

# Application Note AN12

## Electrical Drive Considerations for Bridgelux LED Arrays

### Introduction

The Bridgelux family of LED Array products delivers 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. To achieve optimal performance of the LED Arrays, proper electronic drivers must be selected or designed.

The purpose of this application note is to assist designers in selecting or developing electronic drivers for use with Bridgelux 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 flux and current. A review of these characteristics results in design rules and recommendations for driving Bridgelux LED Arrays. The second step is to define driver requirements, usually specific to the given application. Design considerations include defining the driver's input voltage (i.e., AC line voltage input 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 will provide general guidelines to the designer for 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 first of these characteristics is the relationship between forward voltage and forward current. These relationships are provided in the Bridgelux LED Array Product Data Sheet with further detail included in the appendix of this application note. Key points illustrated by this data are listed below.

1. The relationship between forward voltage and forward current forms a distribution of product performance. The range of the distribution is defined by minimum and maximum values and can be considered as nearly normal (Figure 1) with a minimum, typical and maximum value. The entire range of performance possibilities, not just the typical characteristics, must be considered when designing or selecting a driver. Output power and output voltage requirements for drivers must be designed for maximum forward voltage parts to ensure a successful design.

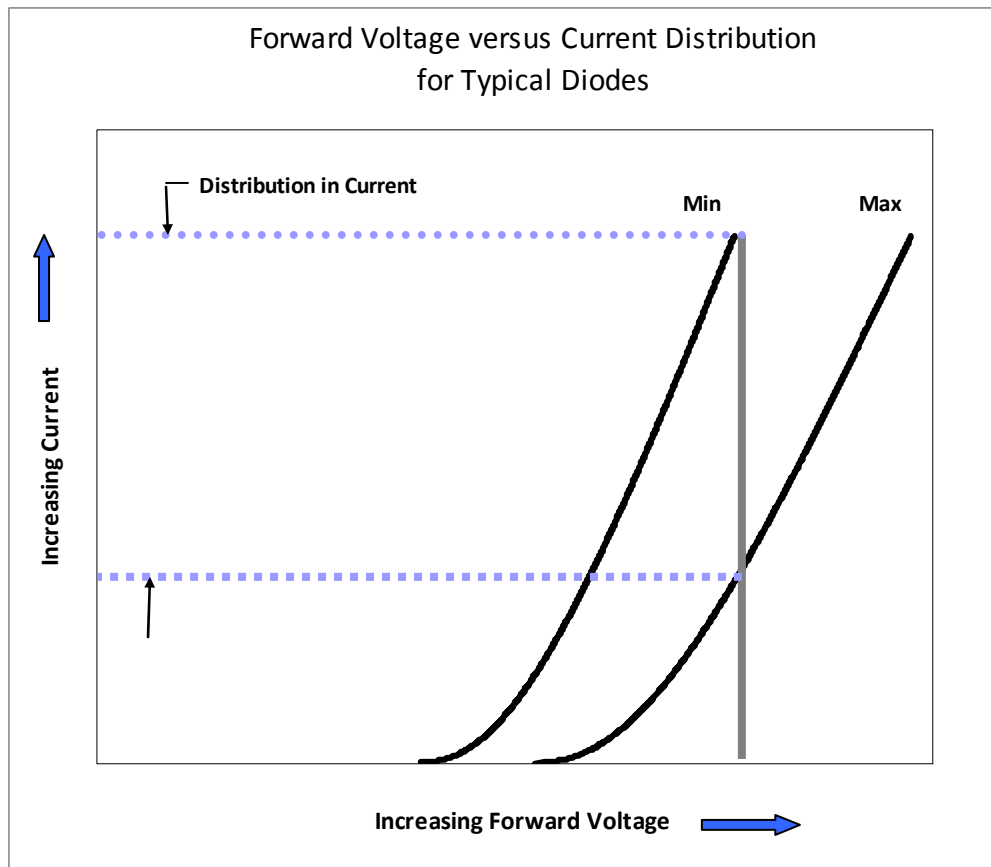


Figure 1: Distribution of forward current at constant forward voltage for a typical diode

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2. A small change in voltage can result in a large change in the forward current flowing through the junction, and ultimately in a large change in flux performance (Figure 2).

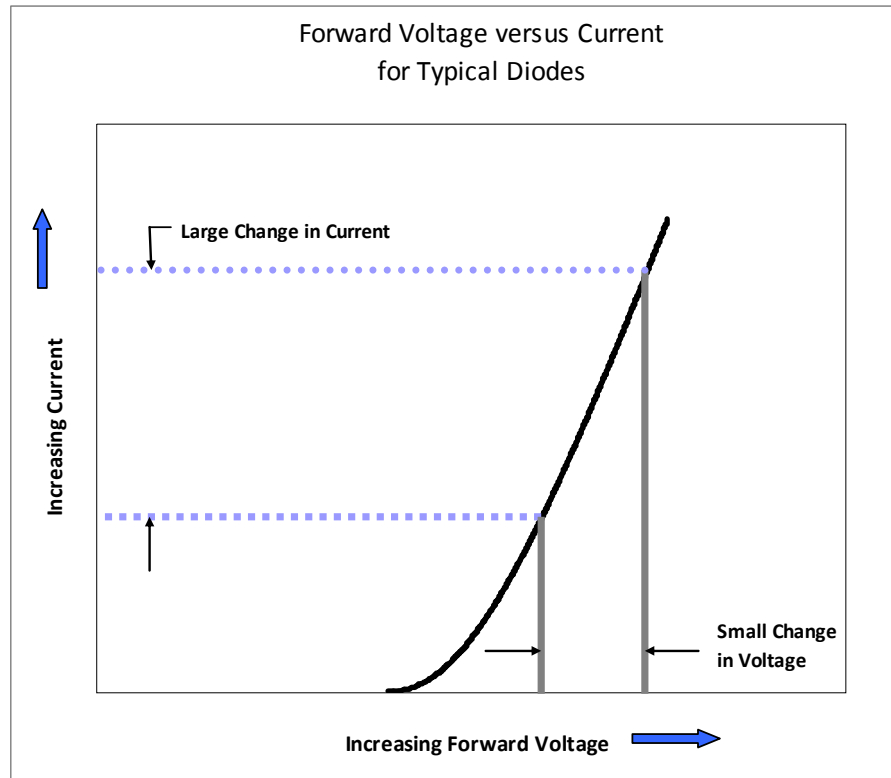


Figure 2: Impact of a small voltage change on forward current for a typical diode

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3. LEDs require a minimum voltage to be applied across the junction before current flows, generating light. This minimum voltage is commonly referred to as the threshold voltage or Turn On Voltage ( $V_{TO}$ ) as shown in Figure 3.

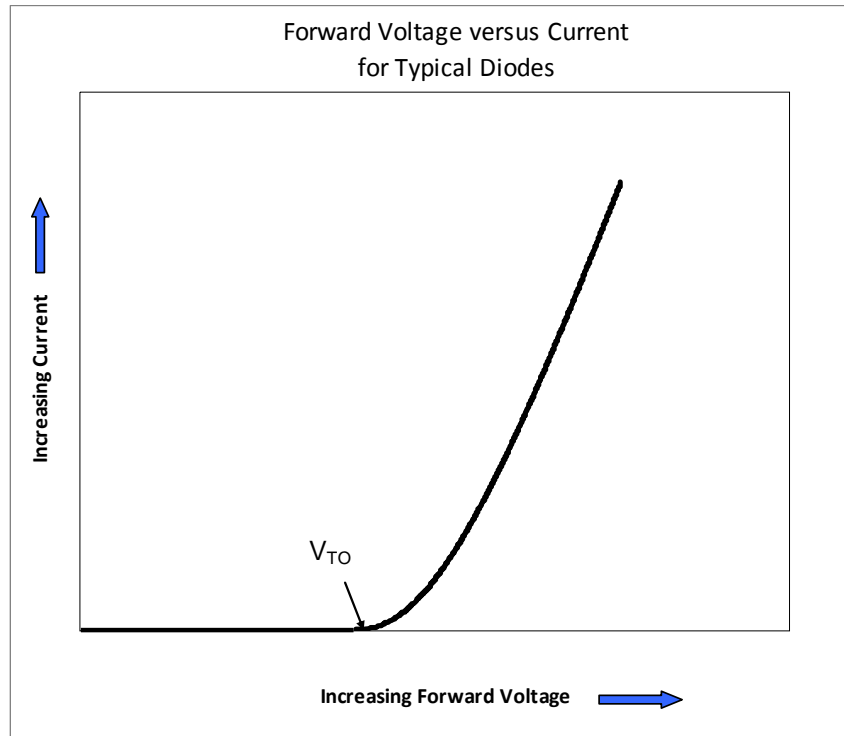


Figure 3: Threshold Voltage or Turn On Voltage for a typical diode

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The light, or flux, emitted by the Bridgelux LED Array is dependant upon the forward current. 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 1A in the Appendix we see that the minimum, typical, and maximum currents for a 400 lumen cool white Bridgelux LED Array (BXRA-C0400) with an applied voltage of 8.4V would be 0mA, 70mA and 370mA, respectively, depending on the forward voltage of the LED Array. If this voltage was applied to adjacent Bridgelux LED Arrays, one would appear out (0 mA), one dim (70mA) and one bright (370mA). It is for this reason that Bridgelux recommends against driving LED Arrays with voltage sources or connecting multiple LED Arrays in parallel.

Due to the nature of semiconductor technology, reverse voltage data is not shown. LEDs are not designed to be driven with reverse voltage as they may be damaged. Drivers should be selected or designed to avoid applying a reverse bias to the LED Array.

As noted before, another important electrical characteristic of the Bridgelux LED Arrays is the relationship between forward current and flux. Figure 4 shows a representative typical flux versus current plot for the BXRA-C0400 product. All Bridgelux LED Array products exhibit similar characteristics, listed below.

1. Increasing the forward current increases the 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.

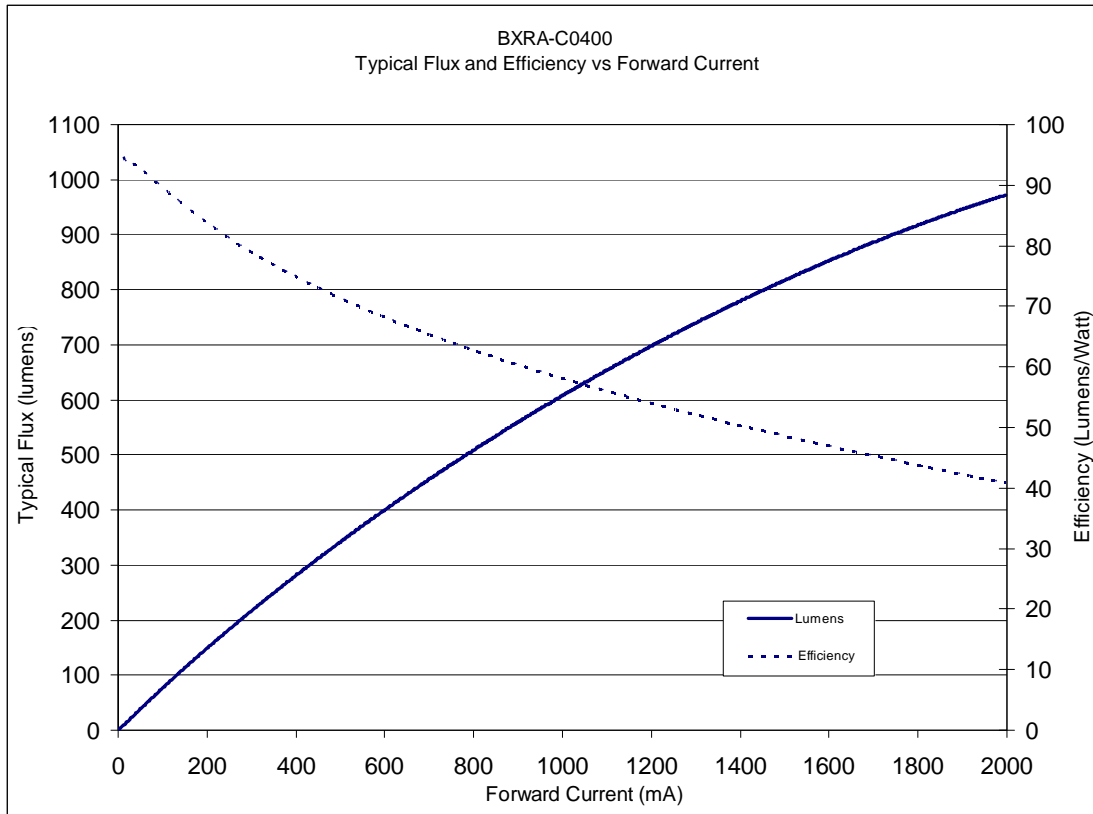


Figure 4: Typical flux and efficiency versus current for a BXRA-C0400 LED Array

### Low Current Performance

The Bridgelux LED Array Product Data Sheet lists minimum recommended drive currents in Table 4. As a result of variation in flux performance under low current operation, Bridgelux does not recommend driving the LED Arrays at currents lower than those specified in the Product Data Sheet.

### High Current Performance

Bridgelux LED Arrays may be driven at currents exceeding the maximum DC drive currents listed in Table 4 of the Product Data Sheet if the LEDs are run in pulsed mode. Maximum pulse currents are listed in Table 4 of the Bridgelux LED Array Product Data Sheet. Pulsing requires a 10% duty cycle at 1 to 10 KHz. Pulse driving LED Arrays at a lower frequency may result in excessive heating of the LED junction, a noticeable flicker to the human eye, or both.

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## Temperature Effects on Electrical Characteristics and Driver Design

The forward voltage of the Bridgelux LED Arrays varies with temperature. The degree of change in forward voltage is listed in Table 3 of the Bridgelux LED Array Product Data Sheet. To minimize the effect of shifts in forward voltage Bridgelux recommends driving LED Arrays using constant current sources rather than constant voltage sources.

## Dimming

Bridgelux recommends dimming LED Arrays using pulse width modulation (PWM). Pulse width modulation is illustrated in Figure 5. Using PWM methods for dimming will result in consistent performance between multiple LED Arrays in a lighting system or installation at reduced light output levels, ensuring luminaire to luminaire consistency over a wide range of output levels.

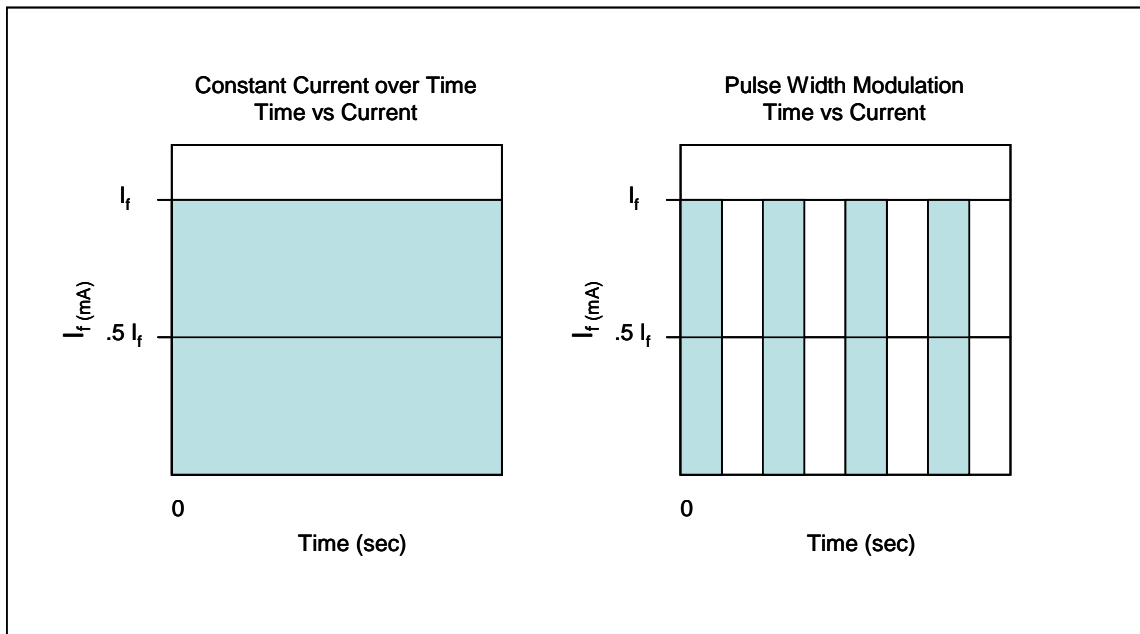


Figure 5: Current over time is shown for two different scenarios. The graph on the left depicts current over time for an LED Array under constant current drive, where the average current is depicted by  $I_f$ . The graph on the right depicts current over time for an LED Array that is pulse width modulated (current is being turned on and off over time), where the average current is depicted as  $0.5 I_f$  due to a 50% duty cycle. This will result in a perceived light output level of 50% (50% dimming) compared to the figure on the left.

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## General Electrical Drive Recommendations

Based on the electrical characteristics of the Bridgelux LED Array, Bridgelux recommends the following basic guidelines for electronic driver design.

1. Drive the Bridgelux LED Arrays using constant current sources, not constant voltage sources.
2. Do not apply a reverse voltage to the LED Array.
3. Use pulse width modulation (PWM) for dimming the LED Array.

Figure 6 illustrates constant current sources driven by different input sources.

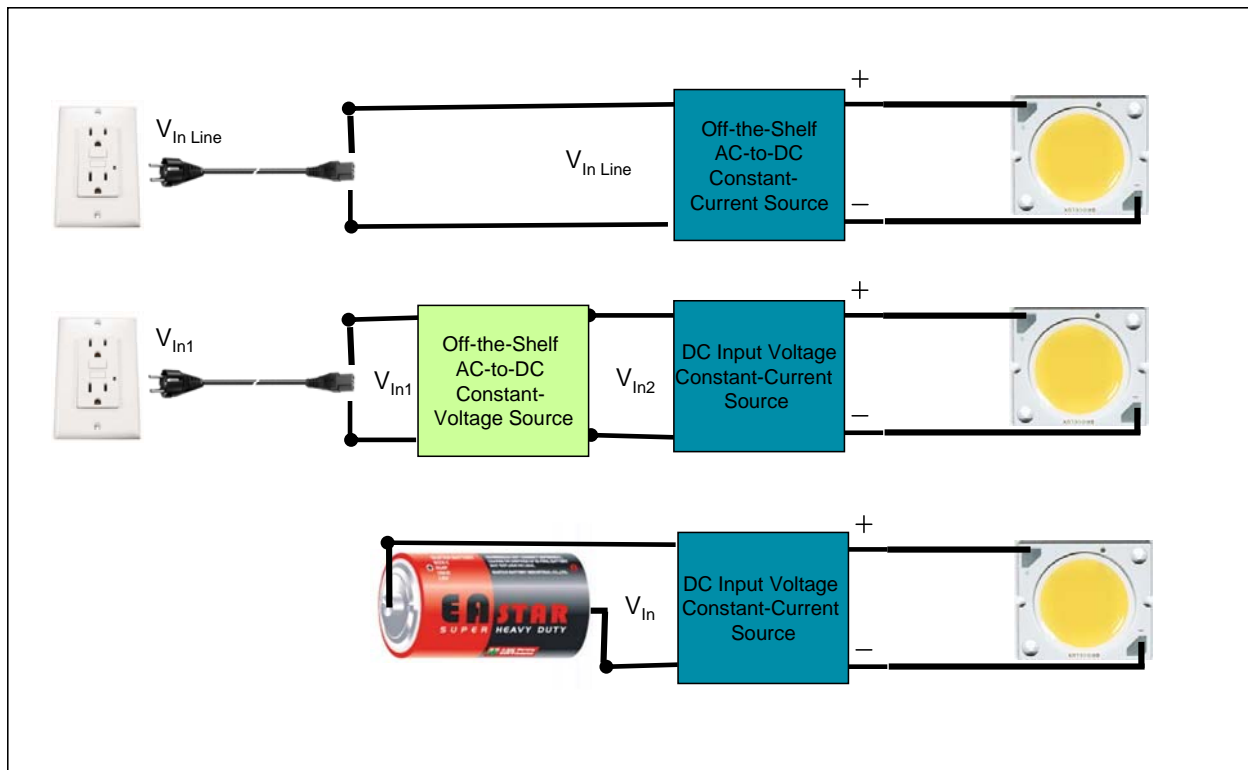


Figure 6: Illustration of drivers that accommodate different input voltage requirements

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## Multiple Array Circuit Design Recommendations

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

1. When using a single driver with a single constant current output channel, connect the LED Arrays in series to complete the electrical circuit (Figure 7). This arrangement ensures that all LED Arrays will be operated at the same current.

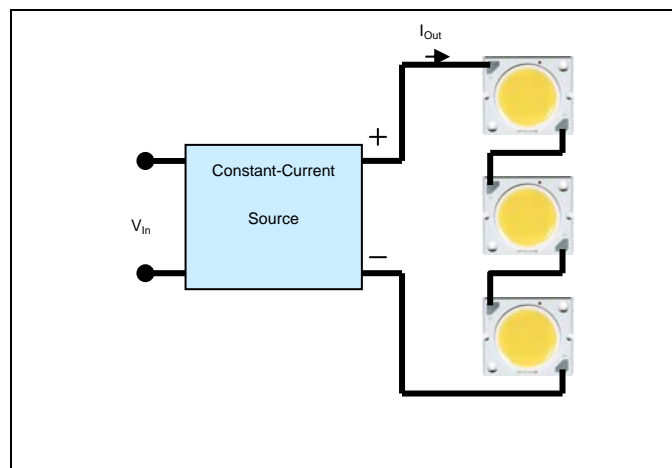


Figure 7: Bridgelux LED Arrays driven in series with a single constant current source

- 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 8).

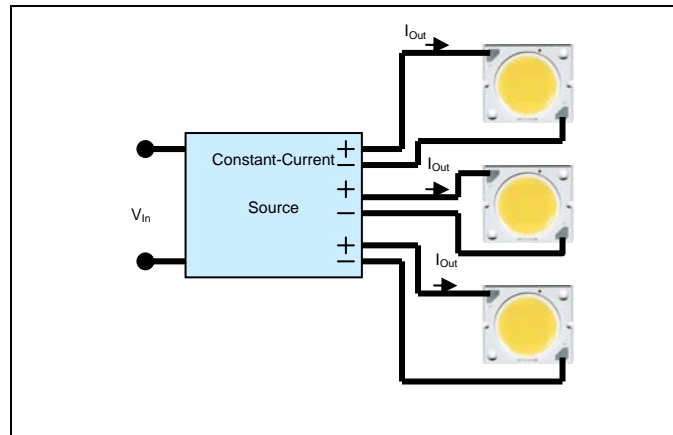


Figure 8: Bridgelux LED Arrays driven by a driver with multiple constant current output channels

- A combination of the two configurations above can also be applied. Multiple 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.

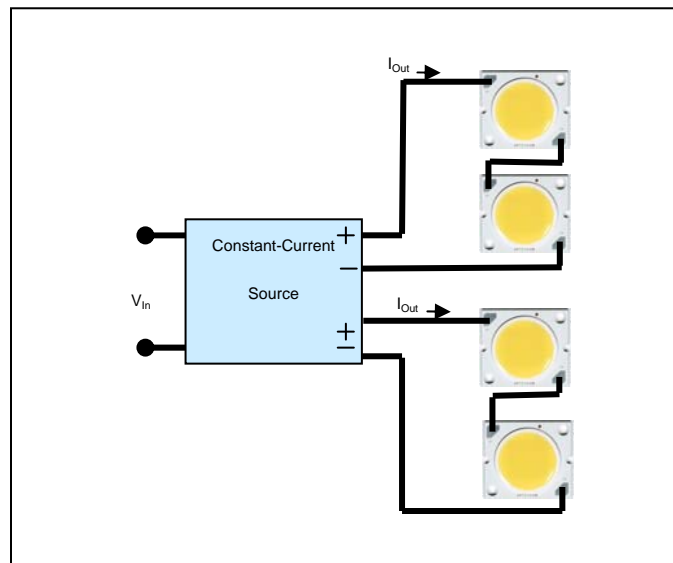


Figure 9: Series strings of Bridgelux LED Arrays driven by a multi channel driver

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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  $V_f$  LED Array may see a higher forward current than the other LED Arrays connected in parallel. This may produce non-uniform flux and color, and may affect the reliability of the lighting system.

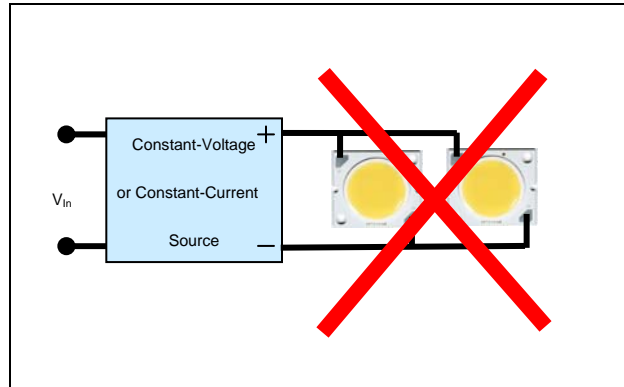


Figure 10: Parallel connection of Bridgelux LED Arrays to a driver – NOT RECOMENDED

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## LED Driver Selection Criteria

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. Table 1 lists the requirements for driving a single Bridgelux LED Array at recommended test currents.

Table1: Bridgelux LED Array  $V_{out}$ ,  $I_{out}$ , and Power requirements for proper driver selection

<b>Bridgelux LED Array Part Number</b>	<b>Minimum Compliance Voltage <math>V_{out}</math> at <math>T_j</math> 25°C (V)</b>	<b>Constant Current <math>I_{out}</math> (mA)</b>	<b>Maximum Power at Rated <math>I_{out}</math> (W)</b>
BXRA-W0400	10.6	900	9.5
BXRA-W0800	14.3	1300	18.6
BXRA-W1200	17.8	1600	28.5
BXRA-N0400	10.5	800	8.4
BXRA-N0800	14.1	1200	16.9
BXRA-N1200	17.5	1400	24.5
BXRA-C0400	10.6	600	6.4
BXRA-C0800	14.1	900	12.7
BXRA-C1200	14.3	1300	18.6
BXRA-C2000	18.0	1750	31.5

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## **Driver Design or Selection Considerations**

It is the responsibility of the luminaire designer to ensure that the selected 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 one 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, and others. As these requirements are based on not only the LED source 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 75% to 93% 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 drivers that are highly efficient over the range of loads expected in the lighting system.

### **Reliability**

The expected life of the driver should match that of the LED 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 ceramic capacitors to fail. It is important to consider these potential limitations during the component selection and design of the 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 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, 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 driver. Bridgelux recommends using drivers with low ripple, defined as a ripple value of less than  $\pm 10\%$ .

## **Noise**

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

## **Dimming**

Dimming is a desired feature for many applications, allowing the user to reduce the apparent brightness of a luminaire. Bridgelux recommends using Pulse Width Modulation (PWM) for dimming to deliver consistent performance between luminaires in a given installation over a broad range of light output.

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

Designers have options when it comes to selecting commercially available drivers. Many manufacturers produce drivers which work well with Bridgelux LED Arrays to enable rapid system design. Table 2 lists a subset of commercially available drivers that meet the technical requirements necessary to drive the Bridgelux LED Arrays, such as output voltage, output constant current, and power requirements. This list is not exhaustive and is for reference only. Bridgelux does not warrant the use of these drivers with our LED Array products. Check with the suppliers of the driver products for the latest information in specifications and availability. This list will be updated on a regular basis as additional driver solutions become available. Any driver that is selected must be thoroughly evaluated by the customer to ensure that all customer requirements are met.

Table 2: Partial list of drivers suitable for use with Bridgelux LED Arrays

Base Part Number	Test Current (mA)	Supplier	Part Number	Power (W)	I out (mA)	V AC in	V DC out
BXRA-W0400	900	MagTech Industries	LA1012	12	900	120/230	3 - 10.6
	900	ROAL	RLDD015L-900-1	15	900	120/230	9 - 10.6
BXRA-W0800	1300	MagTech Industries	LP1020-17-Cxxx	20	1300	90 - 264, 277	9 - 17
	1330	Thomas Research	LED20W-13-C1330	20	1300	100 - 277	9 - 15
BXRA-W1200	1600	ISTL	I40-10-0818D	40	1600	100 - 120	8 -18
	1600	ISTL	I40-20-0818D	40	1600	200 - 240	8 -18
	1600	ISTL	I40-30-0818D	40	1600	277	8 -18
	1600	MagTech Industries	LP1040	40	1600	90 - 264, 277	12 - 24
BXRA-N0400	800	ROAL	RLDD015L-800-1	15	800	115/230	9 - 10.5
	800	Thomas Research	LED12W-16-C0800	12	800	100 - 277	8 - 16
	800	MagTech Industries	LA1012-16-C0800	12.8	800	120/230	3 - 16
BXRA-N0800	1200	ISTL	I40-10-0818D	40	1200	100 - 120	8 - 18
	1200	ISTL	I40-20-0818D	40	1200	200 - 240	8 - 18
	1200	ISTL	I40-30-0818D	40	1200	277	8 - 18
	1200	MagTech Industries	LP1017	17	1200	90 - 264, 277	12 - 14.1
	1250	Tomas Research	LED25W-20-1250	25	1250	100 - 277	12 -20
BXRA-N1200	1400	Advance Xitanium	LED120A1400C24F	34	1400	120	2.4 - 24
	1400	Advance Xitanium	LED120AD024V14F0	34	1400	120	2.4 - 24
	1400	ISTL	I40-10-0818D	40	1400	100 - 120	8 - 18
	1400	ISTL	I40-20-0818D	40	1400	200 - 240	8 - 18
	1400	ISTL	I40-30-0818D	40	1400	277	8 - 18
	1400	MagTech Industries	LP1025	25	1400	90 - 264, 277	TBD - 17.5
BXRA-C0400	600	ROAL	RLDD015L-600-1	15	600	120/230	9 - 10.6
	600	MagTech Industries	LA1012	12	600	120/230	3 - 10.6
BXRA-C0800	900	MagTech Industries	LP1020-22-Cxxx	20	900	90 - 264	12 - 22
	900	ROAL	RLDD015L-900-2	15	900	120/230	12 - 14.1
	910	Thomas Research	LED20W-22-C0910	20	910	100 -277	12 -22
BXRA-C1200	1300	MagTech Industries	LP1020	20	1300	90 - 264, 277	9 - 17
	1330	Thomas Research	LED20W-15-C1330	20	1330	100 - 277	9 - 15
BXRA-C2000	1750	Advance Xitanium	LED277A002418F	40	1750	277	2.4 - 24
	1750	Advance Xitanium	LED120A0024V18F	40	1750	120	2.4 - 24
	1750	Advance Xitanium	LED230A0024V17F	TBD	1750	230	2.4 - 24
	1750	MagTech Industries	LP1040	40	1750	90 - 264, 277	12 -24
	1650	Thomas Research	LED40W-24-C1670	40	1650	100 - 277	12 -24
	1800	ISTL	I40-10-0818D	40	1800	100 -120	8 - 18
	1800	ISTL	I40-20-0818D	40	1800	200 - 240	8 - 18
	1800	ISTL	I40-30-0818D	40	1800	277	8 - 18

It should be noted that there are many additional commercially available drivers which will also work well with the Bridgelux LED Arrays. The LED industry has developed many drivers with output currents in multiples of 350 mA based on commercially available LED emitters. As such, many drivers exist which can provide constant current sources of 500, 700 and 1050 mA (to name a few). Depending on the design requirements of the lighting system, using one of these drivers, even if it does not power the Bridgelux LED Array at the full rated current, may work well for the application.

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## Custom Drivers

Depending on the application requirements, designing a custom driver may have advantages for a given lighting system. Custom 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 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.

A selection of companies offering reference designs for IC based drivers to power Bridgelux LED Arrays is included in Table 3 below.

**Table 3: IC based custom driver solution companies**

<b>Company</b>	<b>Website</b>
Cirrus Logic	<a href="http://www.cirruslogic.com">www.cirruslogic.com</a>
Cypress Semiconductor	<a href="http://www.cypress.com">www.cypress.com</a>
Maxim	<a href="http://www.maxim-ic.com/solutions/hb_led_drivers/">www.maxim-ic.com/solutions/hb_led_drivers/</a>
National Semiconductor	<a href="http://www.national.com/analog/led">www.national.com/analog/led</a>
NEC	<a href="http://www.nec.com">www.nec.com</a>
Power Integration	<a href="http://www.powerint.com">www.powerint.com</a>
SuperTex	<a href="http://www.supertex.com">www.supertex.com</a>
Zywyn	<a href="http://www.zywyn.com">www.zywyn.com</a>

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## Appendix: I-V Characteristics of Bridgelux LED Arrays

Each figure shown in this Appendix contains three curves – a minimum, a typical, and a maximum forward voltage versus forward current curve for the respective Bridgelux LED Array products. These curves can be used to ensure that the driver design is compatible with the full production range of Bridgelux LED Arrays.

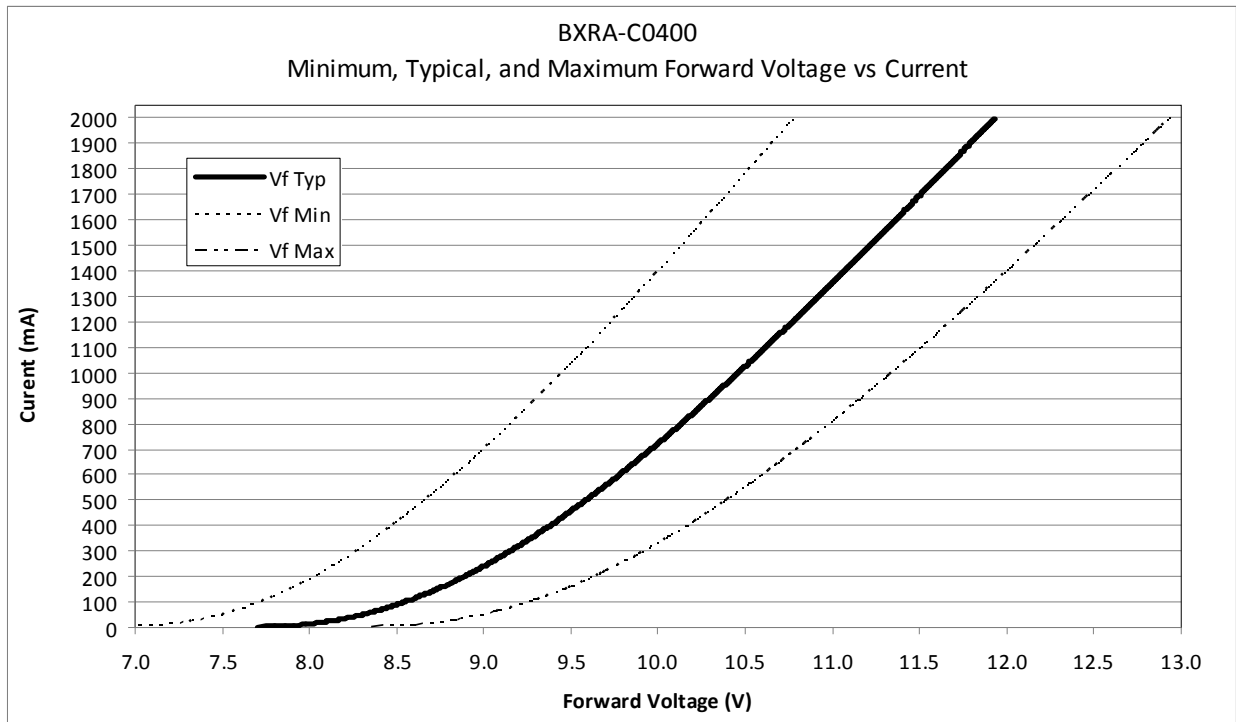


Figure A1: Forward voltage versus current plots for BXRA-C0400 products

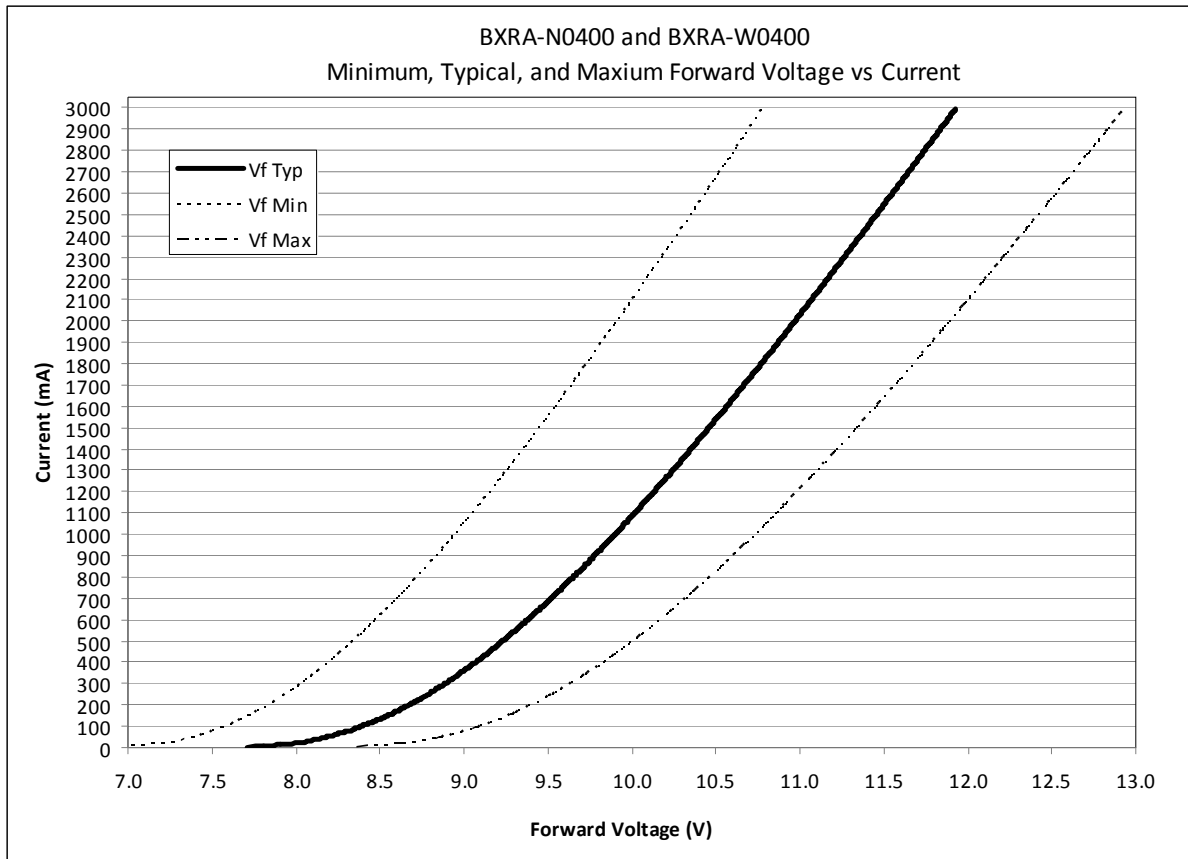


Figure A2: Forward voltage versus current plots for BXRA-N0400 and BXRA-W0400 products

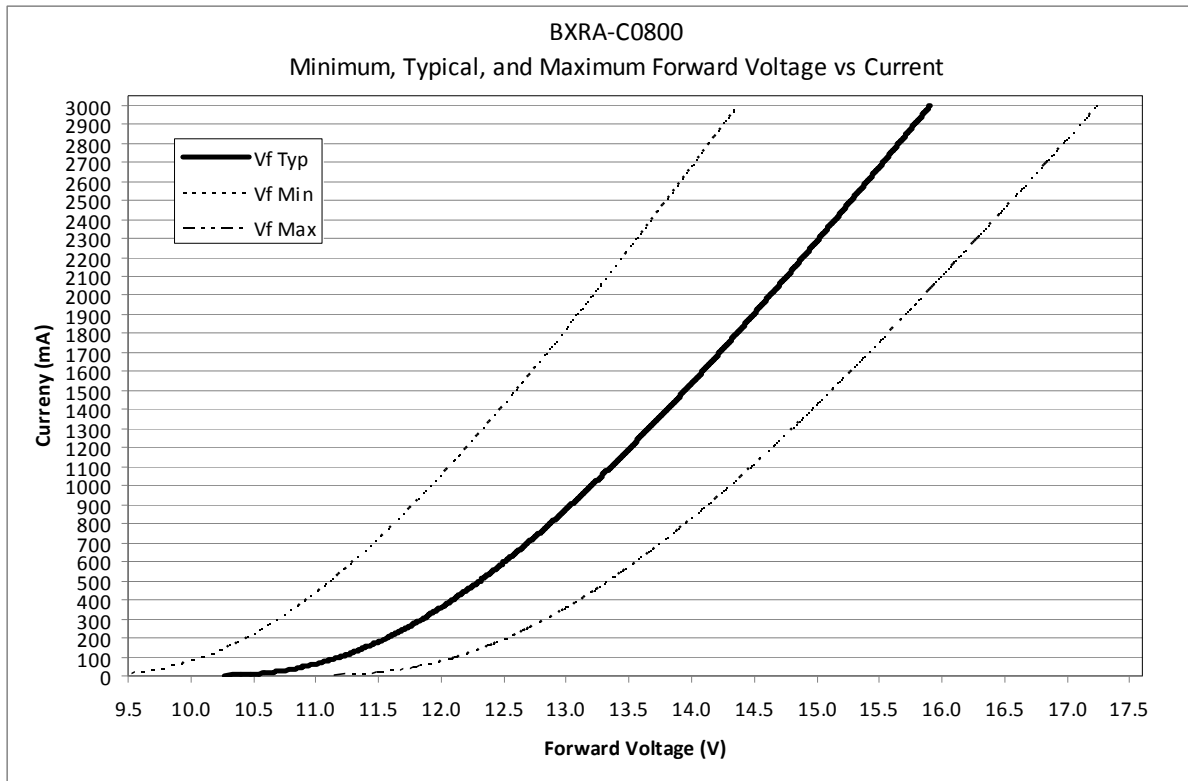


Figure A3: Forward voltage versus current plots for BXRA-C0800 products

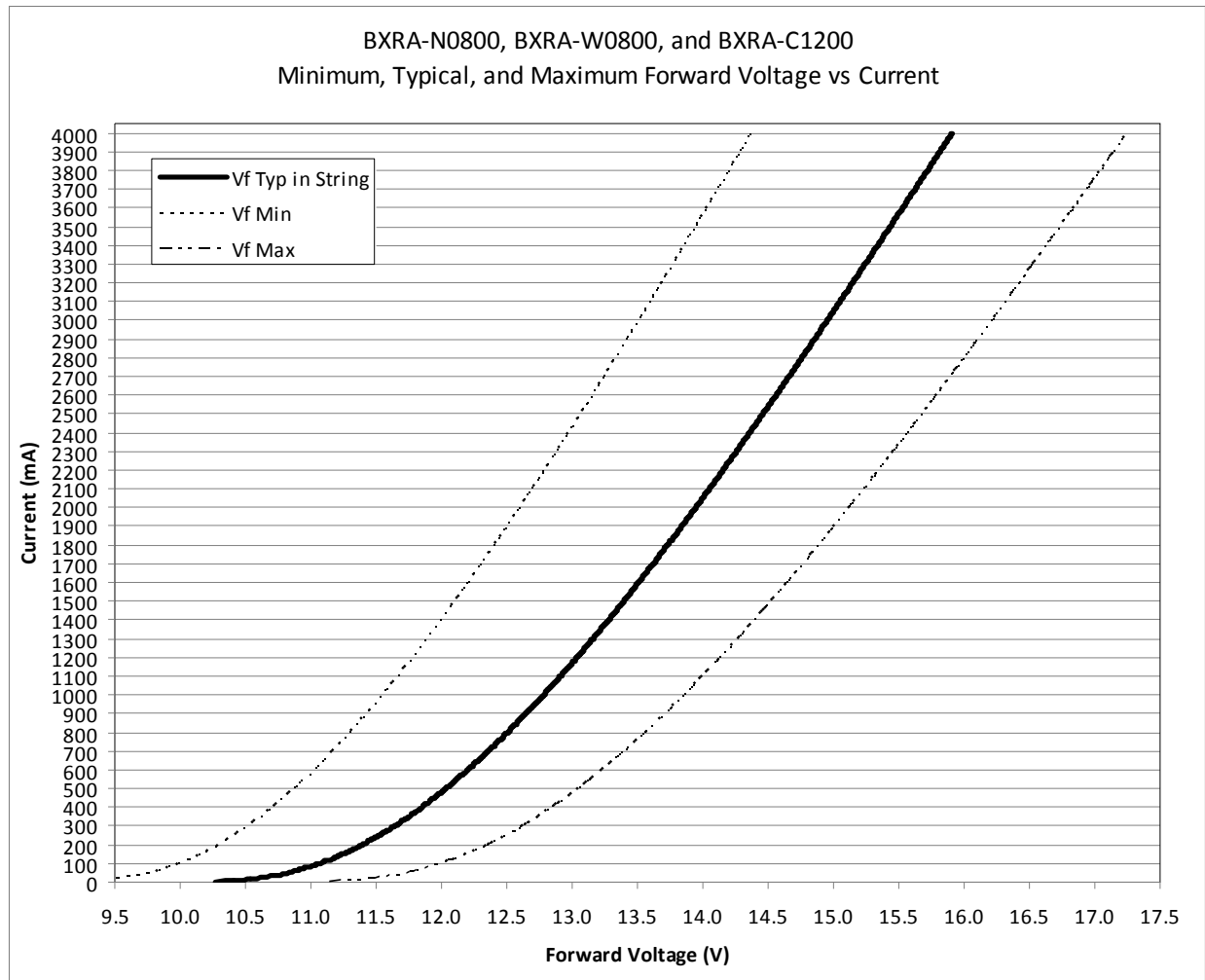


Figure A4: Forward voltage versus current plots for Bridgelux BXRA-N0800, BXRA-W0800, and BXRA-C1200 products

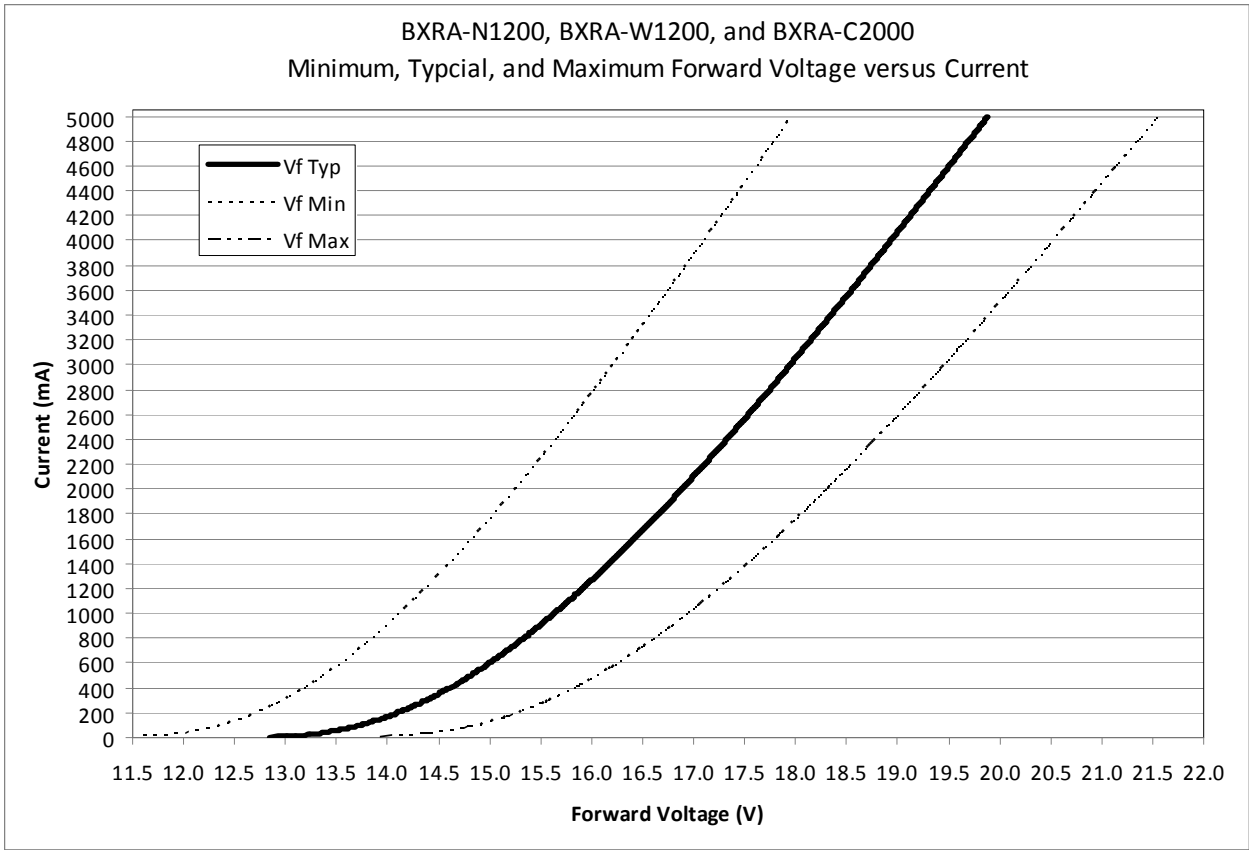


Figure A5: Forward voltage versus current plots for BXRA-N1200, BXRA-W1200, and BXRA-C2000 products

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## Design Resources

General Electronics

<http://hyperphysics.phy-astr.gsu.edu/hbase/emcon.html#emcon>

## References

Steve Winder. Power Supplies for LED Driving. Oxford: Elsevier, 2005.

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## About Bridgelux

Focused on bringing innovation to light, Bridgelux is a leading provider of high-power, cost-effective and energy-efficient light-emitting diode (LED) solutions. The company's proprietary epitaxy technology, innovative chip designs and leading-edge LED packaging technology have enabled the company to develop advanced solid-state lighting (SSL) products that offer superior quality, are lower in cost and environmentally friendly—all without compromising performance. In addition to LED chips, the company delivers a range of SSL light sources that customers can easily integrate into a variety of lighting applications that will open up new markets in solid-state lighting. Founded in 2002, Bridgelux is headquartered in Sunnyvale, California. For more information about the company, please visit [www.bridgelux.com](http://www.bridgelux.com)

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