XICATO

Application Note – Dimming the Xicato Module

Version 20110408

Dimming Architectures

Xicato modules are only compatible with drivers, also known as electrical ballasts, that supply constant current and DC voltage as specified in our Data Sheets. **Xicato modules are not compatible with constant voltage drivers.** Xicato maintains a list of compatible drivers for reference (on the Members Lounge at www.xicato.com). A subset of these compatible drivers have built in circuitry to enable dimming of the module. There are two primary circuitry architectures that drivers use for dimming: pulse-width modulation (PWM) and constant current reduction (CCR).

With a PWM driver, the drive current level is maintained (e.g. 700mA) but it is rapidly pulsed on/off to appear to the eye as being dimmed. LEDs turn on and off extremely rapidly and would perceivably flicker if pulsed at a relatively low frequency (generally less than 75 Hz). If the light fluctuations are sufficiently rapid, the human eye can no longer resolve them and the eye perceives the time average intensity without flicker. As the time between pulses increases, the light level appears to be less. Since the current level does not change, the voltage does not drop, and may actually increase minimally due to the module temperature decreasing (i.e. when the LEDs are in the off state between pulses, they do not generate heat). As a side note, the voltage ranges on Xicato Product Data Sheets do not account for forward voltage changes due to dimming.

The ratio of “on” time to “off” time during pulsing determines the module brightness (lumen output). See Figure 1 for an example of an XSM that is dimmed to approximately 25% using PWM. The 25% level is a result of the current flowing for 25% of the time, then being turned off for the remaining 75% of the time.

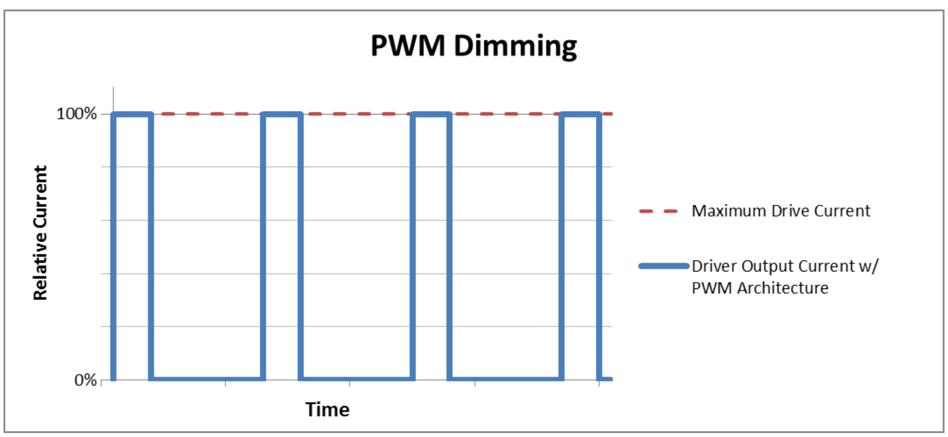

Figure 1: PWM Dimming to 25% Power

Measured light output is the quantifiable value of light measured by a light meter or similar device. Perceived light is the amount of light that your eye interprets because of pupil dilation. The eye’s pupil dilates at lower light levels, causing the amount of light to be perceived higher than measured (e.g. 25% measured light equals 50% perceived light). The equation for determining perceived light is to take the square root of the measured light percentage (e.g. $\sqrt{0.25} = 0.5$). To see a plot of the perceived light versus percent measured light (flux) refer to Figure 5 later in this application note.

In a CCR driver, current flows continuously at a set level for a given lumen output. Since the amount of light output is proportional to the current flowing through the module, the current is reduced to decrease the lumen output from the module. As the drive current decreases, the forward voltage also decreases. However, offsetting this decrease, the voltage will also rise as the module temperature decreases (due to the overall power drop). Sometimes CCR dimming is referred to as "Analog Dimming". See Figure 2 for an example of a module that is being dimmed from 100% power to 25% using CCR.

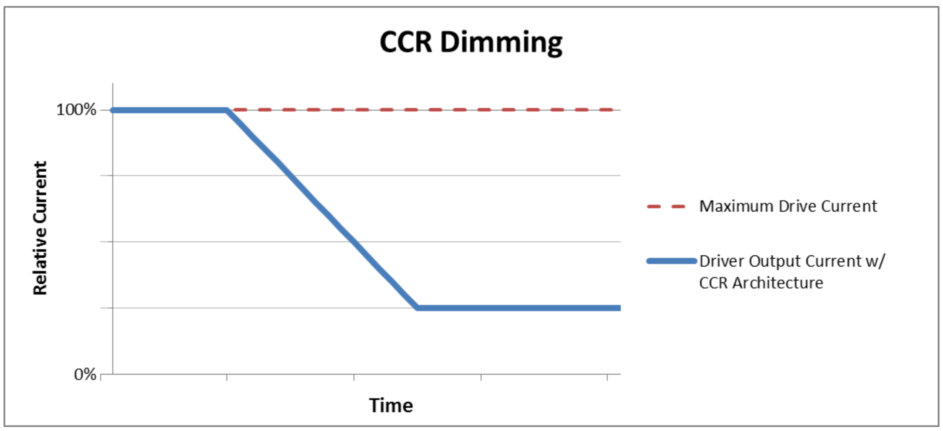

Figure 2: CCR Dimming to 25% Power

Dimming Controls

LED drivers use PWM and CCR architectures, or a combination of the two, to dim the light output of the modules. These architectures are internal to the driver and largely transparent to the end user. In order for the driver to know how much to dim the module, it needs to receive a signal to do so. Such lighting control signaling systems (e.g. dimmer switches and wiring between the control on the wall and the module) are required to provide that signal. There are numerous dimming control technologies (or protocols), but perhaps the most widely used are the following: 0-10V, DALI, Phase, DMX. Each of these dimming controls has advantages and disadvantages, but all are compatible with both PWM and CCR drivers.

0-10V Dimming

0-10 V is one of the simplest dimming controls. The control signal is a DC voltage that varies between 0V (or 1V in some cases) and 10V. Some drivers require this VDC input signal to operate while other drivers allow for an interfacing potentiometer to control the dimming level. The controlled lighting should scale its output so that at 10V, the controlled light is at 100% of its potential output, and at 0V (or 1V) it is at 0% output (i.e. off). The simplicity of this control makes it straightforward to understand and implement, and its low current (typically 1 mA) means it can be run along relatively thin cables. However, since it requires one wire per control channel (plus a common return wire), a large installation could require hundreds of wires and be very complex. Since the control signal is a small analog voltage, long wire runs can produce a significant drop in the signal level resulting in different light levels from different drivers controlled by the same control device.

There are two common methods for installing 0-10V dimming systems. The first is to control one or more luminaires with a single wall mounted dimming switch (or similar control). Another alternative is to equip individual luminaires with on board 0-10V dimming controls (i.e. a potentiometer dial). These individual controls allow for precise variation of each luminaire in an installation, such as a museum, where precise lighting design is critical.

DALI Dimming

Digital Addressable Lighting Interface (DALI) is a technical standard for network-based systems that control lighting. The DALI standard encompasses the communications protocol and electrical interface for lighting control networks. A DALI network consists of a controller and one or more lighting devices (e.g. drivers, dimmers, sensors) that have DALI interfaces. The controller can monitor and control each light by means of a bi-directional data exchange. The DALI protocol permits devices to be individually addressed and it also incorporates Group and Scene broadcast messages to simultaneously address multiple devices (e.g. "Group 1 go to 75%"). Each lighting device is assigned a unique static address in the numeric range 0 to 63, making possible up to 64 devices in a standalone system (per DALI controller). DALI requires a single pair of wires to form the bus for communication to all devices on a single DALI network. The DALI System may be run next to the mains cables or within a multi-core cable that includes mains power and the DALI signal has a high signal to noise ratio which enables reliable communications in the presence of a large amount of electrical noise.

Phase Dimming

Phase control dimming can mean either leading edge (a.k.a. Triac or forward phase control) or trailing edge (a.k.a. ELV or reverse phase control) dimming. Phase control basically works by trimming part of the AC waveform, either on the leading edge or trailing edge of the sine wave as shown below. The more of the AC waveform that is trimmed, the lower the corresponding power into the driver. The driver then interprets the lower power and provides corresponding dimming to the module. See Figure 3 and Figure 4 for representations of forward and reverse phase cut AC waveforms supplied to the driver of a module that is reduced to approximately 75% light.

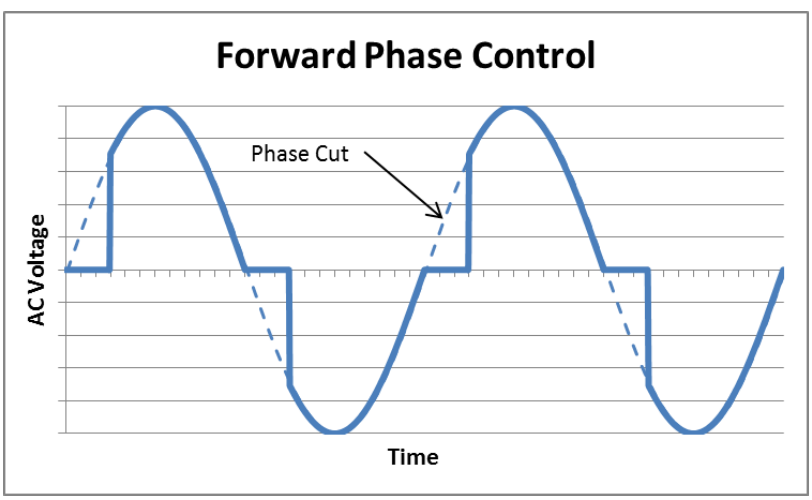

Figure 3: Triac, Forward, or Lead Edge Phase Control

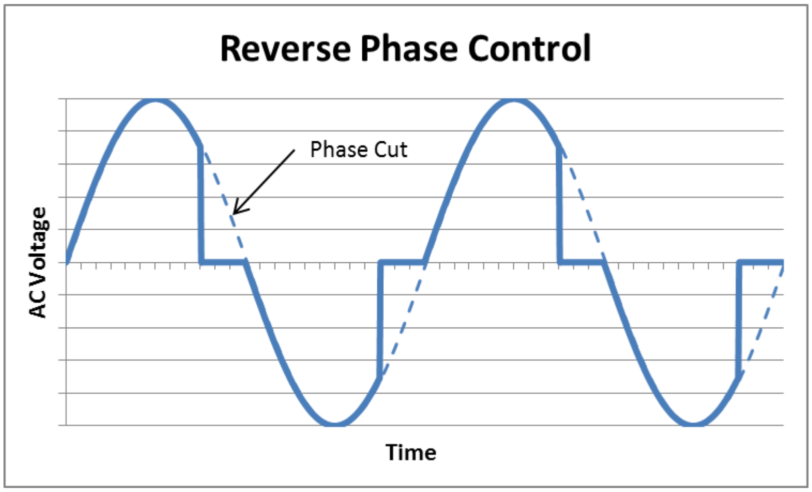

Figure 4: ELV, Reverse, or Trailing Edge Phase Control

3-wire control is a variant of the phase control dimming protocol that uses three wires in the control circuit. Along with black "switched hot" wire and the white "neutral" wire, there is a third wire called "dimmed hot" that controls the dimming level. This wire can be wired directly to an individual dimmer, or a dimming system to control several units. It allows dimmers to set the intensity of the driver by providing a line voltage phase control signal from the dimmer to the driver on the third dimmed hot wire. The dimmer separately switches the power to the driver over the dimmed hot wire.

DMX

Typically used in theatrical or architectural applications, DMX remains popular with RGB LED applications where multiple channels are necessary for individual color control. Some manufacturers are using DMX as the control type for white light in general illumination applications, which can often be complicated in terms of wiring, addressing, and interacting with other controls in the space. For more information, contact your Xicato technical representative or contact DMX directly here.

Dimming Hardware

In its simplest form, a dimming system for a luminaire in a building consists of an LED module, a dimming driver, a compatible wall mounted control device (i.e. dimmer switch), and associated wiring. More complex systems can include multiple sophisticated controls and sensors designed to conserve energy or perform other functions in a room or building.

Xicato modules are compatible with all dimming architectures and all dimming controls. Control devices do not care what dimming architecture the driver uses to dim the module (PWM or CCR), however, **the control device and driver must be compatible with the same dimming control type (0-10V, Forward Phase, Reverse Phase, DALI, DMX, etc.) to work properly together.**

When pairing a dimmer with a luminaire it is important to know that there may be a minimum, and certainly a maximum, number of loads (driver + module) that the dimmer can support. For example, some dimmers require a minimum load of 25W or higher so if the load is less than 25W then multiple loads will need to be wired to the single dimmer. All dimmers also have maximum load ratings. If a particular dimmer is rated up to 600W and the load is 20W, it would seem straight forward that 30 loads would be able to operate with the single dimmer. However, this is not always the case. When the module is first switched on there can be a significant instantaneous inrush of current from the building mains power to the driver. If there are too many loads attached to the dimmer control then the maximum rating could be exceeded, if only for an instant, resulting in tripping the building circuit breaker or other adverse effects to the lighting system.

Dimming Performance

Not all dimming systems perform equally. Performance can be measured in many ways including both visual and non-visual factors. Some of these factors are listed in the following table and explained below. Sometimes a driver and module may perform well with a particular dimmer, but when paired with a different dimmer (of the same compatible dimming control protocol) the performance drastically changes or it does not work at all. The only way to know for sure if a particular driver will work with a particular control is to test it. Xicato tests many compatible drivers and notes observations related to these performance factors as they are applicable.

Visual Performance Factors	Non-Visual Performance Factors
Flicker (static)	Luminaire efficiency
Jumping (while dimming)	Forward voltage fluctuation
Minimum light level	Audible noise
Color shift	
Pop-on	
Drop out	
Dead travel	

Table 1: Dimming Performance Factors

Visual Performance Factors

- Flicker: A strobe effect with high frequency fluctuations in light intensity while not dimming (static). These light changes can include momentary pulses with higher intensity light or dropouts with less light. It is important to note that detecting flicker is highly subjective, and perception varies from person to person.
- Jumping: When dimming, the light output transitions from higher to lower intensity and should be visually smooth and linear. When the light “jumps” from one intensity to the next in a non-linear way, this is referred to as jumping.
- Pop-on: After being dimmed to a low light level and switched off, sometimes the module will not turn back on until the dimmer slider is moved up.
- Drop out: When the light suddenly drops from a low level to completely off without a smooth transition.
- Dead travel: When adjustments to the dimming control are made without any resulting dimming of the light.

- Minimum light level: Some dimming drivers and/or associated controls are only capable of dimming down to a certain light level or percentage of maximum power level. Today, there are only a handful of drivers that can dim below 10% power. High performance drivers can usually dim to 1% power or below. However, depending on the application, dimming to 10% may be acceptable. See Figure 5 as an example of the module power versus percent light output and percent perceived light output.

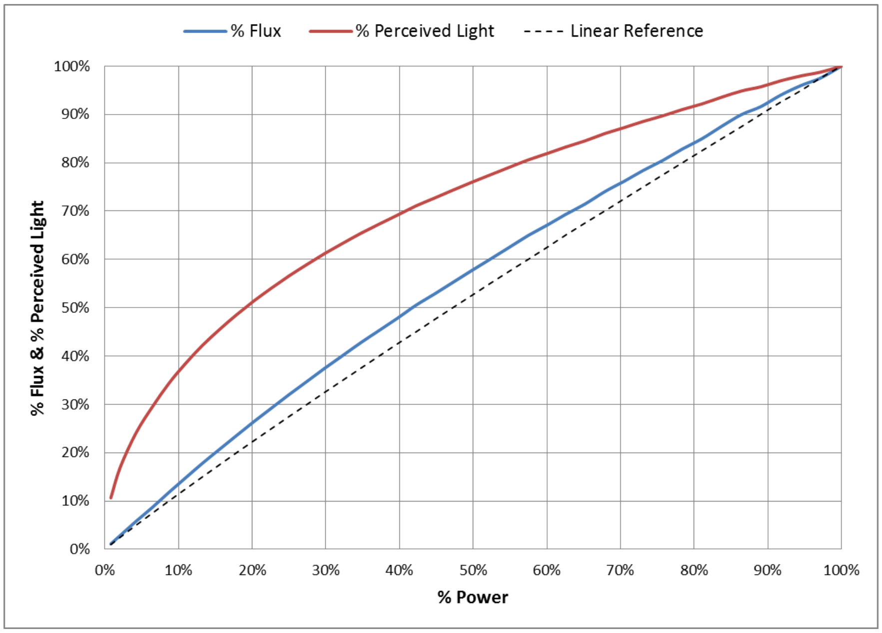

Figure 5: Relative Flux & Perceived Light Level over Dimming Range

- Color shift: Color shift depends on dimming architecture as represented in Figure 6 below. With PWM dimming the current is kept constant so the color shift is primarily caused by the change in module temperature. With CCR dimming, in addition to temperature changes, the drive current fluctuations alter the output from the LEDs and contribute more significantly to color shift. The data shown is for an XSM 1300lm module but is representative for most 3000K XSM modules.

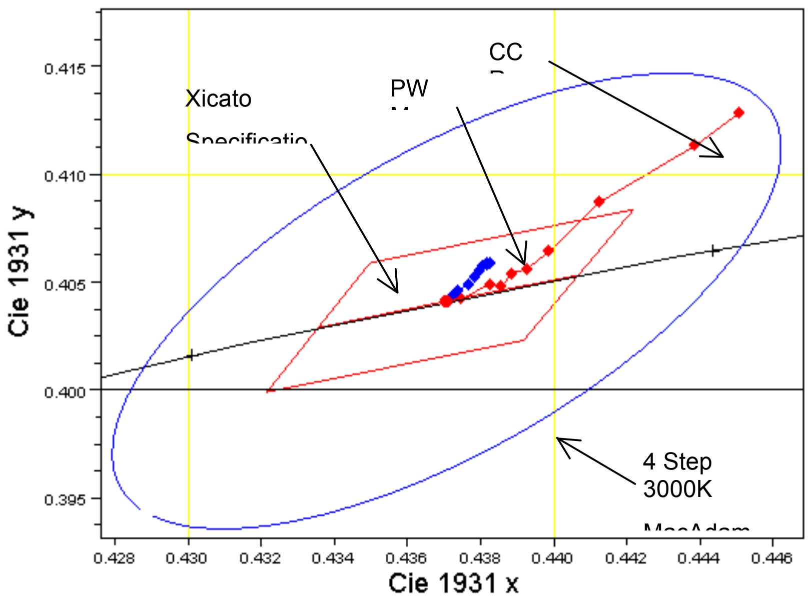

Figure 6: Expected Color Shift with CCR and PWM Dimming

Non-Visual Performance Factors

- Forward voltage fluctuation: The forward voltage of the module may vary based on a number of factors including drive current changes (i.e. with CCR dimming) and module temperature.
- Audible noise: Buzzing from the dimmer or driver.
- Luminaire efficiency: When dimming with CCR drivers, as the drive current drops, the overall power drops and the module temperature drops. When driven at lower current levels and lower temperature the module is more efficient, thus increasing the lumens per watt efficacy.

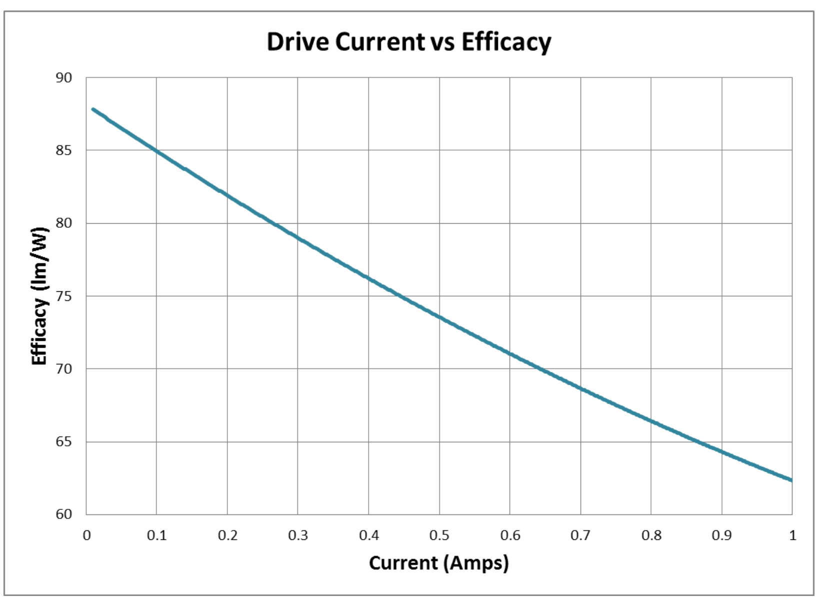

Figure 7: Luminaire Efficacy Increase with CCR Dimming (ex. XSM 1300lm module shown)

Choosing a Dimming Driver

Only drivers that have circuitry built in for dimming can dim the Xicato module (some compatible drivers do not have dimming functionality built in). After a dimming driver is selected, a compatible dimmer needs to be paired with it to complete the system. Not all dimmers are equal and a certain dimmer will behave differently with different drivers. It is recommended that you ask the driver manufacturer for recommendations on dimmers they have tested with their drivers.

The following table lists some of the most important considerations to take into account when choosing a dimming driver for an application.

Checklist for picking a dimming driver
Compatible input VAC range
Compatible output voltage range with the module
Desired maximum drive current (e.g. 700mA)
Minimum dimming power/light level
Dimming Architecture desired (PWM, CCR)
Control Protocol desired (0-10V, Phase, etc.)
Size (fits in desired enclosure)
Power Factor (if specified for an installation)
Safety Standards Compliance (UL, CE, PSE, etc.)
IP Rating required (if any)

Table 2: Driver Selection Criterion

The following lists the major pros and cons for the PWM and CCR driver architectures.

Why use PWM?

- A PWM driver will only run the module at the rated current level or zero, preventing potential color changing characteristics from occurring while dimming with reduced current. Practically, this means the same color temperature is maintained throughout the dimming range (although some shift occurs due to temperature effects).
- PWM based drivers can provide a very precise output level, since the LEDs are always on at the same current level. Changing the operating current linearly, as done with CCR, may not result in a linear change in light output.

Why use CCR?

- When energy savings and higher system efficiency are important.
- For devices that need to be rated as UL Class 2 for dry or damp locations, there is a lower output voltage limit for Class 2 devices that use PWM (42.4 volts for PWM frequency > 200 Hz) than those that use CCR (60 volts). Therefore, a Class 2 power supply that uses PWM will not be able to provide as much voltage as one that uses CCR.
- By definition, PWM power supplies have to run at frequencies high enough to be imperceptible to the human eye. The higher the frequency, the less likely someone is to observe flicker. Frequencies below 200Hz may be observable in peripheral vision, and even higher frequencies are required to eliminate stroboscopic effects in fast motion environments. However, higher-frequency power supplies are generally more complex and expensive to manufacture, especially when low light levels are desired. Other programs, such as Energy Star, may place minimum requirements on PWM frequency.
- Because of the fast rising and falling edges of a PWM driver (faster edges allow for higher frequencies and lower light levels), electromagnetic interference (EMI) can be generated. This EMI may not be suitable for certain applications.
- PWM drivers, due to their fast edges, may experience performance issues if mounted remotely from the light source. This is because the electrical characteristics (capacitance and inductance) of the long wire runs interfere with the fast rise and fall times required for precise light levels. Using twisted shielded wire pairs may help minimize this effect.

Xicato maintains a list of compatible drivers for reference (on the Members Lounge at www.xicato.com). If additional assistance is needed or desired, please contact your account manager, technical representative, or DMX.