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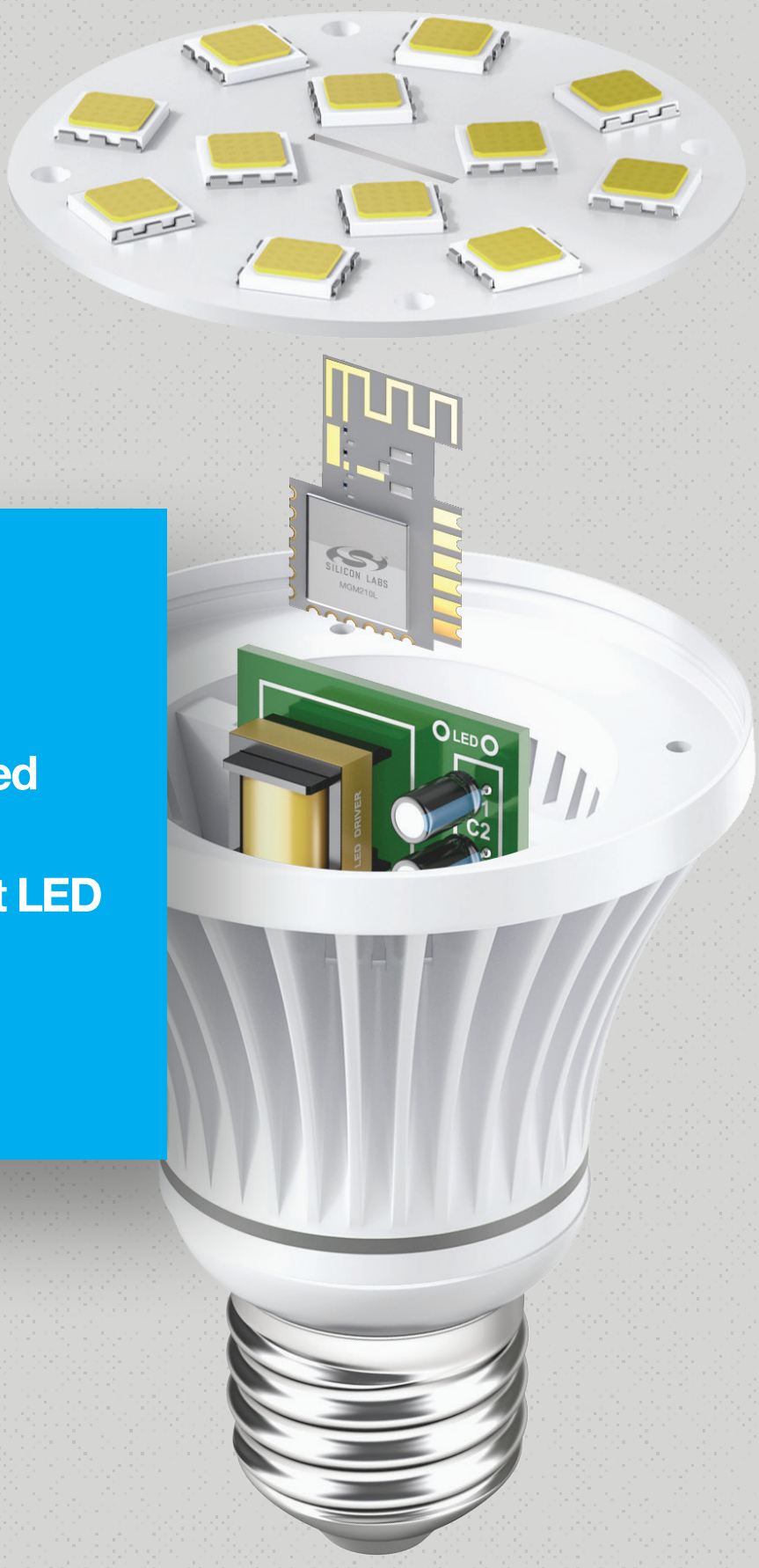

Whitepaper

Application-Optimized Wireless Modules: A Bright Idea for Smart LED Bulb Designs

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Introduction

Light-emitting diode (LED) bulbs are the greatest advancement in lighting since the advent of the first commercially viable incandescent bulb 140 years ago. The benefits of LED lights are myriad and well-documented. They typically use 75 percent less energy than equivalent, modern-day incandescent bulbs and can last more than 50 times longer. Today's LED bulbs are a vast enhancement over their predecessors. They generate minimal heat, don't emit ultraviolet or infrared radiation, contain no mercury, are shock-resistant and operate effectively in extreme environments.

The next wave in the lighting revolution is upon us: *Smart connected lighting*. Adding wireless connectivity and networking capabilities to LED bulbs opens opportunities to do much more than simple on/off functionality. You can adjust brightness, color temperature and timing through simple smartphone apps or voice assistants, and even control lights remotely while traveling. Applications previously unheard of include wireless proximity sensors that trigger smart lights to automatically illuminate hallways and rooms at night as you move through a house or building, bedside lighting that gradually wakes you up in the morning, or hospital lighting that uses color to enhance mood, health and recovery. The convenience and benefits of smart connected lighting are limitless.

Smart lighting is still nascent compared to the scale of traditional lighting, but its adoption rate is steadily increasing in residential, commercial and industrial markets, in part aided through the adoption of green energy incentives and regulation such as California Title 20. Research and Markets forecasts that the global smart lighting market will reach $24 billion (USD) by 2022, a 21 percent compound annual growth rate (CAGR) from 2018-2023.

As more "things" get connected and consumers embrace smart home technology, the acceptance and demand for smart connected lighting will continue to grow. This is why Acuity Brands, Cree, Eaton, GE Lighting, Philips/Signify, Osram and many other top lighting brands are racing to deliver not only smart LED products but also complete lighting ecosystems that are easy to deploy, are interoperable, secure and upgradable.

Smart LED Bulb Design Challenges

Enabling wireless connectivity in LED bulbs in a cost-effective way introduces a new set of design and implementation challenges for lighting OEMs. For instance, smart LED bulbs must meet stringent RF regulatory requirements, demanding energy efficiency standards, high temperature ratings, and rigorous product form factors and space constraints. Lighting developers also must consider device and network security and ensure that smart LED bulbs are as secure from malicious hacking as any other connected IoT product.

Another critical design consideration is the choice of wireless protocols. Many connected lights operate in the 2.4 GHz frequency band and use one of several popular standards-based, short-range wireless protocols such as Zigbee, Bluetooth Low Energy (LE), Bluetooth mesh or Wi-Fi. The use of standards-based protocols helps enable interactivity with common consumer products such as voice assistants, smart phones and tablets without the need for additional network infrastructure products that enable custom gateways. Some smart LED designs may require multiprotocol connectivity – for example, the ability to support Bluetooth LE for device setup and control as well as access to a multi-node, Zigbee-based lighting mesh network through a gateway.

Whether to choose a proprietary wireless protocol over a standard like Bluetooth or Zigbee is also an option. While proprietary may be easy and cost-effective to implement in the short term, this choice can pose longer term challenges of interoperability and upgradability. Standards-based wireless solutions drive higher volumes and thus can be a more cost-effective choice in the long run. Choosing the right wireless technology and vendor from the many options available requires a deep understanding of RF design and performance tradeoffs and risks.

Smart LED designs must also satisfy wireless standard and regulatory performance requirements, such as electromagnetic (EM) emissions and energy consumption, that are not required by traditional lighting products.

Implementation Challenges

To bring a new smart LED product to market, lighting OEMs also face several implementation challenges that involve both engineering and operations resources:

- Develop expertise and allocate resources to conduct and successfully complete standards and regulatory certification testing, such as FCC and CE certifications.
- Consider options for ensuring upgradability of product features and security once the product is deployed in the field, typically through over-the-air (OTA) updates.
- Manage the procurement of materials and inventory of multiple components.
- Verify interoperability with other wireless IoT products and ecosystems in the smart home or smart building.
- Optimize bill of materials (BOM) and development costs to deliver a cost-competitive product while meeting tight production schedules and accelerating time-to-market.

Easing Design and Implementation Challenges with Module Solutions

While adding wireless connectivity to an LED bulb can be a daunting task for a developer with minimal RF experience and expertise, pre-certified wireless module solutions are now available to simplify the task of smart LED product design, minimizing many of the challenges facing lighting OEMs.

A wireless module is designed to provide an all-inclusive, plug-and-play solution that integrates the key components a developer needs to complete the connectivity portion of an LED design. The hard RF-centric tasks of antenna design, impedance matching, tuning and integration of passive components, and protocol development are already completed by the module supplier. This engineering and integration work are huge benefits for OEMs that may lack the necessary RF or protocol expertise in-house. In addition, a wireless module usually ships with all necessary software including the chosen protocol stacks. Module vendors also provide easy-to-use development tools to support and simplify the design and debugging process.

By using a wireless module in an LED design, the lighting OEM does not need to worry about managing procurement and inventories of multiple RF components such as antennas, crystal oscillators and passives. Moreover, the same module can also be used in multiple lighting products, further simplifying procurement and inventory management.

Choosing the Right Module Solution

When evaluating module options for an LED design, lighting OEMs should look for solutions that are purpose-built for the specific requirements of connected lighting applications.

The MGM210L and BGM210L modules from Silicon Labs, for example, are among the first application-optimized module products available for the lighting market. The MGM210L module supports Zigbee and Thread, as well as dynamic

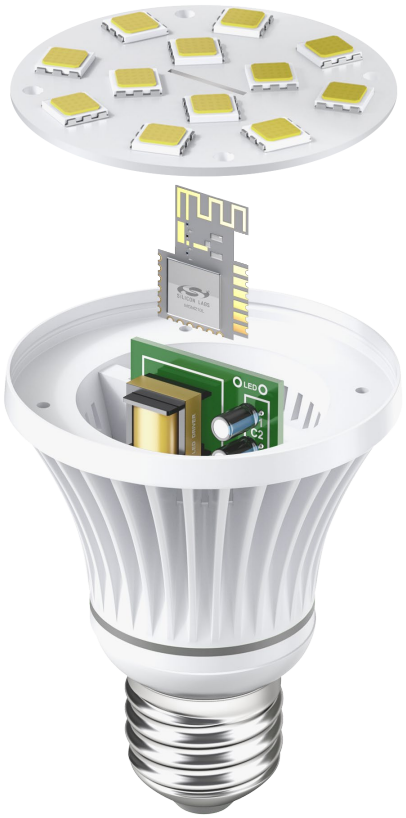
multiprotocol connectivity (e.g., Zigbee plus Bluetooth LE). The BGM210L is designed for Bluetooth LE or Bluetooth mesh networking. These two new modules are designed to simplify and accelerate development of feature-rich, color-selectable and dimmable LED lights, while enabling developers to make use of Bluetooth, Zigbee and Thread-based mesh ecosystems.

The xGM210L modules are based on the Silicon Labs Series 2 EFR32xG21 wireless system-on-chip (SoC) device featuring a peripheral set optimized for lighting applications. The SoC includes a low-power Arm® Cortex®-M33 processor core; ample memory to support dynamic multiprotocol operation and OTA firmware updates to ensure future-proofing of smart lighting products; and a high-performance 2.4 GHz RF transceiver capable of supporting 802.15.4 and Bluetooth mesh protocols as well as Bluetooth Low Energy (LE). The radio handles the wireless networking functions through either single protocol or multiprotocol connectivity. An integrated RF power amplifier also enables the xGM210L module to handle long-range applications requiring hundreds of meters of line-of-sight connectivity.

Energy-efficient modules like the xGM210L devices offer low active power consumption levels optimized to meet California's Title 20 appliance efficiency regulation. Many lighting products shipping into the US market must comply with CA Title 20, which requires manufacturer certification of lighting control devices.

Module solutions can help lighting OEMs reduce R&D cycles related to RF design, protocol optimization and regulatory certification. Pre-certified for use in North America (FCC and ISED), Europe (CE), Korea and Japan, the xGM210L modules are designed to minimize the time, cost and risk factors associated with global wireless certifications, enabling lighting OEMs to accelerate time to market by several months.

With manufacturers adding RF connectivity to more LED products, small-form-factor bulb designs pose complex size, power and heat dissipation constraints that existing wireless solutions cannot easily address. The xGM210L module is designed to address these constraints. The module's custom printed-circuit board (PCB) form factor (16 mm x 23 mm) fits the tight dimensions of most LED bulb housings. It also has a maximum temperature rating of up to +125°C, ensuring reliable operation in lightbulb housings, which can get hot during prolonged use.



Security is another important consideration for smart LED products. Recent media reports of hackers breaking into smart home networks through LED bulbs have alerted both consumers and lighting developers alike to the critical need for security extending from the bulb itself to the cloud. Lighting OEMs should look for modules that provide built-in hardware security features at no incremental cost, enabling developers to implement robust security in smart LED products.

The xGM210L modules, for example, feature a dedicated security core that isolates the application processor and delivers fast, energy-efficient cryptographic operations, along with differential power analysis (DPA) countermeasures. A NIST and AIS-31-compliant true random number generator (TRNG) strengthens device cryptography. Secure Boot with Root of Trust and Secure Loader (RTSL) technology helps prevent malware injection and rollback to ensure authentic firmware execution and OTA updates. A secure debug interface with a unique lock/unlock capability allows authenticated access for enhanced failure analysis. The module's Arm Cortex-M33 core integrates TrustZone technology, enabling system-wide hardware isolation for trusted software architectures.

A complete module solution should ship with robust wireless software stacks, giving developers a choice of standard protocols such as Zigbee, Thread, Bluetooth mesh and Bluetooth LE. Additionally, the developer should expect comprehensive software support including a robust software development kit (SDK) and advanced tools to help verify network performance and aid in

debugging and to help optimize the performance and energy consumption for smart lighting applications. The xGM210L modules come with a powerful suite of development tools such as a Network Analyzer, an Energy Profiler, and more. The SDK should contain all the libraries needed to implement low-energy operation and all the drivers needed to enable the light bulb to communicate with the network.

Conclusion

There is no question that smart LED bulb products are gaining traction in residential, commercial and industrial markets. Comprehensive hardware and software solutions are now available to simplify connected lighting product development. Application-optimized wireless modules are now available to help accelerate time to market, reduce development and certification costs, and resolve many of the wireless design challenges an OEM might face.