

Color mixing with LEDs:

The keys to achieving both beautiful and functional results



Intended for: lighting designers and technicians in the entertainment and architectural industries who already have basic familiarity with the general benefits and performance parameters of LED lighting

selador series
 **by ETC**

This discussion differentiates between the myriad LED offerings on the market by examining the quality of colored light achievable with LEDs.

LED color mixing

There are two big problems associated with LED color mixing:

- 1) LEDs operate under the principles of *additive* color mixing, which is contrary to conventional color from white lamps with filters. Misleading information from LED manufacturers has distorted the fundamental requirements for beautiful additive light.
- 2) Conventional approaches to additive color-mixing fail to produce richly saturated colors and natural-looking soft tones across much of the spectrum, leading to a more unnatural appearance of the light.

When managed properly, LEDs can produce deeply vivid color throughout the spectrum, as well as crisp, white light and vibrant pastels. LED fixtures can operate seamlessly, even invisibly, next to conventional tungsten sources, but it takes a careful approach to color-mixing to tap LEDs' full color potential.

Additive color



RGB additive color mixing

Mixing light by layering saturated colors on top of one another is something that most designers do regularly by using multiple fixtures in a lighting plot. However, additive color-mixing within a single luminaire is a new function, and it can be intimidating to many users. Consequently, confusing marketing hype abounds, and claims such as “full-spectrum light,” “16 million colors,” and “full-spectrum RGB mixing” can easily lead consumers to expect performance that most LED fixtures can't deliver. While red, green and blue are the primary colors of light, using these colors for additive color mixing is far from adequate to achieve beautiful, functional lighting in many situations.

Red-Green-Blue or “RGB” color mixing frequently claims an ability to produce any desired color across the visible spectrum at any level of saturation. RGB mixing is by far the most common kind of color mixing used within conventional LED luminaires.

The term “primary color” is unreliable. So-called primary colors can only produce approximations of other hues when mixed together; they cannot produce exact replicas. Red, green and blue cannot, in fact, produce extremely saturated color at any hue except red, green and blue. Other colors mixed by RGB tend to appear washed-out or grayish, particularly in the amber-yellow, cyan-turquoise, and deep purple regions.

Grayed, washed-out color from RGB fixtures is a consequence of fundamental principles of additive mixing that limits RGB capabilities. It cannot be overcome by simply using better reds, greens and blues within an LED array. No RGB luminaires can ever truly be “full-spectrum” light sources, despite the catch-phrases and taglines frequently used in their promotion. A corollary to this can be seen in the printing industry. Look at the printing-plate registration marks on the edges of breakfast-cereal boxes or brightly printed fabric. There are often many more than three or four inks used in order to get really vibrant colors, sometimes as many as 10 to 15 different inks on a single image. In this case, the color mixing is subtractive rather than additive, but it's always true that more color on the input side equals better color on the output. Whether in print or in light, the same principles apply.

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Some designers describe RGB luminaires as always having an electronic look to them – like the light from a video monitor – with none of the depth or richness of a tungsten lamp or saturated gel. It is sufficient when no other visual reference, such as light coming from a tungsten lamp with a filter, is available for comparison. When tungsten light is visible, RGB light sticks out, looking digital, fake and animated.

Imagine a color wheel with all of the colors around the perimeter: the most saturated color at the edges and the least saturated, whitest colors near the center. An RGB fixture's output can be plotted by marking a spot at the circle's edge for each point representing red, green and blue. Connecting these three points creates a triangle and the area within this triangle denotes the gamut or color capabilities of the RGB fixture.



It should be apparent that at locations within the triangle between the three RGB corners, the saturation of any given color is less than the red, green and blue points. For example, to achieve an amber color, mixing red and green together produces an amber-type light that is less saturated than pure amber light. This is reflected by the fact that the amber point on the line between the red corner and the green corner is some distance away from the edge of the color wheel. Plotting the gamut on a standardized color space like the CIE Chromaticity Diagram produces similar results.

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Deficiencies in the saturation of RGB colors are obvious when illuminating white surfaces. What is not readily apparent on a white wall is the odd behavior that RGB lighting can exhibit when illuminating colored objects and skin tones.

Lighting objects and people

RGB luminaires – or for that matter, any luminaires that use only a few colors of LEDs within their mix – tend to exaggerate the colored surfaces of the objects and people they illuminate. Objects appear to have “hyper-real” color. Everything looks somewhat lurid and unnaturally brash – either too red, too green, or too blue – and it is difficult to distinguish between objects of a similar hue. Skin tones can seem ruddy or slightly greenish, depending on the complexion. In rare circumstances, this may be desirable, but most designers require precise control over the appearance of the people and objects they're lighting. RGB does not provide the control necessary, and it does not operate seamlessly next to tungsten or other conventional lighting.

There are applications in which RGB color-mixing is completely adequate, and the last decade has seen the adoption of RGB-based LED lighting in many innovative projects. However, for lighting applications that require high-quality output, with beautifully deep color all over the spectrum and vibrant fullness in tinted light, RGB can fall far short of designers' demands. In fact, RGB has been so limited that before other color-mixing options became available, LED fixtures in general began to be unfairly characterized as incapable of legitimate illumination work, and the technology was relegated in many professionals' minds to novelty functions and decoration only.

In recent years, other approaches to additive color-mixing have entered the market, and the stigma of digital lighting has started to dissipate.



Alternative color-mixing approaches

Luminaires are available that incorporate amber or white LEDs into their LED arrays, for a combined RGB+A, RGB+W, or even RGBAW mix. The color-mixing gamut and ability to illuminate colored objects and skin tones is an improvement over RGB. However, most of these luminaires fail to properly balance the output of the various colors in the mix to maximize their benefit.

Most amber LEDs are not as bright as red or green emitters of the same package. This fact, combined with the spectral role that amber plays within a color-mixing array, usually requires that large quantities of amber LEDs be used relative to the other colors in order to have a sufficient effect on the performance of the luminaire. In the vast majority of RGB+A and RGBAW fixtures, there is only a single amber LED for each red, green and blue LED. This makes the contribution of the amber LEDs relatively minimal.

Incorporating white LEDs within a color mix can improve the appearance of white-type light and enhance the rendering of illuminated skin tones and colored objects. It does not expand the colored-light gamut of the fixture.

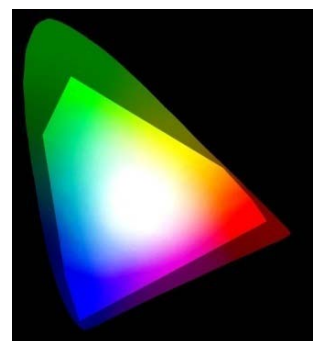
The ultimate multiple-color approach

Returning to the color-wheel diagrams, one can see that by adding many more colors to the LED mix, the gamut of saturated colors can be greatly expanded within a luminaire.



Seven-color additive mixing

These diagrams show an LED array with seven colors in the mix. The colors are spaced across the spectrum to fill many of the large gaps left by RGB. When the ratios of the various colors of LEDs are managed very carefully in a fixture like this – so that their relative output is well-balanced – color mixing becomes intuitive, and the range of beautiful, deep jewel tones and rich, satisfying pastels can surpass that of other luminaires.



Using a balanced, multiple-color mix, lighting designers can more precisely imitate the performance of tungsten and other conventional sources, along with a full complement of gels and filters. In fact, an LED fixture like this can exceed the deep saturation of most gels if the designer wishes them to do so. When desirable, the saturation can be easily pulled back, and the gel output can be duplicated at whatever is the required level of saturation.

Another key benefit of this approach to color-mixing is that illuminated objects and skin tones are rendered much more naturally. Color Rendering Index (CRI) values are much higher in these kinds of LED fixtures, and colored surfaces are illuminated intuitively and predictably every time – no hyper-real color.

When emulating the output from a tungsten lamp with a gel, the multiple-color approach can match not just the apparent color but also the spectral composition of the reference source with good precision. This is essential for accurate reproduction of color on costumes, scenic elements, skin and makeup. It uniquely allows designers to think of LED fixture output in terms of gel colors, with predictable results.

Multiple-color mixing allows LED lighting to excel in large-scale, premium illumination functions that would otherwise be unattainable for the technology.



A fuller palette enables more precise performance. The multiple-color approach epitomizes this, but falls short of what could rightly be called full-spectrum lighting. A multiple-color luminaire is closer to the ideal. RGB has its place, but multiple-color mixing allows LED lighting to excel in large-scale, premium illumination functions that would otherwise be unattainable for the technology.

In situations where the quality of light from an LED luminaire is of critical importance, lighting professionals doing serious illumination should look for the following:

- More than three colors of LEDs within the light engine
- A designed and balanced ratio for intuitive color-mixing and predictable brightness levels, rather than a one-to-one relationship of colors across the spectrum
- Light output that can match the appearance of open tungsten as well as favorite gel colors when shining onto a white surface
- Light output that illuminates people, colored objects, and other elements naturally, with better color-rendering for seamless integration with other sources An LED illuminator that can interact seamlessly with conventional lighting systems

Selador x7 Color System™ by ETC

Selador luminaires by ETC are designed around a unique approach to color-mixing, called x7*. Using this system, color is rich, full and carefully calibrated for the deepest color saturation and finest light production possible from an LED instrument, because from their foundation, Selador products are built for theatrical-grade illumination.

Seven different LED colors are maximized within each Selador fixture for both bright, bold color and soft, clean white light.

The finely-tuned x7 system rejects the over-hyped premise of so-called primary colors and relies instead on long-proven color-mixing principles. Put very simply, x7 is the embodiment of the ‘more color within a light engine equals better light out’ philosophy. Seven different LED colors are maximized within each Selador fixture for both bright, bold color and soft, clean light.

Many designers comment that Selador x7 luminaires are not always immediately recognizable as LED fixtures by their output, because they don’t suffer from the digital dissonance of conventional LED lighting. Rather, they harmonize with tungsten, becoming virtually invisible in a lighting plot whenever necessary. When they need to stand out, the light from Selador luminaires has a weight and fullness that feels earthy and natural. Their spectral richness and sumptuous color capabilities are preferred by lighting professionals for all kinds of applications.

Whether they’re used for deep colors, soft pastels, or brilliant white light, Selador luminaires by ETC are unique among LED fixtures:

- They reach a depth of color-saturation that no other single instrument can attain.
- They mimic conventional lamps and gel colors at a spectral level, meaning that objects and people are lit predictably and intuitively.
- They can operate side-by-side with tungsten and other conventional sources in order to seamlessly perform real illumination work, rather than simple novelty functions.
- They overcome the limitations of three- and four-color additive mixing and fully capitalize on LED potential for beautiful light.

Vibrant color-mixing is a unique benefit of Selador fixtures by ETC. There are also other technologies within Selador luminaires that further enhance their performance and make them distinctively capable of performing high-level illumination. To schedule a demonstration of Selador x7 technology in your own space, please contact your nearest ETC representative.

*The x7 Color System is protected under US patent 6,683,423 B2, Jan. 27, 2004



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