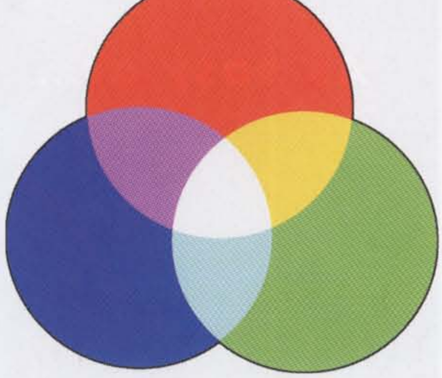
Since the introduction of color film in still photography and motion pictures, it has been known that the color temperature of the light source illuminating the scene is crucial to accurate color reproduction. Later, when video and digital photography came of age, color temperature was found to be as critical in this application as it was in film photography.

So what is color temperature and why is it so important?

In 1900, a German physicist by the name of Max Planck discovered that a "black body," such as a piece of iron, gives off various colors of light as it is heated. For example, imagine a piece of iron heated in a blacksmith's furnace: the iron starts off black but begins to glow red when it is placed in the coals. As the temperature rises, the iron goes from red to yellow until it eventually glows bluish-white as it reaches its maximum temperature.

Planck took his discovery and developed what he called "Planck's radiation formula," which defined a standard for the color of light based on the temperature of a theoretical "black body" measured in degrees Kelvin. Because of this standard of measure, which we now call color temperature, we can accurately identify, match, and compare different colors of light.

For example, candlelight has a color temperature of 1850°K, while a 1000W incandescent Tungsten lamp has a color temperature of 2990°K. Sunlight has a color temperature of 5600°K, and a Xenon Arc lamp has a color temperature of 6420°K. If we think back to the iron being in the blacksmith's fire, the candle would be in the red zone while the 1000W incandescent Tungsten lamp would be more yellow, and the sunlight and the Xenon Arc lamp would be approaching blue.



Mixing equal parts of red, green and blue will result in pure white. Sunlight is the closest thing we have to pure white light.

In lighting, we typically consider the red portion of the color spectrum to be "warm" while the blue spectrum tends to be considered "cool", but on the color temperature scale the reds are cool in color temperature and the blues are warm in color temperature. The lower the degrees Kelvin, the more red there is in the light, and the higher the degrees Kelvin, the more blue there is in the light.

Knowing this information doesn't really explain the importance of color temperature in video and digital photography. To understand the importance of color temperature, there are a few more concepts that have to be understood as well.

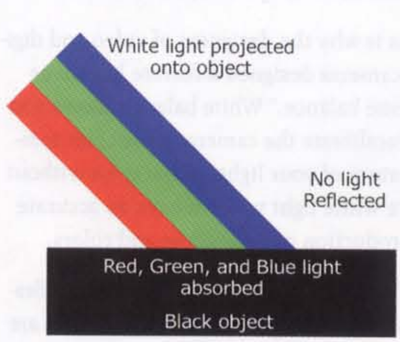
When we look at "white" light we are actually looking at light that has a wide spectrum of colors in it. This spectrum consists of the primary colors red, green, and blue. When these colors of light are mixed together, they produce white light in a process known as additive color mixing.

The laws of physics tell us that if we mix equal parts of red, green, and blue light we end up with pure white light. In the real world the closest thing we get to pure white light is sunlight, but this is not perfectly pure. What happens if the parts of color being mixed are not equal?

With unequal mixing, you get a color shift toward red, blue, or green depending on what quantity of each color is being mixed. If the ratios are drastic, new colors or shades of colors are created and the light will no longer fall into the "white" category. If the ratios are only slightly off, you get a color that may still be perceived as "white," although there is a measurable color shift. This color shifting is the color temperature of the light.

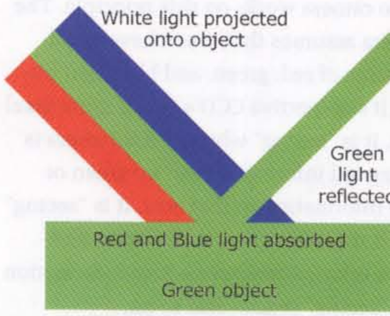
If there is more red than blue, the light has a low color temperature – like our candle flame. If there is more red and green than blue, the light will have a warm color temperature – like our incandescent light. If there is more blue than red, the light will have a high color temperature – like our xenon lamp or sunlight.

The opposite process to additive color mixing is subtractive color mixing. Since most light is "white," or has all the colors of the visible spectrum mixed together already, it would be hard to produce any other color without this process.



In subtractive color mixing, pure white light hits a green surface and all colors of light, except for green, are absorbed while the green component of the light is reflected to your eye. If the surface is white, all colors would be reflected and the surface would appear white. If the surface is black, all of the colors would be absorbed, making the surface look black. If the surface is a mixture of different colors, the mixture of the colors that would reflect would correspond to the ratio of the color mix and the balance of the color would be absorbed.

Of course, the accuracy of the reflected color relies on the illuminating light being pure white or having equal parts of red, green, and blue. If the light is not pure white, the reflected color is shifted away from its true color. An example of this is a blue surface that tends to shift toward brown when illuminated by a red light, while a red surface will just look red.



Another concept that is closely tied to subtractive color mixing is that we only see objects that reflect light. This means that to see an object it has to be lit, and it can't be black because black objects don't reflect light. Instead we "see" the absence of light with black objects and our brain creates the image of the object based on the other color information around the object. But it is not just black objects that our brain adjusts to.

Because of a human perceptual adjustment known as approximate color consistency, we are capable of seeing, processing, and reacting to all the different colors in numerous lighting situations. Although the color of the light is not a "pure" white, it is assumed to be white, so the brain processes the color information being received by the eyes and allows you to "see" the normal color of the object.

For example, if you spend the day shopping with a friend, you don't notice their face having a different color as you go from store to store, but in reality the color changed as the lighting was different each place you went. When you were walking down the street at noon, your friend's face became bluer but it changed to more green when you were in the store lit by florescent lights. Later, when you were in the store lit by incandescent fixtures it was redder but you never noticed a change because your brain always assumed they were being lit by "white" light.

Because of the way our brain works, our perception of color is not greatly affected by the color temperature of a light. But how does color temperature affect a lifeless, brainless piece of equipment like a video or digital camera? Well, it can greatly affect the quality of the pictures you are taking with it.

Since video and digital cameras do not have an onboard brain as powerful as the human mind, they are not capable of making those approximate color consistency adjustments like we are. This creates a problem, since the camera doesn't have any way to know which color is which unless it is calibrated in some way.

In a three-chip CCD video camera, the camera "sees" by taking in light from a scene through the lens and focusing it on a beam divider that splits the light into its primary color components of red, green, and blue.

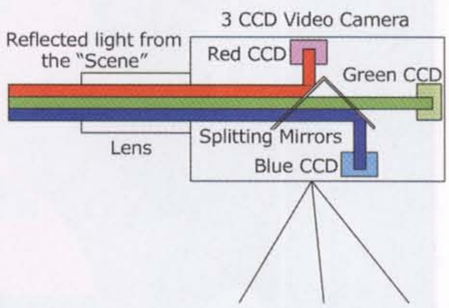
The red, green, and blue light is each focused onto a separate Charged Coupled Device (CCD) chip that registers the intensity and location of the light hitting it. The CCD turns this light information into electronic information that is sent to a video processor to be compiled with the other color information before being transformed into a full color video signal.

The video signal is then converted to a picture on your TV monitor when the monitor fires the red, blue, and green light pixels at the right intensity and in the right places.

During this process, the camera has no way of knowing what color of light it is seeing; it just knows the amount of red, green, and blue light, and the pixel location, hitting its respective CCD chip.

Earlier when I talked about additive color mixing I mentioned the law of physics that says equal parts of red, blue, and green light create pure white light, well here is where this law comes into play since a video camera works on this principle. The camera assumes that if you have equal amounts of red, green, and blue light hitting it's respective CCD's in the same pixel area, it is "seeing" white. If the camera is seeing red information but no green or blue information in that area, it is "seeing" red. If it is seeing red information and green information but no blue information it is "seeing" yellow, and so on.

This means that if we put pure white light onto our scene and point the camera at it we would take beautiful pictures. The whites would be white and all of the colors would be rendered accurately because the law of subtractive mixing says if you put pure white light onto a surface that surface will only reflect the color of the surface. Since the camera is calibrated based on the law of additive mixing, it knows that equal amounts of each color are white and any other red, green, and blue ratio is a mixed color.



But this is purely a theoretical situation that only works if you put pure white light on the scene, and as I mentioned before, sunlight is close to being pure white but it is not perfect. Also, you are not always going to be shooting outside or during daylight hours, so using all sunlight all the time becomes impractical.

You could use incandescent fixtures to light your scene, but that would turn the scene red because of the low color temperature of the incandescent light. Now we are putting more red light on the scene than green or blue, so it will make your whites look pink, your reds look deep red, blues look purplish, and greens look yellowish, which really isn't a very desirable outcome.

Unfortunately, those approximate color consistency adjustments that our brain makes for our eyes do not work when we make a video recording. When we look at the picture on a TV monitor, the colors will look wrong since our brain isn't compensating for the color temperature differences.

This is why the designers of video and digital cameras designed a feature known as "white balance." White balance allows you to recalibrate the camera to the color temperature of your light so that even without pure white light you can have an accurate reproduction of both white and colors.

Let's revisit the scene lit with the incandescent fixtures. We know that the fixtures are going to have a low color temperature when compared to sunlight. This means there is more red in the light than blue or green.

Since the camera is designed around the law of color mixing, it wants to see all of the colors equally when it is looking at white. Instead, it sees more red than blue and green, which gives you a pink "white". With the push of a button, the camera goes into white balance mode and when the picture returns white really is white and all of the colors are accurately being reproduced.

So what happened in the camera? Well, when you pushed the white balance button the camera looked at the amount of red, green, and blue, and saw that the red was the high value and the blue was low the low value and green was somewhere in between. It then did some quick math and averaged out the differences between the red, green and blue signals it was receiving. Once the camera knew how much to turn the red level down, and the blue and green up, it automatically adjusted the gain settings for each output, making the three colors electronically equal. This effectively "tricks" the camera into producing white and accurate colors.

But even white balance has its limitations. When you white balance a camera, the camera makes the assumption that the color temperature of the light source illuminating the scene is all the same. If you have sources with different color temperatures lighting the same scene, the colors will not reproduce correctly in the areas of the non-white balanced source.

For example, if you are shooting an interview in an office with a window, and you are lighting with an incandescent light kit but there is sunlight spilling in the window across the desk, you would white balance for the incandescent light on the subject's face, which will give you nice skin tones. But the area of the desk where the sunlight is hitting now looks blue. We know this is caused by the differences in the color temperature of the light.

Color temperature is important to understand, because digital and video photography want light sources of the same color temperature illuminating a scene for accurate reproduction of colors.

In the next article, I will discuss the things you can do when your color temperatures don't match.

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