Application Note 103

Different Methods of Dimming Controls

Dimming is the process of controlling / changing the light output of a light source. It has become a significant requirement for most LED drivers and plays a big role in the lighting industry. It helps save energy when full light output is not needed and sets a required ambience for specific applications. Today, new methods / technologies for dimming control system were introduced. In this application note, the most common and simplest methods of dimming controls will be discussed.

What is 0-10 V dimming?

The 0-10 V dimming topology is one of the simplest ways to control the output of a light source. Usually, this method is implemented by adding a dimming circuit to the LED driver. Basically, the output level is determined by varying the DC voltage between 0 V and 10 V. Signal below 1 V corresponds to minimum light level (can also be off). On the other hand, signal above 10 V corresponds to maximum light level [1].

What is the difference between sourcing and sinking current 0-10 V dimmers?

There are two types of 0-10 V dimmers, current source and current sink. Dimmers that provide current to the circuit are the current source type. These dimmers are mostly used for theatrical lighting control [1].

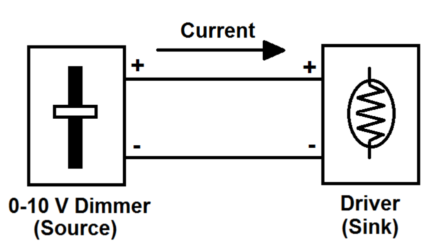

Figure 1. Current Source Type 0-10 V Dimmers

On the other hand, dimmers that dissipate current from a source are the current sink type. These dimmers are commonly used in commercial and residential applications. Most dimmers of this type require a sink current ranging from 10 μA to 2 mA [1]. Usually, LED drivers with dimming capabilities have specifications regarding the amount of source current from their dimming circuit. These parameters determine the maximum number of LED drivers that can be installed / controlled by one dimmer.

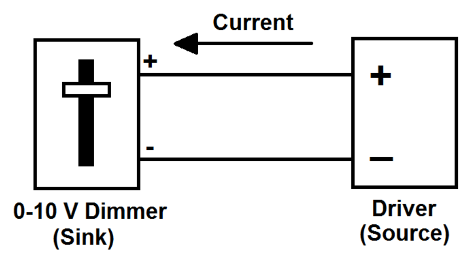

Figure 2. Current Sink Type 0-10 V Dimmers

ERP drivers with 0-10 V dimming capabilities support only sink type 0-10 V dimmers. Table 1 shows the list of some of the 0-10 V dimmers tested for compatibility with ERP drivers.

0-10 V Dimmers		
Manufacturer	**Series**	**Type**
Lutron	Nova	NFTV
Lutron	Diva	DVTV
Leviton	Illumatech	IP710-DL

Table 1. List of Some of the 0-10 V Dimmers Tested for Compatibility with ERP Drivers

What is reverse phase and forward phase dimming?

Another method of dimming is by using phase-cut dimmers. These dimmers chop the AC line input to lessen the power going into the driver. With less input power, there will be less output on the driver.

Forward-phase dimming, also known as "TRIAC dimming", "SCR dimming" and "leading-edge dimming", is the most common form of phase dimming. In this method, power is chopped at the start or leading edge of each half power cycle of the input (see Figure 3). Forward-phase dimmers use a silicon device, usually a TRIAC or an SCR. The amount of power delivered to the driver can be changed by varying the point at which the waveform turns on. This turn-on delay determines the conduction angle of the dimmer. Conduction angle is the total angle through which the dimmer conducts power and it can be varied from 0° to approximately 180°. Shorter turn-on delay yields higher conduction angle, hence, results to higher input power delivered to the LED driver and vice versa. The rapid turn-on time of SCRs and TRIACs produces low losses, however, also produces current surges and unwanted EMI radiations [2].

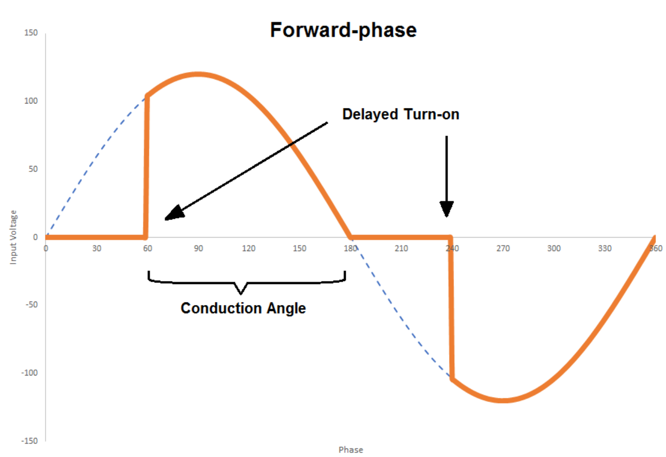

Figure 3. Chopped AC Line Input of Forward-Phase Dimming

On the other hand, reverse-phase dimming, also known as "trailing-edge dimming", is another type of phase cut dimming method, wherein, the power is chopped at the end or trailing edge of each half power cycle of the input (see Figure 4). In this case, the power delivered to the driver is changed by varying the point at which the waveform turns off. Earlier turn-off time yields lower conduction angle, hence, results to lower input power delivered to the LED driver and vice versa. Reverse-phase dimmers use a more complex circuit than forward-phase dimmers, typically by using MOSFET or IGBT circuits. The slow turn-on time of the MOSFETs or IGBTs produces lesser unwanted EMI radiations, current surges and AC distortions than that of the forward-phase dimmers [2].

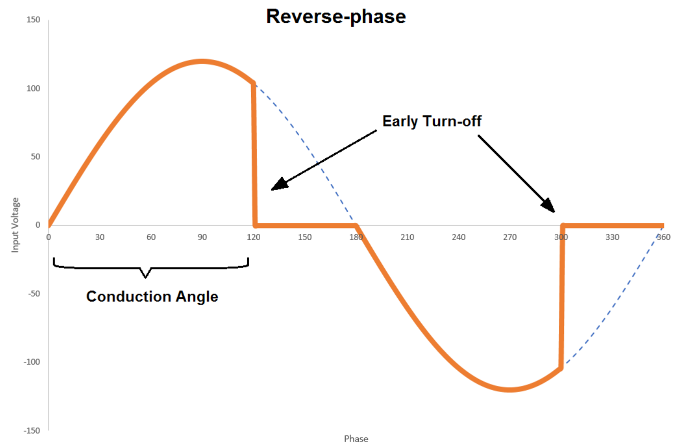

Figure 4. Chopped AC Line Input of Reverse-Phase Dimming

Today, there are a lot of forward-phase (TRIAC) and reverse-phase (ELV) dimmers available in the market. Each dimmer type / model has different effects on the dimming performance of an LED driver. That's why, it is very important to consider and check the dimmer's compatibility with the LED driver first when selecting a dimmer to use. One must consider the following parameters:

- Dimming Range - highest and lowest output level current relative to output of the driver without a dimmer
- Smooth Dimming - driver's response while adjusting the dimming level (smooth or with sudden jump on the light output)
- Sag – percentage away from 100% output current of driver at dimmer's maximum level
- Flicker - highly visible repeating light fluctuations
- Shimmer – low frequency or random variations in light output that are typically less noticeable than flicker
- Start Flash (Pop)– overshoot and undershoot of light output at startup
- Ability to Turn Off the Driver – effectiveness of the dimmer turn-off switch / button
- Audible Noise – buzzing sound / noise induced by dimmer

A dimmer can be very good at one parameter, but at the same time, can be bad on another (e.g. a dimmer that has good dimming range but has light shimmer at certain dimming levels). Each dimmer used with ERP drivers was thoroughly tested and was made sure that it yields a satisfactory dimming performance and no other issues existed. Table 2 and Table 3 show the lists of TRIAC and ELV dimmers tested for compatibility with ERP drivers.

120 Vac TRIAC (Forward-Phase) Dimmers		
Manufacturer	**Series**	**Type**
Lutron	Skylark	S-603PG
Leviton	Sureslide	6631-LW
Lutron	Diva	DVCL-153P
Lutron	Diva	DV-600P
Lutron	Toggler	TGCL-153P
Lutron	Skylark	S-600P
Leviton	Trimatron	6683-IW
Leviton	Illumatech	IPI06-1LZ
Lutron	Toggler	TG-600P
Lutron	Lumea	LG-600P
Lutron	Skylark	CT-103P
Leviton	Decora	6161-W
Cooper	Skye	SLC03P
Cooper	Devine	DLC03P
Cooper	Devine	DAL06P
Leviton	Sureslide	6633-PL

Table 2. List of TRIAC Dimmers Tested for Compatibility with ERP Drivers

120 Vac ELV (Reverse-Phase) Dimmers		
Manufacturer	**Series**	**Type**
Leviton	Vizia	VPE06-1L
Lutron	Diva	DVELV-303P
Lutron	Skylark	SELV-300P
Leviton	Illumatech	IPE04-1L
Lutron	Maestro	MAELV-600
Lutron	Faedra	FAELV-500
Lightolier	Sunrise	ZP260QE

Table 3. List of ELV Dimmers Tested for Compatibility with ERP Drivers

Table 4 shows a sample of the dimmer compatibility test results from an ERP driver with various TRIAC and ELV dimmers. Each parameter for the dimming performance of the LED driver is checked with each of the dimmers and is scored individually. All scores are summed up accordingly and averaged to get the driver's overall performance. Table 5 also shows a sample of the compatibility test results for some 0-10 V dimmers. ERP provides these dimmer compatibility test results for every one of the ERP drivers. It is recommended to refer to this dimmer compatibility table to determine which dimmer performs well for each performance category.

Driver: ESS030W-0500-42																
120 Vac Dimmers		Total Score:		96.7%	Driver Current (mA) with no Dimmer:		498	Driver Light (FC) with no Dimmer:		1228	Scoring					
		Avg. Min. Dimming:		5.3%							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	Sag	No Start Flash	LE Start <1 s	Flicker	Shimmer	Able to turn off	Audible Noise
Mfg.	Model	%	Max	Min	Max	Min	Max	Min		%						
Lutron	S-603PG	92.9%	1162	66	480.2	25.1	95%	5%	2	4.0%	2	2	2	2	2	2
Leviton	IPI06-1LZ	100.0%	1228	0	498.0	0.0	100%	0%	2	0.0%	2	2	2	2	2	2
Leviton	6631-2	100.0%	1228	0	498.0	0.0	100%	1%	2	0.0%	2	2	2	2	2	2
Lutron	DVCL-153P	100.0%	1228	12	498.0	5.5	100%	1%	2	0.0%	2	2	2	2	2	2
Lutron	DV600P	85.7%	1228	76	498.0	28.3	100%	6%	1	0.0%	2	2	2	1	2	2
Lutron	TGCL-153P	100.0%	1228	12	498.0	29.6	100%	1%	2	0.0%	2	2	2	2	2	2
Lutron	S600P	100.0%	1228	79	498.0	29.8	100%	6%	2	0.0%	2	2	2	2	2	2
Leviton	VPE06	100.0%	1228	127	498.0	46.5	100%	10%	2	0.0%	2	2	2	2	2	2
Lutron	DVELV303P	100.0%	1228	104	498.0	38.4	100%	8%	2	0.0%	2	2	2	2	2	2
Lutron	SELV300P	100.0%	1228	100	498.0	36.6	100%	8%	2	0.0%	2	2	2	2	2	2
Leviton	6683-IW	89.3%	1228	2	498.0	1.0	100%	0%	2	0.0%	2	1	2	1	2	2
Leviton	6161	100.0%	1228	128	498.0	47.0	100%	10%	2	0.0%	2	2	2	2	2	2
Leviton	6633-P	92.9%	1228	18	498.0	7.9	100%	1%	2	0.0%	2	2	2	1	2	2
Lutron	TG-600P	100.0%	1228	127	498.0	47.0	100%	10%	2	0.0%	2	2	2	2	2	2
Cooper	DLC03P	92.9%	1228	43	498.0	17.6	100%	4%	2	0.0%	2	2	2	1	2	2
Lutron	LG600P	100.0%	1228	99	498.0	36.0	100%	8%	2	0.0%	2	2	2	2	2	2
Lutron	CT103P	100.0%	1228	128	498.0	46.9	100%	10%	2	0.0%	2	2	2	2	2	2
Cooper	SLC03P	92.9%	1228	13	498.0	5.8	100%	1%	1	0.0%	2	2	2	2	2	2
Leviton	IPE04	100.0%	1228	86	498.0	31.5	100%	7%	2	0.0%	2	2	2	2	2	2
Lutron	MAELV600	100.0%	1228	81	498.0	29.7	100%	7%	2	0.0%	2	2	2	2	2	2
Lutron	FAELV500	96.4%	1228	151	498.0	54.9	100%	12%	2	0.0%	2	2	2	2	2	2
Lightolier	ZP260QEW	100.0%	1228	72	498.0	25.5	100%	6%	2	0.0%	2	2	2	2	2	2
Cooper	DAL06P	82.1%	1228	0	498.0	0.0	100%	0%	1	0.0%	2	1	2	1	2	2

Table 4. Example of TRIAC and ELV Dimmer Compatibility Test Results

Driver: ESS030W-0500-42								
0-10 V Dimmer	Dimmer Maximum Sinking Current (mA)	Maximum Sourcing Current Measured (µA)	ERP Specification Maximum Sourcing Current (µA)	Maximum Dimmed Output Current & Signal Voltage at 120 Vac	Maximum Dimmed Output Current & Signal Voltage at 277 Vac	Minimum Dimmed Output Current & Signal Voltage at 120 Vac	Minimum Dimmed Output Current & Signal Voltage at 277 Vac
Lutron Nova NFTV	30	928	1000	497.8 mA @ 9.98 V	498.3 mA @ 9.98 V	28.9 mA @ 0.63 V	28.9 mA @ 0.63 V
Lutron Diva DVTV	30	924	1000	497.6 mA @ 998 V	498.1 mA @ 9.98 V	36.7 mA @ 0.79 V	36.8 mA @ 0.79 V
Leviton IP710-DL	28	927	1000	472.6 mA @ 9.49 V	472.9 mA @ 9.48 V	33.2 mA @ 0.72 V	33.3 mA @ 0.72 V

Table 5. Example of 0-10 V Dimmer Compatibility Test Results

Pulse Width Modulation (PWM) Dimming vs Constant Current Reduction (CCR)

The light output on an LED depends on the amount of current that flows through it, hence, dimming LEDs can be achieved by varying the current input. There are two methods of dimming for constant current LED drivers, pulse width modulation and constant current reduction.

In pulse width modulation, the LED is turned on and off at its rated current at high frequency. The rapid switching is high enough for the human eye to see. The ratio of the on-time and off-time (also known as the duty cycle of the current source) determines the brightness level of the LED. Drivers that use PWM can provide a very precise output level, however, they are also generally more complex and more expensive. Dimming LED through PWM is advantageous when the application needs to maintain certain characteristics of the LED (i.e. color temperature or efficiency). These characteristics will vary based on the current flowing through the LED. And since PWM is just rapid switching between the rated current and zero, these characteristics are maintained throughout the dimming range. One application that uses PWM is color mixing application wherein precise levels for each color need to be maintained [3].

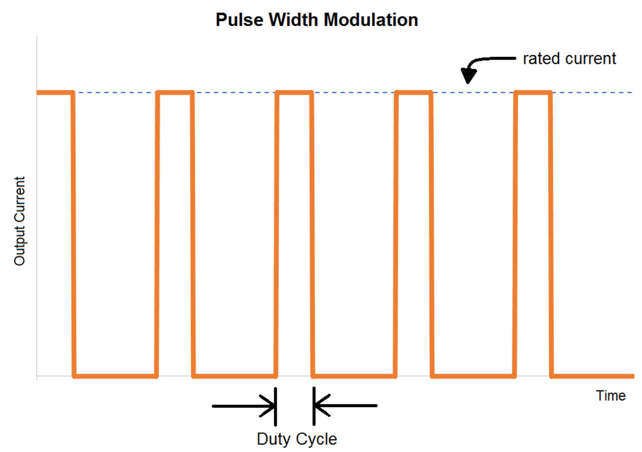

Figure 5. Pulse-Width Modulation

In constant current reduction, the current flows continuously through the LED and the brightness level is varied by changing the output current level (also known as "analog dimming"). CCR has several advantages over PWM. Since PWM uses fast switching, the fast-rising edge and falling edge of each switching cycle produce unwanted EMI radiations. Also, the driver might have performance issues when run with long wires since the stray characteristics of the wire (capacitance and inductance) can interfere with the fast edges of the PWM. CCR can be used with applications with strict EMI requirements and remote applications where long wire runs are used. Another advantage is that drivers that use CCR have higher output voltage limit (60 V) than drivers that use PWM (24.8 V) when classified as UL Class 2 drivers for dry and damp locations. Other applications that use CCR are applications with high motion activity and rotating machinery [3].

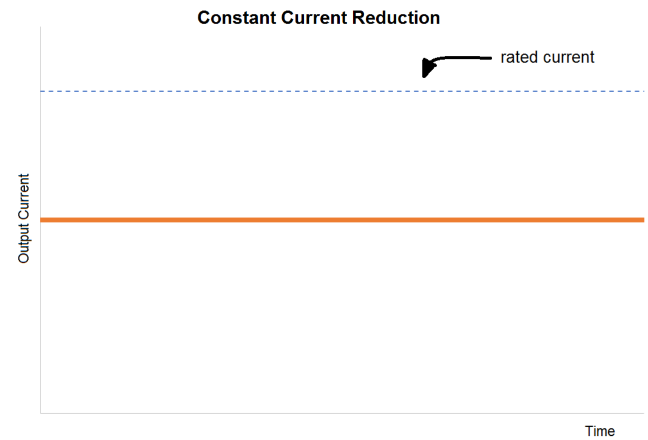

Figure 6. Constant Current Reduction

Conclusion

We learned from this Application Note some of the simplest methods of dimming controls: 0-10 V, forward-phase, reverse-phase, Pulse Width Modulation (PWM) and Constant Current Reduction (CCR). Each of these methods has their own advantages and disadvantages, depending on the type of application. When selecting a dimmer to use, it is very important to consider the factors that can affect the dimming performance of the LED driver, especially the dimmer's compatibility with the LED driver. Therefore, it is highly recommended to use dimmers that are compatible and performs well with the LED driver.

References:

[1] Lutron Electronics Co. *Application Note # 587 Lutron 0-10 V Control Topology.* Revision B. January 2017.
[2] EPtronics Inc. *Application Note # 112 Dimming Methods.* January 9, 2012.
[3] Lutron Electronics Co. *Application Note # 360 Dimming LEDs via PWM and CCR.* Revision C. November 2016.

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