Mixing LEDs to Achieve Variable White

Variable or tuneable white lighting systems are currently a growth segment in lighting due to the benefits they can provide in both aesthetics and health. Most solutions to date have worked around using white LEDs at 2 colour temperatures, but this is certainly not the only way to achieve variable white, nor even necessarily the best way.

Background

Colour mixing of LEDs (be it to achieve a specific colour or a white point) works by varying the intensity of 2 or more LEDs to create a colour that is somewhere in the middle. This can be visualized in the RGB space in the CIE chromaticity diagram (as shown in Figure 1).

In this diagram, single (pure) colour LEDs are located on the outside of the triangular shape (the blue text denotes wavelength). White LEDs are located roughly in the centre. Their exact coordinates are dependent on their colour temperature.

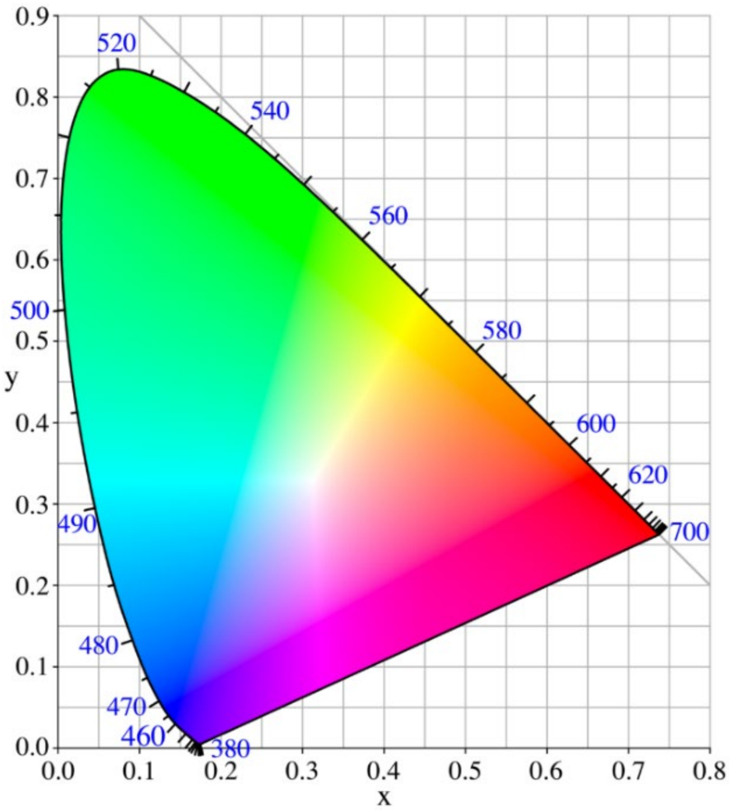

Figure 1 The CIE Chromaticity Diagram

Using 2 White LEDs

The obvious solution of how to mix LEDs to achieve different white colour temperatures is to mix white LEDs. This can be roughly seen as shown in Figure 2. This is a widely used solution, because it is a good solution. It's simple, low cost and achieves a good CRI. It's also very easy to maintain a reasonably constant light output through the whole colour temperature range (presuming the white LEDs have similar light outputs). But it does have its limitations.

The possible colour temperature range is limited by the colour temperature of available LEDs (which is limited to around 2400K to 6000K). Furthermore, as can be seen in Figure 3 (which is a zoomed in view of the achievable colour temperatures), the achievable colour points are on a straight line between the two points. The BBL (Black body locus) is not a straight line. The wider the colour temperature range created by the two LEDs, the worse the deviation from the BBL will be.

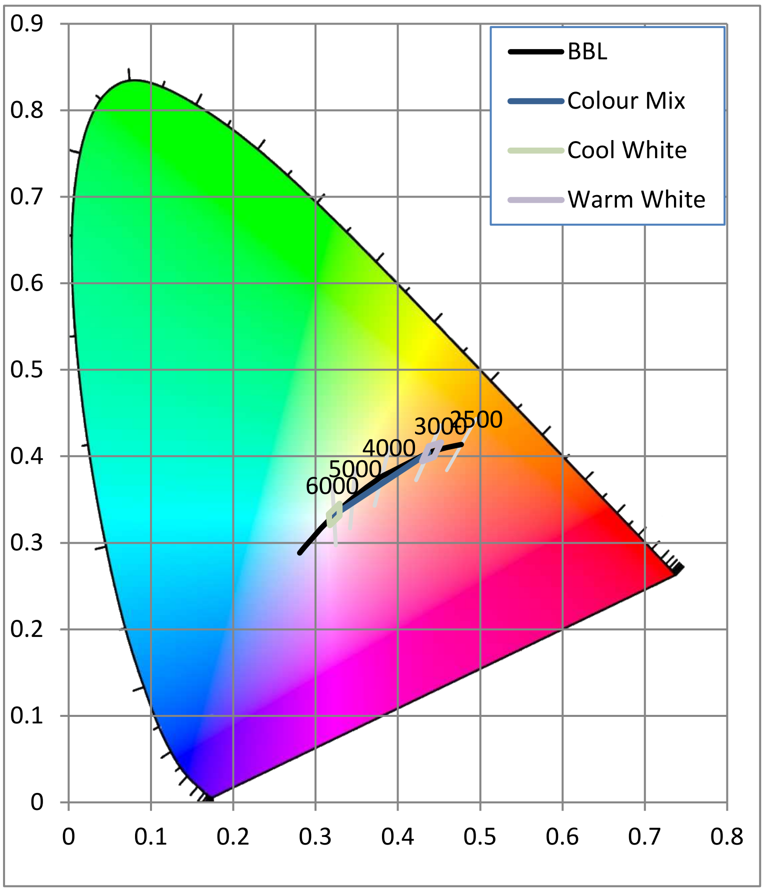

Figure 2 Variable White implemented using 2 white LEDs

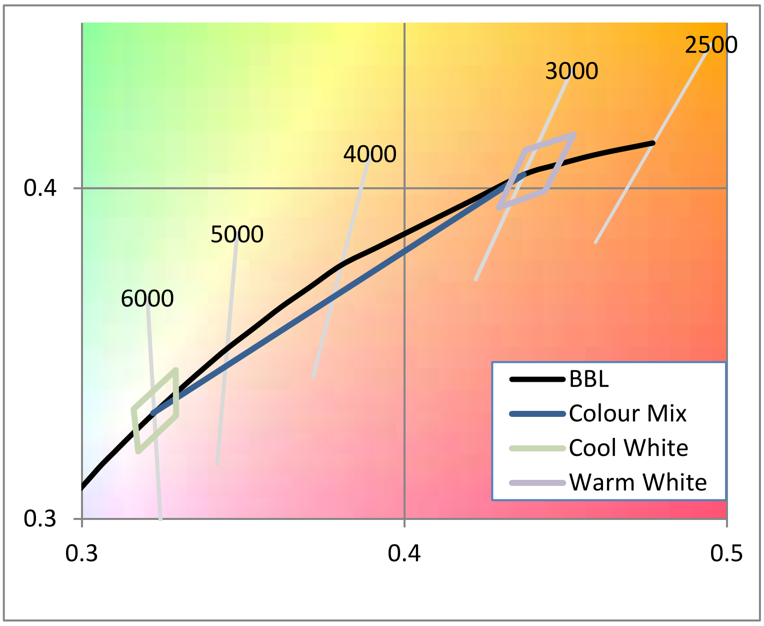

Figure 3 Achievable colour temperatures using a dual white LED solution.

Using RGB LEDs

A solution not often considered when wanting to achieve white is to use RGB LEDs. The reason it's not considered is pretty simple, people consider the white achieved from RGB LEDs to be the white created by mixing equal powers of red, green and blue. Indeed, as you can see in Figure 4, this is a very poor white, with the somewhat ridiculous calculated Colour Temperature approaching 100,000K[1] (this is calculated for Digilin RGB strip).

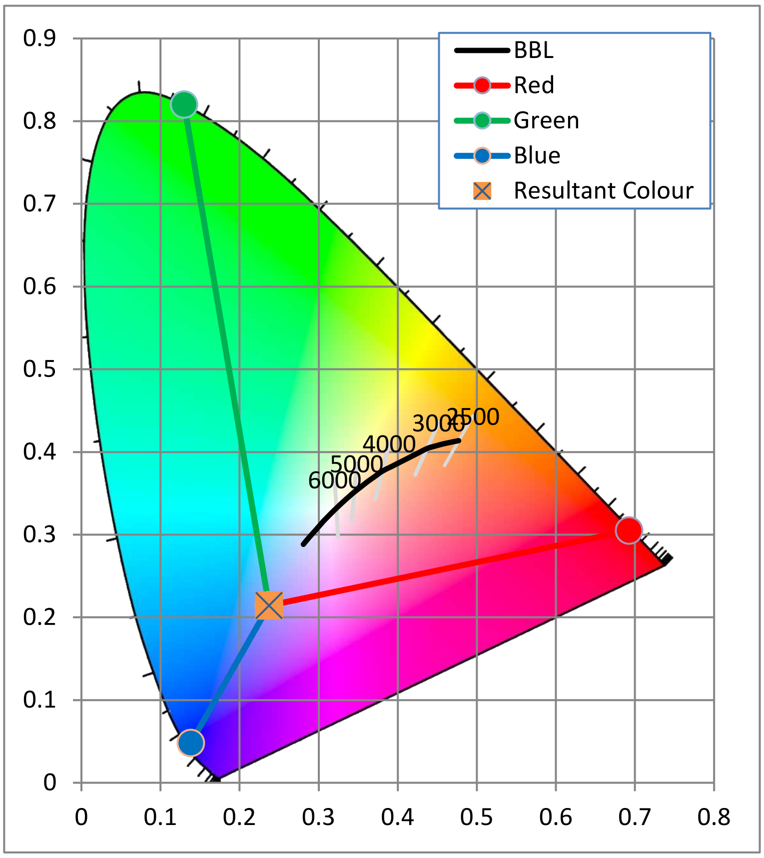

Figure 4 Colour mixing using RGB LEDs. The resultant colour shown here is achieved using equal power of red, green and blue.

But the reality is, using RGB LEDs can create any colour contained within the triangle defined by the 3 LEDs. This includes the points on the black body locus. This means that, if the mixes are properly calculated, a variable white system implemented using RGB LEDs can follow the BBL better than a system using 2 white LEDs and achieve a better range of colour temperatures.

However, the CRI of this solution will be very poor (given the spectrum will contain only 3 peaks correlating to the 3 LEDs). So, in this case, those initial instincts to disregard this solution can be considered to be correct.

[1] It should be noted that this figure is far outside the accuracy range for the calculation used (McCamy Approximation). Furthermore, it is highly unlikely that any meter would measure the CCT to such a high temperature, most likely it would return the upper limit for the measurement.

Using RGBW LEDs

The solution to the poor CRI achieved from using RGB LEDs to create a variable white system is to add a white LED into the mix. This effectively "fills in" the spectrum.

The range of achievable colours is defined by the triangle defined by the red, green and blue LEDs. A variable white system using RGBW LEDs can very closely follow the BBL. It can achieve a wide range of colour temperatures and maintain a high CRI for a good part of that range. Digilin's tests have shown a CRI at least as high as the specifications for the white LED being used for a range from 2500K to 5500K using a 3000K white LED (as shown in Figure 6).

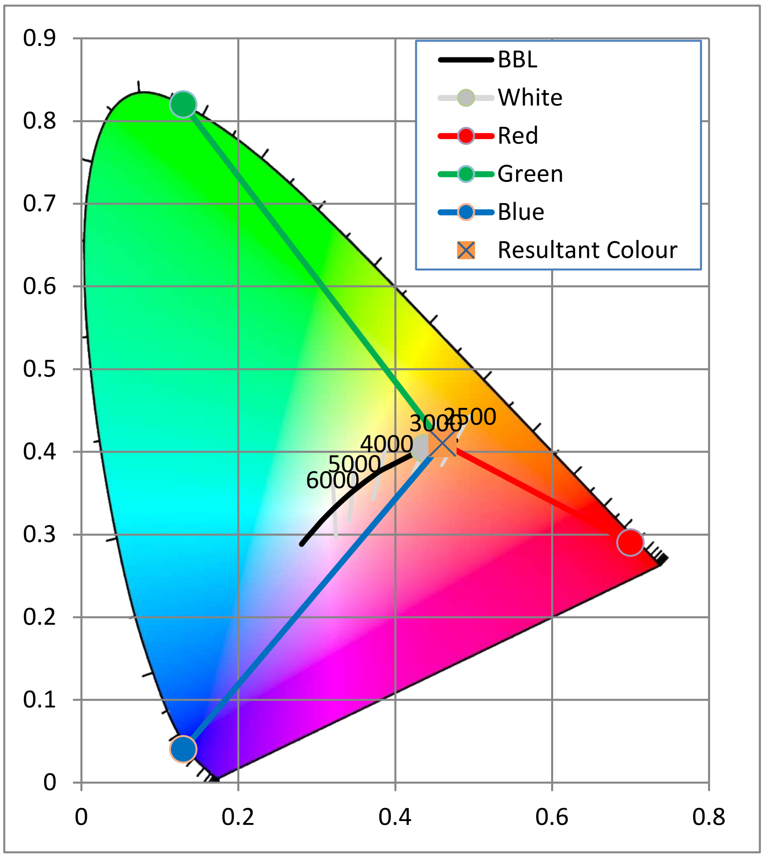

Figure 5 Tuneable white using RGBW LEDs

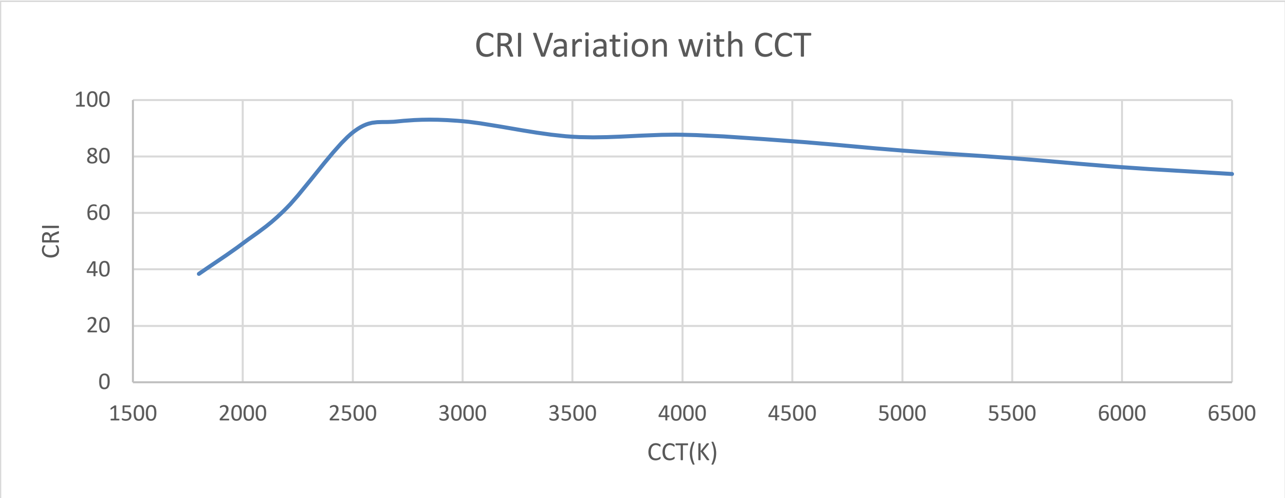

Figure 6 CRI variation in system implemented using RGBW LEDs

Summary Matrix

Solution	Pros	Cons
White LEDs	• Good CRI for full range • Simplest Calculations • Very simple to maintain a constant light level • Cheapest for a standalone Variable White solution (ie no colour requirement)	• Deviates from BBL • Colour temperature range is limited to the availability of LEDs
RGB LEDs	• Follows BBL	• Poor CRI
RGBW LEDs	• Follows BBL • Good CRI for a central range • Price benefits for full colour + white solution • Can implement a wider range of colour temperatures	• Most complex calculations