EVALUATING SENSORS IN CONNECTED LIGHTING PRODUCTS
Sensors in connected lighting products have become essential to the efficient management and control of lighting systems in public infrastructure as well as commercial, industrial and, soon, consumer applications. Sensors serve a critical function in the optimization of performance and energy efficiency of lighting products. Sensors also facilitate timely maintenance by signaling lighting component performance issues, failures and outages. And sensors contribute to the overall safety and security of buildings through their integration with building automation and security systems.

For these and other reasons, the implementation of advanced sensor technology in and on connected lighting products and as part of systems represents a significant and growing market for manufacturers. At the same time, however, standardized methods for evaluating the performance of sensors used in connected lighting products have been slow to emerge. In this vacuum, sensor manufacturers and integrators evaluate and test sensors to their own specific requirements, potentially leading to significant variations in the characteristics, quality and reliability of lighting sensors. And, over time, as older sensors reach the end of their useful life and must be replaced, interchangeability with newer sensor technologies is uncertain.

This UL white paper discusses the use of sensors in connected lighting products and presents a case for the standardization of sensor performance. Beginning with a review of sensor technology and an overview of their growing importance, the paper then examines a sampling of current sensor standards, and identifies key considerations for future technical standards for sensors used in connected lighting products. The white paper concludes with information about UL’s contributions to the current and future development of Standards and protocols for lighting sensors and other connected technologies.
WHAT ARE SENSORS?

Sensors used in lighting products are generally low-powered, often microelectronic elements that are designed to detect one or more specific physical, electrical or chemical property. When packaged with a communication technology (e.g. wireless radio), the resulting sensor device can transmit data on changes in that property over time. A sensor can be a simple, single-function device designed for a specific application, such as a photoelectric eye used with a switch to turn on or turn off a piece of lighting equipment. A sensor can also consist of multiple sensing elements and be integrated into more advanced equipment, such as machinery used in industrial, commercial and consumer applications to monitor and control multiple functions.

Today’s generation of microelectronic sensors are commonly based on microelectromechanical systems (MEMS) technology, resulting in highly advanced devices that are significantly more capable, sensitive and accurate than conventional sensors. This development makes MEMS-based sensors essential components in the development and widespread deployment of interconnected devices and technologies that make up the Internet of Things (IoT). By translating the characteristics of the physical world into information that can be used to monitor, control and optimize the performance of other connected devices and systems, sensors are the driving force behind such 21st century advancements as smart homes and smart cities, autonomous vehicles and the introduction of intelligent systems in automated factories and production facilities (the so-called Industry 4.0).

The increasing utility of the smartphone, growth and expansion of the IoT and the Industrial IoT (IIoT) will fuel dramatic increases in the market for sensors. Global sales of sensor elements and sensor devices, estimated at approximately $130 billion (U.S.) in 2016, and are projected to exceed $240 billion in 2021, a compound annual growth rate (CAGR) of more than 13 percent. Separately, Gartner predicts that sensor-dependent IoT/IIoT-connected devices will grow globally from 8.4 billion in 2017 to more than 20 billion by 2020. These projected trends strongly correlate with the IoT’s/IIoT’s dependence on sensor technology.

THE ROLE OF SENSORS IN CONNECTED LIGHTING PRODUCTS

According to the U.S. Energy Information Administration (EIA), energy usage related to lighting products has dropped dramatically in recent years, from about 18 percent of U.S. electrical consumption in 2013 to approximately 10 percent in 2016. While economic growth in the U.S. and elsewhere in the world continues to drive an overall increase in the demand for energy, today’s advanced lighting products consume significantly less energy than comparable products from just a few years ago, making important contributions to overall energy savings. The growing market acceptance of solid state lighting (SSL) products and other advanced lighting technologies in both commercial and residential applications has been an important factor behind these savings.

IT IS ESTIMATED THAT SENSOR-DEPENDENT IOT/IIOT-CONNECTED DEVICES WILL GROW GLOBALLY FROM 8.4 BILLION IN 2017 TO MORE THAN 20 BILLION BY 2020.
In addition to reducing energy consumption, the widespread adoption of SSL technologies has also paved the way for the integration of sensors into lighting products. For millions of consumers, for example, this integration now makes it increasingly possible to program sophisticated residential lighting systems, permitting manipulation of illumination through an almost unlimited range of output levels, intensities and colors, all from a smart phone or comparable electronic device. More generally, sensors can be used to detect ambient lighting levels to power down lighting during daytime hours, or to detect motion, sound or even body heat to adjust lighting systems based on occupancy.

But sensor-enabled connected lighting products, including lighting products serving as a platform for sensors, can potentially support a host of broader capabilities in all types of settings and applications. Here are just a few examples:

- **ENERGY EFFICIENCY**: Data from sensor-enabled lighting products can be downloaded and analyzed for specific occupancy and usage patterns, enabling infrastructure, building and plant operators to more easily monitor and control energy usage associated with lighting products and other systems. And sensors in lighting products can be programmed to communicate with heating, ventilation and air-conditioning (HVAC) systems to coordinate additional potential energy savings.

- **FACILITIES MAINTENANCE**: Lighting sensors can signal when repair or maintenance of a lighting system or component is required or imminent, for example, when a burned-out light source requires replacement. Sensors can also measure lighting system performance (as well as the performance of other facility systems) against theoretical specifications, enabling asset managers to proactively plan routine servicing and maintenance.

- **SECURITY**: Sensor-enabled lighting products can be programmed to contact security services when the lighting is unexpectedly activated or when other localized activity (such as a window breaking) signals a potential intrusion. Intelligent lighting products can also be equipped with cameras or infrared motion detectors that can be integrated into building monitoring systems to provide more comprehensive security.

- **BUILDING AUTOMATION**: The operation of connected lighting systems can be integrated with that of other infrastructure operations, such as plant and equipment activation, elevator operation, access control, etc., as part of a comprehensive effort to more effectively manage building and infrastructure operations.

- **CUSTOMIZED APPLICATIONS**: The current technology behind sensor-enabled lighting products provides a platform for the development of a wide range of customized lighting applications. And future advances in sensor technology and photonics is likely to offer new ways to monitor the use environment and share data, supporting additional applications for connected lighting systems.
CURRENT SENSOR STANDARDS

The development of standards applicable to sensors used in connected lighting products has not kept pace with their growing importance and future potential. Instead, many currently available, sensor-related standards focus generally on sensor technology or on sensors intended for use in very specific applications. Some industry and professional organizations, such as NEMA (the National Electrical Manufacturers Association), and the IEEE (the Institute of Electrical and Electronics Engineers), as well as the International Electrotechnical Commission (IEC) have contributed to the standardization of sensor technology by developing industry-accepted standards that have been adopted by sensor manufacturers and integrators.

HERE IS A SAMPLING OF CURRENT SENSOR-RELATED STANDARDS:

- **IEC 61757 SERIES, FIBER OPTIC SENSORS**: This international standard series covers sensors that measure a physical or electrical quantity, property or condition as it applies specifically to fiber optic sensing applications.

- **IEC 62047-1, SEMICONDUCTOR DEVICES - MICRO-ELECTROMECHANICAL DEVICES - PART 1**: Terms and definitions: This IEC standard defines terms for micro-electromechanical systems (MEMS) and devices, including the process of producing such devices.

- **(IEEE) 2700—IEEE STANDARD FOR SENSOR PERFORMANCE PARAMETER DEFINITION**: Presents a common framework for sensor performance specification terminology, units, conditions and limits.

- **NEMA WD-7, OCCUPANCY MOTION SENSORS**: Developed by NEMA, WD-7 provides a reference definition and measurement characteristics for the use and application of occupancy motion sensors.

- **NEMA WD-9, DIMMERS, PHOTOELECTRIC CONTROLS, PRESENCE SENSORS, AND MULTI-OUTLET BARS ENERGY CONSUMPTION TESTING AND LABELING**: Another NEMA standard, WD-9 provides a standardized testing method to measure and label the standby energy consumption of dimmers, photoelectric controls, presence/motion sensors and multi-outlet bars.

- **NFPA 72, NATIONAL FIRE ALARM AND SIGNALING CODE SCOPE**: Developed by the National Fire Protection Association (NFPA), NFPA 72 covers the installation, performance, inspection and testing of fire alarm systems, fire warning equipment, emergency communication systems and their components.

- **ANSI/UL 217, STANDARD FOR SMOKE ALARMS**: This UL Standard covers electrically operated single and multiple station smoke alarms and remote accessories intended for open area protection in indoor locations, as well as portable smoke alarms.

- **ANSI/UL 268, SMOKE DETECTORS FOR FIRE ALARM SYSTEMS**: UL 268 establishes requirements for smoke detectors and accessories, such as releasing device controls like electromagnetic door holders and fire and smoke dampers, in accordance with NFPA 72.

- **ANSI/UL 639, STANDARD FOR INTRUSION-DETECTION UNITS**: Another UL Standard, UL 639 addresses the performance of intrusion-detection units intended to be used in burglary-protection signaling systems.

- **ANSI/UL 1434, STANDARD FOR THERMISTOR-TYPE DEVICES**: This UL Standard covers thermistor-type devices that may be used as temperature sensors for various products.

- **ANSI/UL 1484, STANDARD FOR RESIDENTIAL GAS DETECTORS**: This UL Standard covers electrically-operated gas detectors intended for installation in residential occupancies and recreational vehicles.

- **ANSI/UL 2075, STANDARD FOR GAS AND VAPOR DETECTORS AND SENSORS**: This UL Standard covers toxic and combustible gas and vapor detectors and sensors intended for portable, indoor or outdoor use.

Absent from these lists are standards specifically applicable to the newer and more complex sensors used in connected lighting products. Without the availability of such standards, individual sensor manufacturers are left to develop new sensors based on proprietary technical specifications and protocols. This approach may help to support technical innovation and strengthen first-to-market advantages, but it does little to promote sensor-enabled connected lighting technology in general since it introduces new challenges concerning compatibility, interoperability and interchangeability.
SPECIFIC AREAS FOR FUTURE SENSOR PERFORMANCE STANDARDIZATION

Sensor standards development will become increasingly necessary as the marketplace depends more and more on the performance of sensors. It must focus on more than just the safety performance of detector-type sensor technology. Indeed, as the market for connected lighting products expands, buyers and specifiers will be concerned about a broader range of sensor-specific issues, including battery life, functional integration, performance and reliability, and vulnerability to cyberattacks. Increased marketplace reliance on sensors to achieve results can be expected. Therefore, future standards development activities will need to take a more holistic approach in addressing technical requirements for sensors for connected lighting products, evaluating sensors in the context of system-wide integration.

SOME SPECIFIC PERFORMANCE EXPECTATIONS TO BE CONSIDERED IN THE DEVELOPMENT OF NEW STANDARDS FOR SENSORS USED IN CONNECTED LIGHTING PRODUCTS INCLUDE:

- **ENERGY ECONOMY:** Many sensors rely on batteries or wireless charging technologies to provide a backup energy source in cases where a primary source of energy is unavailable, (e.g. a power outage), or to provide developers with maximum flexibility regarding their installation and use. Sensor designs that have low power demands can support their continued operation for extended periods, reducing maintenance and unanticipated downtime.

- **INTEROPERABILITY:** The seamless interoperability of individual and bundled sensors is essential for their effective deployment in connected lighting products. Interoperability is facilitated by the adoption of non-proprietary industry communications standards and protocols, along with product designs that foster easy performance and physical integration with connected lighting systems and other smart infrastructure systems.

- **INTERCHANGEABILITY:** Because many advanced lighting products and luminaires can have a useful life of fifteen years or more, the adoption of standardized sensor interfaces will support the ability to continually upgrade lighting system performance to keep pace with new and more advanced sensor technologies. Over time, sensor interchangeability can also help foster the more widespread use of connected lighting systems, increasing their value.

- **SPECTRUM EFFICIENCY:** Commercial and industrial settings equipped with smart technologies may have dozens of different connected systems, devices and applications operating simultaneously, potentially increasing the risk of interference in wireless spectrum such as what might be used for street lighting. Therefore, sensor devices designed for use in connected lighting products will need to make the most efficient use of available spectrum to minimize the risk of interference with other connected devices.

- **SECURITY AND PRIVACY:** Like all connected technologies, sensors are potentially vulnerable to hacking and other forms of cyberattack, originating from both external sources as well as other connected systems and components. As such, sensors in connected lighting products must be rigorously evaluated and tested for cybersecurity vulnerability.

- **PARAMETRIC MEASUREMENT ACCURACY AND PERFORMANCE:** Last but not least, sensors should be evaluated against industry and other stakeholder standardized accuracy and performance metrics to enable pre-selection for an intended application, simplify installation calibration and commissioning, and increase expected and actual consistency in operational accuracy and reliability.
UL’S ROLE IN THE DEVELOPMENT OF
STANDARDS FOR CONNECTED PRODUCTS

From the earliest beginnings of the Internet of Things (IoT), UL has been actively engaged in supporting the development and widespread deployment of smart technologies that make up the IoT ecosystem, including sensors. UL technical experts serve in key standards development efforts, including those addressing lighting system and component safety, power, control, compatibility and interoperability. UL staff participate in numerous domestic and international technical fora, including most notably committees and working groups involved in the development of standards for IoT technologies.

In addition to standards development activities, UL is an authorized and experienced IoT testing laboratory for the NFC Forum, the Wi-Fi Alliance, the Power Matters Alliance and the Thread Group. UL provides Bluetooth compatibility and performance testing services for the leading automotive companies, and wireless device producers and carriers. And near its Fremont, CA laboratories that provide numerous IoT-related services, UL has a real-world lab in a suburban home to observe how IoT devices communicate with one another, and to evaluate and resolve any interoperability issues which may arise.

Addressing a potential impediment to the ubiquitous deployment of IoT, UL has developed a first-of-its-kind Cybersecurity Assurance Program (CAP) that takes a holistic approach in mitigating cybersecurity risks in connected products and components. In accordance with newly-developed UL Standards, the CAP evaluates both product-specific and systemic preparedness for cyber threats. This approach can help to minimize the vulnerability of sensors and other connected technologies to cyberattacks, and provide device manufacturers with greater assurances regarding the performance and security of their products.

Overall, this broad involvement in the development of Standards and testing of sensors and IoT components complements and informs UL’s comprehensive portfolio of Standards and testing services. Taking what it knows about evaluation and testing for safety, performance, usability and sustainability, UL is seeking to be a catalyst for raising the standards bar for lighting sensor technologies so that the sensors our world will soon be relying upon provide the optimized, reliable and resilient performance we all will come to expect.
SUMMARY + CONCLUSION

Sensor-enabled connected lighting products and those that serve as a platform for other building and infrastructure systems will be significant contributors to the advancement of smart cities, industry and homes. However, to maximize their potential, there is a critical need for the development of standards for these applications that address performance, reliability, compatibility, interoperability and interchangeability, among other considerations. UL is actively working with the lighting and other industries, professional associations and other organizations involved in driving the adoption of IoT technologies. One of UL’s objectives is to facilitate the development of comprehensive, stakeholder-supported, lighting-specific sensor Standards that will bring consistency and predictability to sensor performance, and that will contribute to the continued growth in the deployment of connected lighting products and systems.

For more information about the evaluation of sensors in connected lighting products, and UL’s ongoing contributions to the development of sensor Standards and protocols, visit WWW.UL.COM/LIGHTING, or contact LIGHTINGINFO@UL.COM.


