Not Everything in Engineering is Black & White: Driving Color LED Solutions

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White mid- and high- power LEDs are rapidly taking over the market space previously held by incandescent light sources. Edison's long-held domain is quickly ending. This has given light to new application development. However, there is much more that can be done with LEDs by taking advantage of the rainbow of colors they can create. Today, there are a variety of LEDs that fill the gamut of the full color spectrum, enabling a wide variety of applications. These applications include wall washing, entertainment stage/theatrical lighting, and architectural design lighting, which often employ up to seven (7) different LEDs colors for precise control of the spectrum. Architectural designers are also considering applications in residential ceiling lights (fixtures), which most often utilize three (3) different color LEDs: red, green, and blue (also known as RGB). Color LEDs are also easily incorporated into emergency vehicle lighting (EVL) applications.

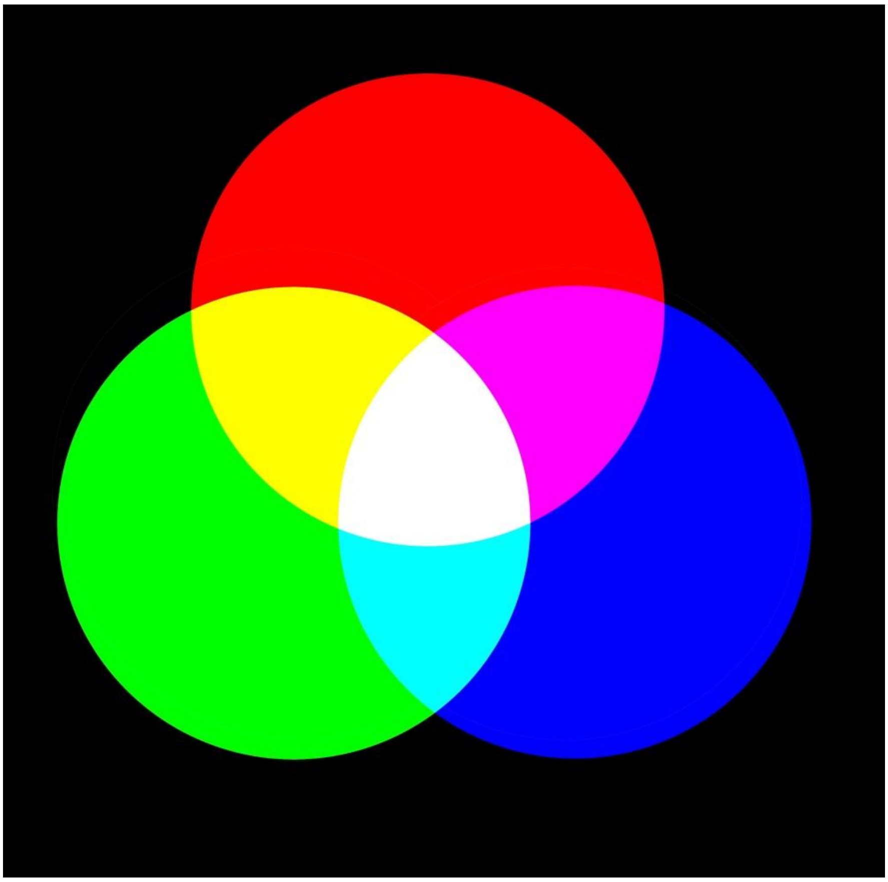

Figure 1: *Red, green, and blue light color mixing yields colors unexpected with that of opaque paints, for example.*
https://en.wikipedia.org/wiki/RGB_color_model

Color LEDs

The choice to employ color LEDs has never been more black and white. Of great importance in the above mentioned applications is that the LED supplier is able to provide multiple colors. These LEDs should come in color and light output combinations that make color mixing easy (Figure 1). Color mixing is greatly facilitated by having excellent quality LEDs in the red, green, and blue color spectrum.

A significant issue with the production of color LEDs is their output wavelength consistency. The human eye is extremely sensitive at distinguishing different colors. LEDs need to be produced to ensure that each are extremely consistent in their nominal wavelength. This allows easy integration with other colors so that the combined mix (color mixing) of all of the various LEDs can be adjusted to accurately hit the correct targeted color in a highly repeatable fashion. One such supplier that has a maintained a long leading position in producing such color LEDs is Lumileds. Nearly a decade ago, Lumileds launched the LUXEON Rebel Color Line - the market-leading color LEDs that have been transforming lighting designs ever since. Today, Lumileds delivers the broadest range of colors available, from far red to cyan, ultraviolet (UV), and even “lime” and “mint.” Lumileds offers the most comprehensive family of mid- and high- power color LEDs with the industry’s best quality of light.

LUXEON 3535L Color Line LEDs (Figure 2) is a mid-power LED that is available in six (6) colors and are packaged in an industry standard 3.5mm x 3.5mm footprint. Its single die and single source architecture provides excellent optical control, while its common focal length with LUXEON Rebel and LUXEON Z Color LEDs allows for easier optical design.

Luxeon 3535L Color Line

Color	λ (nm)	I (A)	E (V_{DC})	P (W)
Red	625	0.10	2.10	0.21
Red-Orange	615	0.10	2.10	0.21
PC-Amber	*	0.10	3.05	0.31
Lime	*	0.10	3.05	0.31
Green	530	0.10	3.20	0.32
Blue	475	0.10	3.00	0.30

Figure 2 *The Luxeon 3535L Color Line. *PC-Amber and Lime are binned by chromacity coordinates. All other colors are binned by dominant wavelength.*

Lumileds has recently introduced its new LUXEON C Color Line LEDs (Figure 3b), which are high power LEDs. These LEDs are great for colored general illumination applications; where now the trend is to add color changing capability to products that have traditionally only been “white” before (Figure 3a). They come in seven (7) colors with a single focal length that allows flawless color mixing to maximize optical efficiency and remove halos. Its low-dome design eliminates trade-offs between flux and source size, and it provides the industry’s lowest thermal resistance—helping engineers lower heat sink costs while achieving greater light output. Its small symmetrical package enables dense packing and limits the impact of rotation during reflow.

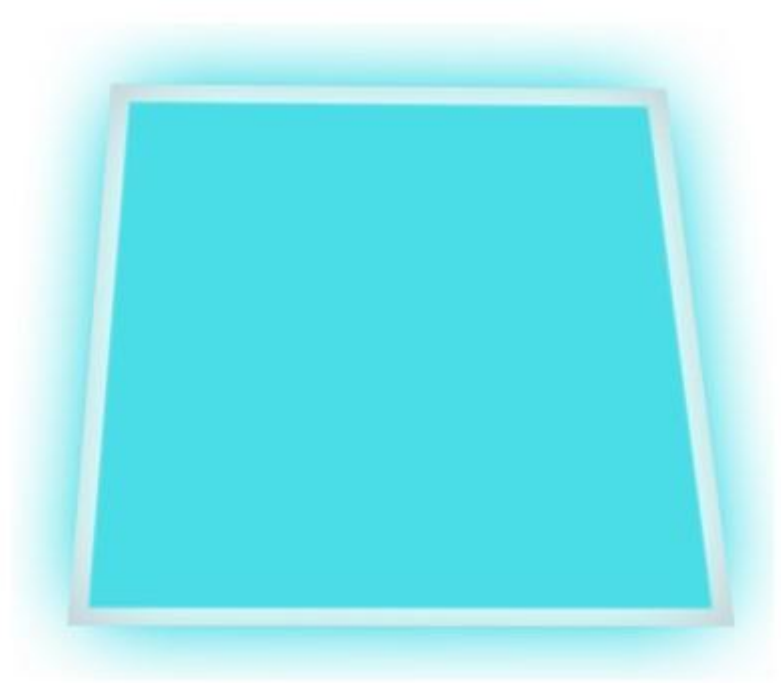

Figure 3a *Illustration of LED Flat Panel*

Luxeon C

Color	λ (nm)	I (A)	E (V_{DC})	P (W)
Red	629	0.35	2.00	0.70
Red-Orange	619	0.35	2.05	0.72
PC-Amber	*	0.35	2.75	0.96
Green	530	0.35	2.55	0.89
Cyan	500	0.35	2.60	0.91
Blue	475	0.35	2.90	1.02
Royal Blue	455	0.35	2.75	.96

Figure 3b *The Luxeon C line.*
**PC-Amber is binned by chromaticity coordinates. All other colors are binned by dominant wavelength.*

LED Drivers for Colored LEDs

Accurate color mixing requires precise current control. Ideally one can design using LED drivers from sup- pliers with a history for excellence and innovation such as Texas Instruments. TI's award winning AC/DC and DC/DC LED design solutions enable customers to build differentiated products across all power levels and form factors that are energy efficient, reliable and cost effective.

A traditional way to drive color LEDs is using constant voltage AC/DC powering LEDs with a simple linear control circuit using a MOSFET and resistor to ballast the Vf variation. Another way is to design in buck regulators, providing an efficient, ideal way to convert the constant voltage to constant current. Color illumination applications may also call for higher efficiency LED drive electronics and ideally one string per color. Let's look at a couple of LED driver design ideas related to operation in the DC/DC domain.

Driving Color LED Solutions

LED Driver: Linear Regulator

Since different color LEDs come with distinct and unique forward voltages requirements, design engineers usually want to consider how significantly the system's overall power efficiency will be impacted, based upon potential design configurations. For the purposes of simplicity, let's consider the example of operating with a 21VDC output that has been converted from an original 120VAC input. The $21V_{DC}$ would be operating across three lines of LED strings consisting respectively of blue, green, and red LEDs. By way of example, String 1 consists of 6 blue LEDs; String 2 consists of 6 green LEDs and Sting 3 consists of is 6 red LEDs of the Luxeon 3535L Color LEDs series, all running at 100mA each. Such an LED arrangement would yield blue ($6 \times 3V_{DC} = 18V_{DC}$); green ($6 \times 3.2V_{DC} = 19.2V_{DC}$); red ($6 \times 2.1V_{DC} = 12.6V_{DC}$). If a multi-channel DC LED solution with the electrical characteristics of a linear regulator style part was designed in, such as the Texas Instrument TLC59xx series, it would be a good fit for the Luxeon 3535L Color LEDs because it can deliver 40–100mA/channel (Figure 4). In implementation, noticeable power inefficiencies would be realized due to the differences in voltage drops across each of the respective strings. However, the design is easily improved with by consideration of a buck regulator.

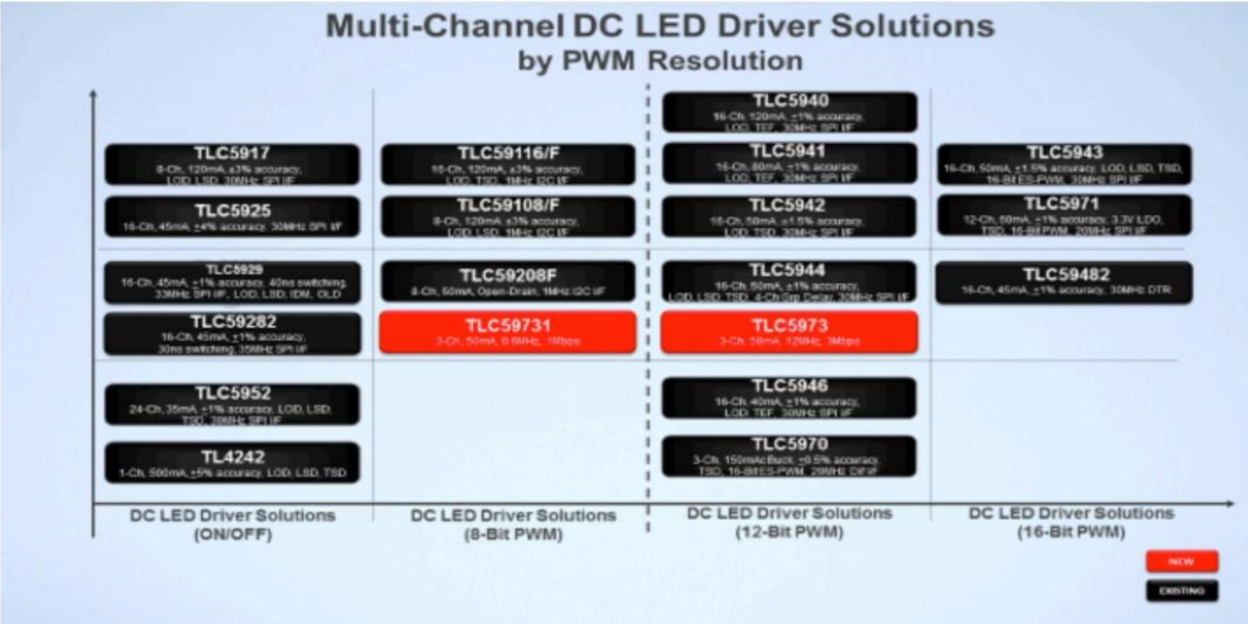

Figure 4 *A few Texas Instruments; multi-channel LED driver families*

LED Driver: Buck Regulator

To increase efficiency, one could design with switching buck LED drivers like the Texas Instruments TPS92513. (Figure 5)

Figure 5 *Texas Instruments 1.5A Buck LED Driver with integrated Analog Current Adjust*

The TPS92513 is rated at 0.1–1.5A and is a good candidate to look at as a buck LED driver for use with the Luxeon C LEDs. TPS92513 allows for accurate current adjustment by providing separate inputs for PWM (>100:1) or analog (DC) (>10:1) methods to control output light intensity. This feature provides no compromise on brightness control because such a topology allows greater distinctions to be made internally, ensuring that the most accurate measurement of input dimming is utilized and processed. The ±5% LED current accuracy of the TPS92513 means colors can be easily predicted and controlled to prescribed color mixing. The TPS92513 also has a wide input range (4.5 V_{DC}–42V_{DC} (HV)), allowing it to work well when multiple LEDs are employed. As a switching regulator, it maintains high energy efficiency and its 5mm x 5mm HVSSOP-10 package comes standard with integrated undervoltage-lock-out (UVLO), overcurrent protection, and overtemperature protection, protecting the IC during fault and abnormal operating conditions.

If color LEDs require more or less current as part of the design, engineers could look further at the 2.5A TPS92512 and/or the 0.5A TPS92511. These products offer PWM dimming (> 100:1 ratio), common anode LED configuration, and simple external circuitry (a small number of external passive components). (Figure 6)

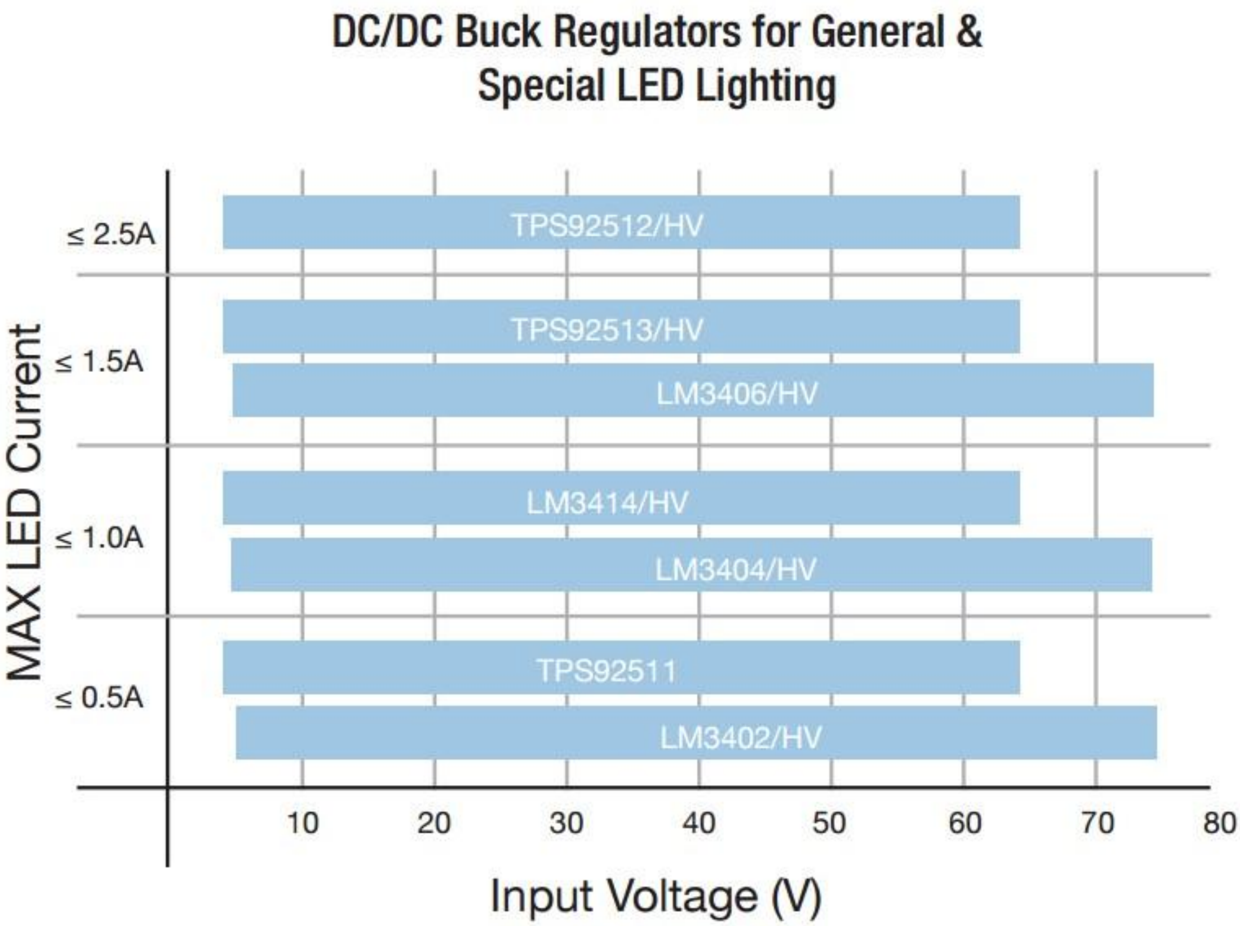

Figure 6 *DC/DC Buck Regulator for Color LED Applications, Courtesy of Texas Instruments*

LED Driver: Dynamic Headroom Controller

Consider a third way to operate a set of color LED strings that combines the advantages of both linear and switching converters. Dynamic Headroom Controllers (DHC) such as the LM3463, delivers accurately regulated current to LEDs while maximizing the system efficiency.

This part functions as a linear LED driver with increased efficiency by adding tailored dynamic headroom control to each individual string voltage. It makes this approach reasonably efficient—assuming the LED string voltages are in actuality somewhat close to each other. It automatically adjusts the boost converter output to optimally drive the LEDs. It supports all the common dimming control methods in the market today, while providing protection for the LEDs, MOSFETs and LM3463 from common fault conditions.

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The LM3463 is well suited to handle the drive currents associated with high power color LEDs such as the Luxeon C LEDs. Additionally, it is cascadable, giving designers the advantage of extending the number of output channels. It is suitable for very high lumen (light) output applications, making it a natural consideration for outdoor applications.

Conclusion

No longer is everything in engineering lighting design simply black and white. Color LEDs are being de- signed into all sorts of applications. Color illumination applications require well designed and consistent LEDs combined with efficient LED drivers. There is a variety of ways that these designs can be configured to optimize the color solution. Lumileds and Texas Instruments are long-term global leaders at providing the components required to satisfy engineering designers’ color LED demands.