

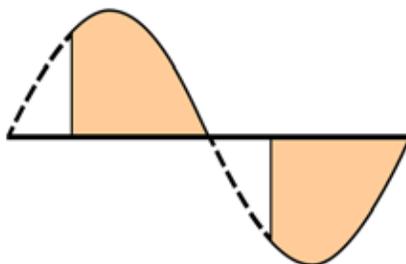
LED Application Series:

Dimming LEDs

Lack of effective and affordable dimming has hampered the adoption of CFLs in the residential sector. LEDs are in theory fully dimmable, but are not compatible with all dimmer controls designed for incandescent lamps. What are the prospects for dimming LEDs in residential applications?

Standard dimming controls

Typical residential incandescent lamp dimmers are essentially electronic switches that toggle on and off 120 times per second. By delaying the beginning of each half-cycle of AC power (known as “phase control”), they regulate the amount of power to the lamp filament. Because this occurs so quickly, most people do not detect flicker, but see continuous dimming. Although the general operation of such electronic dimmers is the same, the specific electrical characteristics of residential dimmers can vary considerably. These variations are immaterial to incandescent lamps, but matter greatly when used with electronic devices such as compact fluorescent lamps (CFLs) and LEDs.



Alternating current (AC) wave form, showing one complete cycle. AC cycles at 60 hertz, or 60 times per second. Typical household dimmers switch off the current twice per cycle, or 120 times per second.

Dimming CFLs

Some screw-in (integral) CFLs can be dimmed using line-voltage incandescent dimmers but must be specifically designed to do so. They typically dim only to about 20% of maximum intensity, due to limitations of the low-cost ballast. More sophisticated electronic ballasts providing continuous dimming below 5% are available, but are simply not cost-effective for use in screw-in CFLs. Some fixtures (e.g., torchieres) successfully use pin-based CFLs in combination with on-board dimming controls. Four-pin CFLs using separate dimming ballasts can be dimmed via line voltage or 0-10 volt DC control, with dimming range as low as 1%, but more commonly 5% or 20%.

Will LEDs solve the dimming problem?

LEDs face a dimming challenge similar to that of CFLs: their electronics are often incompatible with dimmers designed for incandescents. An LED driver connected directly to a line-voltage incandescent dimmer may not receive enough power to operate at lower dimming levels or it may be damaged by current spikes. Some LED products can be used with line-voltage incandescent dimmers, but the dimmer and the LED driver electronics must be carefully matched. Because of variability in installed dimmers, it is not possible to guarantee that a given LED fixture will work with all dimmers. Some LED light fixture manufacturers publish lists of specific dimmer products tested and approved for use with their fixtures.

More sophisticated LED dimmers use low-voltage controls (either variable resistors or 0-10 volt DC control) connected separately to the electronic driver. Full AC power is provided to the driver enabling the electronic controls to operate at all times, thus allowing LEDs to be uniformly dimmed (typically down to 5% or lower). However, they may require additional low-voltage wiring for retrofit applications.



Photo credit: Miro™ Dimmer photo courtesy of Watt Stopper/Legrand

Terms

Line voltage – a voltage supplied by the electric grid. In US residential buildings, this refers to 120-volt alternating current (AC) power.

Low voltage – some electrical devices are designed to work with voltage lower than that supplied by the electrical system. Such devices use a transformer or power supply to convert 120v AC power to the voltage and current needed by the device.

CCT – correlated color temperature indicates the relative color appearance of a white light source, from yellowish-white or “warm” (2700-3000 K) to bluish-white or “cool” (5000+ K).

Luminous efficacy – light output of a light source, divided by nominal wattage, given in lumens per watt (lm/W). Does not include driver, thermal, or luminaire optical losses.

Luminaire efficacy – light output of a luminaire, divided by total wattage to the power supply, given in lumens per watt (lm/W). Luminaire efficacy accounts for all driver, thermal, and luminaire optical losses.



Flicker and dimming

Most LED drivers use pulse width modulation (PWM) to regulate the amount of power to the LEDs. This technique turns the LEDs on and off at high frequency, varying the total on time to achieve perceived dimming. Driver output frequency should be at least 120 Hertz (Hz) to avoid perceptible flicker under typical circumstances.

LED light fixtures may appear to flicker at the lowest settings, but only when the dimmer control is moved. This is due to the finite “resolution” of the digital electronics. Good-quality electronic drivers feature 12-bit or greater resolution to obtain flicker-free operation throughout their dimming range.

Changes in color and efficacy with dimming

When an incandescent lamp is dimmed, the filament temperature decreases, causing the emitted light to appear “warmer,” changing from white to yellow to orange/red. The luminous efficacy of the lamp also decreases: a 15 lm/W lamp at full power will be 10 lm/W at 50% dimmed.

CFL color temperature does not change with dimming as dramatically as with incandescents, running counter to our expectation of significantly warmer color at low light levels. Luminous efficacy of fluorescent sources stays approximately constant with dimming until about 40%-50%; thereafter it decreases, but not as steeply as with incandescent lamps.

Most “white” LEDs are actually blue LEDs with a phosphor coating that generates warm or cool white light. Their light does not shift to red when dimmed; some may actually appear bluer with dimming. White light can also be made by mixing red, green, and blue (RGB) LEDs, allowing a full range of color mixing and color temperature adjustment. Overall LED luminaire efficacy decreases with dimming due to reduced driver efficiency at low dimming levels.

Future developments

As LED lighting becomes more common for household applications, fully integrated LED dimming controls may become a reality in new construction. In the meantime, LED products will need to be designed to use dimmers that were made for incandescent products, requiring manufacturers to indicate compatibility with specific dimmers. This will also continue to be necessary for retrofit products intended for existing homes, given the expense and trouble of changing out installed dimmers.



In summary, dimmability of LEDs will be limited in the near term by the installed stock of dimmers, which were designed for use with incandescent lamps. In the longer term, new design options are likely to emerge that greatly improve the dimming function of LEDs.

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