Application Note AN32

Electrical Drive Considerations for Bridgelux Vero Series LED Arrays

June 3, 2013

Introduction

The Bridgelux Vero Series LED Array products deliver high performance, compact and cost-effective solid-state lighting solutions to 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 Vero Series LED Arrays requires careful consideration of thermal management solutions, handling and assembly, selection of electronic drivers and selection of secondary optics. Application Notes AN30, AN31, AN32 and AN36 respectively deal with each of these topics in depth. To achieve optimal performance of the LED Arrays, proper electronic drivers must be selected or designed.

A key feature of the Vero LED Array is the wide range of current drive capabilities of each member of the series, making it possible for LED lighting designers to create luminaires that are scalable in optical power output to meet different application needs while keeping the overall mechanical and optical design unchanged. This feature enables luminaire manufacturers to easily offer LED luminaires with a wide range of optical performances and keeping the design and manufacturing cost low because of the economy of scale that the Vero series enables.

The purpose of this application note is to assist designers in selecting or developing electronic drivers for use with Bridgelux Vero LED Arrays. The first step is to become familiar with relevant electrical characteristics of the LED Arrays. This includes the relationship between forward voltage and current, and the relationship between light output (luminous flux) and current. A review of these characteristics results in design rules and recommendations for driving Bridgelux Vero LED Arrays.

The second step is to define LED driver requirements, usually specific to the given application. Design considerations include defining the driver's input voltage (i.e., 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.

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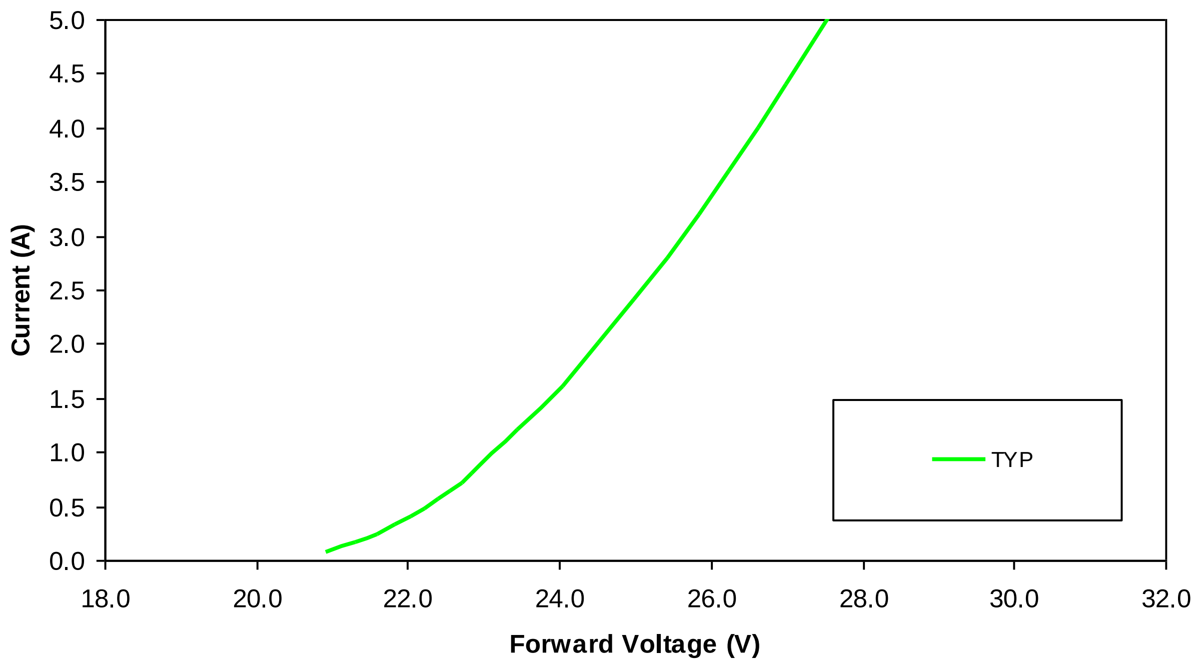
LED Array Electrical Characteristics

Bridgelux LED Arrays are manufactured using high power InGaN 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 of concern is the relationship between the voltage applied to the LED Array and the resultant current through the LED Array. 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: Typical LED Array I-V (Current vs. Voltage) curve



An "I-V" curve is provided in each Bridgelux Product Data Sheet as a figure with the title "Current vs. Voltage". The curve <u>may</u> be different for each LED Array product, dependent on the configuration of and the exact diodes within the device so it is important to always refer to the correct I-V curve for the particular LED Array 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 (Vf) 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.

The "Current vs. Voltage" graph provided in Bridgelux LED Array data sheets accounts for both of the above considerations by providing a set of curves that bound the typical operating possibilities for the device. Figure 2 below shows an example of this "Current vs. Voltage" graph. Note that in addition to the

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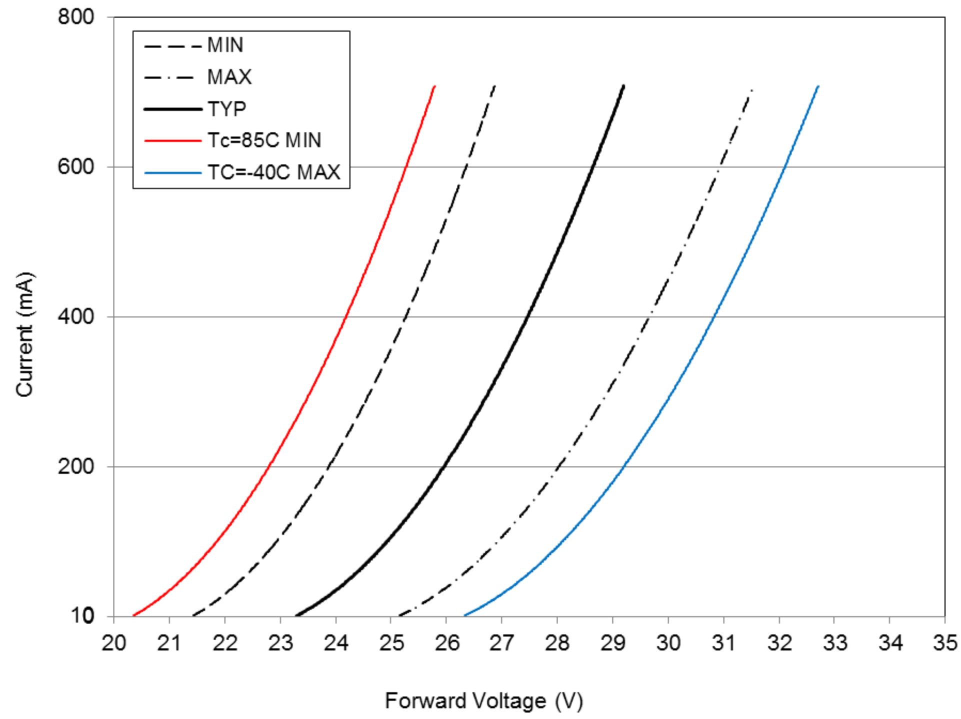
“typical” I-V curve (shown in solid black), there is also a “MIN and a MAX” curve (shown in dashed black). The TYP, MIN and MAX curves all apply at Tcase = 25C. Effectively, these curves are showing the worst case variation that can occur as a result of manufacturing variances. Although in many cases parts will actually fall closer to the typical curve, the driver selected should be able to cover the spread in Vf shown in this curve for the particular drive current which the array 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=85C. Since the Vf will drop with increasing temperature, the lowest possible Vf will occur at the highest operating temperature point. Even though the arrays may be operated at Tc up to 105C, Bridgelux recommends targeting designs for a Tc no greater than 85C, to ensure the light output of the array does not degrade over time (lumen depreciation).

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



Unlike a rectifier or signal diode, a LED diode 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 LED Array.

For the maximum reverse potential that can be applied to a Bridgelux LED without causing damage, please refer to the table titled “Maximum Current and Reverse Voltage Ratings” in the data sheet for that device. A sample of this table appears in table 1 below:

Table 1: Maximum Current and Reverse Voltage Ratings (sample table)

	Part Number	Maximum DC Forward Current (mA)	Maximum Peak Pulsed Current (mA) [1]	Maximum Reverse Voltage (Vr)
Vero 10	BXRC-30E1000-B-03	900	1000	-45
Vero 13	BXRC-30E2000-C-03	1350	1500	-55
Vero 18	BXRC-30E4000-F-03	2700	3000	-50
Vero 29	BXRC-30E10K0-L-03	5400	4000	-65

[1] Bridgelux recommends a maximum duty cycle of 10% when operating LED Arrays at the maximum peak pulsed current specified. Maximum peak pulsed currents indicate values where the LED array can be driven without catastrophic failures.

Also shown in Table 1 is maximum DC forward current for the LED array. The maximum DC forward current is self-explanatory – to avoid potential reliability issues do not operate the array continuously 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 datasheet (normally 10% duty cycle). As for the minimum value this needs a bit of explanation, since the LED Array will very happily illuminate down to a few milliamps of driver current. The colorimetric performance of the array can be affected by very low drive levels. So at very low drive levels, the color can shift, however the array will continue to illuminate stably until the Vf falls below the turn on voltage of the LED, at which time the LED will extinguish. Significant light output can be generated at milliamp levels, and for very deep dimming, operation to those levels may be desired and is permitted.

Bridgelux recommends the use of a CONSTANT CURRENT driver, because the light output of the array is directly proportional to the current through the array. If a constant voltage source, as opposed to a constant current source, is used to apply power to the LED Array, a small change or difference in the forward voltage of the LED Array 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).

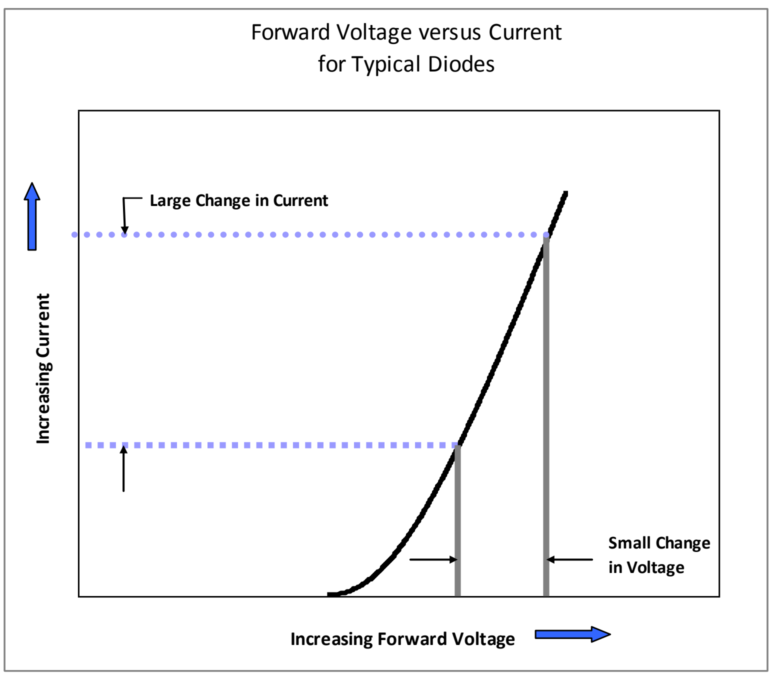


Figure 3: Impact of a small voltage change on forward current for a typical diode

The light, or luminous flux, emitted by the LED Array 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 LED Array. Consider the range of currents that occur at a fixed voltage. If we look at Figure 4 we see that the minimum, typical, and maximum currents for this hypothetical LED Array with an applied voltage of 26.5V would be 650mA, 260mA and 20mA, respectively (at 25C), depending on the I-V characteristic of the particular array. Another array, even from the same production lot could have a different I-V characteristic (curve position). Obviously 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 LED Arrays with constant voltage sources or connecting multiple LED Arrays in parallel.

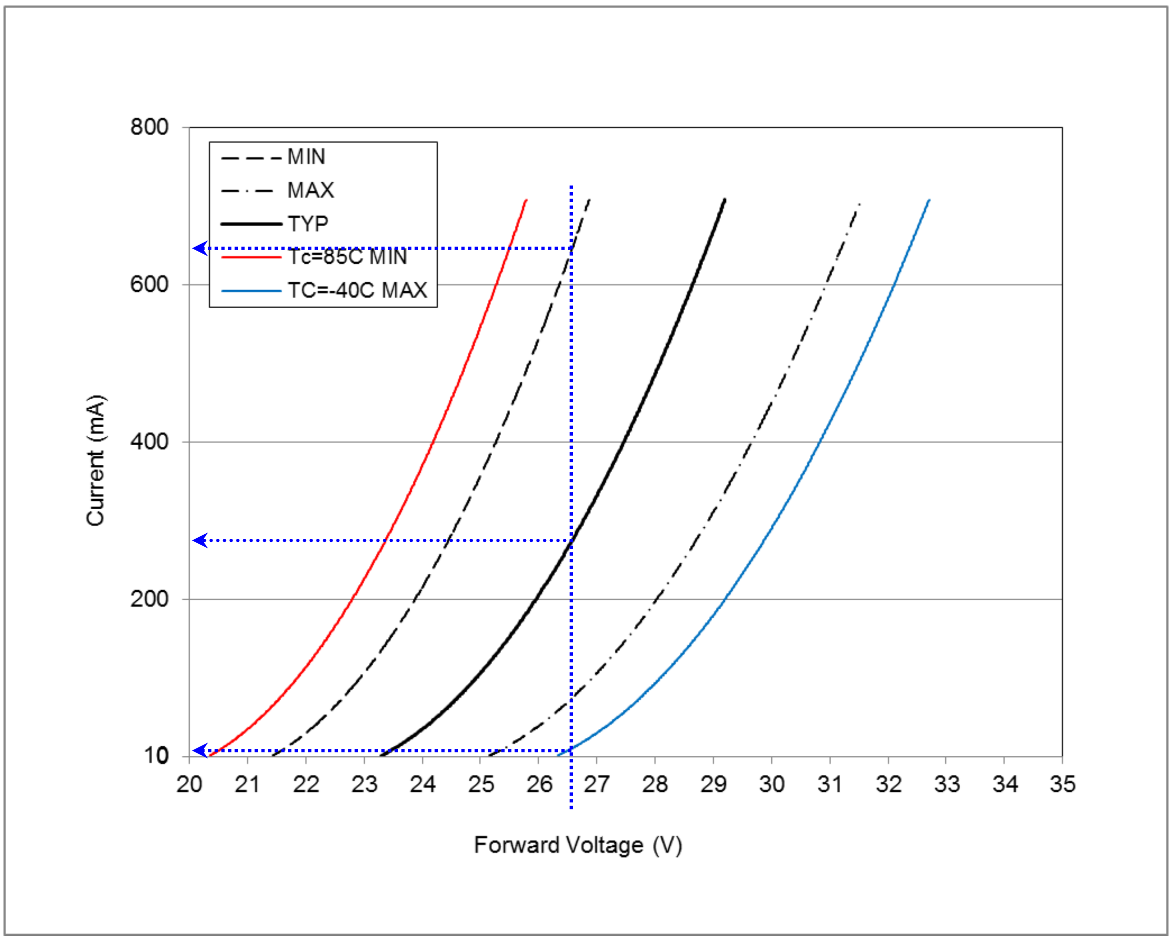


Figure 4: Current vs. Voltage Curve of Vero 10

As noted before, another important electrical characteristic of the Bridgelux LED Arrays is the relationship between forward current and luminous flux. Figure 5 shows a representative typical flux versus current plot for a hypothetical product. All Bridgelux LED Array products exhibit the following similar characteristics:

1. Increasing the forward current increases the luminous flux output of the LED Array. However, the relationship between flux performance and forward current is not linear, a common characteristic for all LEDs. 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 (see above). Driving the LED Array with a fixed current will maintain a given efficiency level.

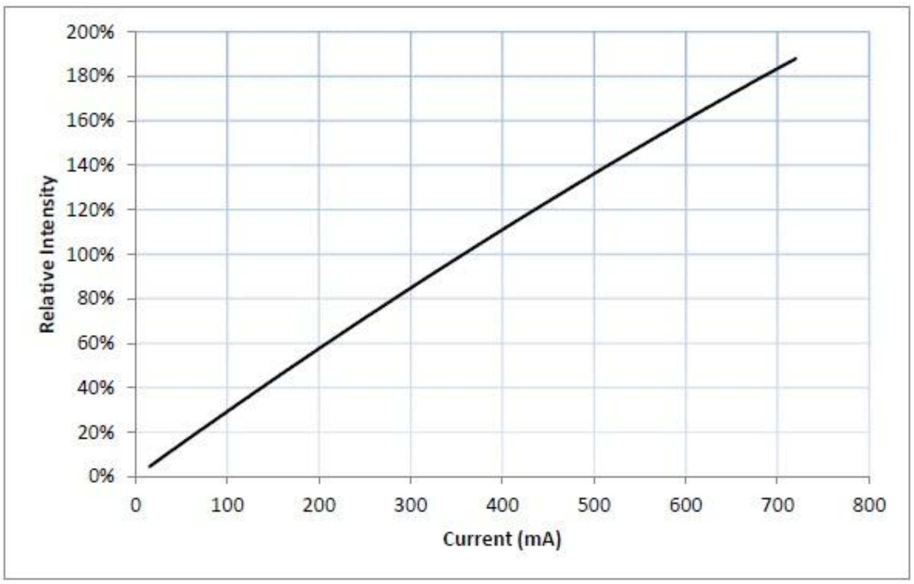


Figure 5: Typical Vero 10 Flux vs. Current

Dimming

Dimming is the action of reducing the light output of the LED array 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. As previously mentioned, the light produced by an LED is proportional to the current flowing through the LED. However, that relationship is not linear. In addition, 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 non-linearity 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. Both of these will likely need to be related to the light output of the system, which can only be done once the driver and LED pair has been selected.

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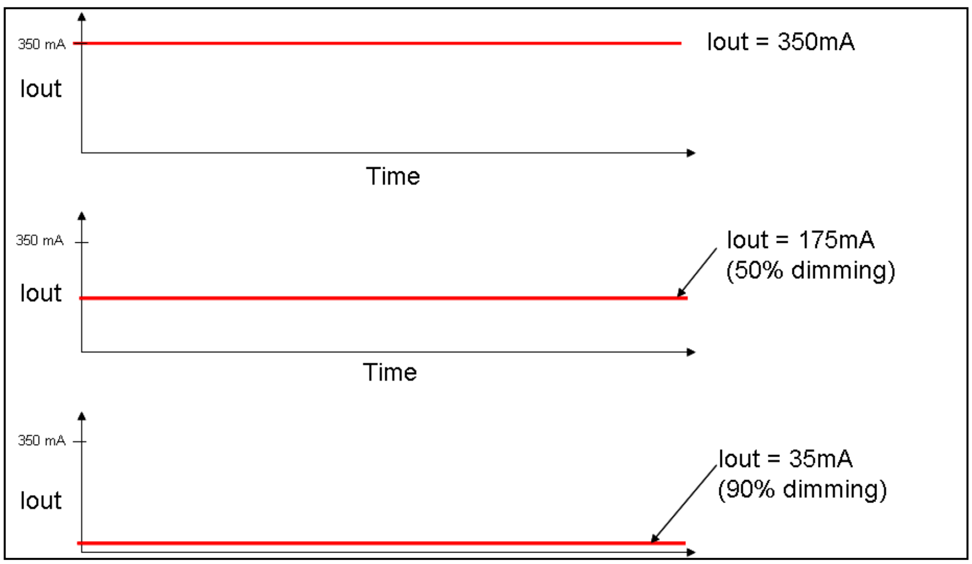
From the driver perspective there are two aspects regarding dimming that should be distinguished and clarified:

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.

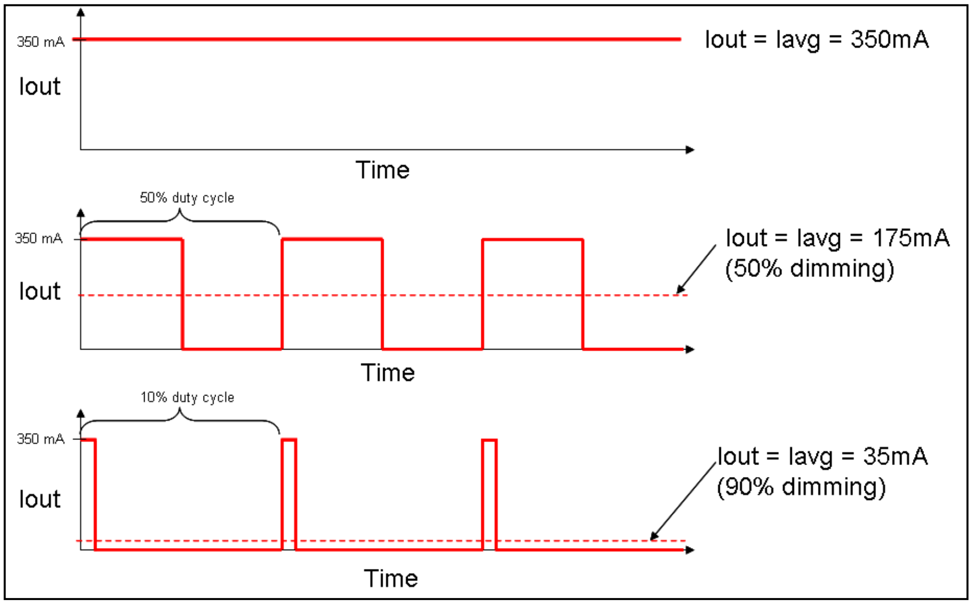
Commonly used technology to control the drive to the LED for dimming are based on two approaches – analog or Pulse Width Modulated (PWM). In analog dimming, the output current of the driver is reduced to the percentage of full level as requested by the dimming control signal. This is illustrated in figure 6a. 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 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 draft 2, 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 6b).

Figure 6a: Analog Dimming output to LED



Note: As discussed earlier, 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 6b: PWM Dimming output to LED



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

With the analog method, since the driving current "If" is continuously conducting through the LED, there is no possibility of flickering. Also, 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. Also, 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. There are many good drivers existing that address these issues effectively. 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 LED Arrays, Bridgelux recommends the following basic guidelines for electronic driver design:

1. Drive the LED Arrays using constant current sources, not constant voltage sources.
2. Ensure that the driver “Vout” range is sufficient to cover the full range of Vf that may occur for the array chosen at the drive level specified.
3. Do not apply a reverse voltage to the LED Array.

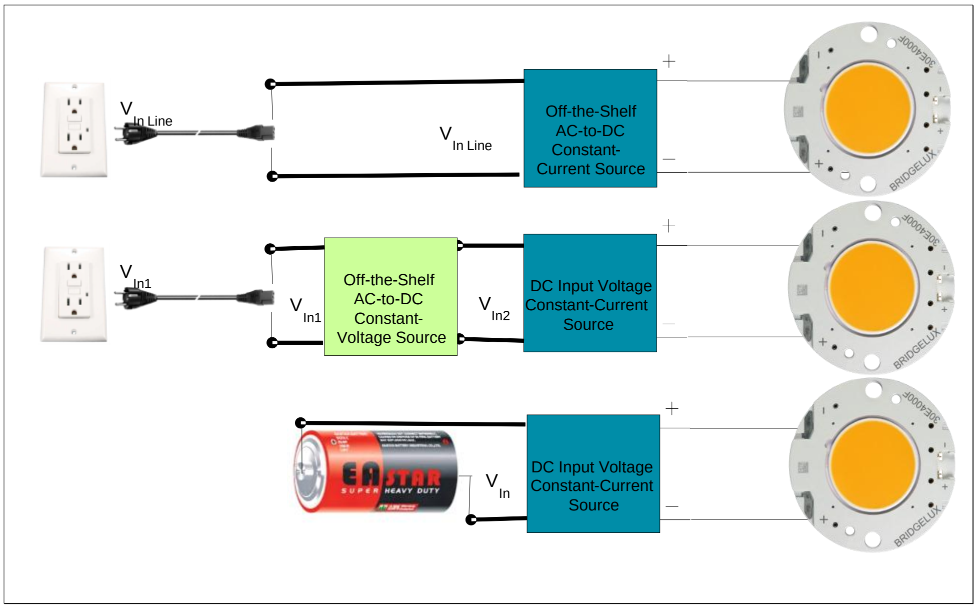


Figure 7: Illustration of drivers that accommodate different input voltage requirements

Multiple Array Circuit Design Recommendations

For some luminaire designs it may be desired to incorporate multiple LED Arrays driven at the same forward current. For these designs Bridgelux provides the following recommendations.

1. When using a single LED driver with a single constant current output channel, connect the LED Arrays in series to complete the electrical circuit (Figure 8). This arrangement ensures that all LED Arrays will be operated at the same current.

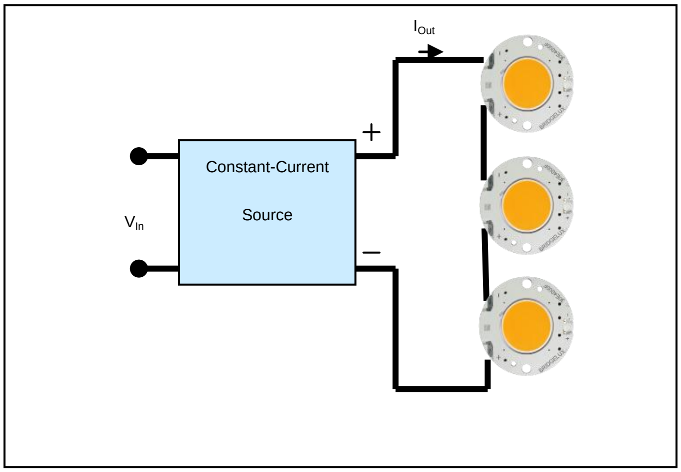


Figure 8: Multiple LED Arrays driven in series with a single constant current source

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 LED Arrays (Figure 9).

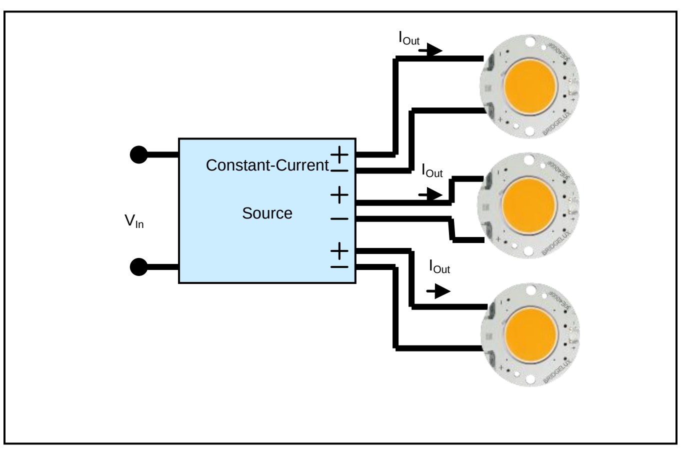


Figure 9: Multiple LED Arrays driven by a driver with multiple constant current channels

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

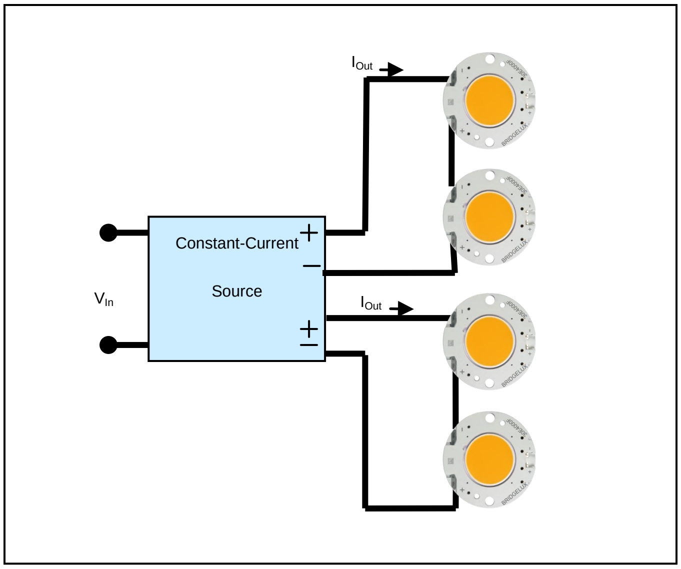

Figure 10: Series strings of multiple LED Arrays driven by a multi-channel driver

4. Bridgelux does not recommend connecting multiple LED Arrays in a parallel circuit. Variation in the forward voltage of the individual LED Arrays can result in current hogging, where a lower Vf LED Array may see a higher forward current compared to a higher Vf LED Array connected in parallel. This may produce non-uniform flux and color, and may affect the reliability of the lighting system.

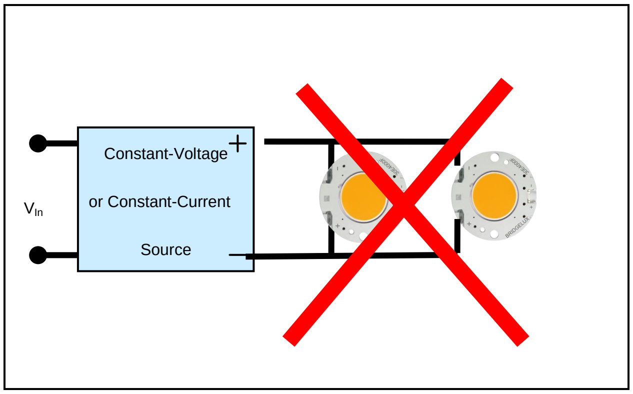

Figure 11: Parallel connection of multiple LED Arrays to a driver – *NOT RECOMENDED*

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 LED Arrays. 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.

As previously discussed, all of the design information required for successful specification of driver requirements to match Bridgelux LED arrays are contained in the LED array data sheets. If you have any questions or wish for assistance in selecting a driver for evaluation, please contact your local Bridgelux sales representative.

For example, a luminaire is to be designed using the Bridgelux "Vero 10" BXRC 30E1000-B array to be driven at a 350mA level to get the desired optical output, and the luminaire designer wishes to select a LED driver/power supply to power and drive the array.

First step is to locate "table 5" from the "Vero 10 Array Series datasheet", reproduced in Figure 12 below:

Figure 12: Example "table 5" from Vero 10 datasheet

Vero 10 datasheet table 5: Electrical Characteristics and Driver Selection Voltages

Current (mA) [1]	Forward Voltage Pulsed, T_j = 25ºC [1,2]			Typical Coefficient of Forward Voltage $\Delta V_f / \Delta T_j$ [4] (mV/°C)	Typical Thermal Resistance Junction to Case $R\Theta_{j\text{-}c}$ (C/W)	Driver Selection Voltages [3]	
	Minimum (V)	Typical (V)	Maximum (V)			V_f Min. Hot T_c = 105ºC (V)	V_f Max. Cold T_c = -40ºC (V)
115	23.3	25.3	27.3	-18	1.38	22.0	28.3
250	24.0	26.1	28.2	-18	1.42	22.5	29.4
350	**25.0**	**27.2**	**29.4**	**-18**	**1.50**	**24.0**	**31.1**
500	26.0	28.3	30.6	-18	1.55	24.5	31.9
700	27.4	29.8	32.2	-18	1.60	25.8	33.5

Notes for Table 5:
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. Bridgelux maintains a tester tolerance of ± 0.10 V on forward voltage measurements.
3. Forward voltage minimum and maximum values at the rated test current are guaranteed by 100% test. Values provided at alternative drive currents are provided for reference only and are not guaranteed by test.
4. Vf Min hot and Vf 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.
5. Typical Coefficient of Forward Voltage tolerance of ± 10% from nominal current.

The power rating of the driver to be designed or selected will have to be able to deliver 350mA at the maximum Vf expected. So 350mA x 29.4V would mean that the output power of the LED driver selected will have to be no less than 10.29W, and a 12W driver would probably be an appropriate choice (with typical 15% safety margin build in). It should also be confirmed that the driver will maintain acceptable current regulation down to a 24V output (even at Tc 105C operating condition), so that compatibility over LED production variations will be maintained.

If it is desired to operate at a drive level other than 350mA, the current vs. voltage graph contained in the LED array data sheet (Figure 1 p.13 of the Vero 10 datasheet) can be consulted to determine the required Vout range for the driver.

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LED Driver Design and Selection Considerations

It is the responsibility of the 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 LED Array but on the entire lighting system, it is important to select an LED 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 LED Array 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 LED Array 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.

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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 less than ± 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 LED without damaging the LED. 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 LED array.

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

There are many commercially available drivers which work well with Bridgelux LED Arrays to enable rapid system design. Bridgelux works with many of these commercial LED driver manufacturers to confirm compatibility between our LED arrays 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, let's use the array in the previous section, BXRC 30E1000-B as an example here.

By reading the "Current" column and the "Forward Voltage Vf" columns, it can be determined that for BXRC 30E1000-B, the constant current output needed from the driver should be 350mA. But besides being a 350mA constant current source, the "Forward Voltage Vf" columns shows that the BXRC 30E1000-B arrays have a distribution of Vf between 25.0V to 29.4V when the Tj = 25°C, and from the "Typical Temperature Coefficient of Forward Voltage" column, it's indicated that Vf will change at a rate of -18mV 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 350mA with output voltage between the Vf min and Vf 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 BXRC 30E1000-B will be maintained at 60°C or lower, the junction temperature of the BXRC 30E1000-B can be calculated using the information from the "Typical Thermal Resistance Junction to Case" column:

Tj at case temperature 60°C = 60°C + 1.5°C/W x 10.22W = 75.33°C

At Tj = 75.33°C, Vf min = 25.0V – 18mV/°C x (75.33°C - 25°C) = 24.09V

So the LED driver to be selected should be one with 350mA constant current output over an output voltage range of 24.09V to 29.4V or wider (in 25C ambient operating environment) and with minimum power rating of 12W (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	18-54 VDC	350 mA Constant	20W

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

Bridgelux LED Arrays 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 LED Arrays, however, the designer is free to set the drive current to meet application specific requirements.

For example, a customer may decide to power the LED Array 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 LED Array at a higher drive current to deliver increased light output in order to meet application requirements. So long as the drive current is within the maximum rating for the LED array there will be no electrical or optical problem driving at these alternative levels. Of course care must be given to ensure that the thermal solution is appropriate – especially at higher power levels. Please refer to AN10 "Thermal Management of 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 (to name a few). 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. In addition, 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.

Special Considerations for Selecting or Designing Drivers for Vero Series LED Arrays

The Vero Series LED arrays are different from previous generations Bridgelux LED arrays in one aspect; that the driving current range is substantially wider while keeping the overall array optical output efficacy relatively constant over this wide range of drive current levels.

For example the Vero 10 30E1000-B part, according to the datasheet listed specifications, at the suggested nominal drive current levels, the output and overall efficacy are listed in table 3 below:

Table 3: Typical Product Performance at Alternate Drive Currents (from Vero 10 datasheet)

Part Number	CRI	Current (mA) [1]	Typical V_f (V)	Typical Flux T_j = 25ºC (lm) [2,3]	Typical Flux T_c = 85ºC (lm) [2,3]	Typical Efficacy T_j = 25ºC (lm/W)
BXRC-30E1000-B-03	80	115	25.3	370	330	127
		250	26.1	760	670	116
		350	**27.2**	**1050**	910	**110**
		500	28.3	1380	1170	98
		700	29.8	1945	1610	93

As can be noted from the data, within the current drive range of between 250mA and 700mA (2.8 times ratio), the efficacy remains within 15.5% of each other. The Vero series manages to achieve the level of stable optical performance based on Bridgelux's advanced LED die and phosphor technology and also high optical efficiency and high performance thermal management technologies.

The Vero series LED arrays are highly flexible and scalable LED light sources that allow luminaire designers to come up with broad product portfolios with a wide performance range based on identical optical and mechanical designs.

With such flexibility in the LED Array, luminaire designers may wish to pick one driver model to cover the full series of luminaires at different light output levels based on the current setting on the driver. This way, only one driver need be stocked for a complete series of different models of luminaires.

In order to achieve this goal, the driver should have a voltage output range wide enough to cover the driving requirements of the subject Vero LED array at the different current levels expected.

For example, if the Vero 10 BXRC-30E1000-B based lighting series consists of three models that require the Vero 10 to be driven at 350mA, 500mA and 700mA respectively. Below is how the driver output voltage range and power handling capability is determined (using the information contained in "table 5" of the Vero 10 datasheet, shown in figure 12 of this appnote):

1. Power handling capability: Maximum power = 22.54W = 700mA x 32.2V (this is the max Vf of BXRC-30E1000-B when driven at 700mA).
2. Driver output high end voltage = 32.2V + additional voltage needed to account for cold start up in certain geographic location (e.g. -40C for some outdoor application in the northern territories see page 16 for detailed calculation method and for -40C the Vf is expected to be 1.17V higher so Vf max can be as high as 33.37V in this condition).
3. Driver output low end voltage = 25.0V – Vf de-rating expected when the LED runs up to operating temperature at steady state, e.g. Tc = 75C (25.0V is the 25C Vf min of BXRC-30E1000-B when driven at 350mA, see page 15 for detailed calculation method). Note: If "analog" dimming is being used, the output low end voltage will need to go lower (and by reading the I-V curve, at 10mA driving current level at Tc = 85C the Vf is approximately 20.5V). In this case check the driver manufacturers datasheet carefully to determine if the minimum output voltage range accounts for dimming or not (manufactures vary in how they specify this point).

For this example, seek out a 12W or larger driver with an output voltage range of 20V to 34V or wider.

In summary:

Power handling capability and maximum output voltage is determined by characteristics of the LED at the max current drive level and at lowest start up temperature condition.

Minimum output voltage of the driver is determined by the characteristics of the LED at the min current drive level and at max expected junction temperature in steady state operation.

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 LED Arrays. These designs can be "customized" to meet application specific needs and are capable of working with a wide spectrum of input and output requirements.

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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

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About Bridgelux

Bridgelux is a leading developer and manufacturer of technologies and solutions transforming the $40 billion global lighting industry into a $100 billion market opportunity. Based in Livermore, California, Bridgelux is a pioneer in solid state lighting (SSL), expanding the market for light emitting diode (LED) technologies by driving down the cost of LED lighting systems. Bridgelux’s patented light source technology replaces traditional technologies (such as incandescent, halogen, fluorescent and high intensity discharge lighting) with integrated, solid state lighting solutions that enable lamp and luminaire manufacturers to provide high performance and energy efficient white light for the rapidly growing interior and exterior lighting markets, including street lights, commercial lighting and consumer applications. With more than 550 patent applications filed or granted worldwide, Bridgelux is the only vertically integrated LED manufacturer and developer of solid state light sources that designs its solutions specifically for the lighting industry. For more information about the company, please visit www.bridgelux.com.