

1 - Introduction to Dimming Concepts

Basic Overview

This section is a novice's guide to some of the general dimming techniques, technologies and loads used in architectural dimming.

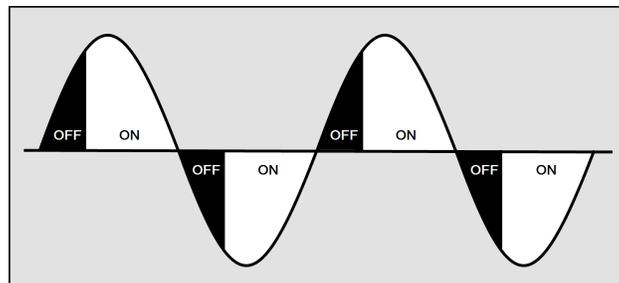
The architectural dimming market encompasses a wide range of dimming methods. These dimming methods fall under two broad sub-categories: Power Line Dimming and Low-Voltage Dimming.

Power Line Dimming Methods

There are several methods of controlling the direct dimming of line-voltage loads. This tutorial will discuss the most frequently used techniques. This includes the most common methods of Forward and Reverse Phase Control, and less common methods of Center Notch, Sine Wave, and DC Dimming.

Forward Phase Control

Forward phase control uses a dimmer that chops each half cycle of the power sine wave. Power is off during the initial part of each half cycle and then turns on. Extending the period of time that the power is off during the half cycle results in a lower power output to the load. Shortening the off period results in higher power output to the load. This method is also referred to as Leading Edge dimming because the turn on edge leads the voltage being applied to the load.



Residential grade, low-cost dimmers use forward phase control. There may be lack of symmetry between the positive and negative cycles that can introduce DC voltage levels into the load. Lack of filter chokes results in a fast rise time of voltage to the load. For these reasons, residential dimmers are used mainly for incandescent lighting. They are unsuitable for controlling the input of inductive transformer or ballast loads such as Magnetic Low-Voltage and neon/cold cathode or capacitive loads such as Electronic Low-Voltage.

Professional grade architectural dimming systems ensure slow rise times and symmetrical positive and negative half cycles by introducing large filter chokes and edge control components. Slow rise times filter large current or voltage spikes that can negatively impact Electronic Low-Voltage loads. Slow rise times may also assist with acoustical noise suppression of some load types. Architectural dimming systems tend to be physically larger than residential or commercial grade wall box dimmers and dissipate more heat.

Technologies

There are three main technologies that are used to produce forward phase dimming signals: the Triac and Choke, Dual SCR and Choke, and Gate Controlled Semiconductors (IGBT).

Triac and Choke

In a Triac and Choke based dimmer, a single semiconductor acts as a switch, controlling both positive and negative half cycles. An inductor (choke) slows the rise time of the voltage. In the event of triac failure, the triac typically fails on both the negative and half cycles simultaneously, preventing output of DC voltage in failure mode. This helps to protect magnetic loads in failure mode.

Dual SCR and Choke

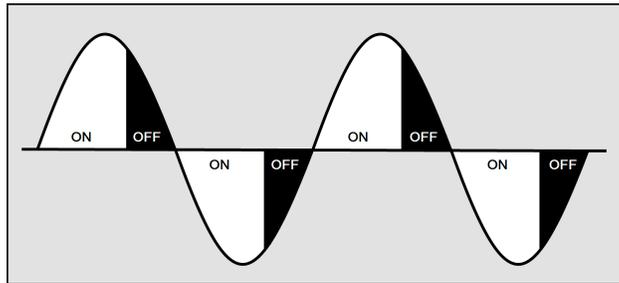
The Dual SCR and Choke method uses two semi-conductors. One semi-conductor controls the positive half cycle while the other controls the negative half cycle. A choke controls the rise time of the voltage during the transition. This design is cost effective as well as simplifies the thermal design of the dimmer; however, in the event of a failure, if one SCR fails before the other, a DC output voltage will result. Magnetic loads will experience significant overheating in this failure mode.

Gate Controlled Semiconductors

When used in dimming, Gate Controlled Semiconductors perform the duties of switching on the load and controlling the rise time, removing the need for the choke. Like SCR dimming, this design often uses two semiconductors, usually FETs or IGBTs, to control the negative and positive half cycles. The control circuit requirements are more complex. Most devices on the market have the ability of detecting the failure of one of the semiconductors, protecting magnetic transformer loads. As switching and rise time are both controlled in the semi-conductor, heat is a concern. Most gate controlled dimmers are fan cooled to prevent overheating.

Reverse Phase Control

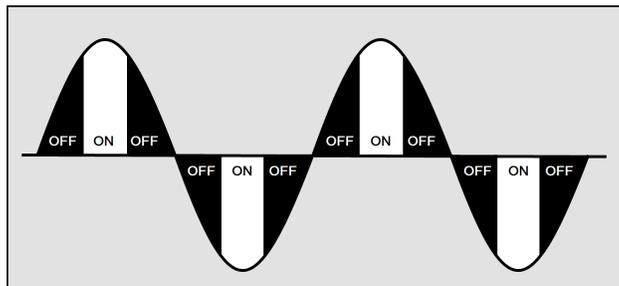
Like Forward Phase control, Reverse Phase control chops each half cycle of the power sine wave; however, with reverse phase control, power is on during the initial part of each half cycle and then turns off. This technique is also called trailing edge dimming. Dimmers that use this technique have a smooth turn on and then discontinue power. Power is switched on at the zero cross point rather than at the peak of the voltage waveform, minimizing voltage spikes that can occur. This is ideal for use with most electronic low-voltage transformers. The slow rise can help to reduce acoustic noise in incandescent dimming for applications where noise is a significant concern. This dimmer type is not compatible with inductive loads run from magnetic transformers; they do not react well to the quick interruption of power.



Reverse phase control dimmers use Gate Controlled Semiconductor technologies.

Center Notch Dimming

Center Notch Dimming is a specialized, 3-wire fluorescent control method that is not commonly practiced. In this technique, the dimmer provides power to the load in the center of each half cycle, switching off at the start and at the end. This technique eliminates changes in ballast voltage thresholds and line noise that might affect the three-wire ballast. This type of dimmer always uses gate controlled semiconductor technologies.

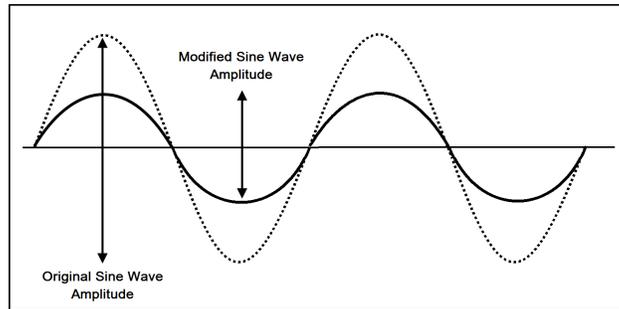


Sine Wave Dimming

Sine Wave dimmers convert supplied power from the mains voltage into a sine wave with a reduced voltage. The reduced voltage is constantly supplied with no interruptions.

The dimmer accomplishes this by converting the incoming AC supply through Pulse Width Modulation (PWM) to the desired voltage. Pulse

Width Modulation switches the power at an extremely high frequency. The duration or duty cycle of the pulse determines the resulting output. The high-frequency switching signal is then filtered into a new sine wave with the desired magnitude and no interruptions.



Sine Wave Dimmers are significantly more complex and therefore more expensive. They are used mainly for high-end dimming of directly powered or transformer fed lighting loads. They are not usually used for ballasted lamps as the ballasts and lamps may not be compatible with the reduced voltage output. Because the power is not being switched on and off, sine wave dimmers are electrically and acoustically very quiet.

DC Dimmers

DC Dimmers are a highly specialized dimmer, used almost exclusively in sensitive environments such as MRI rooms and high-end recording studios where electro-magnetic interference and noise are a major concern. Used specifically with incandescent lamps, these dimmers provide a DC voltage output. Light level is controlled by varying the value of the DC Voltage output. These dimmers are large and more costly.

Low-Voltage Dimming Methods

Low-voltage dimming methods use additional ballast control wires. The control wires are used to receive low-voltage signals, triggering the ballasts to adjust the light output based on the signal received. Low-voltage dimming methods include 0-10V dimming, DSI, DALI, DMX, and PWM.

0-10V Dimming

0-10V dimming or 4-wire dimming uses an analog low-voltage signal to adjust the dim level of the attached load. Many load types, including fluorescent, metal halide, and LED, use this method of dimming.

Wiring consists of the switched high-voltage circuit wiring and a secondary set of low-voltage control wires, which connect the ballasts to the dimmer control. While the ballast manufacturers may state that low-voltage wiring can be Class 1 or Class 2, most device manufacturers treat the 0-10V wiring as Class 2 low-voltage signals.

IEC60929 specifies that the 0-10V ballasts source the required power to the dimmer control. It also specifies that voltage mapping consist of 1V at the lowest light output and 10V the highest output.

While IEC standard 60929 details this control method, many manufacturers do not comply. This is especially true in the LED market.

Some models source the required power for the low-voltage dimming. Others may require that the dimmer control provide the necessary power.

Voltage mapping varies from manufacturer to manufacturer. Some manufacturers expect 0-10V or 1-10V ranges where the lowest voltage indicates the lowest output level and the highest level indicates the brightest output. Other manufacturers may use a 10-1V or 10-0V scheme where the highest level indicates the lowest output level while the lowest level indicates the highest output level.

Research the devices with the manufacturer to determine the correct control method.

Due to voltage drop over longer wiring runs or improper wiring, it is possible for a long run of 0-10V loads to decrease in brightness at the far end.

DSI

The DSI (Digital Signal Interface) protocol is a proprietary protocol owned by Tridonic. Applications using DSI are mainly seen in the European market. Digital signals are sent along the low-voltage control wires to adjust dim level as well as the on/off signal. DALI, the open protocol equivalent to DSI, is more commonly used.

DALI

The DALI (Digital Addressable Lighting Interface) digital dimming method is an open protocol defined by the DALI standard. Wiring topology is simplified as up to 64 ballasts may be wired to the same control wire pair. Light sources wired to the same control pair may be separately controlled by commanding their unique addresses. Light sources may also be assigned to up to 16 groups so that they respond to a single command issued to the group address. This protocol allows for bi-directional communication between the light source and the dimmer allowing for power monitoring, failure reporting and emergency lighting tests.

Broadcast DALI is a simplified approach that has the same control features as 0-10V dimming. In broadcast DALI, any DALI light sources wired to the same pair of control wires will respond to the same signals and to the same light intensity. Individual light source control or group control is not possible through broadcast DALI. The advantage of using broadcast DALI over the 0-10V method is that DALI is not subject to voltage drop over long wire runs. This allows the lamps to dim more uniformly.

DMX512

DMX512 is an RS485 control method used predominantly in the theatrical realm. Devices are daisy chained along a twisted pair from the Master device. The Master device may be a dimming console, computer software package or other DMX command generator. Up to 32 unit loads may be connected to the same wire run. (Some devices may state that they are a ½ load or ¼ load or a full load. Totaled together, this number should not exceed 32 unit loads). Splitters or repeaters may be used to extend the number of devices.

Devices that are part of the same wire run are considered one “universe”. Within the universe, up to 512 addresses, or channels are assigned to devices to allow control. One device may use several channels to address different functions such as intensity, tilt, pan, gobo, etc... Devices that need to respond together may share the same channel numbers. If there is a need for more than 512 channels in a DMX system, additional DMX universes may be added up to the capacity of the Master device.

Commands are constantly refreshed. Commands include the device address and level (0-255) that the device should assume. When used with lighting, level 0 corresponds with the lowest intensity while level 255 corresponds with the highest intensity.

Some manufacturers have implemented DMX over Ethernet. While the DMX data is universal, the Ethernet methods to transfer the data may not be. This may make devices from different manufacturers incompatible with each other.

DMX512A is an isolated version of the DMX512 standard. DMX512A compliant receivers have a high impedance connection between signal and ground, isolating the connection. This aids in preventing ground faults and signal disruption.

RDM or Remote Device Management is a new version of DMX that allows for bi-directional communications. This developing standard will allow for increased functionality such as configuration, monitoring and management functions.

Pulse Width Modulation (PWM)

A lesser used method of low-voltage dimming, PWM or pulse width modulation, switches the low-voltage signal on and off at a high frequency. The length of the duty cycle determines the ultimate voltage of the low-voltage signal delivered to the ballast. When the on time is less than 5%, the lights will be full bright. When the on time is more than 95%, the lights will be full dim. This method is not subject to voltage drop and may allow for uniform dimming along longer lighting runs.

Nippo, a Japanese manufacturer, uses this technique for some of its luminaires. Nippo offers a 0-10V DC converter to make it compatible with 0-10V dimmers. (This converter does not follow IEC standards for 0-10V dimming. 10V is used for the lowest intensity while 1V is used for the highest intensity.)

Dimmable Lighting Loads

There are many different types of dimmable light sources. Some of the more common light sources are discussed in the following pages. As many light sources may use multiple methods of control, it will be necessary to check the correct control method with the manufacturer.

High-Voltage Incandescent/Halogen

Incandescent and Line Voltage Halogen lamps operate by passing current through a tungsten filament causing the filament to glow. Tungsten particles burn off and deposit themselves on the bulb walls. Halogen lamps have the added benefit of being able to regenerate the filament by redirecting the tungsten particles back to the filament, extending the life of the lamp.

When dimming halogen lamps, it may be necessary to burn the lamps at 100% for a few minutes each day to allow the halogen regeneration process to operate. Verify with the lighting designer or lamp manufacturer if this is necessary.

Incandescent and halogen loads are most often controlled from forward-phase control methods although they may be used successfully with other line-voltage dimming methods.

Magnetic and Electronic Low-Voltage Loads

Magnetic and Electronic Low-voltage loads are used where concentrated beams of light are desired such as in display lighting, product highlighting, and task lighting. The transformer receives the AC sine wave and either through magnetic or solid-state methods outputs a secondary voltage of 12VAC or 24VAC. Lamps are often tungsten halogen.

Magnetic Low-Voltage

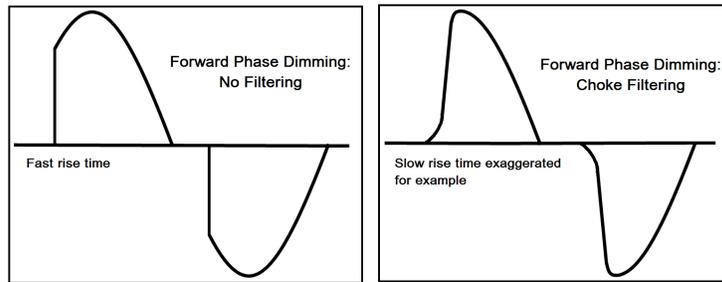
Magnetic transformers are inductive loads due to their core and coil design. Forward Phase dimming is the traditional control method; however, it is important to ensure that the positive and negative half cycles are symmetrical to prevent DC voltage introduction. Reverse phase dimmers should not be used with this load type.

Electronic Low-Voltage

Electronic Low-Voltage transformers are capacitive in nature and use a solid-state design. Due to their capacitive nature, they are sensitive to sharp rises in voltage. Reverse-phase dimmers, which ensure a slow rise in voltage, are available from some manufacturers for use with ELVs.

Depending on the design of the controller and the ELV manufacturer, they may not be compatible with forward-phase dimmers. Some forward phase dimmers are equipped with large choke filters that slow and smooth the rise in voltage. This may allow them to be used with

ELVs. Compatibility with forward phase dimmers should be qualified by the manufacturer.



Fluorescent Loads

With fluorescent lighting loads, proper dimming is dependent on a combination of using the correct ballast and lamp. A ballast functions to: deliver the proper starting voltage to ignite the lamp; control the flow of electric current through the lamp(s) once ignited; and smooth out variations in line voltage. Not all ballasts are dimmable.

Ballasts specific to dimming promote continuous cathode heating to prevent the lamp from extinguishing at lower dimming levels and to assist with starting the lamp at low levels. When using a dimmable ballast, ensure that the lamps are compatible.

There are multiple technology options available for dimming ballasts for fluorescent loads. This includes but is not limited to:

- 2-Wire: Uses high-voltage conventional AC dimming methods
- 3-Wire: Uses three high-voltage wires for power and dimming. Connections include a switched hot, neutral and dimmed hot for control of the dimming functionality.
- 0-10V: Uses a pair of low-voltage signal wires to control the dimming signal and a high-voltage pair of switching wires for ON/OFF functions.
- DSI
- DALI
- DMX
- PWM

Special Considerations for Fluorescent Dimming

Unlike incandescent/halogen dimming, fluorescent loads do not dim to OFF. Depending on the ballast, minimum light level output may be in the range of 1% to 20%.

There has been much debate over the necessity of burning in lamps prior to dimming to prevent premature blackening and failure. The New Building Institute Guidelines in 2001 recommended seasoning lamps for 100 hours prior to dimming. NEMA in 2002 issued an alternate recommendation of seasoning linear fluorescent lamps for 12 hours. Some linear fluorescent manufacturers state that burn in is not necessary. There is still a consensus that Compact Fluorescent lamps should be seasoned for 100 hours. Always refer to the lamp manufacturer's recommendation for burn in for best performance.

Neon/Cold Cathode

Cold cathode load types use a transformer to step up the primary voltage to a higher secondary voltage level. Voltage output on the secondary side of the transformer is in the 2,000V to 15,000V range. As the cathodes are not independently heated as in many fluorescent lamps, a higher output voltage on the secondary side is used to accomplish the gas ignition.

Dimmable cold cathode loads often use magnetic transformers that are by nature an inductive load type. Forward Phase dimming is the traditional control method; however, it is important to ensure that the positive and negative half cycles are symmetrical to prevent DC voltage introduction. This load type should not be used with reverse phase dimmers.

Additional advances have been made to allow control of Neon/Cold Cathode loads from 0-10V, DALI and other low-voltage dimming methods. Please consult the manufacturer to determine the correct control method.

Special Considerations

The design of a cold-cathode dimming load must be carefully implemented. Lamps must be pressurized properly and be free of impurities. Transformers must be properly de-rated for dimming applications as well as for the length of tubing.

When properly designed and implemented, Neon and Cold Cathode luminaires should have a range of approximately 10% to 95% light output.

High Intensity Discharge

HID luminaires require a ballast for proper ignition. HID dimming requires a special dimming ballast for proper dimming operation.

It will be necessary to verify the proper control method with the manufacturer. It is also important to heed the manufacturer's recommendations for minimum dim level. Metal Halide luminaires typically dim within a 50% to 100% range while High Pressure Sodium luminaires typically dim within a 30% to 100% range.

Dimming below the lamp manufacturer's recommended range may void the manufacturer's warranty, will greatly decrease lamp life, and may have other undesirable affects. Most manufacturers recommend that lamps operate at 100% output for at least 15 minutes from strike before dimming.

LED

LEDs are available in multiple color ranges. Architectural applications usually use white LEDs for general lighting. More specialized red, green, and blue LEDs can be used for color mixing/sequencing applications to generate architectural effects.

LED lamps require the use of a driver to ensure proper operation. Similar to the functions of a ballast, the driver functions to convert the

AC Signal into the voltage level required by the LED lamps. The LED driver also limits the supplied current within the operating range of the LED. The driver must be capable of varying the LED intensity in order to be compatible with dimming. Research dimming compatibility and suggested method of control with the manufacturer.

Currently, many methods are used for LED dimming including but not limited to direct standard AC Dimming methods, 0-10V, PWM, DALI, DMX512.

Special Considerations with LED Dimming

When dealing with an LED light source that uses Forward Phase, Power Line dimming, due to the efficiency of these lighting loads, the minimum load rating of the dimmer must be taken into account. If the load is under the minimum load rating, the LEDs will not dim properly.

When dealing with low-voltage dimming of LEDs, there is much variation in how manufacturers have implemented 0-10V technologies. Always check with the manufacturer for the control expectations.

If RGB LED light sources are being used, they will have at least three control inputs to control the ratio of the red, green and blue output. Some will have an optional fourth input that controls the intensity.

Dimming and the iLumin Source Controller

The iLumin Source Controller is compatible with most of the load types discussed in this section.

With High-Voltage Dimming Loads, the iLumin Source Controller uses forward phase dimming methods through a Triac and Choke design. The choke is appropriately sized to ensure a 350- μ sec rise time. The minimum load rating of the dimmer is 40 Watts. Loads under 40 Watts should be qualified by Cooper Controls to ensure compatibility.

Supported High-Voltage Loads include:

- Incandescent
- MLV – Magnetic Low-voltage
- ELV – Electronic Low-voltage: Must be qualified by Cooper Controls for use with Forward phase dimming techniques.
- 2 wire fluorescent loads (Advance Mark X, Osram/Sylvania)
- 3 wire fluorescent loads (Lutron ECO-10, Hi-Lume, Compact SE)
- Neon / cold cathode
- Non-dim (switched)

Supported Low-Voltage Loads include

- 4 wire fluorescent loads, 0-10 VDC, LED, HID Dimmable
- 4 wire fluorescent loads, 0-10 VDC (Advance Mark VII, Osram/Sylvania, Universal)
- Digital fluorescent ballast control (Canada and Mexico only) including DSI and broadcast DALI. If needed for a specific application, please contact the factory on the potential of obtaining a DALI specific Source Controller in the United States market.