Understanding LED dimming

Introduction

Dimming is an important requirement in the lighting industry.

It is useful for saving energy as well as creating an ambiance for the space being lit.

As LED lighting continues to take market share from traditional lighting, these LED systems are expected to offer high performance dimming, in addition to all the advantages of solid state lighting, with the existing installed base of dimmers of various types.

In this application note we cover the various dimming scheme used in the lighting industry and address the issues that may be encountered and how to solve some of the most commonly seen problems.

Concept of dimming

It is important to mention at the outset that dimming performance is dependent on the end user experience. Dimming level in Constant Current LED drivers is set by the output current driving the LEDs. This current level is translated into a light level by the LEDs. But the measured light level is perceived by the human eye at a different brightness level. It is the perceived light level that matters the most since it is the light that is visible to the users for the application in question.

Dimming means different things to different people. LED driver designers refer to the drive current, fixture designers use the measured lumen output and end users evaluation is based on the perceived light ie the light that the eye sees.

Methods of dimming and Dimmer types

There are several dimming methods in use in the lighting industry today.
Lighting designers will encounter on the premises, some or all of the dimmer types discussed below.

Traditionally dimming has been accomplished with dimmers that modify the AC input signal going into the lighting fixture. These dimmers are known as Phase dimmers or phase cut dimmers because they dim by cutting a portion of the AC signal.

Because there are a number of lighting technologies available, specific phase dimmers have been designed and optimized to dim certain lighting technologies.

Two types of legacy phase dimmers are widely installed in the industry: the TRIAC dimmer designed for incandescent and halogen lamps and the ELV dimmer designed for electronic low voltage halogen lights. Because legacy phase dimmers have compatibility issues with LED lighting, which will be discussed later in this application note, dimmer manufacturers in recent years have brought to market TRIAC and ELV dimmers that are designed specifically for LED lighting to improve the user experience.
Other dimming methods exist such as the 0-10V analog dimming scheme. This scheme is widely used in the lighting industry in commercial applications where the 0-10V dimmer simply provides a low voltage DC signal to the lighting fixture, that ranges from 0V to 10V.

Building Automation applications and theatrical/stage lighting use digital dimming protocols like DALI and DMX. These standards have many advantages that will be covered in a later section.

PWM dimming is another popular dimming method that is used in LED lighting where the current applied to the LEDs is not a constant DC current but it is in the form of a square wave that turns the light on and off at high frequency that is not noticeable by the human eye. Modifying the on time of the waveform (ie its duty cycle) dims the lights to the desired level.

How dimmers work?

Dimmers use various techniques to achieve the dimming function.

In this section, we will cover briefly how the various types of dimmers available on the market operate.

1. AC Phase cut dimming

AC phase cut is a dimming method where the dimmer chops part of the AC input voltage sine wave before sending it to the driver and thus reduces the power delivered to the driver. The driver in turn produces an output current that is proportional to the reduced power applied by the dimmer. In other words, the light output will be proportional to the phase angle of the modified sine wave. This results in the dimming of the light output.

Because Phase cut dimming occurs on the input AC lines to the driver, this method is referred to as primary side dimming, meaning that the dimming signal goes into the primary side of the driver electronics. The phase dimmer is placed in series with the AC Line input as shown in figure 1 below while the 0-10V dimmers are connected on the secondary side. ERP offers dimmers with all three dimming options but we do not recommend using more than one dimmer at the same time.

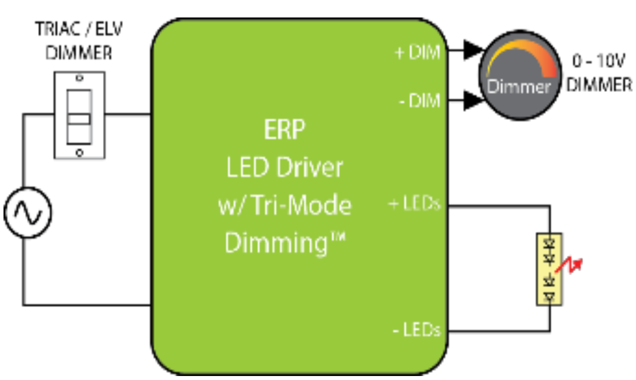

Figure 1. Block diagram with AC phase and 0-10V dimming.

Two types of AC phase cut dimmers are in use in the industry.

a) Forward Phase dimmers

The first is the Forward Phase dimmer also referred to as a TRIAC dimmer or a leading-edge dimmer because the internal circuit of the dimmer (fig. 2a) uses a TRIAC device to chop the front end or leading edge of the AC sine wave as seen in fig 2b. The TRIAC-based dimmer consists of a switch (the TRIAC) and a delay element (RC circuit) that sets the time at which the TRIAC switch is turned on to allow the AC voltage to be applied to the load.

Forward phase dimmers have been in use in the lighting industry for decades. They are simple, low cost and easy to install. Because of that they have found widespread acceptance in the industry. All it takes to install a forward phase dimmer is for an electrician to remove a light switch and replace it with a dimmer/switch in the same junction box with no additional wiring required.

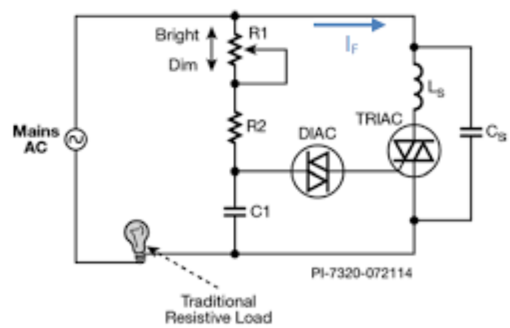

Figure 2a. TRIAC dimming circuit
(Source LED Journal)

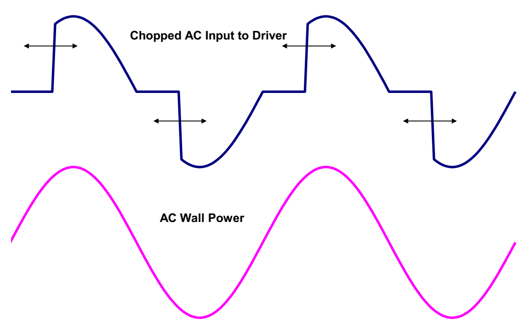

Figure 2b. AC Forward phase TRIAC dimming

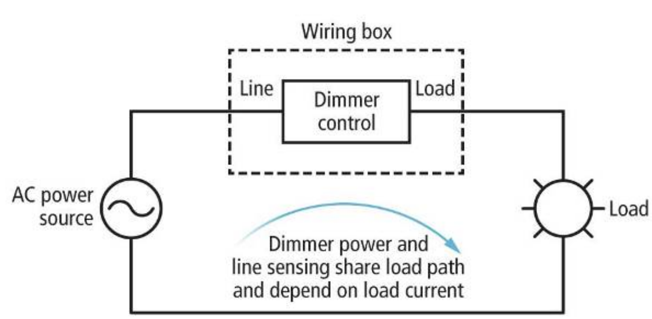

Figure 2c. TRIAC dimmer wiring diagram
(source: LED Magazine)

b) Reverse Phase dimmers

The second phase dimmer type is the Reverse Phase dimmer referred to as ELV or trailing-edge. ELV dimmers (Electronic Low Voltage) are much newer compared to TRIAC dimmers. They were initially developed to improve the dimming performance of low voltage halogen lamps when driven with Electronic Low Voltage transformers.

ELV transformers, which are essentially switching power supplies, replaced MLV (Magnetic Low Voltage) transformers in low voltage applications because of their small size, low weight and good efficiency. However, when TRIAC dimmers were used with ELV transformers their performance was not optimum. For that reason, the ELV dimmer was designed to offer better performance with the capacitive nature of the ELV transformers.

Unlike the forward phase case, the ELV dimmer cuts the trailing edge of the AC sine wave as shown in Fig. 3. That is why Reverse phase dimmers are also referred to as Trailing-edge dimmers.

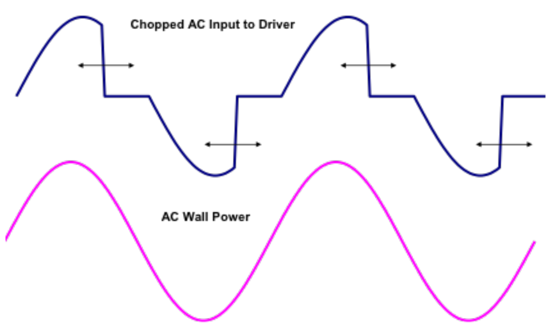

Figure 3. AC Reverse phase ELV dimming

Note that cutting the leading edge of the sine wave creates a sharp rise in the AC signal as seen in fig 2. This steep turn on causes high inrush currents which generate EMI in switching power supplies, such as LED drivers, and put stress on the dimmers. Whereas in the reverse phase scheme the voltage cut off is on the back end of the sine wave which has no adverse effect on the driver circuits. Here the turn on is slow with the slow rise of the sine wave, and that greatly reduces the inrush current and therefore EMI. In fact, one of the reasons the ELV dimmers were developed was to eliminate this high inrush problem when dimming low voltage halogen lamps that use ELV transformers, which as stated before are effectively switching power supplies. Another advantage of ELV dimmers is their ability to consistently detect the zero-crossing point in the AC voltage waveform ie to be fully synchronized with the input AC sine wave, and thus avoid fluctuation in the chopped signal sent to the driver. Those fluctuations cause flicker in the LEDs.

To achieve the above advantages, ELV dimmers have a more complex internal control circuit that drives a fast MOSFET switch element to generate precise AC voltage trailing edge chopping.

ELV dimmers have the disadvantage of being higher priced and need to have additional wiring in the wall. They require the AC Neutral wire to be present in the wall electrical box to connect to it (see figure 4). The Neutral connection makes power always available to the dimmer's internal circuitry regardless of how much current is drawn by the LED load.

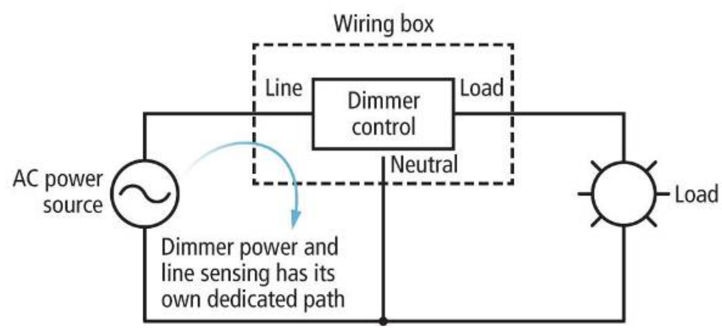

Figure 4. ELV dimmer wiring diagram. (source: LED Magazine)

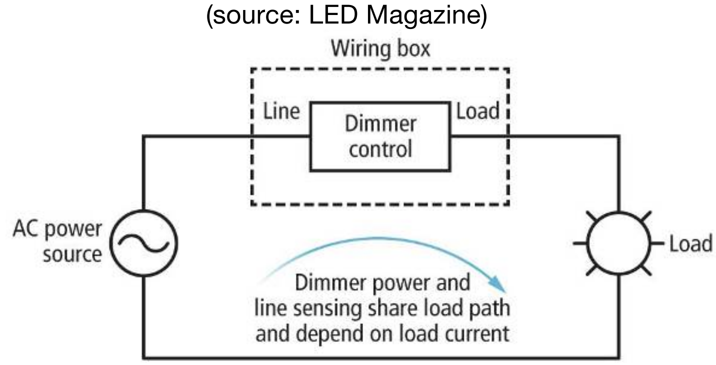

Figure 5. TRIAC dimmer wiring diagram. (source: LED Magazine)

This is an improvement over TRIAC dimmers that are actually powered by the current flowing through them that is drawn by the LED load (see figure 5). When the load pulls less current than the minimum TRIAC holding current (to be discussed in a later section), the TRIAC device inside the dimmer turns off (misfires) and completely cuts the power to the LEDs. That misfiring causes flicker in LED lights.

2. 0-10V Dimming

Unlike phase dimming, 0-10V analog dimming is a secondary side dimming scheme where the dimming voltage is applied on the secondary side of the driver (Figure 1) ie on the secondary side of the internal transformer. 0-10V is a DC voltage standard that uses two wires between the dimmer and the driver.

This scheme has been in use for fluorescent and theatrical applications for many years and has recently found its way into LED lighting systems.

It is a straight forward standard where the dimmer applies a voltage between 0V and 10V to the driver. The voltage level is translated by the driver to a proportional output current level, to drive the LEDs. Note that in practice the driver provides the 10V signal to the dimmer and the dimmer reduces the voltage to dim the lights.

Typically there is a linear relationship between the applied voltage and the light output. At 10V the driver outputs a current for full brightness, at 5V the output is at half brightness and at 0V it outputs a current for the lowest brightness level.

Other dimming profiles exist that are used with 0-10V dimming where drivers implement a non-linear response with a dim-to-off function which allows the lights to completely turn off at the lowest dimmer setting. ERP drivers offer linear and non-linear profiles with dim-to-off capability. We will discuss this topic further at a later section.

Two types of 0-10V dimmers are available; sinking dimmers and sourcing dimmers. These are defined by two standards bodies. The IEC defined the IEC 60929 Annex E 1-10Vstandard for general lighting. In this standard, the driver sources the current and the dimmer sinks the current and the voltage varies from 10V for maximum light output to < 1V for minimum output. The second standard is the ESTA 0-10V standard defined for theatrical applications, where the driver sinks the current and the dimmer sources the current and where at 10V the lights are at the maximum output and at 0V they are completely off. The IEC 60929 Annex E standard for general lighting is the more prevalent standard in the market place.

ERP drivers only support sinking dimmers where our drivers source the current to the dimmer. Current sourced from the driver for sinking dimmers, is usually at 1mA or less.

3. DALI digital dimming

The DALI standard (Digital Addressable Lighting Interface) defined in IEC 62386 was initially released in 2001. It is a digital protocol that enables the control of lighting fixtures in building automation applications via a bus architecture where a controller addresses individual or groups of lights for control and status purposes. It is an open standard that has received widespread acceptance in the lighting industry because of its many advantages. Devices that support the protocol are compatible with other devices from different manufacturers and can be used interchangeably.

The DALI protocol defines a master/slave architecture where a controller/master sends command and address information to lighting devices/slaves across a two-wire serial bus. Commands are decoded and acted upon by the addressed lights. The DALI controller is also able to request status from each of the lights to monitor the network and make control decisions. This capability makes DALI a bidirectional protocol. The DALI network can have up to 64 devices with a maximum length of 300m.

DALI offers many advantages over traditional dimmers like simplified wiring and individually addressable lighting fixtures. These enable very flexible and powerful controls of the lighting environment. For example, re-arranging a lighting area and changing the dimming controls becomes as simple as moving a few icons on a computer screen or selecting from pull down menus in a GUI.

One of the most important advantages of the protocol, is dimming compatibility and consistency. Since dimming information is sent as digital commands, not analog like in the 0-10V scheme, all the lights will receive the same command and will execute in the exact same way leading to a uniform dimming response.
DALI is very popular in Europe and is gaining acceptance in the US.

4. DMX512 digital dimming

DMX (Digital MultipleX) is also a digital communications standard used to control theatrical and stage lighting. It offers the same advantages to lighting controls as described in the DALI section above. DMX uses an architecture that is similar to DALI in that it is a Master/Slave protocol with individually addressable devices/lights, a two-wire serial bus (RS485 in this case) and bidirectional communication.

However, DMX offers much faster communications at 250Kbps vs DALI's 1200bps. The higher speed makes it preferable for theatrical/stage application where there is a need for fast control of the lighting system such as fast color changing. The maximum practical bus length is 300m which is similar to DALI.

The standard supports 32 devices/lights but each of the devices can be assigned several channels of the available 512 channels from the controller. A channel can be thought of a communication channel to control a specific function within a light like the dimming level. The controller is connected to the light fixtures in a daisy chain configuration.

5. PWM dimming

PWM dimming is a digital dimming scheme that is implemented by driving the LEDs with a square wave current waveform. Unlike constant current reduction where the driver reduces the output current to dim the lights, the PWM signal waveform swings the LED current from full on to off. By adjusting the duty cycle of the waveform, ie the on time, the average current going into the LEDs is changed which causes the lights to dim.

PWM dimming has the advantage of not affecting the color or efficiency of the LEDs because the current level is kept the same while only changing the duty cycle of the current signal (ie pulsing the current) to dim the lights.

ERP drivers only support constant current reduction for dimming the light output.

The PWM frequency needs to be high enough for the flicker not to be visible to the eye. A frequency at or higher than double the line rate ie at greater than 120Hz in a 60Hz system, is recommended. According to some tests in the industry, at 200Hz there will be no noticeable flicker.

0-10 V Dimming curves/profiles

In this section we will discuss four dimming profiles; the Linear profile, the Non-Linear profile, the Non-Linear profile with dim-to-off and the logarithmic profile.

1. Linear profile

0-10V wall dimmers vary from manufacturer to manufacturer and from model to model. In most cases these dimmers are not capable of delivering the full 0-10V range to the drivers. When these dimmers are used with drivers that have a linear dimming curve the light output at the low end does not dim very low and at the high end you will not get to full brightness. Drivers with a linear dimming curve, output a current that is proportional to the voltage it receives, across the full 0-10V scale as shown in figure 6.

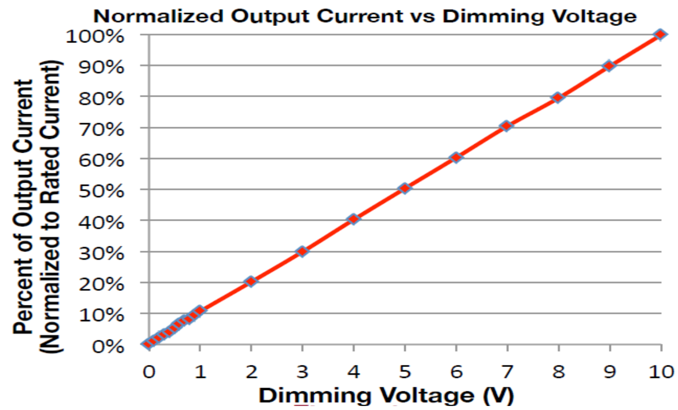

Figure 6. Linear dimming profile.

Most customers expect 1% dimming from their lighting system but that can only be achieved when the driver/dimmer pair is fully tested. ERP provides dimming compatibility lists with detailed test results to simplify the selection process. Table 1 below shows a typical ERP 0-10V dimmer compatibility table. Dimmers on this list are proven to produce good dimming performance with the driver they were verified with.

0-10V Dimmer	Dimmer Max Sourcing Current (mA)	Max Sourcing Current Measured (µA)	ERP Spec Max Sourcing Current (µA)	Max Dimmed Output Current and Signal Voltage at 120 V_{AC}	Max Dimmed Output Current and Signal Voltage at 277 V_{AC}	Min Dimmed Output Current and Signal Voltage at 120 V_{AC}	Min Dimmed Output Current and Signal Voltage at 277 V_{AC}
Lutron Nova NFTV	30	510	1000	1200mA @9.45V	1200mA @9.45V	0mA @0.62V	0mA @0.62V
Lutron Diva DVTV	30	568	1000	1200mA @9.16V	1200mA @9.16V	2.8mA @0.79V	2.8mA @0.79V
Leviton IP710-DL	28	560	1000	1196mA @8.15V	1196mA @8.15V	0mA @0.69V	0mA @0.69V

Table 1. 0-10V Dimmers compatibility list

FORM-DQE-001-A3

120Vac Dimmers	Total Score:	91.8%	Driver Current (mA) with no Dimmer:	1201	Driver Light (FC) with no Dimmer:	4280	Scoring
	Avg. Min. Dimming:	6.5%					0 - Needs improvement 1 - Unlikely to be noticed 2 - No issues

Dimmer List		Indiv. Score	Light Output (Foot Candle)		Current (mA)		Light Dimming Range		Smooth Dimming	No Start Flash	Flicker	Shimmer	Able to turn off	Audible Noise	Comments
Mfg.	Model	%	Max	Min	Max	Min	Max	Mi							
Lutron	S-603PG	91.7%	3960	200	1085	45	93%	5%	2	2	2	2	2	1	
Leviton	IPI06-1LZ	91.7%	4280	0	1201	0	100%	0%	2	2	2	2	2	1	
Leviton	6631-2	91.7%	4280	0	1201	0	100%	2%	2	2	2	2	2	1	
Lutron	DVCL-153P	91.7%	4280	110	1201	25	100%	3%	2	2	2	2	2	1	
Lutron	DV600P	91.7%	4280	270	1201	61	100%	6%	2	2	2	2	2	1	
Lutron	TGCL-153P	91.7%	4280	250	1201	56	100%	6%	2	2	2	2	2	1	
Lutron	S600P	91.7%	4280	100	1201	23	100%	2%	2	2	2	2	2	1	
Leviton	VPE06	100.0%	4280	440	1201	98	100%	10%	2	2	2	2	2	2	
Lutron	DVELV303P	100.0%	4280	320	1201	71	100%	7%	2	2	2	2	2	2	
Lutron	SELV300P	100.0%	4280	330	1201	74	100%	8%	2	2	2	2	2	2	
Leviton	6683-IW	87.5%	4280	0	1201	0	100%	0%	2	1	2	2	2	1	
Leviton	6161	83.3%	4280	750	1201	167	100%	18%	2	2	2	2	2	1	
Leviton	6633-P	87.5%	4280	70	1201	17	100%	2%	2	1	2	2	2	1	
Lutron	TG-600P	87.5%	4280	610	1201	136	100%	14%	2	2	2	2	2	1	
Cooper	DLC03P	91.7%	4280	90	1201	21	100%	2%	2	2	2	2	2	1	
Lutron	LG600P	91.7%	4280	260	1201	59	100%	6%	2	2	2	2	2	1	
Lutron	CT103P	91.7%	4280	430	1201	96	100%	10%	2	2	2	2	2	1	
Cooper	SLC03P	83.3%	4280	200	1201	7	100%	5%	1	2	2	2	2	1	
Leviton	IPE04	91.7%	4280	280	1201	62	100%	7%	1	2	2	2	2	2	
Lutron	MAELV600	95.8%	4280	550	1201	121	100%	13%	2	2	2	2	2	2	
Lutron	FAELV500	95.8%	4280	540	1201	119	100%	13%	2	2	2	2	2	2	
Lightolier	ZP260QEW	100.0%	4280	360	1201	79	100%	8%	2	2	2	2	2	2	
Cooper	DAL06P	83.3%	4280	0	1201	0	100%	0%	1	2	2	2	2	1	

Table 2. Example Phase Dimmers compatibility list

2. Non-Linear profile

To improve the dimming experience with dimmers that are not able to provide the full 0-10V voltage range, newer drivers offer non-linear dimming curves where at a certain voltage on the low end of the range the driver sets the light to 1% and at a certain voltage at the high end, the light is set to the maximum brightness of 100% as shown in figure 7.

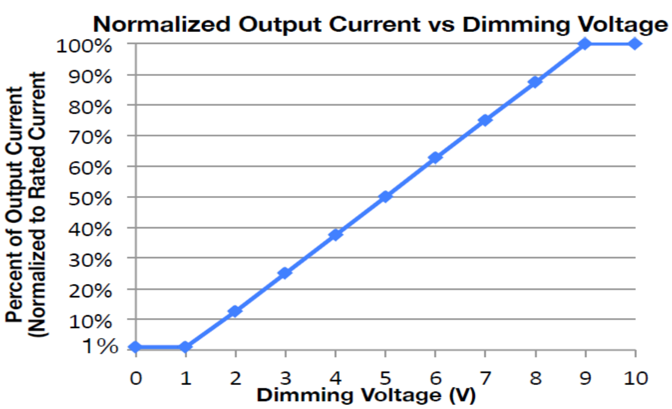

Figure 7. Non-Linear dimming profile.

3. Non-Linear with Dim-To-Off profile

Another non-linear dimming profile is offered where the low and high thresholds are modified and the dim-to-off functionality is implemented as shown in figure 8. Dim-to-off means the driver will turn the light off at or below the lowest threshold. In this case it is at 0.6V. ERP's Draco family of drivers support the dim-to-off feature.

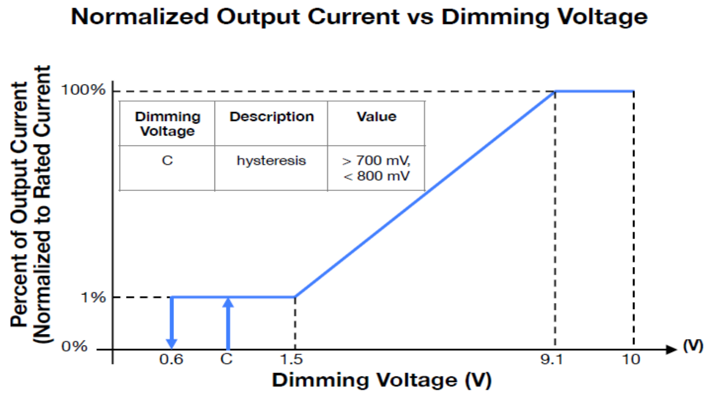

Figure 8. Non-Linear dimming profile with Dim-to-off

The ANSI standards body is working on a standard that will define the thresholds and should simplify the task of providing a common response curve. The graph above (Fig. 6) shows a profile that closely resembles the proposed standard.

4. Logarithmic profile

The Logarithmic profile (Fig 9) is another dimming response that tries to emulate how the eye perceives brightness. In this case drivers will output a lower level of light in the lower half of the dimming range because the human eye can perceive lower intensity light as a higher brightness light. In the second half of the dimming scale the light output will be increased faster as the dimmer is moved towards the max position.

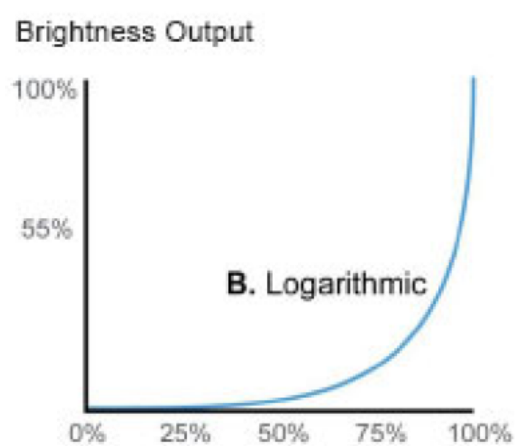

Figure 9. Logarithmic profile brightness vs dimmer position.

Performance of LED lighting with legacy phase dimmers

As described earlier, phase dimmers have several advantages like low cost and simplified installation. However, they have some disadvantages that lighting designers need to be aware of if they want to replace traditional lighting technologies with LED lighting successfully. We will address the most common limitations in this section.

The problems encountered when using legacy dimmers with LED lighting stem from the fact that these dimmers were designed for incandescent and halogen lights which are resistive in nature. When using resistive loads, the current drawn from the dimmer is in phase and has a linear relationship with the voltage (Fig 10) which generates smooth dimming.

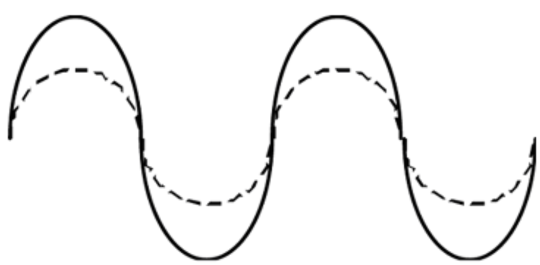

Figure 10. Voltage and current relationship when driving a resistive load

LED drivers on the other hand, are switch mode power supplies that are capacitive. This means switching drivers draw current from the mains in bursts every cycle when charging their internal capacitors. In this case the current waveform shows current spikes that have a non-linear relationship with the input AC voltage as can be seen in figure 11.

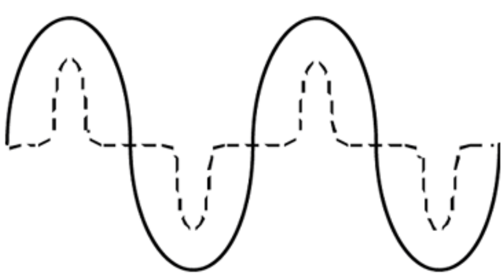

Figure 11. Voltage and current relationship when driving a capacitive load

1. **TRIAC Dimmer minimum load requirement**

When the current bursts die down, the driver stops drawing current from the dimmer. TRIAC phase dimmers require a minimum current, referred to as the holding current, to be drawn to keep them turned on. When the minimum current is not flowing through the TRIAC during the conduction period set by the dimmer, the TRIAC cannot stay on (misfires) and that essentially turns the AC power off to the driver which leads to flicker and undesirable dimming performance.

Although drivers nowadays use a PFC stage to smooth the current and make it linear and in phase with the voltage, this issue is still present at very low currents toward the end of the AC cycles.

Because of that TRIAC dimmers specify that a minimum load be connected which is determined by the holding current requirement.

To satisfy this requirement, LED drivers are designed to draw current from the phase dimmer even when the LED lights are off. Also, newer dimmers have been designed to reduce their holding current requirement to a very low level, therefore it is important to make sure a minimum load is connected to the dimmer.

A better solution would be to use ELV dimmers that do not have a holding current requirement as they are always powered from the mains by virtue of their connection to both the Line and Neutral wires. Of course, ELV dimmers can only be used if a Neutral wire is available in the wall.

2. **Inrush current**

In-rush current is generated by the drivers when first powered, and periodically during operation (referred to as repetitive peak current) on each rising edge of the chopped AC signal produced by forward phase dimmers (see figure 12). These currents can be as high as several Amps. Inrush current is caused by the capacitive inputs of drivers and is governed by the following equation:

$$i = C\, dv/dt$$

which states that the current is proportional to the rate of change of the voltage. When a fast-rising voltage is applied, a large (inrush) current will flow. These high currents can cause damage to dimmers and other components. Drivers are designed to have circuits that limit the in-rush current to meet the NEMA410 requirement but they do not completely eliminate it. A lighting designer must insure that the dimmer used can handle the total amount of in-rush current generated by the LED loads attached to it. This is essentially a dimmer maximum load specification.

In addition to the bad effects stated above, the sharp rise in the voltage causes oscillation in the input EMI filters of drivers. This translates to driver input current oscillation that can move below and above the TRIAC holding current which will force the TRAIC to turn off and back on repeatedly and that will result into light output flicker.

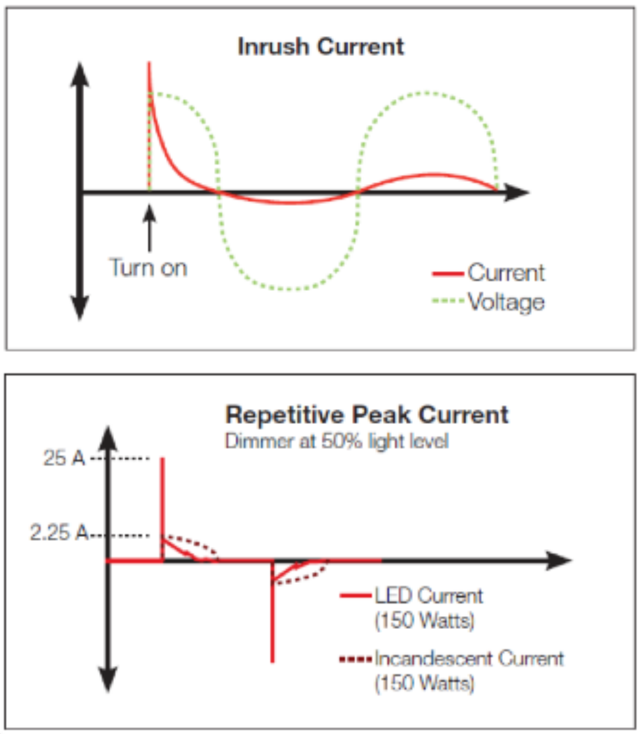

Figure 12. Inrush and repetitive peak current with forward phase dimmers (Source Lutron)

3. Flicker

Flicker is the visible fluctuation of a light source. All lighting technologies flicker when powered by the varying AC line voltage. Flicker is present in incandescent as well as LED lights but it is less visible with incandescent lights because of the persistence property of the filament ie when the power is turned off the filament continues to glow for some time afterwards. LEDs on the other hand show flicker more easily because of their fast response to minor changes in the drive current. That's because LEDs are semiconductors that have a very fast response time in the nanoseconds range.

Flicker can be caused by many sources in a lighting system such as the driver output current ripple, line voltage noise, dimmer operation (since it varies the AC line voltage), and the light source itself. In fact, different LEDs have different characteristics that can cause some drivers to perform well with some LEDs but not others.

Output current ripple is the major contributor to flicker. Ripple is dependent on the driver topology. Early driver designs used single-stage power topology but newer drivers are moving into two-stage which greatly reduces ripple. The ERP Draco family of drivers are two-stage drivers with current ripple at 10% or lower. This results into a much-reduced flicker and enables fixtures to easily meet or exceed the California Title 24 flicker specs.

For best flicker performance with older single stage drivers, it is advisable to only use dimmers from compatibility tables or conduct testing prior to installations.

4. Dimming range

A phase dimmer's range is referred to as the conduction angle which is a measure of the time the dimmer is conducting within the 180-degree AC voltage sine wave. In figure 2 it is the range from the rising edge to the zero crossing of the voltage waveform.

Phase dimmers have different conduction angles within the 0-180 degrees span. When they are paired with drivers that have a fixed dimming response ie fixed minimum and maximum settings, only a subset of dimmers will perform well. The dimming performance will depend on how well the dimmers' range matches up with that of the driver. That's why it is important to test drivers with many dimmers and come up with a compatibility list.

The ERP Draco family of drivers will be capable of supporting a programmable TRIAC dimming transfer function to adapt to the various dimmer ranges on the market.

5. Low end dimming

Of particular importance in certain LED lighting applications is the low end dimming level. In these applications the user requires the light output to be at a very low level when the dimmer is set at its lowest physical position.

This problem occurs when the dimmer range does not match the driver range as described in the previous section. Another issue experienced at the low end of the dimming scale is flicker. When the dimmer is set at its lowest position, very little power is delivered to the driver. In this case the driver is not able to turn the LEDs on and keep them on with the very low power available. This will cause the LEDs to flicker. To alleviate this problem, some dimmers have a manual trim adjustment that allows the user to raise the minimum dim level to provide enough power to the driver to operate.

6. Compatibility

Even though LED lighting needs to be compatible with phase dimmers there is no industry standard that defines dimmer characteristics. This causes compatibility issues between the many dimmers on the market from different manufacturers and even from the same manufacturer, and LED lights.

It is not uncommon to have a dimmer work well with an LED fixture and not be compatible with another.

The best and easiest solution to this problem is to conduct dimmer/LED lamp pair testing and publish compatibility lists for end users to refer to. ERP and other LED driver and dimmer manufacturers do make such lists available as shown in Tables 1 and 2 above.

Performance of LED lighting with 0-10V dimmers

0-10V dimmers tend to perform better than phase dimmers but they come at a cost. They require additional wiring to be installed between the dimmer and the fixtures as opposed to phase dimmers. Although this dimming method is simpler and offers better performance than phase dimming it does require careful attention to a few things when installing such a system.

1. Noise induced on wire runs

0-10V DC wires are susceptible to noise pick up from nearby AC power lines. The noise induced on the 0-10V wires will affect the voltage levels and cause dimming issues. To avoid this problem, it is advised not to bundle 0-10V wires with AC wires in a conduit or run them near AC lines. Careful attention needs to be paid to this very common mistake by installers.

2. Wire length and multiple drivers

The 0-10V dimming method uses DC voltage wires to connect a dimmer to the drivers/fixtures being controlled. Long wires can have voltage drop across them which leads to different drivers receiving different voltages at their inputs. For example, the first driver in the link (closest to the dimmer) will see a higher voltage than the last driver (furthest away). This causes inconsistency of light output between fixtures as well as dimming range and accuracy issues. Although voltage drop is minimal, installers that run into this issue can reduce the voltage drop along the wires by using lower gauge wires (thicker lower resistance) and/or by limiting the length of the wires

3. Dimmer range

Many 0-10V dimmers have limited voltage range and are not able to provide the full 0-10V voltage span to the driver. Therefore, it is important to check dimmer compatibility lists to make sure that the right dimmer is used with a specific driver. In applications where the full light output range is desired, it is recommended that a driver with a non-linear dimming profile is used as described in an earlier section.

Conclusion

The conversion to LED lighting is expanding at a rapid rate due mostly to its low power consumption and long life. When working with LED lighting where dimming in required it is important to understand the various dimming options available, how they work and how they perform in the real world. This app note was an attempt to offer the reader a full overview of the dimming technologies available to lighting designers and installers and to highlight common issues that can arise in the field.

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