Application Note AN93

Electrical Drive Considerations for Bridgelux Vesta™ Tunable White Series Products

Introduction

The Bridgelux Vesta™ Series Tunable White products, including Vesta Tunable White arrays and emitter on board products, deliver high performance, compact and cost-effective solid-state lighting solutions that serve the general lighting market. These products combine the higher efficiency, lifetime, and reliability benefits of LEDs with the light output levels of many conventional lighting sources.

Optimizing performance and reliability of a lighting system using Bridgelux Vesta Series requires careful consideration of thermal management solutions (AN30), handling and assembly (AN31 and AN101) and selection of secondary optics (AN36).

To achieve optimal performance of the Tunable White products, proper electronic drivers must be selected or designed. This application note will assist designers in selecting or developing electronic drivers for use with Bridgelux Vesta Tunable White Series products. The first step is to become familiar with relevant electrical characteristics of the Vesta Tunable Series White products. This includes the relationship between forward voltage and current, and the relationship between light output (luminous flux) and current for these dual channel products.

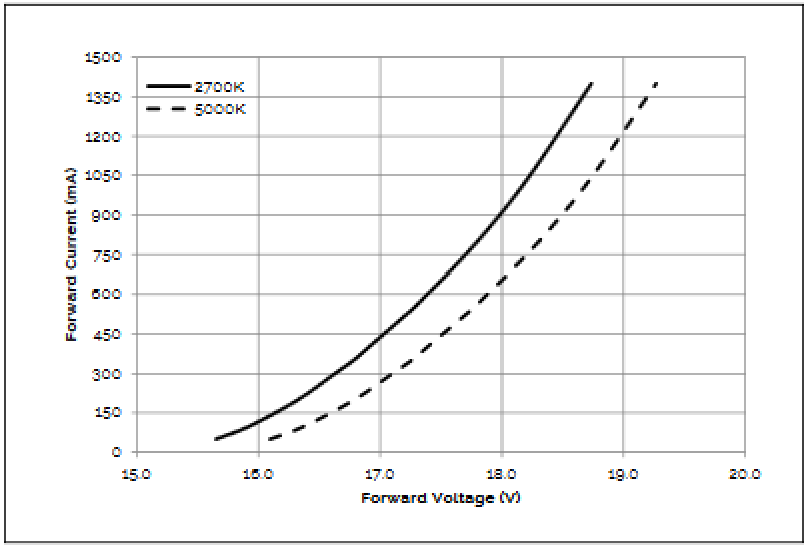
The second step is to define LED driver requirements, usually specific to the given application. Design considerations include defining the driver's input voltage (e.g., AC line voltage input, a combination of AC-DC and DC-DC drivers, or DC input from batteries), defining an optimal driver output current, establishing dimming requirements, and determining both temperature and lifetime requirements to satisfy the needs of the application. This application note provides general guidelines to the designer to assist in enabling a successful design.

Table of Contents

LED Electrical Characteristics

Bridgelux tunable white products are manufactured using high power light emitting diodes, a technology that is proven to be a robust solid state light source and one that exhibits specific electrical characteristics relevant to driver selection and design. The main electrical characteristic is the relationship between the voltage applied to the Tunable White products and the resultant current through the tunable white. This relationship is nonlinear and is usually shown as a graph which is commonly called the "current-voltage" or "I-V" curve (Figure 1).

Figure 1: Vesta Voltage vs Current



Since the Vesta Tunable White products are made up of 2 different products, a high CCT and a low CCT, each channel is driven independently, therefore the I-V curves of the Vesta Tunable white consists of 2 different I-V curves.

An "I-V" curve is provided in each Bridgelux product data sheet as a figure with the title "Forward Voltage vs Forward Current". The curve may be different for each tunable Tunable White product depending on the configuration of and the exact diodes within the device. It is important to always refer to the correct I-V curve for the particular LED tunable Tunable White product being used.

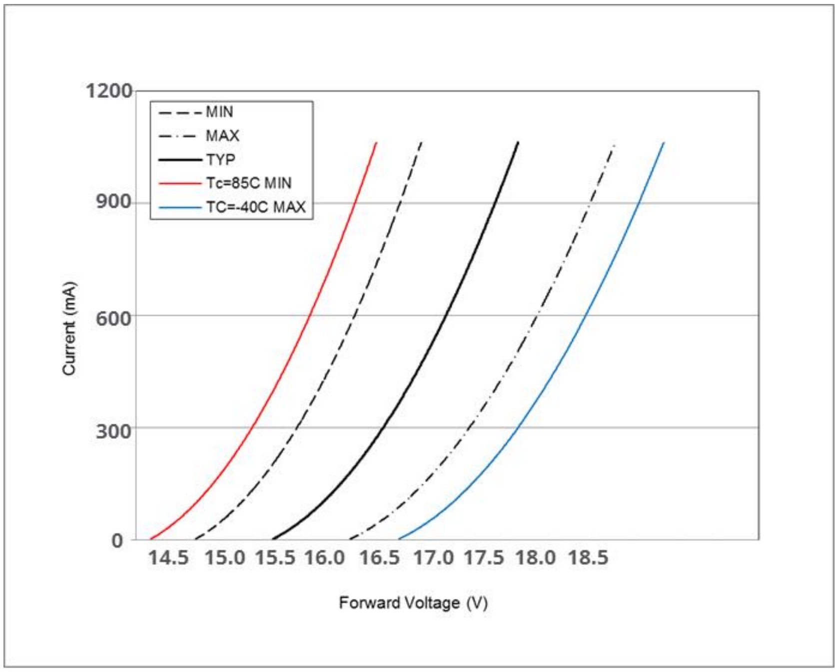
Two additional real-world considerations need to be made before using the simple "I-V" curve of Figure 1:

1. The current-voltage relationship of a diode is a function of temperature. The higher the diode junction temperature, the lower the forward conduction voltage (V_f) at a given current (i.e. the curve shifts to the left with increasing temperature).

2. Each LED will have some manufacturing tolerance which will affect the I-V curve. The shape of the curve will remain essentially the same, but there will be some variation which can be used to derive "minimum" and "maximum" curves that bound the possibilities of all devices built for that particular device number.

Figure 2 shows an example of these two conditions for a single channel. Note that in addition to the "typical" I-V curve (shown in solid black), there is also a "MIN and a MAX" curve (shown in dashed black). The TYP, MIN and MAX curves all apply at T_c = 25°C. Effectively, these curves are showing the worst case variation that can occur as a result of manufacturing variances. Although in many cases parts will actually fall closer to the typical curve, the driver selected should be able to cover the spread in V_f shown in this curve for the particular drive current which the tunable white is to be driven at. Also note that there is an additional curve, drawn as a solid red line to the left of the graph, labeled MIN Tc=85 deg C. Since the V_f will drop with increasing temperature, the lowest possible V_f will occur at the highest operating temperature point.

Figure 2: LED Tunable white I-V curve with MIN and MAX limits



Unlike a rectifier or signal diode, an LED is not intended to operate reverse-biased; therefore the “negative” forward voltage characteristics of the I-V curve are not shown. LEDs are not designed to be driven with reverse voltage as they may be damaged. LED drivers should be selected or designed to avoid applying a reverse bias to the tunable white.

For the maximum reverse potential that can be applied to a Bridgelux Tunable White product without causing damage, please refer to the table titled “Absolute Maximum Ratings” in the data sheet for that device. A sample of this table appears in Table 1 below.

Table 1: Maximum Ratings (sample table)

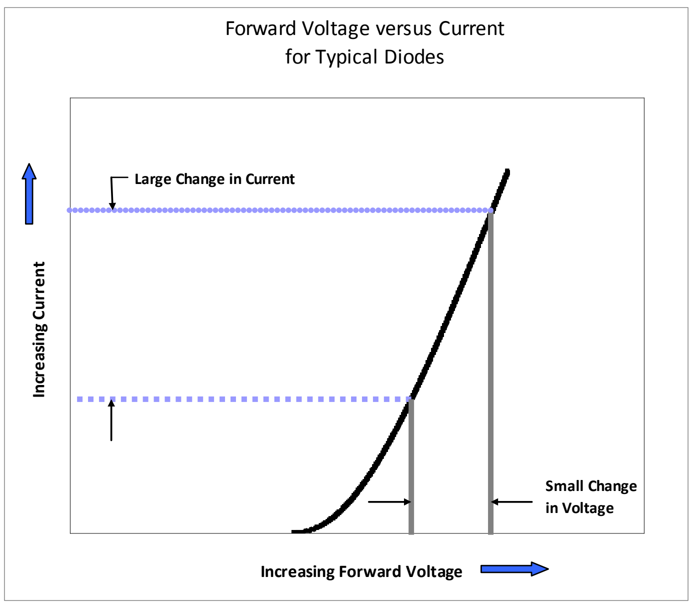
Vesta Series	Part Number	Maximum DC Forward Current (mA)	Maximum Peak Pulsed Current (mA) [1]	Maximum Reverse Voltage (Vr)
Vesta 9mm	BXRV-TR-2750G-1000-A-15	1400	2000	-30
Vesta 13mm	BXRV-TR-2750G-2000-A-15	1400	2000	-60
Vesta Linear 280mm	BXEB-TL-2750G-1000-A-13	1000	N/A[2]	Linear products are not designed to be driven in reverse bias
Vesta Linear 560mm	BXEB-TL-2750G-3000-A-13	2000	N/A[2]	Linear products are not designed to be driven in reverse bias

[1] Bridgelux recommends a maximum duty cycle of 10% when operating LED Tunable white products at the maximum peak pulsed current specified. Maximum peak pulsed currents indicate values where the LED tunable white can be driven without catastrophic failures.
[2] N/A = Not Applicable

Also shown in Table 1 is maximum DC forward current for the tunable white. The maximum DC forward current is self-explanatory – to avoid potential reliability issues do not operate the tunable white at drive levels above this maximum. For pulsed operation the higher "Peak Pulsed" limit may be used, not to exceed the duty cycle specified in the data sheet (normally 10% duty cycle). As for the minimum value, the tunable white will illuminate down to a few milliamps of driver current. The colorimetric performance of the tunable white can be affected by very low drive levels. At very low drive levels, the color can shift, however, the tunable white will continue to illuminate stably until the V_f falls below the turn on voltage of the tunable white, at which time the tunable white will turn off. Significant light output can be generated at milliamp levels, and for very deep dimming, operation to those levels may be desired and is permitted. Note that for a parallel configuration dimming at low levels will be an issue due to the amount of light output for each Tunable White might vary due to current hogging.

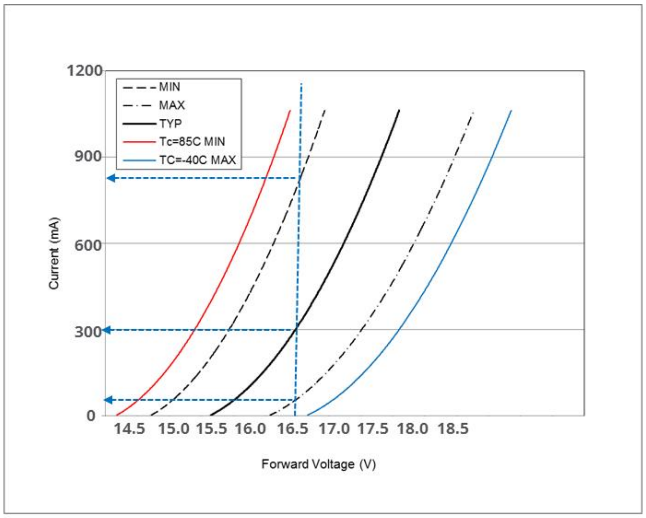
Bridgelux recommends the use of a constant current driver because the light output of the tunable white is directly proportional to the current through the tunable white. If a constant voltage source, as opposed to a constant current source, is used to apply power to the tunable white , a small change or difference in the forward voltage of the tunable white can result in a large change in the forward current flowing through the junction, and ultimately in a large change in flux performance (Figure 3).

Figure 3: Impact of a small voltage change on forward current for a typical diode



The light, or luminous flux, emitted by the tunable white is dependent upon the forward current applied across the junction. At a fixed voltage the current flowing through the devices can vary dramatically depending on the forward voltage of the individual tunable white. Consider the range of currents that occur at a fixed voltage. If we look at Figure 4 we see that the maximum, typical, and minimum currents for this tunable white with an applied voltage of 16.5V would be 825mA, 300mA, and 60mA, respectively (at 25C), depending on the I-V characteristic of the particular tunable white . Another tunable white, even from the same production lot could have a different I-V characteristic (curve position). The light output from a single luminaire using a constant voltage driver could be dramatically different than that of a nearby luminaire also with an equivalent constant voltage driver. This is generally not very desirable. It is for this reason that Bridgelux recommends against driving tunable white products with constant voltage sources or connecting multiple tunable white products in parallel.

Figure 4: Current vs. Voltage Curve of a Tunable white

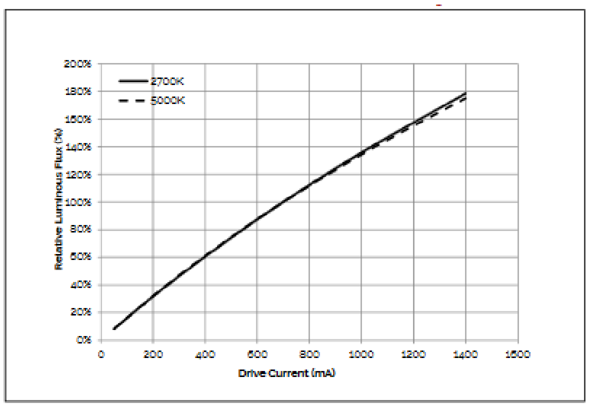


Another important electrical characteristic of the Bridgelux tunable white products is the relationship between forward current and luminous flux. Figure 5 shows a representative typical flux versus current plot for a Vesta tunable white. All Bridgelux tunable white products exhibit these similar characteristics:

1. Increasing the forward current increases the luminous flux output of the tunable white. However, the relationship between flux performance and forward current is not linear, a common characteristic for all tunable white products. For example, doubling the forward current does not lead to doubling of the flux output. This non-linear relationship of flux vs. forward current (or LED efficacy vs. forward current) is typically referred to as “droop.”

2. LEDs are less efficient at higher driver currents than at lower currents. Driving the LED tunable white with a fixed current will maintain a given efficiency level.

Figure 5: Typical Vesta Flux vs. Current

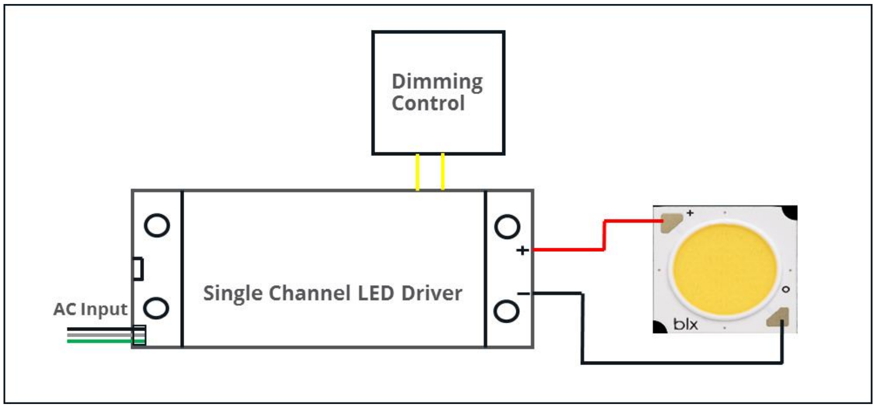


White Color Tuning

White color tuning is achieved when the light output of two or more different LED's with different CCT are combined. The Vesta Tunable White series combines LED's of two different CCTs (2700K and 5000K). To achieve color tuning, two Tunable White products of different CCT (2700K and 5000K) are placed closed to each other and the current is varied for each individual channel to vary the CCT of the total light combined of the two individual tunable white products. By varying the current of each individual channel, the two channels combined to produce a white light that varies from 2700K to 5000K. To vary the intensity of the light output, both channels will need to be varied simultaneously.

For a single LED array, the CCT and color point is fixed throughout the dimming range. A single channel driver is shown in Figure 6, the dimming control (DALI, Bluetooth, Wi-Fi, and Triac) varies the current output of the driver which varies the light intensity, but the CCT and color point will not vary.

Figure 6: Single Channel LED Driver



The Vesta tunable white products allow the user to vary the CCT and color points by varying the current for the two independent channels, cool white (5000K) and warm white (2700K). The color point is determined by the current ratio between the warm white channel and the cool white channel. Figure 7 shows the CCT curve that the Vesta tunable white achieves versus the current ratio. Figure 8 illustrates the color points for the Vesta tunable white products.

Figure 7: CCT vs Warm White Current Ratio

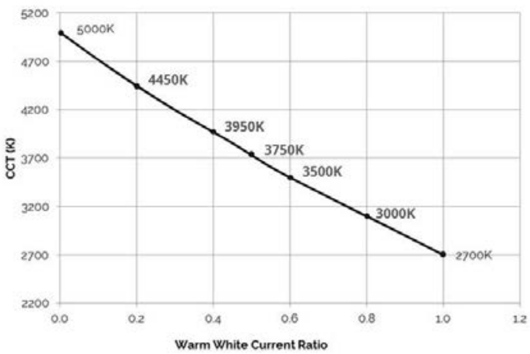
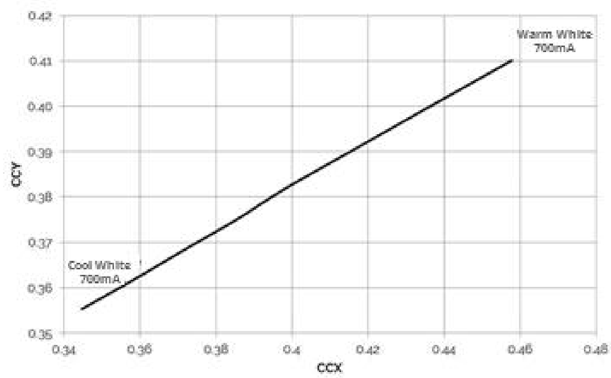
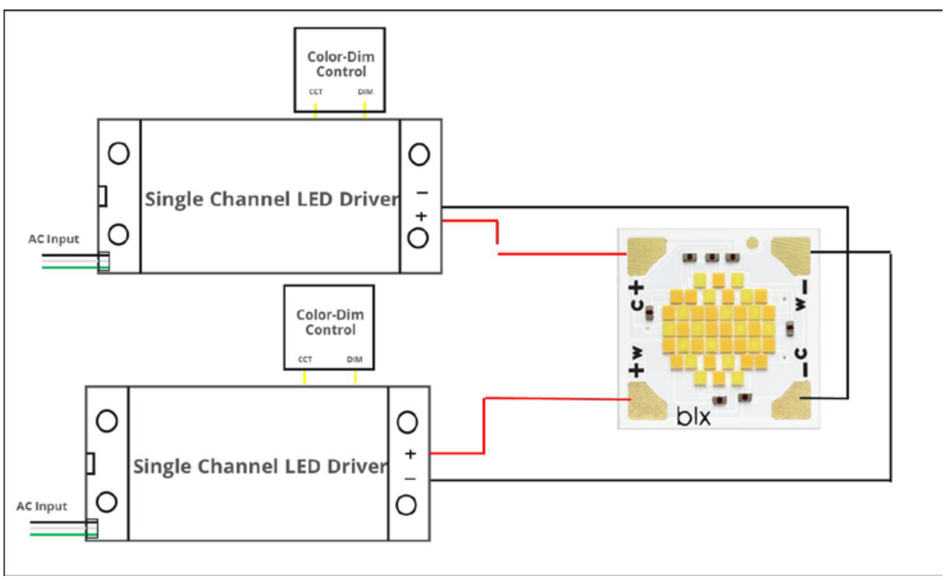


Figure 8: Color Point vs Forward Current



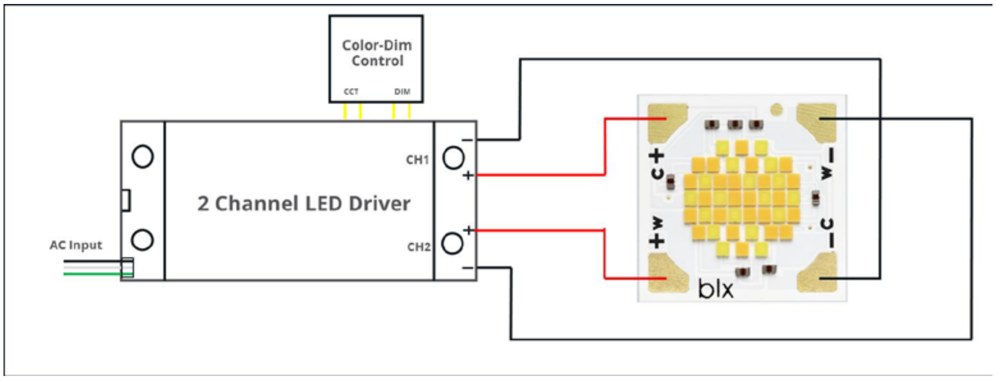
Since the Vesta Tunable White has two independent channels there are multiple options to drive these devices. The first option is to use two single channel LED drivers with dimming input which will independently drive a channel. An issue with this approach is it will make the dimming control more complex by having to dim each channel separately and require the end user to integrate the dimming in software. The two driver solution increases the cost and size of the overall system. An example of the two driver approach is shown in Figure 9.

Figure 9: Two Single Channel Drivers



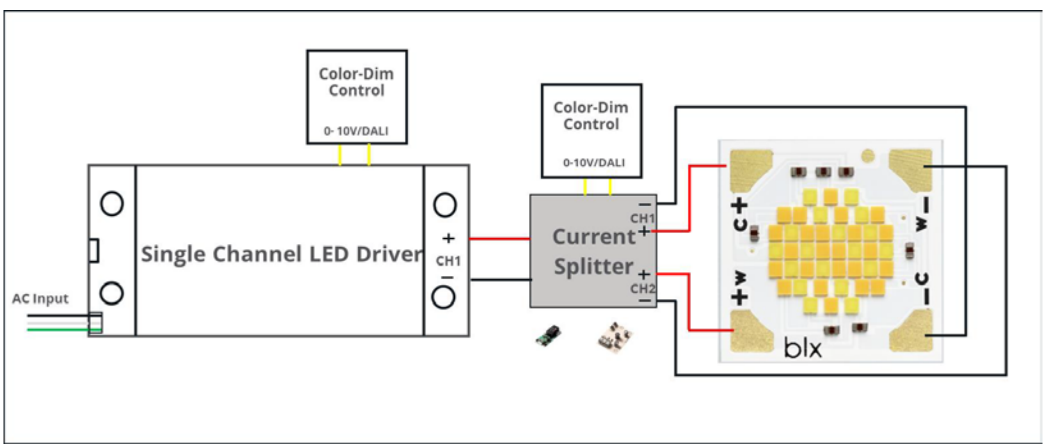
A single driver that has a single dimming control input and two independent outputs is a more optimal overall system solution. With a single dimming control input, that has independent control for CCT and intensity the user is able to control both channels simultaneously for a smoother transition between CCT and color points. Changing of the CCT and intensity will be done through an interface such as an App on a mobile device. Figure 10 shows a single driver with 2 channel output.

Figure 10: A single 2 Channel LED Driver



Another option is the use of a current splitter which allows the use of a single channel LED driver and the current splitter to create two independent channels to drive the Vesta Tunable White. For example if the LED driver output has a 1400mA current output, that current will get split into two independent channels driving 700mA each. The current splitter allows dimming through a 0-10V or DALI interface or through manual push button control. The use for a 0-10V or DALI application requires that the LED driver have 0-10V or DALI input. For manual push button control, no dimming input is required of the driver. An example of this application is shown in Figure 11.

Figure 11: Single Channel LED Driver with Current Splitter



Dimming

Dimming is the action of reducing the light output of the Tunable White below its normal operating level. It may be done with the intention of energy savings, or just to create an ambiance or a more appropriate lighting level for the task at hand. The dimming effect is usually specified as a percentage of full driver output. This is also one of the first areas of confusion, because the percentage of dimming is expressed by the driver manufacturer as a percentage of *ELECTRICAL* output. The end customer is usually concerned about dimming to a percentage of *LIGHT* output.

The light produced by an LED is proportional to the current flowing through the LED. However, that relationship is not linear. The light produced is also a function of LED junction temperature, and as the drive current is reduced, the junction temperature will drop (assuming that the thermal solution remains unchanged), adding additional nonlinearity to the dimming characteristic and range. The two considerations from a specification standpoint that should be kept in mind for dimming are the range or depth of dimming, and the linearity or dimming curve.

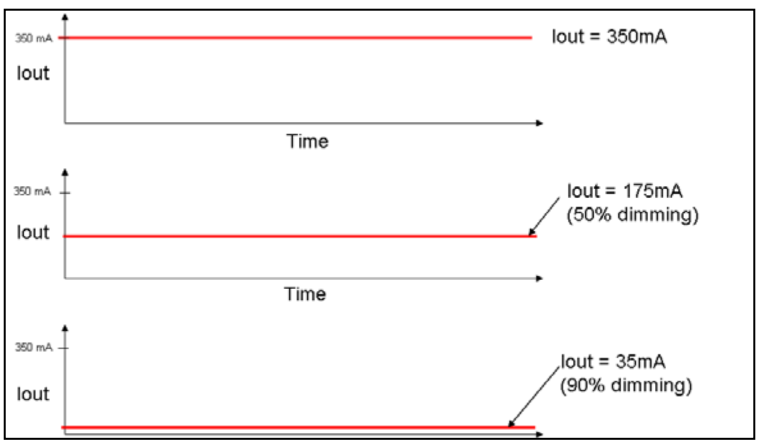
From a driver perspective, there are two aspects regarding dimming that should be distinguished and clarified:

1. The dimming control signal is an input to the driver, and
2. The actual technology employed to achieve the dimming effect which is the output from the driver.

Commonly used dimming control signaling methods include 0-10V (analog), triac (phase cut), PWM, DALI control, and many other signaling methods. Regardless of the method used, the result is the same – the desired level of output is communicated to the driver.

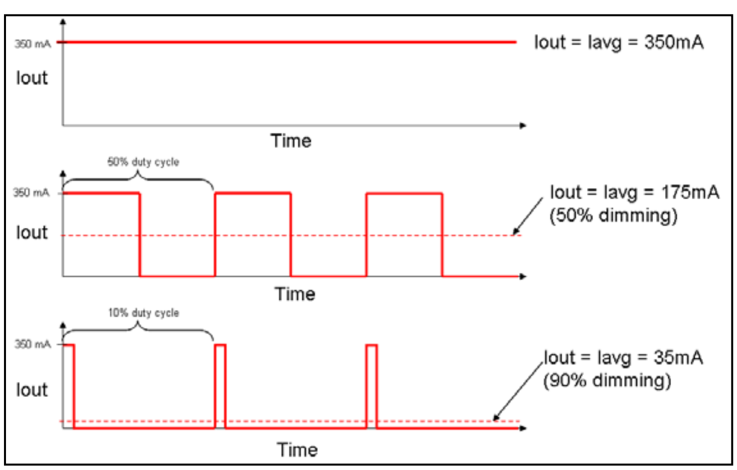
Commonly used technology to control the drive current to the LED for dimming are based on two approaches – analog or Pulse Width Modulated (PWM). In analog dimming, the output current of the driver is reduced to the percentage of full level as requested by the dimming control signal. This is illustrated in Figure 12a. Since the current through the LED is reduced, the luminous flux produced by the LED is also reduced and dimming is achieved. In PWM the current to the LED is always either 100% or 0% (on or off) and the ratio of "on" time to "off" time is changed to achieve dimming. Assuming that the frequency of the change is high enough to not be visually perceptible (e.g. at least 120Hz per -ENERGY STAR® Program Requirement for Integral LED Lamps, but preferably several thousand Hz, to avoid stroboscopic effects), the human eye will average the light intensity produced, and the net result is that for a given percentage duty cycle the light will look the same as if the LED was driven by an analog drive of that same percentage (Figure 12b).

Figure 12a: Analog Dimming output to LED



Note: A linearly dimmed current level does not bear a linear relationship to the actual light output (LOP) level of a LED and therefore the dimmed current percentage does not necessarily correspond to the same percentage of LOP reduction versus the maximum LOP level at 100% current level.

Figure 12b: PWM Dimming output to LED



Each of these two dimming implementation methods has advantages and disadvantages.

With the analog method, since the driving current "I_f" is continuously conducting through the LED, there is no possibility of flickering. Since there are no high frequency switching effects, the possibility of electromagnetic interference (EMI) is reduced, possibly simplifying testing for regulatory compliance. On the downside, at very low drive levels, the possibility of electrical noise on the drive signal is very real, and that noise can sometimes be visually disturbing, resulting in a flickering or "popping", especially because the human eye is so sensitive to small changes in light at very low ambient light levels.

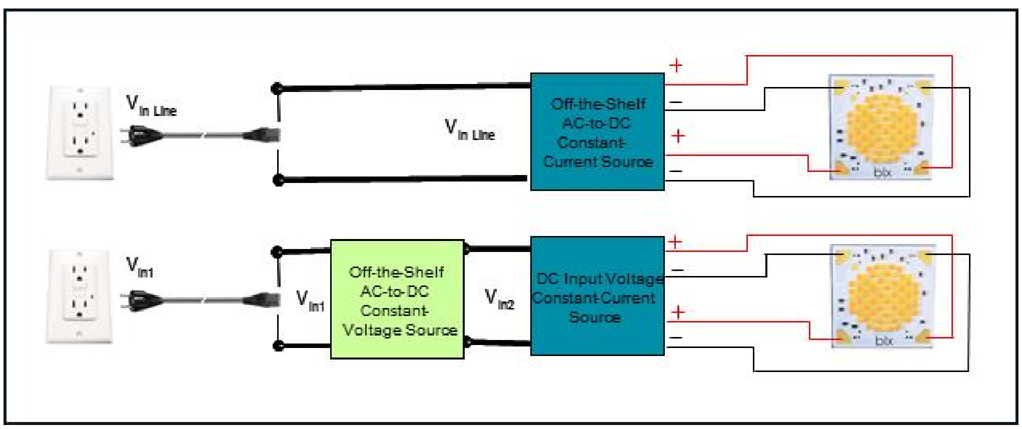
With the PWM dimming method, the PWM frequency has to be chosen carefully to avoid stroboscopic effects in some applications. With current pulsing with fast slew rates in both rising and falling edge, the driver and the wiring installation will have to be designed carefully to avoid EMI and other switching noise related problems. An advantage of PWM dimming is that it can be more electrically efficient than analog dimming, and is less sensitive to the "popping" noise problem at very low duty cycles (light levels).

General Electrical Drive Recommendations

Based on the electrical characteristics of Bridgelux tunable white products, Bridgelux recommends the following basic guidelines for electronic driver design:

1. Drive the tunable white products using constant current sources, not constant voltage sources.
2. Ensure that the driver "Vout" range is sufficient to cover the full range of V_f that may occur for the tunable white chosen at the drive level specified.
3. Do not apply a reverse voltage to the Tunable White.

Figure 13: Illustration of drivers that accommodate different input voltage requirements

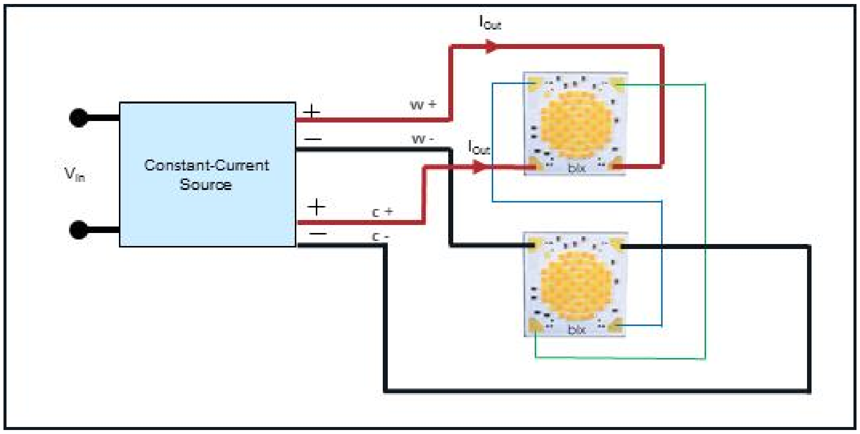


Multiple Tunable White Circuit Design Recommendations

For some luminaire designs, multiple Tunable White products driven at the same forward current may be incorporated. For these designs, Bridgelux provides the following recommendations:

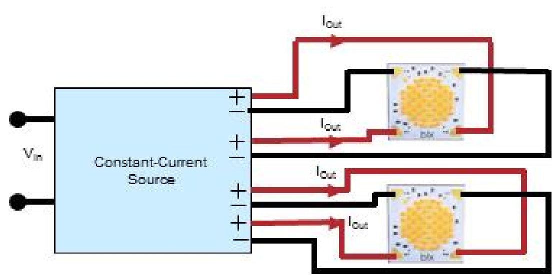
1. When using a single LED driver with a dual constant current output channel, connect the tunable white products in series to complete the electrical circuit (Figure 14). This arrangement ensures that all tunable white products will be operated at the same current.

Figure 14: Tunable White products driven in series with a dual channel output



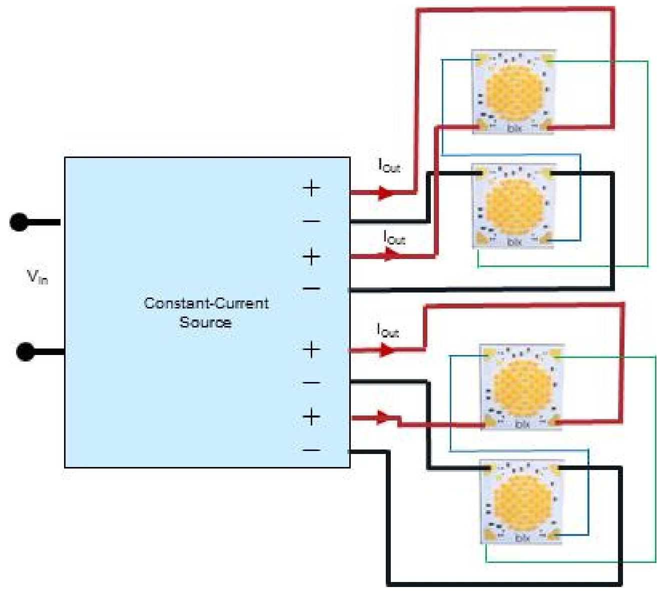
2. LED drivers are also available which have multiple output channels. If a driver with multiple constant current output channels is selected, the number of channels needs to be sufficient to drive all of the tunable white products (Figure 15).

Figure 15: Multiple Tunable White products driven with constant current channels



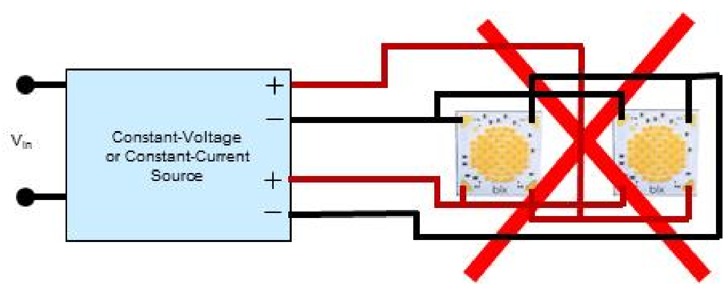
3. A combination of the two configurations above can also be applied. Tunable White products can be connected in multiple series strings from a multi-channel LED driver, allowing for an increased quantity of tunable white products to be powered from a single driver.

Figure 16: Tunable White products driven in series by a multi-channel driver



4. Bridgelux does not recommend connecting multiple Tunable White products in a parallel circuit if using full V_f distribution product. Variation in the forward voltage of the individual tunable white products can result in current hogging, where a lower V_f Tunable White may see a higher forward current compared to a higher V_f tunable white connected in parallel. This may produce non-uniform flux and color, and may affect the reliability of the lighting system.

Figure 17: Parallel connection of multiple Tunable white products to a driver – ***NOT RECOMMENDED FOR FULL V_f DISTRIBUTION PRODUCT***



LED Driver Input Power Requirements

LED drivers convert available input power into the required output current and voltage, analogous to ballasts used with fluorescent and other conventional light sources. Bridgelux recommends the use of constant current sources to drive the tunable white products. In addition to meeting input requirements specified by the user (such as 110V AC input, 220V AC input, 12V DC input etc.), the driver selected must meet the output requirements as specified for the application. These include, but are not limited to, V_{out}, I_{out}, and Power.

All of the design information required for successful specification of driver requirements to match Bridgelux tunable white products are contained in the tunable white data sheets. If you have any questions or need assistance in selecting a driver for evaluation, please contact your local Bridgelux sales representative.

The following is an example of how the driver for a luminaire is to be designed using the Bridgelux "Vesta Tunable White" BXRV-TR-2750G-xxxx-x-15 to be driven at a 700mA level to get the desired optical output.

First step is to locate the electrical characteristics from the "Vesta series data sheet", reproduced in Figure 18 below:

Figure 18: Example of Vesta Datasheet

Sample Vesta Datasheet: Electrical Characteristics and Driver Selection Voltages

CCT	**Current** (mA)[1]	**Forward Voltage Pulsed, T_C=25°C**[1,2]			**Typical Coefficient of Forward Voltage $\Delta V_f/\Delta Ti$[4]** (mV/°C)	**Typical Thermal Resistance Junction to Case $R\Theta j$-c** (C/W)	**Driver Selection Voltages**[7] **(V)**	
		Minimum (V)	**Typical (V)**	**Maximum (V)**			**V_f Min. Hot T_C = 105°C** (V)	**V_f Max. Cold T_C = -40°C** (V)
2700K	700	16.5	17.6	18.7	-11.8	0.83	15.6	20.1
	1400	17.7	18.8	19.9	-11.8	0.98	16.8	21.5
5000K	700	17.0	18.1	19.2	-13.4	0.83	15.6	20.1
	1400	18.2	19.4	20.6	-13.4	0.98	16.8	21.5

Example from Vesta Tunable White Series datasheet

Notes for Table 2:

1. Parts are tested in pulsed conditions at the rated test current (indicated in bold font), Tj = 25°C. Pulse width is 10 ms.
2. Voltage minimum and maximum are provided for reference only and not a guarantee of performance.
3. Bridgelux maintains a tester tolerance of ± 100mV on forward voltage requirements.
4. Typical coefficient of forward voltage tolerance is ± 0.1mV for nominal current.
5. Thermal resistance value was calculated using total electrical input power optical power was not subtracted from input power. The thermal interface material used during testing is not included in the thermal resistance value.
6. V_f Min hot and V_f max cold values are provided as reference only and are not guaranteed by test. These values are provided to aid in driver design and selection over the operating range of the product.
7. This product has been designed and manufactured per IEC 62031:2014. This product has passed dielectric withstand voltage testing at 500V. The working voltage designated for the insulation is 45VDC. The maximum allowable voltage across the array must be determined in the end product application.

The power rating of the driver to be designed or selected will need to deliver 700mA at the maximum V_f expected. 700mA x 19.2V would mean that the output power of the LED driver selected will have to be no less than 13.44W, and a 15W driver would probably be an appropriate choice (with typical 15% safety margin built in). It should also be confirmed that the driver will maintain acceptable current regulation down to a 15.6V output voltage (even at Tc 105C operating condition), so that compatibility over tunable white production variations will be maintained.

If it is desired to operate at a drive level other than 700mA, the current vs. voltage graph contained in the tunable white data sheet can be consulted to determine the required Vout range for the driver.

LED Driver Design and Selection Considerations

It is the responsibility of the system designer to ensure that the selected LED driver meets all local regulatory requirements. Bridgelux also recommends considering the following specifications when selecting or designing an LED driver.

Power Factor

The power factor of an AC electric power system is defined as the ratio of the real power to the apparent power, specified as a number between 0 and 1. A power factor of 1.0 is the goal of any electric utility. For LED drivers, power factors greater than 0.9 are recommended.

Efficiency

Many lighting applications are governed by local energy use requirements, such as ENERGY STAR, Title 24, Part L and other global standards. As these requirements are based on not only the tunable white but on the entire lighting system, it is important to select a driver with an appropriate efficiency to meet these regulatory requirements. Driver efficiencies can range from 50% to 95% for switch-mode power supplies depending on the design and manufacturer. Losses are typically due to switching, internal resistances, and transformer selection. Efficiencies may also vary considerably as a function of the load. Bridgelux recommends designing or selecting LED drivers that are highly efficient over the range of loads expected in the lighting system.

Reliability

The expected life of the LED driver should match that of the tunable white over the required operating temperature range of the lighting system. Vibration, heat, moisture, and other environmental conditions can have negative effects on components that comprise the LED driver. For example; FETs typically have maximum junction temperatures of 125°C, electrolytic capacitors can dry out when exposed to heat, and mechanical vibrations can cause sensitive electronic assemblies to fail. It is important to consider these potential limitations during the component selection and design of the LED driver.

Safety

Please ensure compliance to all regulatory and approbation requirements. Certain approvals such as UL, CE and others may be required for the lighting system, which may pose requirements on output voltage, electrical isolation, maximum operating temperature, and other parameters critical to the design of the LED driver. It is the responsibility of the designer to ensure a safe and compliant design of not only the LED driver but of the entire lighting system.

Feedback Features

Some applications may benefit from, or require, LED drivers that include active feedback. For example a temperature sensor may be included to safeguard against thermal run away, adjusting the current in the event that a maximum case temperature for the tunable white is reached or exceeded. Light or motion sensors may also be desired to provide feedback to the driver circuit, enabling additional system functionality and power saving capabilities in the lighting installation for some applications.

Ripple

Ripple is the small and unwanted residual periodic variation of the direct current output of an AC to DC LED driver. Ripple does not have any detrimental effect to the LED, but may cause objectionable visual effects. Bridgelux recommends using LED drivers with low ripple, defined as a ripple value of within ± 10%. While higher levels of ripple, especially if at frequencies above 120Hz may not yield any objectionable visual effects, care should be exercised to ensure that there is no problem with stroboscopic effects or possible medical hazards (i.e. triggering epileptic seizures)

Noise

Electromagnetic and radio frequency noise is not desirable and often regulated by standards. Care should be taken to specify an LED driver with low noise to avoid interference and/or violation of regulated standards.

Hot Swapping

Hot swapping is the ability to connect and disconnect an energized driver from the tunable white without damaging the tunable white. While most applications do not intentionally use hot swapping, hot swapping situations may occur during field installation if the driver is not integral in the luminaire. If hot swapping is possible, testing should be performed on the driver to make sure that it will not cause surge currents during the hot swap that can damage the tunable white.

Commercially Available AC-to-DC Constant Current Source LED Drivers

There are many commercially available drivers that work well with Bridgelux tunable white products to enable rapid system design. Bridgelux works with many of these commercial LED driver manufacturers to confirm compatibility between our tunable white products and their drivers. Information on commercially available drivers that have been reviewed by Bridgelux can be obtained by contacting your local Bridgelux sales representative. Bridgelux does not warrant the suitability of any of these drivers for a particular application and it is the luminaire designer's responsibility to thoroughly evaluate the suitability of a driver to ensure that all application specific requirements are met. Always check with the supplier of the LED driver for the latest information, specifications and availability.

To illustrate the process of selecting a commercially available LED driver for a particular lighting luminaire, the same tunable white, BXRV-TR-2750G-xxxx-x-15 will be used. Dual channel drivers will have the same electrical characteristics for both outputs. The column data referenced comes from the tables in the product data sheet.

By reading the "Current" column and the "Forward Voltage V_f" columns, it can be determined that for BXRV-TR-2750G-xxxx-x-15, the constant current output needed from the driver should be 700mA. At 700mA constant current source, the "Forward Voltage V_f" columns shows that the BXRV-TR-2750G-xxxx-x-15 tunable white products have a distribution of V_f between 17.0V to 19.2V when the T_j = 25°C, and from the "Typical Temperature Coefficient of Forward Voltage" column, it's indicated that V_f will change at a rate of -11.8mV per °C rise in junction temperature. And this should be factored into the driver design or selection process such that the driver designed or selected will have to be able to deliver 700mA with output voltage between the V_f min and V_f Max adjusted for the junction temperature at the operating condition.

For example, assuming that a lighting luminaire is constructed with specification that the case temperature of the BXRV-TR-2750G-xxxx-x-15 will be maintained at 60°C or lower, the junction temperature of the BXRV-TR-2750G-xxxx-x-15 can be calculated using the information from the "Typical Thermal Resistance Junction to Case" column:

Tj at case temperature 60°C = 60°C + 0.83°C/W x 13.44W = 71.16°C

At Tj = 71.16°C, V_f min = 17.0V – 13.4mV/°C x (71.16°C - 25°C) = 15.96V

So the LED driver to be selected should be one with 700mA constant current output over an output voltage range of 15.96V to 18.7V or wider (in 25C ambient operating environment) and with minimum power rating of 15W (as we established in the previous section).

Driver manufacturers would list their driver products' key specifications similar to Table 2 below:

Table 2: Sample Driver Specifications

Model no.	Input	Output Voltage	Output Current	Power Rating
xxx	90-305VAC 47-63Hz	14-30 VDC	700mA Constant	15W

The results from the estimations done above can be used to assist in the selection of an appropriate LED driver.

Bridgelux tunable white products are tested and binned at their rated nominal current, a current optimized to deliver the desired performance in terms of lumen output and efficacy. In designing with the Bridgelux tunable white products, however, the designer is free to set the drive current to meet application specific requirements.

For example, a customer may decide to power the tunable white at a drive current lower than nominal conditions to achieve a higher LED efficacy or to fall within thermal constraints in the system design. Alternatively, a customer may decide to drive the tunable white at a higher drive current to deliver increased light output in order to meet application requirements. As long as the drive current is within the maximum rating for the tunable white, there will be no electrical or optical problem driving at these alternative levels. Care must be given to ensure that the thermal solution is appropriate – especially at higher power levels. Please refer to Bridgelux Application Note AN30 "Thermal Management for Bridgelux Vero LED Arrays" for more information on thermal solutions.

The LED driver industry has developed many drivers with output currents in multiples of 250 and 350 mA based on nominal drive levels of commercially available LED components from many different LED manufacturers. As such, many constant current drivers exist with typical drive currents of 250, 350, 500, 700, 1000, 1050, and 1400 mA. In addition, there are many drivers with "programmable outputs" which can set the drive level as required either by switches, jumpers, external resistors or software programming tools. Dimmable drivers can be used, where the dimming function allows the desired drive level to be 'dialed in' by the luminaire manufacturer to meet the needs of the particular application.

Custom LED Drivers

Depending on the application requirements, designing a custom LED driver may have advantages for a given lighting system. Custom LED drivers are typically IC based solutions, requiring a DC input voltage. These drivers may be advantageous in the fact that they can deliver miniaturized designs. Several IC suppliers have standard driver ICs with associated reference designs available to enable the development of suitable drivers for Bridgelux tunable white products. These designs can be "customized" to meet application specific needs and are capable of working with a wide spectrum of input and output requirements.

Information on IC driver solutions that have been reviewed by Bridgelux can be obtained by contacting your local Bridgelux sales representative. Bridgelux does not warrant the suitability of any of these IC driver reference designs for a particular application and it is the luminaire designer's responsibility to thoroughly evaluate the suitability of a driver to ensure that all application specific requirements are met. Always check with the supplier of the LED driver IC for the latest information, specifications and availability.

Design Resources

References

Steve Winder. Power Supplies for LED Driving. Oxford: Elsevier, 2008. ISBN: 978-0-7506-8341-8

Disclaimer

This application note has been prepared to provide guidance on the application of Bridgelux LED tunable white products in customer products. Bridgelux provides this information in good faith, but does not assume any responsibility or liability for design deficiencies that might exist in the design based on the information contained in this document.

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It is the responsibility of the customer to ensure that their design meets all necessary requirements and safety certifications for its intended use.

About Bridgelux

At Bridgelux, we help companies, industries and people experience the power and possibility of light. Since 2002, we've designed LED solutions that are high performing, energy efficient, cost effective and easy to integrate. Our focus is on light's impact on human behavior, delivering products that create better environments, experiences and returns—both experiential and financial. And our patented technology drives new platforms for commercial and industrial luminaires.

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WeChat ID: BridgeluxInChina

46430 Fremont Boulevard
Fremont, CA 94538
Tel (925) 583-8400
www.bridgelux.com