the Construction Specifier

SOLUTIONS FOR THE CONSTRUCTION INDUSTRY August 2005

Fluorescent Dimming Ballasts

Glass Block Masonry

Reflective Roof Coatings

Architectural Woodworking

The Magazine of the Construction Specifications Institute

Photo courtesy Lutron Electronics Co.

Fluorescent Lighting Control

Defining success for conference rooms, classrooms, and meeting rooms

by Ken Walma, IESNA

Since its introduction, fluorescent lighting technology has experienced continuous improvements in both efficiency and lamp diameter, with 38-mm (1.5-in.) tubes making way for 12.7-mm (0.5-in.) styles. These improvements, as well as enhanced color and performance, have expanded fluorescent lighting use from offices into industrial warehouses, commercial spaces, and even residential projects. In the 1980s, the industry made large efficiency gains (*i.e.* between 15 and 50 percent) by moving from inefficient magnetic ballasts to electronic counterparts and from T-12 lamps to superior T-8 models. Today, similar efficiency percentage gains simply by changing lamp type or ballast are unlikely, leaving some to wonder whether there will ever be another breakthrough in fluorescent technology. While current products are efficient, lighting remains the single largest source of energy consumption in an office or classroom—between 35 and 45 percent or 55 and 65 percent, respectively.[1]

The next frontier in minimizing waste lies in lighting controls and dimming ballasts. More efficiently managing fluorescent sources can save an additional 25 to 50 percent of the building's lighting energy use. Although many different fluorescent control systems are available, most were designed with boardrooms, hotel ballrooms, and auditorium spaces in mind. Few addressed the large open areas and small classrooms now commonplace in U.S. office buildings and schools. Despite providing energy savings, the few systems designed for these spaces were costly, complicated to maintain, and did not consider the life of the building.

Table 1 Dimming Applications

Architectural dimming (one percent)	High-performance dimming (five percent)	Lighting management dimming (10 percent)
• conference room/boardroom • classroom/lecture hall • theater • partitioned meeting room • graphic art workstation	• small meeting room • customer service area/call center • lobby	• load shedding • occupant detection • daylight harvesting • large, open office • restroom • corridor/stairwell • utility room

Since working and learning environments must support multiple activities, they demand a system as flexible as those who occupy the space. Rising energy costs, the desire for adhering to sustainable design standards, and increasingly stringent building codes and regulations also play a key role in lighting design for these applications. There are numerous fluorescent lighting controls that attempt to satisfy these needs, but specifiers must familiarize themselves with the systems to provide a greater value to both the building owner and the rest of the design team. No technology is right for every situation.

Determining lighting needs

In working and learning environments, light directly affects occupant performance. Studies by the Light Right Consortium show ergonomic lighting (lighting and controls designed and installed in a way that considers the physical and psychological needs of building occupants) leads to positive effects such as improved productivity, reduced health complaints, and increased occupant satisfaction.[2]

Over the last two years, advancements in fluorescent lighting control technology have made it a simple and cost-effective solution for many seemingly complex lighting projects. When designing fluorescent lighting for meeting rooms, conference rooms, and classrooms, it is important to start with some basic, but essential, considerations before launching into the specification. Understanding the use of space is essential to the project's ultimate success.

Get to know your space

The project's size and scope must be understood, whether it is a sensitive application (*e.g.* boardrooms, auditoriums, ballrooms, lobbies, A/V rooms) or an energy-savings one (*e.g.* offices, meeting rooms, classrooms). Another important consideration is whether there is a desire to connect the lighting system with a larger system for personal computer (PC)-based operation or Web integration. Additionally, one must understand whether the design integrates controllable window shades and electric light controls.

Increasingly, such systems are being used to control the daylight and electric light in a room, taking advantage of natural illumination while managing glare and saving energy. The window is a powerful light source that, when controlled properly, can provide substantial efficiency gains as part of the lighting environment.[3] Challenges to specifying and commissioning such an integrated system include fabric selection, sensor placement and calibration, and coordination by multiple manufacturers and design teams. However, advances in lighting control technology simplify this integration to the point where things are almost 'plug and play.'

Anticipated light levels

Specifying fluorescent lighting controls demands an understanding of dimming range. Depending on the specified control and ballast, fluorescent lamps can be dimmed to as low as one percent of full light—desireable for many sensitive applications. (For more information on the requirements of certain applications, see Table 1.) For typical energy saving applications, a dimming range to 10 percent of full output is appropriate. Common settings for this include open office spaces, perimeter offices, and day-lit classrooms.

Use and maintenance

Knowing the space's intended use is key to specifying appropriate lighting, as the level of required maintenance significantly influences the suitability of fluorescent controls. One of the greatest benefits of fluorescent lighting control is the ability to integrate automated control and operation of the system, which significantly reduces maintenance and energy costs. Systems can either be completely automated or require some level of user interaction. Many offer the ability to produce energy, lamp condition, or ballast condition reports, which could prove a useful attribute for certain owners.

Throughout the project, the specifier should understand whether offices and meeting rooms need to be flexible to support re-purposing. The lighting control

Figure 1

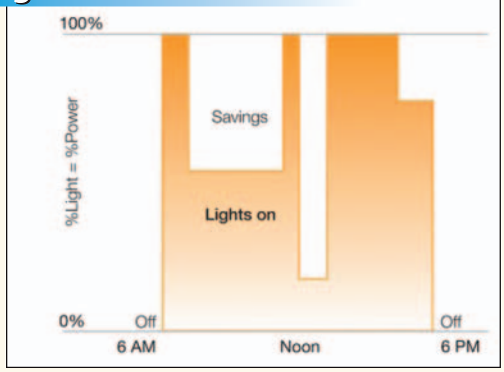
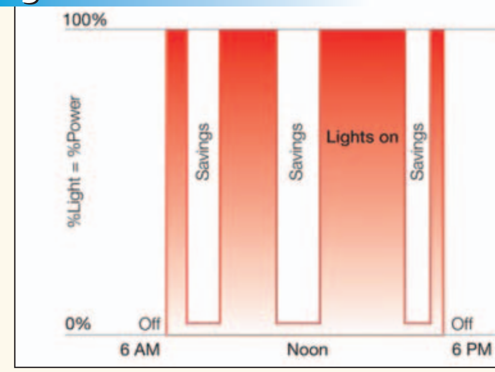


Figure 2



system for these environments must be easily configured (and reconfigured) to unobtrusively and quickly adjust to changing space needs. In reconfigurable open spaces, today's conference area may be transformed to tomorrow's open office space. Similarly, as building tenants change, so do their lighting needs. When implementing daylighting and occupant-sensing strategies as the facility opens, the specifier should be aware plans are going to need to evolve. Lighting requirements change with space reconfiguration, as landscaping matures, or when facilities are built adjacent to the existing building—the flexibility of a digital ballast system can prevent future maintenance by allowing modifications without rewiring.

Considering the components

Combining manual and automatic dimming controls can yield significant energy savings and a more comfortable and productive working and learning environment. Manual dimming options allow users to immediately adjust light levels based on need and preference, with newer systems giving occupants personal control of their overhead light. Familiar drawbacks to traditional fluorescent lighting—such as harsh glares, irritating flicker, eyestrain, and headaches—can be avoided through this personal control of light. Systems integrating dimming control can produce sizeable decreases in energy consumption in overall building operations—sometimes as much as 50 percent.[4] Some newer control systems even allow users to turn on/off their own lighting fixture without relays or control units of any kind.

Personal control

These systems allow occupants to dim or brighten illumination depending on the task, time of day, and individual preference in a cubicle environment. With a personal control system, it is possible for workers to control the overhead lighting in their own area to dim lights for computing and make them brighter for reading, writing, and up-close work. Allowing individuals to set lighting to their preferred level can have a significant impact on the bottom line. Ergonomic lighting leads to improved productivity and satisfaction and reduced health complaints, according to the Light Right Consortium.[5]

Infrared receivers (IR) and remote controls make personal control convenient and immediate. Some control systems allow individuals to control the overhead fluorescent light right from their PC or personal digital assistant (PDA). As an additional advantage, while employees dim lights to their preference, the system saves energy consumption in direct proportion to the light level.

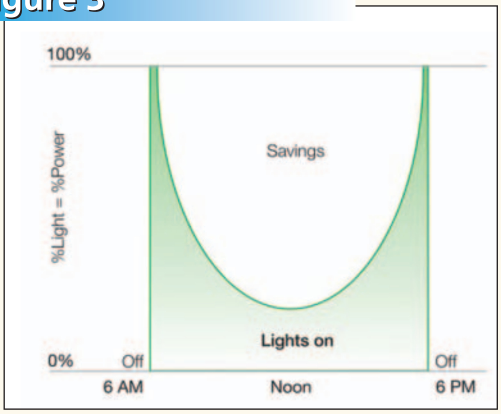
Manual dimming

Manual dimming control saves energy and provides on-demand control of light levels using wall controls or via software. Spaces can be adapted for different tasks and activities by manually adjusting the fixtures for simple on/off and raise/lower functionality from a wall-station. Scene control wall-stations are also available for saving and recalling different light scenes in multi-purpose and meeting rooms. Manual preset dimming is best applied in areas such as meeting rooms, lecture halls, and other multi-use spaces (Figure 1).

Automated occupant-based control

For enclosed areas, occupant-based sensors automatically shut lights off for assigned fixtures in unoccupied spaces, saving energy and money. (Some systems allow lights to slowly dim or turn off.) When the building closes, automated occupant-based sensors can synchronize up to security systems to adjust indoor/outdoor illumination levels and activate all lights when the facility goes into 'emergency mode.' Occupant-based sensors can provide

Figure 3



significant energy and cost savings by monitoring and dimming lights in unoccupied spaces during normal operating hours (Figure 2).

Daylight harvesting

Most common office space and classrooms now incorporate daylighting strategies into building designs. Studies have shown better behavior rates, superior learning environments, and reduced absenteeism in spaces with significant natural light.[6] However, these spaces must be designed as if there was no available daylight to account for nighttime usage or cloudy days. The result is during normal operating hours, even when there is sunlight, electric lighting is often wasted by being at 100-percent output all day. (Indeed, technology solves little if it is not used in practice due to ignorance of users or an overly complex interface.)

To maintain proper luminance levels, electric light must be reduced proportionately as daylight is increased. Sensors detect and monitor daylight for harvesting natural light and dimming electric light smoothly, unobtrusively, and continuously. Daylight harvesting is best applied in areas with large windows or skylights, such as perimeter offices, classrooms, and atria (Figure 3). These daylight sensors can also be used for non-dimming applications to switch lights on and off.

Wiring

Although similar in function, fluorescent lighting control systems are very different in their wiring and installation. Some require extensive control rewiring, some are wireless, and others are designed specifically around standard wiring procedures to allow for easy retrofit or new construction. Specifiers should be aware when the system has control wires for both ballasts and controls. Some wireless systems also exist, but one must be certain the application would permit wireless lighting control. (Generally, this is relegated to residential applications, as lighting—similar to fire alarm systems—is a primary building system and needs the reliability achieved with wired systems or small single rooms.)

One must also consider the project location. While in most localities Class-2 wiring does not require conduit, some areas require protection as though this wiring were high-power. This means a control system with power and control wiring requires twice the conduit. Other systems allow for power and control to be wired Class-1 and do not require the extra conduit.

Building codes and guidelines

Energy efficiency is rapidly becoming the design requirement of the new millennium. Many states and cities have already adopted specific energy-saving guidelines and more will continue to follow suit. As sustainable design requirements expand to become more compulsory, it is essential to integrate lighting design into the building's overall sustainable plans.

ASHRAE

The American Society of Heating, Refrigerating, and Air-conditioning Engineers/Illuminating Engineering Society of North America (ASHRAE/IENSA) standard 90.1-2001, *Energy Standard for Buildings Except Low-rise Residential Buildings*, encourages the use of energy-efficient lighting controls in design and practice for both interior and exterior lighting. Most states have adopted (or will soon adopt) energy codes based on the standard—the specifier should check with the local authority having jurisdiction (AHJ) to see which version of the code has been adopted.

LEED

The U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design® (LEED®) rating system provides a national standard for what constitutes a sustainable building. Efficient electrical and natural lighting controls may contribute to obtaining up to 22 points (of the 26 required for certification) in five of six LEED credit categories.

In addition to the possibility of generating points under the Innovation and Design Process (ID) category, lighting controls can contribute towards the following LEED credits:

- Sustainable Sites (SS) Credit 8, *Light Pollution Reduction;*
- Energy and Atmosphere (EA) Prerequisite 1, *Fundamental Building Systems Commissioning;*
- EA Prerequisite 2, *Minimum Energy Performance;*
- EA Credit 1, *Optimize Energy Performance;*
- EA Credit 3, *Additional Commissioning;*

• EA Credit 5, *Measurement and Verification;*
• Materials and Resources (MR) Credit 5, *Local/regional Materials;*
• Indoor Environmental Quality (EQ) Credit 6, *Controllability of Systems;* and
• EQ Credit 8, *Daylight & Views.*

Title 24

California's building efficiency code (along with those for energy-efficiency appliances) has saved more than $36 billion in electricity and natural gas costs since 1978, according to the California Energy Commission (CEC). A new, even more stringent code takes effect on October 1, 2005.[7] In particular, it addresses the urgency to adopt energy efficiency building standards for outdoor lighting and lower power limits for indoor lighting.

Fluorescent control technologies

With regard to office space, meeting rooms, conference rooms, and classrooms, there are numerous fluorescent lighting technologies, each providing a different level of flexibility, energy-efficiency, maintenance, and cost-effectiveness. In addition to various control features, these systems can also vary in installation cost. In this article, a rating system of one to three is used, where the lowest number represents the lowest cost.

Dual-level switching

In dual-level switching, the standard power wires are used to turn on alternate lamps and produce multiple light levels either by turning on/off various fixtures or operating two ballasts in a fixture. Controlled by manual switching, up to three different lighting levels can be achieved using two standard toggle switches, or some type of control device. (However, in-room adjustment of lighting is rarely used). Integration with daylighting and occupant sensing is easy, but daylighting functioning is only marginal and typically disabled within the system to prevent disruption changes in light levels. While dual-level switching is not designed for optimal energy saving, it does provide control capabilities and can meet certain code requirements.

Advantages

• low-cost ballasts;
• no control wires to ballasts; and
• meets code requirements in certain jurisdictions.

Disadvantages

• no wiring zones independent of circuits;
• noticeable/distracting difference when light levels change; and
• two times the amount of circuit wiring and conduit.

Cost summary

These systems are a small step above no controls. Generally, costs for a small room are under $1500. Installation costs can be kept low if the ballasts are installed at the fixture manufacturer. These systems have an installation cost of 'one.'

Two-wire electronic dimming ballasts

Two-wire fluorescent systems are designed to be used with an incandescent dimmer and comprise dimming ballasts that use the power wiring as control wiring. An incandescent dimmer will vary the voltage, which the ballast will interpret as a dimming signal. The ballasts were designed to be an easy retrofit for simple dimming via an incandescent dimmer. With regards to energy-savings projects, currently there are few controls designed to operate two-wire dimming ballasts, and those that do require many parts and interfaces. These systems are the lowest cost for retrofit applications where zoning remains the same and only simple dimming is needed. In larger architectural applications where high dimming is required, power instability from standard commercial building systems can cause light level changes or problems near the low end.

Advantages

• easy to retrofit when appropriate zones exist;
• low-cost controls where applicable; and
• no control wires.

Disadvantages

• total harmonic distortion (THD) higher than 30 percent when dimmed;
• no flexibility of zoning without rewiring;
• lamp stability problems with power wire fluctuations; and
• limited energy savings control offerings.

Cost summary

Although two-wire dimming ballasts are generally cost effective, they must be controlled by an incandescent dimmer. In commercial applications, this means dimming panels or other systems typically used for theaters, ballrooms, or restaurants, need to drive the dimming ballasts. For these environments, performance is crucial, with two-wire ballasts tending to fall short of other ballast types. Additionally, there are few incandescent dimmer-based systems designed around daylighting, occupant sensing, and simple controls; therefore many components would be required to use these ballasts. Systems for a small room generally would be in the $2500 to $3500 range, with an installation cost of 'two.'

Three-wire

The primary dimming ballast in the United States, three-wire systems have a long history due to their ability to provide reliable, superior quality dimming for architectural applications from 100 to one percent. The system adjusts the voltage on an extra line voltage wire to the dimming ballasts. Three-wire systems are designed for permanent, non-reconfigurable spaces where zoning is established by circuit wiring so simple energy saving controls are limited.

Advantages

- historically, the primary dimming ballast in the United States;
- very stable and reliable; and
- offers a variety of controls.

Disadvantages

- extra line voltage wire;
- no flexibility of zoning without rewiring; and
- some lamp types have higher-cost ballasts

Cost summary

These ballasts incur a premium for one percent lighting levels but are comparable to other types at 10 percent. They are typically used in architectural applications for their stability and superior performance. Control systems are frequently panel-based and largely designed around incandescent applications. There are some systems designed around energy savings projects that use three-wire dimming ballasts where costs range from average to high. Systems for small rooms generally range from $2500 to $3500 for 10-percent dimming and higher for one percent (installation cost of 'two').

0–10V systems

In addition to power wiring, two Class-2 low-voltage wires provide 0–10V ballasts a signal to dim (*i.e.* 0 being low, 10 being high). These systems require relatively low-cost controls and support a wide variety of ballasts. While installation is simplified because the zones can be wired independent of circuits, all control wiring must be Class-2 (a power miswire can destroy the ballasts and controls). Although rare, another drawback of the 0–10V system is low-voltage signals can be susceptible to noise and wire length issues. Additionally, as with other systems, up-front zoning is necessary, requiring rewiring if any changes are desired.

Advantages

- zones can be wired independent of circuits;
- low-cost controls; and
- wide variety of ballasts.

Disadvantages

- miswiring can destroy all ballasts and controls;
- two-control wires;
- only Class-2 control wires;
- analog controls with dials and manual adjustments above the ceiling; and
- noise and wire length could cause different light levels.

Cost summary

0–10V dimming ballasts are generally low-cost dimming ballasts. Rarely used in architectural applications, systems are typically small, standalone, and analog designed with energy savings projects in mind. Class-2 ballast control wires can add to installation costs in most areas. Designed around small rooms these systems would typically come in at the $2000 to $3000 range and meet simple energy savings requirements. Installation costs vary between 'two' and 'three,' depending on the locality.

DALI ballast control systems

With the digital addressable lighting interface (DALI) protocol, ballasts are digital (rather than analog), offering greater functioning and flexibility than their 0–10V counterparts as they can be directly controlled via computer. The DALI concept was to be a completely open digital protocol (*e.g.* Bluetooth® or Wi-Fi technology), but that has not happened—compatibility issues between controls manufacturers remain.

DALI ballast control systems offer many new advantages with addressable ballasts and easier control wiring. They allow for reconfiguring of the office space without rewiring and eliminate the need for power wire to zone the lighting, saving design time and allowing for future flexibility. DALI ballast systems use two Class-1 or Class-2 wires, along with power wiring for digital communication to the ballast.

Currently, many DALI ballast systems are incapable of daylighting integration—the ones possessing this ability often require heavy programming, especially with the addition of raise/lower wall-stations. When ballasts fail, new ones need to be reprogrammed—although some systems can handle one ballast failure, all systems require reprogramming when more than one fails at the same time.

Advantages

- zones can be wired independent of circuits;

- addressable ballasts for re-zoning; and
- control wiring is polarity- and topology-free.

Disadvantages

- few daylighting options;
- requires commissioning;
- currently no control-compatibility between manufacturers;
- failed ballasts require re-commissioning;
- commissioning through PDA or PC for more than out-of-box functionality; and
- new technology.

Cost summary

DALI-compatible ballasts require a premium over their analog dimming counterparts, varying between manufacturer, lamp type, and voltage. Some control systems based on presets and occupant sensors are cost-effective, but they cannot scale to larger systems and are not capable of daylighting. (Those that can require extensive commissioning.) All systems require some form of reprogramming when components fail. Costs can range in a small room from $2500 to $8000, depending on the technologies desired and the commissioning agent. Installation is relatively simple and can vary between 'one' and 'two,' not including commissioning.

Multiple input digital addressable systems (MIDA)

In the last year, new technologies have solved many issues coming from the aforementioned control systems. Digital-communication multiple-input ballasts can provide superior control in design, functionality, and cost for energy-saving commercial applications. Beyond all the benefits of digital ballasts, two Class-1 or Class-2 wires and a bus supply provide digital communication to a ballast with various low-voltage inputs. Each ballast has the ability to connect daylight and occupant sensors, as well as IR receivers and wall stations. (No interfaces or power packs are required.) Sensor and wall-station groups are programmed and not wired, so reconfiguration and adjustments are simplified and require no rewiring. The latest systems integrate daylighting, occupant sensing, and manual controls without required commissioning. These same systems then allow for enhanced functioning with set-up tools via a PDA or PC.

New MIDA ballast systems have revolutionized fluorescent lighting control by overcoming reservations about the costs, simplicity of design, and ease of maintenance. The latest systems are suitable for new construction with Class-1 control wiring in the conduit, but also ideal for retrofits because communication wiring can be run as Class-2 and in any order. Fluorescent lighting control can increase the flexibility of any workspace where changing functionality must be complemented by a versatile lighting environment. For projects of any size—from a single fixture to building-wide control—multiple input ballast systems provide the most comprehensive functionality, flexibility, and control in an easy-to-install and easy-to-use solution.

Advantages

- all the benefits of digital ballasts;
- simple system designs without interfaces or power packs;
- easy low voltage connection of any sensor or wall-station directly to single ballast;
- manual and automated dimming control options;
- Class-1 or Class-2 control wiring; and
- no reprogramming of failed ballasts or controls.

Disadvantages

- commissioning through PDA or PC for more than out-of-box functioning; and
- new technology.

Cost summary

These newer technology systems promise to lower the cost and complication traditionally thought to be associated with fluorescent dimming. MIDA systems reduce the number of devices and eliminate interfaces, power packs, and programming time. Additionally, failed components do not require reprogramming when replaced. The first MIDA systems use 10-percent dimming ballasts and are designed solely for energy savings applications. Time will tell, but initial costs put the system in the $1800 to $3000 range for small rooms with labor costs comparable to standalone dual-level switching (*i.e.* price level 'one').

Room to grow

Fluorescent lighting is the standard in design for an estimated +90 percent of commercial lighting needs, but remains the largest single user of energy in an office or classroom building. With the range of fluorescent lighting technologies available, fluorescent control systems can be specified for nearly all applications. These new dimming technologies make design, installation, and maintenance simple and cost-effective. MIDA provides a comprehensive lighting system combining all the latest functions (*e.g.* daylighting, occupant sensing, and manual/preset control) to deliver a simple and flexible lighting control solution.

When it comes to choosing the right light for today's open offices, conference rooms, meeting rooms, and classrooms, it is important to remember while each has its own unique lighting requirements, they all carry a common theme. That is, lighting

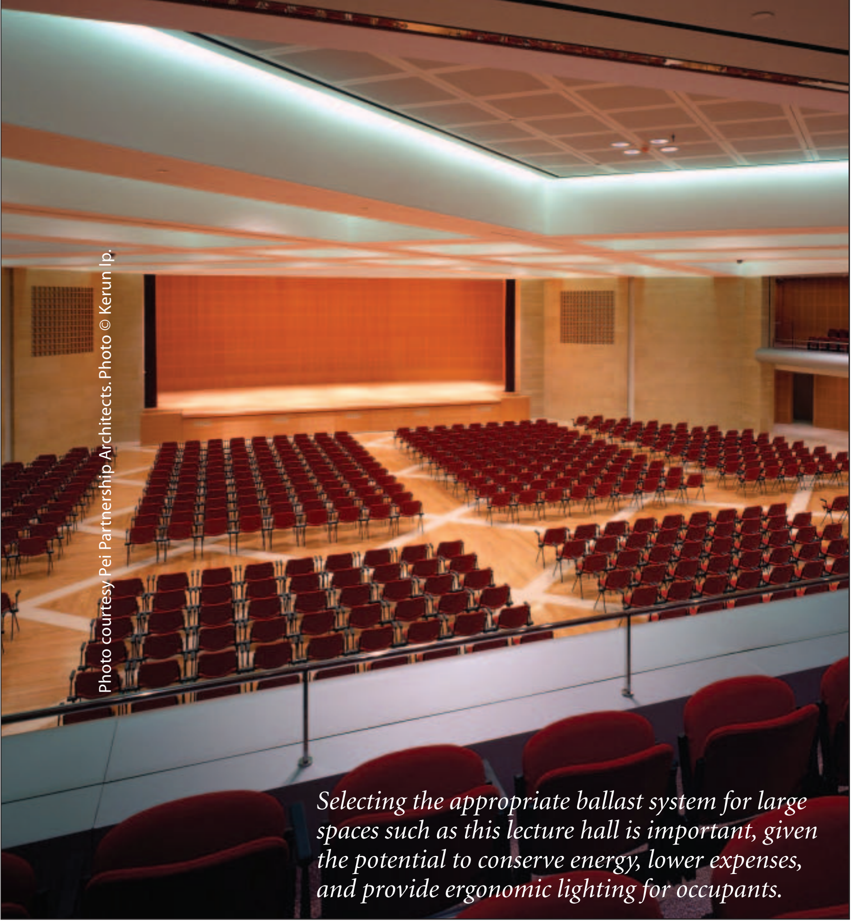


Photo courtesy Pei Partnership Architects. Photo © Kerun Ip.

Selecting the appropriate ballast system for large spaces such as this lecture hall is important, given the potential to conserve energy, lower expenses, and provide ergonomic lighting for occupants.

directly affects the occupants and their ability to perform efficiently and effectively in each of these environments.

Classrooms have more effective learning environments with greater amounts of daylight. Similarly, ergonomic lighting can lead to positive worker productivity, reduced health complaints, and increased satisfaction. MIDA systems provide flexibility and room for growth while reducing overall operating expenses and consumption.

Beyond planning and building advantages, end-users realize sizeable long-term cost and energy savings, easy maintenance, increased occupant productivity, and compliance with increasingly stringent green building codes. Fluorescent dimming creates more than an efficient, superior lighting environment—in effect, it fosters the institution's mission of providing effective working and learning environments.

Notes

[1] Visit www.eere.energy.gov/buildings for more information.

[2] The Light Right Consortium comprises manufacturers and various academic associations. For more information, visit www.lightright.org.

[3] To read on about daylighting strategies, see "Getting the Green Light from the Sun—The benefits of daylight harvesting" by Jim Nicolow, AIA, LEED AP (*CS* November 2004).

[4] Examples are covered in the online column, "Personal Lighting Control can Increase Worker Satisfaction and Motivation" by Craig diLouie. Visit www.buildings.com/articles/detail.asp?ArticleID=1765.

[5] Ibid.

[6] See ww.eere.energy.gov/consumerinfo/factsheets/cb4.html or www.nyserda.org/programs/pdfs/highperfbldg.pdf.

[7] For more information, visit www.energy.ca.gov/title24.

Additional Information

Author

Ken Walma, IESNA, is product manager for Lutron Electronics Co. Inc. A member of the Illuminating Engineering Society of North America (IESNA), Walma holds a B.S. in mechanical engineering. He can be contacted via e-mail at kwalma@lutron.com.

MasterFormat No.

26 09 00–Instrumentation and Control for Electrical Systems

26 51 13–Exterior Lighting Fixtures, Lamps, and Ballasts

UniFormat No.

D5020–Interior Lighting

Key words

Division 26

Dimming ballasts

Energy efficiency

Light Right Consortium

Abstract

This article delves into fluorescent lighting control for classrooms, meeting rooms, and conference rooms. Its purpose is to demonstrate the cost- and energy-saving benefits of fluorescent lighting control in these particular applications by analyzing the currently available technologies and their significance to these environments.