How Lutron's Daylighting Control System Works

Pekka Hakkarainen,
Lutron Electronics Co., Inc.

Technical white paper
7 January 2005

Lutron controls your light.™

1. Daylight sensors

Daylighting control employs ceiling mounted sensors that actively measure available daylight, and are used for maintaining light level to within a predetermined range. In these cases, we decide on the critical task surface or surfaces on which the target light level is maintained.

Generally speaking, photosensors respond to light that is incident on the sensor surface. Other than direct sun light, which in most cases we want to eliminate from the task surface anyway, the other source of daylight is the reflected (and relatively diffuse) sunlight from the sky and from clouds. In daylighting applications, the challenge is to orient the sensor in such a way that it measures this reflected daylight in proportion to how it varies on the task surface. The ideal placement is such that the sensor has a high level of illumination from daylight, but is shielded from any exterior glare sources.

2. Electric Lighting Control: Proportional vs. Set point control

The choice of the control method for electric lighting plays a significant role as far as overall success is concerned. A set point control method aims to keep the photosensor signal constant during the operation of the system – somewhat like a thermostat – while a proportional control method allows the signal to vary during the operation. It has been found through practice that the proportional control method is greatly superior to the set point method in interior applications. In a proportional control system, the sensor signal varies during the course of the day, and it is implicitly assumed that the photosensor signal is mostly composed of the daylight contribution. In some cases the signal is a mixture of daylight and electric light (this is called closed loop proportional control), while newer methods of control eliminate the contribution of electric lighting to the sensor signal completely (known as open loop proportional control). Thus, the placement, directionality and area of view of the photosensor are closely linked with the choice of the control method. Lutron uses the proportional control method, which can be configured as either open loop or closed loop.

When the control system incorporates both window shades and electric lights, we put the above control methods together and operate the window shades in a “set point” or “dead band” fashion, while the electric lighting is operated in an open loop proportional fashion. The term “dead band” rather than “set point” is preferred, since it more accurately describes the preferred implementation, where the sensor illumination is allowed to vary within a preset band without moving the shades. When the illumination moves outside this band, the shades are moved to bring it back in the center of the band. This operation ensures that the shades do not move continuously, which would be annoying to the occupants. If the control system is for skylights that are covered with motorized solar fabric, the photocell has to be mounted in the skylight well, preferably pointing towards the north so that the sun does not directly illuminate the sensor.

3. Principle of operation – proportional control systems

The photosensor converts the amount of light it detects to a DC current signal that varies, for example, between 0 and 3 mA. In the proportional control operating mode, which is used with electric light control, the photosensor signal level is allowed to vary during the course of the day. The output signal from the control system that determines the level settings for the electric lights is then proportional to the photosensor signal, the higher that signal the lower the electric light level.

The "dead band" control mode is used with the shade control. In this mode, three threshold levels are defined that correspond to three light levels incident on the photosensor. These levels can be thought of as "goal level", "too bright" and "too dim". There is a finite gap between all these levels that should be defined to be large enough to provide a hysteresis for the system that prevents lights and shades from oscillating. When a threshold level is crossed, the control system issues a command that changes the lighting preset or the shade position to move the sensor signal back to the acceptable range.

4. Location of the photocell – optimize signal relevance and strength

The correlation of ceiling illumination near the windows and desk illumination is generally not very good, but improves when moving away from the window. Locating the sensor about two window heights into the room works well in this case. When window shades are used, this correlation is improved near the window, and the sensor can be located so that it has a direct view of the window being controlled. In a side lighted room with the sensor mounted in the ceiling, a good location is about one window height into the room from the window. In these cases, the same sensor location provides a good signal for controlling the electric lighting.

5. Calibration issues

The initial installation of a daylighting control system involves a calibration procedure. It is necessary to 'tell' the system when the target illumination level meets goal, and this defines the contribution of electric light (output to lighting zones is of course known) required at a particular daylight level, as measured by the photosensor. In addition, a night time set point is needed, which defines the electric light contribution when no daylight is present. (This can also be done using blackout window shades, if they are available.) During the night time calibration procedure, a further step should be taken that improves the performance of the system by making it completely open loop: When the electric lights are at full, the sensor reading is recorded in the control system. This information can then be used during the day to subtract the electric light contribution from the sensor reading at all times (by scaling from the full light output using the known electric light dimming level), thereby making the system a true open loop proportional control system. The reason why this control method is preferred is that it improves the signal to noise ratio of the sensor reading.

In addition to calibrating the electric light output, when window shades are used, the commissioning agent needs to define the upper and lower bounds for acceptable window luminance. These limits will determine how often the shades move as well as how bright the window will appear.

6. Photosensor characteristics

The characteristics of the Lutron photosensor are listed below:

a) spectral response is close to human eye response
b) uses spatial cosine correction, which properly accounts for light sources at various angles of incidence
c) 60 degree angle of view vertically, 180 degrees horizontally gives a wide angle of view appropriate for proportional control systems
d) the view is oriented to one side, providing directionality to the sensor and making it easily adaptable to a variety of mounting locations
e) large dynamic range (0 to 2000 fc) and linear response within that range

Tel: 610.282.3800
International: +1 610.282.3800

World Headquarters
Lutron Electronics Co., Inc.
7200 Suter Road
Coopersburg, PA
18036-1299 USA

Barcelona +34 93 496 5742
Beijing +86 10 8525 1867
Berlin +49 30 9710 4590
Hong Kong +852 2104 7733
London +44 (0) 207 702 0657
Madrid +34 91 567 8479
Paris +33 1 44 70 71 86
Shanghai +86 21 6288 1473
Tokyo +81 3 5575 8411

www.lutron.com

LUTRON

Lutron controls your light.™