Electronic Design

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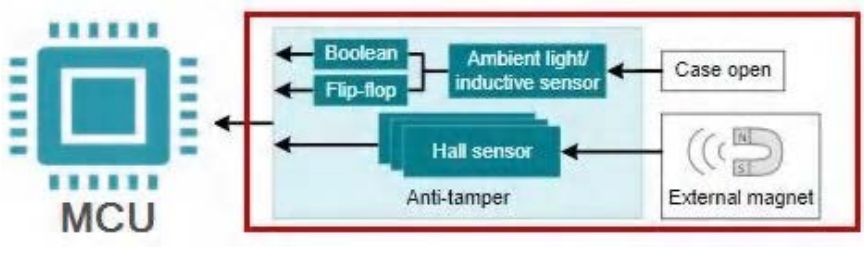
Light Sensing: Seeing Beyond the Human Eye

Sponsored by Texas Instruments: From safer cars to smarter homes, intelligent light-sensing solutions enhance user experiences.

Light sensors detect the presence or absence of light, and the intensity of that light. These sensors then convert light energy into an electrical signal, which can be analyzed or lead to further action.



1. Diagram of a smart meter with a light sensor block. (Source: TI)

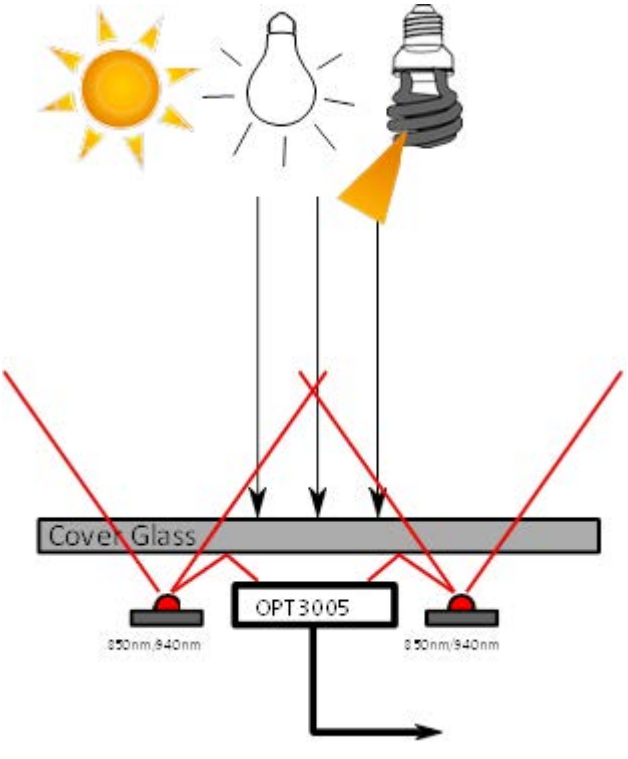
Industry-changing sensor solutions are enabling electronics to see beyond the capabilities of the human eye. They increase the safety and efficiency in automotive, industrial, and personal electronics applications, ranging from controlling the brightness of display screens to alerting security systems of a possible intrusion. Such solutions ultimately enhance user experience, optimize power usage, and enable automation in both consumer and industrial applications *(Fig. 1)*.

With the adoption of smart technologies and energy-efficient systems across multiple industries, long-awaited upgrades in sensor applications are rapidly emerging, especially in areas such as smartphones, automotive systems, IoT devices, security systems, and healthcare equipment. A Persistence Research & Consultancy Services Ltd. (London, England) study values the 2025 light sensor market at approximately US$2.9 billion. The industry is projected to surpass US$4.8 billion by 2032, according to Persistence, growing at a CAGR of 8.2% over the forecast period (2022-2032).

Key Light-Sensing Applications

Ambient light and color sensors enable intelligent light control to improve energy in homes and factories. Moreover, they enhance vehicle safety via adaptive headlights that can dim and brighten when there's a change in light intensity, such as when entering or exiting a tunnel.

For applications that introduce infrared (IR) into the environment, such as video doorbells, IP network cameras, and video surveillance, a strong IR rejection is necessary for ac-



2. TI's OPT3005 ALS is built into a video surveillance application. (Source: TI)

curate sensing. High IR rejection is also needed to filter out the infrared light from LEDs used for camera night vision.

These benefits, however, also come with substantial design challenges, including how to achieve the best accuracy, sensitivity, and resolution while accommodating package constraints and the need for system-level integration. TI's ambient light and color sensors address these challenges with features that improve functionality *(Fig. 2)*.

It's also possible to use light sensors for tamper detection and brightness adjustment in equipment such as electric vehicles (EVs) and EV charging stations. With adaptive brightness control, the screen on an EV charging station remains visible in various lighting conditions without excessive power consumption.

Accurate light-intensity (lux) sensors, such as that found in TI's OPT4003-Q1 digital light sensor, enable reaction times to environmental changes ranging from 600 µs to 800 ms per channel. These conversion times work well in automotive applications where rapid adjustments are necessary for safety, such as when driving into and out of tunnels.

The OPT4003-Q1 is a dual-channel, light-to-digital sensor (single-chip lux meter and NIR power meter) that independently measures the intensity of visible and near-infrared (NIR) light. The OPT4003-Q1 can identify light sources, including incandescent, halogen, sunlight, LED, and fluorescent, to help improve system operating conditions—for example, detecting whether light is coming from a well-lit indoor environment or from outside, which impacts the type of headlight needed.

Tamper-detection light sensors can detect a brightness change in ambient-light levels. They indicate that a device or system has been tampered with or when the ambient light levels change significantly, such as someone opening or blocking the system. This process is commonly used in security systems like alarm systems, access control systems, ATMs, and smart meters,

Brightness adjustment is a popular application of light sensors, especially in personal electronic devices, e.g., smartwatches, tablets, and laptops. These sensors also find homes in automotive and industrial applications such as infotainment and human-machine interfaces. Light sensors measure the ambient-light level and adjust the display brightness accordingly, providing a comfortable viewing experience and saving battery life.

Choosing the Right Light Sensor

There are many fundamental design considerations when choosing a light sensor to achieve optimal performance in various use cases. They range from tamper detection and display brightness adjustment to color adjustment and more.

Specifically, one of the hurdles facing engineers when it comes to light utilization is measuring color temperature and adjusting the colors of a display accordingly. This process is commonly used in TVs, monitors, laptops, smartphones, and tablets to optimize the display colors based on the surrounding lighting conditions. The color temperature of the display is adjusted to a warmer or cooler temperature to make the colors appear more natural and accurate.

TI offers the tools needed to more accurately measure lighting conditions and control colors. The company's automotive-grade OPT3001-Q1 and OPT4001-Q1 ambient light sensors target automotive applications and end equipment influenced by high temperatures. TI light sensors also have interrupt pins for setting threshold triggers without host or processor intervention, thus saving power.

Conclusion

As we've discussed, light sensor applications vary from simple light-intensity thresholds to active color-adjusting displays. Light sensors improve user experience, optimize energy consumption, and extend device lifetime. Fundamental design considerations include spectral response, speed, resolution, power, size, and measurement range.

Texas Instruments offers a diverse light sensor portfolio. Its optical sensors come in multiple package options, including the PicoStar package available in the OPT3006, OPT3007, and OPT4001 devices. The PicoStar package's ultra-small, ultra-thin form factor enables light sensing in very space-constrained designs. And light-sensing devices like the OPT4001YMN-Q1 offer a 5X reduction in device area (1 × 0.8 mm) and 3X reduction in device thickness (0.226 mm) over conventional optical packages such as the SOT-5x3 package.