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Whitepapers

Dimming Screw-in Compact Fluorescent Lamps – Residential Applications

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Acknowledgements

The author of *Dimming Screw-in Compact Fluorescent Lamps – Residential Applications*, Richard Black, is an Engineering Manager with Lutron Electronics, Inc., Coopersburg, PA, developers of the world's first solid-state electronic device used to dim lights in a home. In his 14 years with Lutron, he has been a named inventor on 24 US and foreign patents. Richard’s design career has focused on products for the CEDIA industry and he has particular expertise regarding RF technology. Additionally, he is a spokesperson and educator on the topics of high-efficiency energy solutions and energy legislation for lighting controls and light sources for the CEDIA industry.

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Introduction: Document Scope

The objective of this document is to educate the reader regarding the benefits, performance, correct use, and limitations of screw-in compact fluorescent lamps (siCFLs). This is often achieved by comparing the siCFL to halogen and incandescent lamps. Pin-based CFL and linear fluorescent (FL) lamps are referenced occasionally but not thoroughly covered. For a basic understanding of how FL, CFLs, halogen bulbs, and incandescent bulbs emit light, visit `www.howstuffworks.com`, and/or `www.wikipedia.org`.

Using Screw-in Compact Fluorescent Lamps addresses lighting needs and concerns from the perspective of mid- to high-end residential lighting applications, which differ significantly from commercial applications that have used linear fluorescent lighting for decades. Also note that there are many rapid developments being made in many different light sources and that some of the information here will likely become dated quickly. In that regard, LED lighting is not covered here but likely will be covered in future papers. This light source does show promise in meeting all the residential requirements from a satisfactory to superior manner (cost will be an issue in the short term; most efficient, longest life, controllable color, etc.), but it is not yet ready for widespread application.

Halogen Lamps. Briefly stated, halogen lamps are incandescent bulbs that are more efficient and last longer than standard incandenscents, but still have great color – slightly different than standard incandescent but still very pleasing. They are readily available in most of the different bulb and base types and wattages. Given that the reader is likely looking for energy-efficient and green alternatives for lighting, it is asserted that the halogen bulb would likely be the default choice in the situations where a FL solution is not the correct one. While they do cost more than standard incandescent bulbs, their lifetime value compares favorably.

While not as efficient as FL, the halogen bulb has many overall advantages without the FL disadvantages (discussed below). The initial step from the standard incandescent to the halogen equivalent is a reasonable "no-brainer." An educated consumer, customer or homeowner may find halogens provide an acceptable solution toward meeting the various and competing goals described in this document.

Energy legislation. While it is often said that the incandescent light bulb has been "banned," leading people to believe that the only option will be fluorescent or LED lighting, current existing legislation in the United States does not support that over-simplified and extreme statement. Very briefly, the Energy Independence and Security Act of 2007 (EISA 2007) has set efficiency standards for A-type lamps (most lamp types are actually exempted) with a timeline for when each of the different wattages must comply. Halogen bulbs, which one could call a "high tech" incandescent bulb, are already compliant with these higher limits. So unless new stricter legislation is passed, the replacement for Edison's original design will be the halogen bulb beginning in 2012 with the 100W A-type bulb.

Screw-in CFLs vs. Pin-based CFLs

It is very important to distinguish between the screw-in CFL (siCFL), the "swirl bulb," and the pin-based CFL (2-pin, 4-pin and other bases - single to triple and other tube configurations) lamp, as they are very different. The screw-in CFL has integral ballast; that is, the control electronics are built directly into the base of the lamp. The lamp, the ballast and the base are one inseparable unit. The ballast is housed in the small section between the screw-in base and the FL bulb. It is intended to replace a standard incandescent bulb without the need for any changes to the control (largely assumed to be a switch), the fixture, or the wiring. Screw-in CFLs are low-cost and energy efficient, but overall have poor residential performance characteristics as detailed below.

Pin-based CFLs have an external ballast. Therefore a fixture is typically purchased with the ballast built in and it has the sockets designed to accept the pin base of the lamp. Because of this external ballast, pin-base CFLs have several advantages over the siCFL:

- Lower lamp cost, because it doesn't include the cost of the ballast electronics
- Longer life, and
- Better dimming performance, because the ballast is generally comprised of higher quality components and has more space for the necessary dimming circuitry.

Note that there are some screw-in ballasts without integral bulbs. They are designed to accept pin-based CFLs. The performance of these varies from no different than a siCFL to "good" but generally not as good as a fixture that was specifically designed for a FL load. Fixtures designed specifically for a fluorescent load can optimize the optical reflectors, do the best job with thermal management, and can provide enough room for a ballast that has enough circuitry to provide good performance over a wide range of operating conditions.

Why use a pin-based CFL?

As stated above, pin-based CFLs are more efficient than siCFls. However, due to the ubiquitous nature of screw in fixtures, pin-based CFLs are not currently used on a mass residential scale. Despite the currently low penetration rates of pin-based CFLs, it is advisable to use pin-based fixtures in new construction projects and remodels.

Beyond the performance advantages, using pin-based fixtures enable an accurate calculation of power consumption in regards to a lighting load for breaker and wiring sizing (i.e., a standard fixture is rated at its maximum power consumption level, so while you may intend to use 13 watt CFLs, the load calculation will be based on the fixture's maximum load, for instance, 100 watts). Since a pin-based CFL fixture can only accept a specific load, the lighting load calculation is greatly diminished, allowing for either more lights on a single zone or using a smaller breaker and consequently smaller gauge romex.

Why use a screw-in CFL?

FL lighting offers advantages as a light source: energy efficiency, low operating costs, and long lamp life. These advantages have been realized for decades in commercial space general lighting. Recently various motivations such as energy-efficiency, environmental concerns and legislation are pushing their use into residential spaces.

While they deliver the same advantages in the residential space, there are more and different performance requirements residentially. This has led to some confusion and disappointment. They have often not met expectations because they have been misused and misapplied. Below the performance of siCFLs is compared to halogens and incandescent bulbs. Performance of CFLs, Halogens, and Incandescent Lamps

Performance details and pros and cons of each light source — CFLs, halogens, and incandescent bulbs– are discussed at:

http://www.lutron.com/cms400/default.aspx?app=bulbtypes

Also, since the desire to use siCFLs comes from the desire to save energy, the following will be of interest:

http://www.lutron.com/CMS400/default.aspx?app=energywb *

Purchase name brand lamps – at this point in time the saying "you get what you pay for" is largely holding true. Testing has revealed that not only are there performance variations from manufacturer to manufacturer and model number to model number, but even bulb to bulb with the same model number.

The siCFL is intended to fit in the fixture just as the incandescent lamp did. While the siCFLs generally fit, the bulb dimensions are generally greater and they have a different pattern of light output. The change in light pattern may move light from a desired target location to somewhere else. Many of the early siCFLs for recessed cans would stick out of the fixture and down into the living space but there have been improvements lately. Some lamp shades attach to the bulb and don't work well with the siCFLs.

The change in physical shape and light pattern can lead to an effective reduction in the net light output from a fixture (not generally a problem with a table lamp but with any fixture that has a function of directing or reflecting the light output). This is because the optics design of a fixture was based on an incandescent bulb. Sometimes this can be corrected by moving up to the next larger size siCFL, e.g., instead of a 60W equivalent bulb use a 75W equivalent bulb. The 75W equivalent siCFL will still use less energy than the 60W incandescent. These issues may warrant consideration and testing.

Dimming Screw-in CFLs

Not all screw-in CFLs are dimmable. Read the packaging carefully. Dimming of fluorescent lamps requires specialized ballast circuitry. As a generalization, screw-in dimmable CFLs in past years had "very poor" dimming performance. At the time of the writing of this paper, (Jan '09), they have progressed to "fair". They will hopefully continue to improve.

They generally only dim to about 50% (Measured Light Output) of their full light output as measured using a light meter. Unfortunately because of the way the human eye and our perception of light works, this will be perceived as ~71% light output. This phenomenon is known as "Square-Dimming Law" where

$$(\text{Perceived Light Output})^2 = (\text{Measured Light Output})$$

Or, rearranging the equation,

$$(\text{Perceived Light Output}) = \sqrt{\text{Measured Light Output}}.$$

In this example,

$$\sqrt{0.50} = 0.71 \text{ or } 71\% \text{ Perceived Light Output.}$$

* *Please note that the provided links are for informational purposes and not a CEDIA endorsement of Lutron or its products.*

Dimmers and "Dimmable" Screw-In CFLs

If your definition, or more importantly your customers definition of the word "dimmable" means "the ability to vary light from very low levels that barely glow to full brightness", then it is fair to say that screw-in dimmable CFLs do not yet meet this perceived criterion. Actually if using this definition, most siCFLs are not so much actually dimmable but more so *compatible* with a dimmer. This means that the ballast has been designed to accept somewhat gracefully and safely the input waveform from a dimmer that may already be present at that location. However, be forewarned: the dimming range will likely be narrow. While a FL light source is capable of much better dimming performance – 10%, 5% and even 1% ballasts exist for various pin-based and linear FL lamps – screw-in lamps just don't have the physical space to implement the necessary circuitry nor the cost margin to achieve these low dimming levels.

Mechanical ("analog" or "standard") dimmers – that is, the classic rotary knob, slide or paddle dimmers – can work well, but the dimming range is typically very narrow. If, for example, you had a rotary dimmer connected to a dimmable siCFL, you would notice that when you turn the dimmer on you might rotate about 25% of the travel before the siCFL will turn on and then you will begin to see some dimming action until you reach about 75% of the travel. Thereafter the light output will flatten out and will not seem to get appreciably brighter – this is called "dead travel". This combined with the aforementioned Square-Dimming Law, means that many current low wattage dimmable CFLs would have a very small perceptible dimming range.

Electronic ("smart" or "system") dimmers, ones that are microprocessor based, have LEDs, advanced functionality, and are part of a whole-home or intelligent lighting have several other considerations. Because they need a small amount of energy to run the power supply inside of them, dimmers with neutral-wire connections should be used. Without a neutral wire this power supply current will pass through the CFL, which will store the energy until it can strike the lamp. This can cause the CFL to flash on briefly every few seconds to every few minutes even when the dimmer is off. Some dimmers even with a neutral wire still allow some "leakage" current to flow through the load and the results can be the same.

Electronic dimmers can have an advantage over analog dimmers in that some incorporate high-end and low-end "trim settings." This allows the dimmer to rescale its dimming range thereby eliminating the dead travel at the top and bottom as described above. Not all electronic dimmers have this functionality – check with the manufacturer. Some manufacturers have specific model numbers that have the narrower dimming range hard-coded in (could be implemented in hardware or software). Some allow setting the trim values locally at the dimmer and other system-based dimmers may require a database upload to change the dimming range.

ELV dimmers utilize reverse phase control and will generally have better siCFL dimming performance than forward phase control INC/MLV dimmers. ELV control of a siCFL will result in lower current spikes to "charge" the capacitive front end of the siCFL. Electrically, this is less stressful to the dimming control and to the siCFL presumably extending lifetimes. Lower current spikes will result in less conducted and radiated electrical noise coming from the circuit that could cause interference to radios, and sensitive AV equipment

Dimmers have minimum load requirements that typically range from 10 to 50w. You must ensure that the CFL's load satisfies the dimmers minimum load requirements. This is the actual load of the CFL – for example, 14W, *not* its equivalent light output of 60w. Dimmers with a neutral wire will have a lower minimum load when compared to an equivalent non-neutral-based dimmer.

Bad siCFL behavior attributable to minimum load issues can often be alleviated by mixing incandescent and siCFL loads. For example if there are 6 x 65w recessed cans on a lighting zone, making three of them recessed halogen can meet the dimmers' minimum load requirements, often stop siCFL flashing issues, will give some instant-on light and may improve color rendering issues. While it does not matter, electrically speaking, what order the mixed lamp types occur, you may want to alternate them to optimize the instant-on light and color benefits. These sources will look different when you look at the ceiling and this may not be acceptable aesthetically.

Some dimmer manufacturers sell "load" boxes that are installed in parallel with the lamp to satisfy the dimmers minimum load requirements. Look for a high-quality "active" load box that intelligently satisfies the dimmers needs for a fraction of a line cycle but then looks substantially like an open circuit for the rest of the time. These "active" loads save energy and run cooler than a passive "resistor-in-a-box" designs. Installation of a load box is typically only feasible in new construction or renovation, so the preferred solution would be to use a pin-based or linear FL dimming solution rather than a using a siCFL.

As a general note on dimming and future developments of lighting loads it would be good practice to require a neutral-wire in every wall box and use dimmers with a neutral-wire. This gives the best chance to easily adapt to changes or mistakes in the lighting plans and compatibility with future light sources.

It is recommended that one not use solid-state occupancy sensors with CFLs unless they include a mechanical break or air gap that ensures current cannot flow through the lamp when it is turned off. Incorrect switching devices shorten the life of the lamp.

It is also worth mentioning that, according to the UK National Health Service (NHS), certain CFLs emit UV radiation and should not be used uncovered in very close proximity to people for long periods of time. At the present, this is only an advisory currently under evaluation in the UK and the European Union.

Recommendations for FL dimming

Refer to the links above for more details, but some general guidelines follow below.

WHEN TO USE A siCFL

- Areas where lights are left on for long periods of time
- Utility areas and large areas that need significant amounts of light coverage – Laundry, garage, basements, equipment closets, gym, kitchen

WHEN NOT TO USE A siCFL

- Places that are cold – Long warm up time; difficulty striking the lamp (flashing until lamp starts)
- Pass-through areas of the home such as hallways and stairwells – Long warm up time
- Nesting or comfort areas of the home such as the bedrooms, family room, kitchen – Cold color of FL
- Architectural areas – Color rendering of siCFL and limited dimming range

Some rooms may fit into multiple categories such as an eat-in kitchen. It is a large area that often requires a lot of task lighting but it is often architecturally significant and it is a nesting area where friends and family often gather. Therefore the best lighting design will incorporate both halogen and FL light sources. For example, Title 24 legislation (California's Energy Code) has recognized this and requires that there be at least as much FL lighting load as incandescent in a kitchen.