Advanced LED Downlighting System

The Issue

Light-emitting diodes (LEDs), with high efficiency, dimmability, long life, and directional light output, could be the ideal light source for the common recessed-can downlight. However, many existing LED downlight products fail to live up to expectations, providing poor light distribution, glare, and low system efficiencies.

The Solution

Newly designed downlights use LEDs to their full potential while maintaining the features and functionality that have made them popular. Through the Public Interest Energy Research (PIER) program, the California Lighting Technology Center, Architectural Energy Corporation, Samsung Electronics, and Philips Capri Lighting collaborated to develop a dimmable downlighting system based on an indirect optical design that reduces glare, decreases installation time, smooths out LED color variations, and improves thermal management. Although manufacturing and cost constraints ultimately prevented this specific prototype design from being produced commercially, Philips Capri Lighting has developed and commercialized a new LED downlight system based on the lessons learned during this project. The product draws about half the power as a typical compact fluorescent downlight system, produces 41 lumens per watt, and offers an estimated life of 50,000 hours—five times longer than the typical compact fluorescent lightbulb.

Features and Benefits

The Advanced LED Downlight is designed to meet ENERGY STAR® performance requirements, provides a high level of control, and offers easy installation.

Indirect design. Light emitted by an LED is highly directional, making it easy to get high efficiency from a downlight fixture. However, this feature also makes it crucial that the fixture be designed to eliminate glare and provide an even light distribution. To provide these benefits, the Advanced LED Downlight uses an indirect design, where the light from the LEDs is directed upward, then bounced off a highly reflective concave dome (**Figure 1**).

Effective heat management. LED life and performance degrade in the presence of excessive heat—a challenge for the advanced design, which features eight high-output LEDs per downlight. To achieve effective thermal management, the design employs an integrated cross-blade heat sink with a trim that diverts heat away from the LEDs without adding any additional bulk.

Design for retrofits. To ensure that potential products will be effective in a wide range of retrofit installations, the design was constrained to fit a standard 6.5-inch-diameter housing. In addition, the housing height is only 2.5 inches, enabling it to be installed in a conventional 2-inch-by-4-inch wood-stud construction.

Centralized power supply. The Advanced LED Downlight features a single central power supply that allows for additional downlights, or other LED fixtures (up to a total of 10), for retrofit or expanded lighting levels. Low-voltage wiring between the power supply and the downlights allows for simplified wiring and low-cost installation.

Flexible controls. The power supply for the downlights offers several control options, including occupancy sensors, manual dimmers, scene controllers, timers, and photosensors.

Performance criteria. Through the Advanced LED Downlight project, researchers developed and adopted a set of performance specifications that may be helpful in future LED downlight development efforts. Using the ENERGY STAR solid-state lighting criteria as a baseline to ensure a minimum level of efficacy (the amount of light produced for each watt of electricity consumed by the light source), researchers developed a number of additional criteria to ensure that the product would provide appropriate visual comfort, reduce glare, and increase flexibility (**Table 1**, next page).

Figure 1: Indirect LED downlight design

The indirect downlight design bounces light from the light-emitting diodes (LEDs) off of a reflective dome, creating a more appealing light distribution.

Source: California Lighting Technology Center

Applications

Downlights are commonly employed in a wide range of residential and commercial applications, including kitchens, hallways, bathrooms, conference rooms, restaurants, and lobbies. Using lessons learned from the research regarding the optical system, the power supply, and the driver, Philips Capri Lighting commercialized a more traditional direct LED downlight system (the CRL6K-14) that provides significant energy savings over incandescent downlight technology and can be retrofitted into a variety of existing downlight housings.

Table 1: Indirect LED downlight specifications

To ensure that the design of the Advanced LED Downlight maximized energy efficiency, optical efficiency, and controllability, researchers developed a customized set of performance criteria that was built to ENERGY STAR specifications.

Component	Function
Optical system	Utilize an indirect design to reduce brightness and increase visual comfort
	Meet ENERGY STAR criteria for total lumen output and efficacy
Power supply	Utilize switch-mode power supply technology
	Deliver electrical efficiency greater than 87%
	Operate up to 10 downlights
	Ensure total harmonic distortion less than 10%
	Deliver power factor greater than 90
	Provide inputs for optional controls
	Withstand insulation contact at 55° C ambient temperature
Driver	Deliver electrical efficiency greater than 94%
	Operate up to 2 downlights
	Accept maximum input of 48 V
	Produce maximum output of 700 mA
	Drive 14 LEDs at 700 mA maximum
	Ensure that current follows voltage between 48 V and 32 V
	Turn system off if voltage falls below 32 V

Notes: C = Celsius; LED = light-emitting diode; mA = milliampere; V = volt.

Source: California Lighting Technology Center

California Codes and Standards

With a system efficacy of around 45 lumens per watt (depending on the trim used), the commercialized LED downlight product offered by Philips Capri Lighting meets the minimum 40 lumens per watt required by the 2008 Title 24 standards for high-efficacy LED luminaires drawing between 5 and 15 watts.

What's Next

The California Lighting Technology Center will continue to research and develop new indirect-LED downlight concepts along with other light-distribution designs. As manufacturers develop next-generation optical coatings and films to improve optical efficiency, the system efficacies of indirect designs are likely to improve, making them more appealing to manufacturers.

Collaborators

The organizations involved in this project include the California Lighting Technology Center, Architectural Energy Corporation, Samsung Electronics, and Philips Capri Lighting.

For More Information

A report documenting this project and providing more details may be downloaded from www.energy.ca.gov/2011publications/CEC-500-2011-011/CEC-500-2011-011.pdf.

To view PIER Technical Briefs on other topics, visit www.esource.com/public/products/cec_form.asp.

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About PIER

This project was conducted by the California Energy Commission's Public Interest Energy Research (PIER) Program. PIER supports public interest energy research and development that helps improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

Edmund G. Brown Jr., *Governor*

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