EE103: Dimming Controls, Section 1 Part 2: Dimming Controls and Systems

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INTRODUCTION

Welcome to Part 2 of EE103: Dimming Control, Dimming Controls and Systems.

The first major light source, incandescent lamps, was originally dimmed by rheostats (resistant dimming). In the 1950s and 1960s, dimmers were invented that used electronic components. All subsequent major light sources can be dimmed but require dimmers and/or dimmable drivers/ballasts designed to work with them. LED, today’s most popular commercial light source, is typically controllable without a significant cost premium or most compatibility concerns, democratizing dimming applications within buildings.

The variation in different types of nonresidential dimmers and dimming systems has greatly increased, based in part on electronics enabling devices to communicate and new communication methods, including wireless. These technological advances allowed manufacturers to create a wide variety of dimmers that work on a standalone basis or as part of a larger system.

This learning module describes this equipment, starting with simple wallbox dimmers and working up to more complex systems.

LEARNING OBJECTIVES

- Students will be able to apply dimming as a control strategy to buildings based on an understanding of its availability and how it’s implemented.
- Students will be able to select the right equipment to satisfy evolving common dimming applications.
- Students will be able to provision dimming from singular to very large applications.
- Students will be able to discern traditional from modern lighting and dimming systems to make the most appropriate selection for a given project.
DIMMING IN TODAY’S BUILDINGS

Initially, dimming was primarily used with incandescent lamps, typically driven by visual needs such as mood setting. Over time, dimming became available for fluorescent, HID, neon, and cold cathode, which required dimmable ballasting at a premium cost. As a result, dimming was historically limited to applications where visual needs was a primary concern.

This has changed for two reasons. The first is a major technological shift to LED light sources, which are inherently controllable. Currently, the majority of LED luminaires feature a dimmable driver (usually 0-10VDC) as standard or standard option. The second reason is the evolution of commercial building energy codes to require bilevel switching and more detailed control activity during occupancy, such as daylight response, providing opportunities for dimming to reduce lighting use without disruptive switching or turning the lights OFF. Developing applications such as demand response and high-end trim—along with energy codes such as California Title 24, which requires LED lamps and luminaires to be dimmable from 10-100%—may accelerate the use of dimming.

As a result, for the first time, it is quite possible if not likely that dimming for energy management has eclipsed dimming for visual needs, and is fast becoming a staple lighting capability in commercial buildings.
WALLBOX DIMMERS

Image courtesy of Lutron Electronics

Wallbox dimmers are simple control devices that are typically mounted in a junction box on the wall between the power supply and the lighting load. They are typically controlled manually (e.g., rotary knob or slider), though they may be designed to accept commands from other devices (e.g., keypad or 3-way).

The device either dims the lamps directly as in the case of incandescent/halogen or signals a compatible dimming driver/ballast to dim as in the case of LED, fluorescent, and HID. Some dimmers are designed to digitally communicate with other dimmers and/or with lighting control systems, either wired or wirelessly. Meanwhile, functionality is expanding.

As a result, the simple wallbox dimmer has evolved, and simply specifying a “wallbox dimmer” today is typically not sufficient.
WALLBOX DIMMERS: APPLICATIONS

Wallbox dimmers are desirable anywhere flexibility of light levels is needed. Their use is primarily driven by visual needs in applications such as residential, classrooms, conference rooms, restaurants, etc. Because LED luminaire are typically dimmable, however, they can provide flexibility and energy cost savings wherever local space controls are needed.

WALLBOX DIMMERS: THEORY OF OPERATION

Typically, wallbox dimmers for line-voltage incandescent/halogen lamps employ the phase-control method, turning the lamps ON and OFF 120 times per second (based on standard 60 Hz frequency) and “chopping” the ON/OFF cycle to create what is perceived as smooth, continuous dimming. The longer the light is OFF versus ON, the lower the output and resulting energy consumption.

The diagrams shown below are examples of forward phase-control, in which the dimmer electronics chop the front end of the waveform. Reverse phase-control chops the waveform’s trailing edge and is typically used for LED or low-voltage halogen lamps with drivers/electronic transformers.
In an LED, fluorescent, or HID dimming system, the actual power and light reduction is done by a dimmable driver or ballast designed to accept control signals as an input and dim the lamps as an output. The control signal circuit may be low- or line-voltage. The ballasts are typically wired in parallel so the load can be controlled in unison.

Due to this variation, it is recommended to check with the lamp/luminaire and dimmer manufacturer to verify compatibility between products.

**WALLBOX DIMMERS: BASIC MODEL**

The basic wallbox dimmer is a manual control that enables users to control light levels. Various configurations are available including linear slides, rotary knobs, and raise/lower buttons. Various types of styling are available to complement architectural interiors.

Most phase-control (line-voltage) wallbox dimmers have what’s called an “air-gap” OFF feature. That is typically evidenced by a click at the bottom end of the range. This physically disconnects the circuit in the same way that a non-dimmable switch does. Alternately, the device may separate dimming and switching with, say, a slider used to select light level and a switch to turn the lights OFF and then ON at the last designated light level.

Some wallbox dimmers that seem very basic may still have some advanced functions. One example is a dimmer with high-end trim; some also have a low-end trim function. Some dimmers even fade between different light levels and also allow adjustment of the fade rate.
Wallbox dimmers can be categorized as single-pole, three-way or multi-location. Single-pole dimmers control the lights from a single location.

**Single-pole switches and dimmers** essentially “open” the circuit (to turn lights OFF) or “close” the circuit (to turn lights ON). A dimmer function is added to chop the waveform and dim lights.

**Three-way dimmers** dim the lights from one location, with connected three- and four-way switches added to turn the lights ON to the dimmer level or OFF from multiple locations.
Multilocation dimmers can be used with accessory dimmers for full control of the lights from an unlimited number of locations. These devices communicate control signals, enabling dimming from multiple locations.

WALLBOX DIMMERS/SENSORS

A wallbox dimmer can also be combined with an occupancy or vacancy sensor. In a wallbox vacancy sensor with a dimming function, a manual switch is used to turn the lights ON, as well as to act as a manual override (for example turning the lights OFF even if the space is occupied). The sensor element automatically turns the lights OFF when the space is unoccupied. In a wallbox occupancy sensor, the switch is essentially provided as a manual override, since turning lights ON and OFF are both automatic functions.

Incorporating a dimmer function into these devices provides an extra level of control for the occupant. Some of these devices feature the ability to set a time delay, retriggering, hold-OFF function based on input from an integral photosensor, and more.

Image courtesy of Lutron Electronics
WALLBOX DIMMERS: INTEGRATED (PRESET) DIMMERS

Integrated or preset dimmers are programmable dimmers with a bank of preset controls. In some cases, these devices have universal circuitry that allows each dimmer output (channel) to control multiple designated types of lighting loads. Typically, the user can program and then recall multiple lighting scenes for multiple zones by pressing a button or based on a programmed schedule. Auxiliary controls such as handheld IR remotes may be available.

Some multi-zone, multi-scene dimmers come in the form of a unified multi-gang device. This may contain sliders or raise/lower buttons to control light levels for two, three, or even more zones of lights. It also incorporates the scene selector buttons, full OFF, and sometimes other buttons as well, such as a master raise/lower. Often, a single-gang standalone scene selector device is offered as a companion product and communicates with the master (multi-gang) device to command lights to dim. You might, for example, locate this remote scene selector device in the finished space and then mount the master device in a closet to prevent unauthorized access to the dimmer settings.
WALLBOX DIMMERS: INTEGRATED (PRESET) DIMMERS

In a conference room, for example, this system could create unique lighting scenes to support a variety of functions, such as lectures, presentations, slide projections or meetings.

Images courtesy of Lutron Electronics

WALLBOX DIMMERS: NETWORKING

Some wallbox dimmers are designed to respond to commands from other devices such as keypads, master control stations, and other wallbox dimmers. The devices may communicate using dedicated low-voltage wiring, power-line carrier wiring, or via wireless signals.
GROUPING WALLBOX DIMMERS

Multiple dimmers may be needed for control of multiple lighting zones in the same space. For this purpose, wallbox dimmers may be co-located in two- and multi-gang configurations. Dimmers dissipate heat through the metal plate; but this plate may need to be physically altered so that two or more dimmers can fit into the junction box with a standard multi-gang faceplate covering all devices.

If the dimmers must be spaced similarly to switches, then two- or multi-gang configurations are used, which often involves removing part of the heat sink (as shown below). This reduces the capacity (load) the dimmer can control.
Also called power extenders or boosters, power packs increase wallbox dimmer capacity to handle larger lighting loads. In this scenario, the dimmer sends a signal to the power pack which dims or switches the lights. As a result, a remotely mounted power pack can handle considerably more load than the wallbox dimmer, depending on the product.

Some of these power packs are also designed to accept additional inputs from other devices such as timeclocks and occupancy and photosensors to create a simple integrated system.
Unlike wallbox dimmers and power packs, architectural preset dimming systems have a centralized dimming panel(s) containing dimmers for control of multiple zones, typically located in spaces such as electrical closets. This allows dimming control for much larger, more complex projects such as ballrooms.

The dimmers in these panels are commanded by interfaces called control stations typically installed in the room being controlled. The control station sends signals to the panel, which actually controls the load. The panel may accept inputs from other control devices such as switches, sensors, and timeclocks.
ARCHITECTURAL PRESET DIMMING SYSTEMS VS. NETWORKED LIGHTING CONTROLS

Compared to traditional architectural preset dimming systems, networked lighting control (NLC) systems offer significant advantages and have become even more compelling due to the growing predominance of controllable LED lighting. Wiring is simplified, and many systems use wireless communication to establish network connections. Zoning of luminaires occurs using software, rezoning is simple, integration with other control functionality is simple, and some systems also provide additional functionality such as color tuning.

*WALC, CLM and SensiLUM are not supported.

Image courtesy of OSRAM Encelium

CONTROL STATIONS

The control station is the “brain” of the architectural preset dimming system allowing multizone control, including scene select, recall, and potentially scheduling. They install at the wallbox in a 2+ gang size, though they do not directly control the load but instead generate control signals for lighting control and potentially control other systems such as automated window shading and HVAC. They allow control of multiple lighting circuits from one unit, which can be more convenient and visually pleasing than a row of dimmers on the wall. The interface may feature buttons or an LCD touchscreen with text and/or graphics.
DIMMING SYSTEMS: DISTRIBUTED PANELS (ROOM CONTROLLERS)

Another type of dimming system uses distributed micro panels for small and/or individual spaces with a digital communication architecture instead of a centralized panel for larger and/or multiple spaces. These systems, as in the example shown below, are also commonly referred to as “room controllers,” though they may be connected for larger projects.

These devices can only control a limited number of switch legs, which is what differentiates them from larger, centralized systems. With this approach, the micro panels are distributed close to the loads they control and can provide switching or dimming of standard analog dimming ballasts or LED drivers—e.g., using the 0-10V protocol.

In this executive office, a two-relay dimming room controller is configured for automatic-ON to 50%/automatic-OFF operation for the pendant luminaires and manual-ON operation for the whiteboard lighting. All lighting is dimmable using analog 0-10V LED drivers and digital dimmers with a four-scene personal remote.

Unlike in networked lighting control systems, individual luminaires in these room controller systems are not typically addressable. For example, the two Type D luminaires lighting the whiteboard are in the same zone, as determined by the wiring from the room controller. They cannot be individually switched or dimmed.
Image courtesy of Wattstopper
In the 1990s, standards were developed for digital dimming ballasts for fluorescent lamps. The predominant open-source standard is the Digital Addressable Lighting Interface (DALI), though a variety of proprietary standards followed.

The method used to dim the lamps wasn’t new, as fluorescent dimming ballasts were available for decades but were limited in application due to their cost premium. What was new was that each ballast was designed to be addressable for control individually or as part of a group on a network.

Unlike architectural preset dimming systems that were primary designed to dim incandescent lamps in hospitality spaces such as ballrooms, networked lighting control systems controlling fluorescent luminaires are primarily intended for use in commercial and institutional space types such as offices.

Because networked lighting control systems are designed from the outset to take input from devices such as occupancy sensors, photosensors, schedules, and dimmers, early systems that relied on digital dimming ballasts were predominantly employed to reduce energy usage.
The past decade has seen the meteoric rise in the use of LED lamps and luminaires. Similar to fluorescent lamps requiring a ballast, LEDs require a driver to provide the appropriate electrical output on the secondary side to the LEDs chips on printed circuit boards.

Unlike fluorescent ballasts, the majority of LED drivers are dimmable due to how the market for these light sources developed and the associated economics. Commonly, these LED drivers use an analog dimming signal (e.g., 0-10V), though manufacturers make digital LED drivers as well. The latter operates in much the same way that digital fluorescent dimming ballasts work.

Another relatively recent development in the lighting industry is that many networked lighting control manufacturers now provide preset functions in the software, enabling programmable and recallable scenes. The system allows preset functions only where needed while implementing other control strategies in other spaces. With these robust features, the latest networked systems are more versatile than architectural preset dimming systems.