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COVER STORY

Smart Buildings: Making Buildings Smarter, Greener, and More Energy-Efficient

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In the future, more and more people will live in cities. The United Nations predicts that by 2022, 56% percent of the world's population will be urban dwellers; by 2050, the total is set to rise to 68%. This means that existing resources have to be used more efficiently, and overall energy consumption and carbon dioxide emissions have to be reduced.

Buildings can play a decisive role in solving this challenge. In the European Union alone, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. At the same time, 75% of the existing building stock in the EU has been assessed as energy-inefficient. Clearly, there is huge potential for improving energy efficiency in buildings.

As a result, the European Union has agreed on a new set of rules for its Energy Performance of Buildings directive, which requires that EU members ratify national policies to improve energy efficiency in the building sector.

The directive specifies smart-building technology as a key element for reaching this goal. Having proved their benefits in Industry 4.0, smart sensors and technologies are now being used in building automation. Intelligent building automation and control systems can significantly increase the efficiency of a building's operation by leveraging sensor-based data insights. A Smart Readiness Indicator for buildings is also being developed. The indicator will rate a building's capacity to use new technologies and electronic systems in order to reduce energy consumption and emissions and to adapt buildings to the needs of their occupants.

Higher efficiency is not the only benefit that smart buildings deliver. Intelligently placed sensors and actuators can continuously monitor and adjust air quality and lighting settings, guaranteeing optimal working environments, increasing productivity, and maximizing occupants' comfort.

The Edge, in Amsterdam, is a prime example of how smart technology is already cutting costs and increasing productivity in buildings. This 40,000-m² office building is equipped with approximately 28,000 sensors that enable the building management system (BMS) to collect information about crucial parameters such as humidity, brightness, and temperature. Based on those parameters, the BMS automatically triggers adjustments in the building's operations, ensuring that heating, ventilation, and air conditioning (HVAC) systems, lighting, and other systems run as effectively as possible. As a result, The Edge consumes 70% less electricity than conventional office buildings, making it one of the most energy-efficient and intelligent structures in the world.

While The Edge is an exception today, smart buildings are definitely on the rise. Recent market research predicts that the market for smart-building devices will double

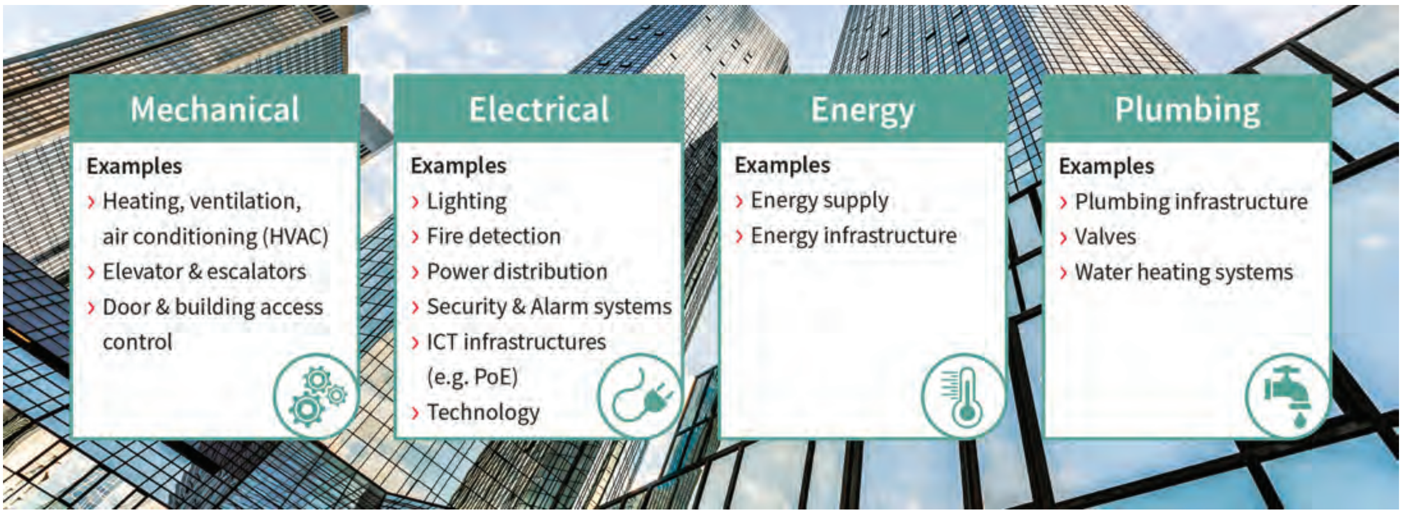


Figure 1: *Elements of a smart building*

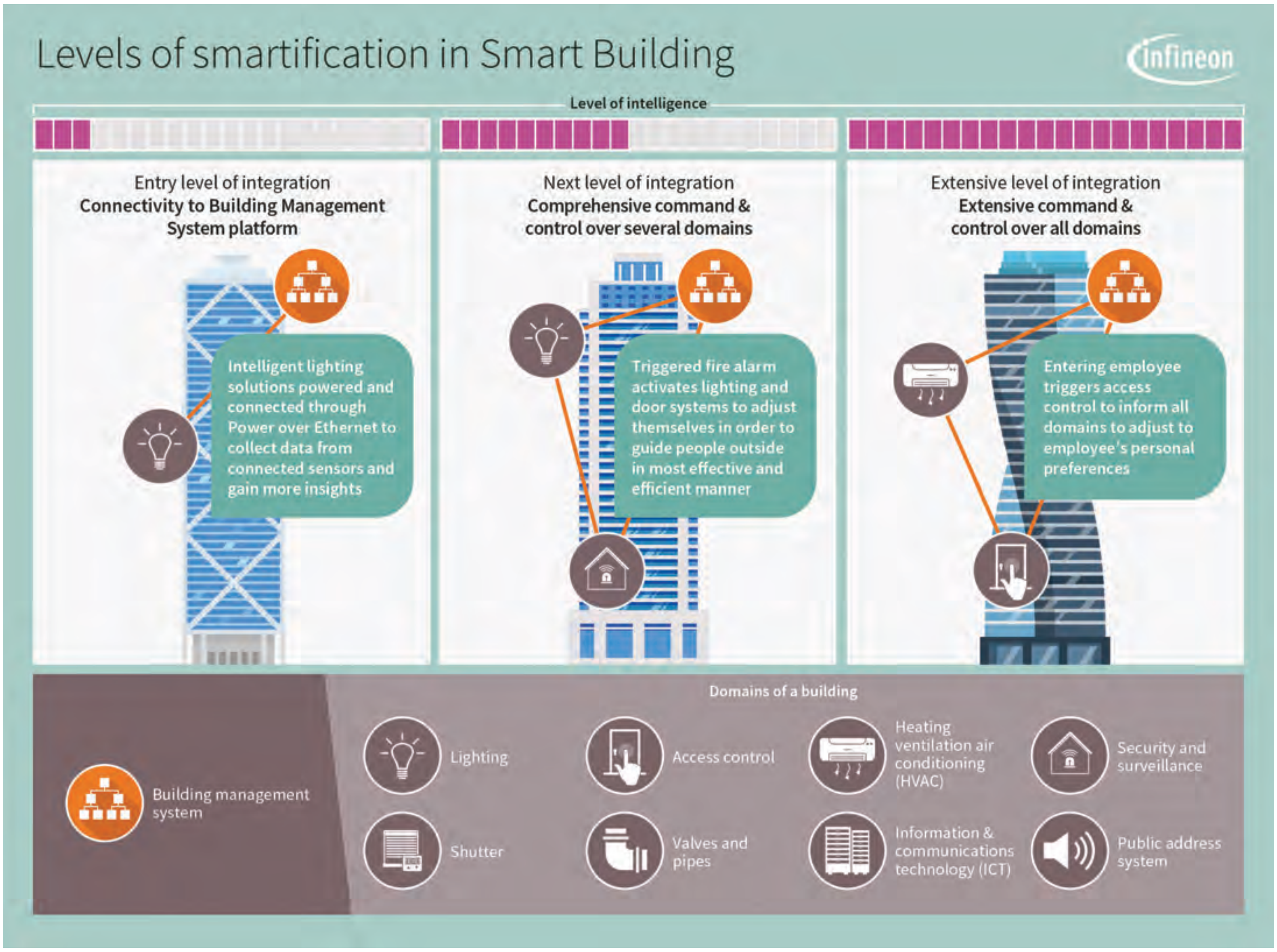


Figure 2: *Levels of smartification in smart buildings*

by 2022 at a compound average growth rate (CAGR) of 16%.

WHAT IS A SMART BUILDING?

Unlike smart homes, smart buildings are non-residential buildings such as office complexes, shopping centers, and hotels. Equipped with sensors that are connected to devices, these buildings can provide in-depth information on consumption levels and make automated decisions to optimize operations.

The smart downlight that Infineon Technologies is slated to showcase at this year's Light + Building trade fair in Frankfurt, Germany, is a prime example. The light combines power and sensor solutions to create powerful insights into building performance. In these systems, the XDPL8221 digital control IC monitors relevant error conditions such as undervoltage, overvoltage, open load, or output short at the LED driver. A 24-GHz radar sensor enables presence detection and counts occupants, allowing the system to dim the lights and save energy when a space is unoccupied. The sensor can also send this data to the BMS and the building operator for further analysis and building system optimization.

Following a more abstract version of "sense, compute, actuate," an array of connected sensors collects environmental information and data about a building's operations and usage. This information can either be processed at the edge (edge computing) or sent to a central BMS running locally or in the cloud. The information is then used to trigger automated actions that adjust HVAC systems, lighting systems, shutters, and many other devices inside a building.

Buildings can thus be "smartified" by using sensors, actuators, and control units to cross-connect domains (**Figure 1**). With connectivity providing the skeleton for the smartification of a building, the actual devices and control units form the muscles and the brain of the building.

This interplay of smart components enables ventilation, for example, to be controlled based on indoor air quality (IAQ) and CO_2 levels in rooms. Lighting can also be automatically adjusted based on the presence of people and additional factors such as indoor brightness. This can significantly cut energy consumption while improving occupants' comfort and well-being.

Buildings can be classified into three smartification levels (**Figure 2**):

- **entry level**, or basic connectivity of individual domains to a building management system;
- **intermediate level**, enabling comprehensive command and control over several integrated domains, including sensor-based data collection; and
- **extensive level**, or extensive command and control over all domains with cross-domain intelligence and actuation.

It goes without saying that today's buildings will not reach the extensive level of smartness overnight. Instead, many small steps are needed. Next, we spotlight two examples — Power over Ethernet (PoE) and Condition Monitoring — to show how buildings can transition to the next level of smartness.

EXAMPLE 1: POE AS CONNECTIVITY BACKBONE

The ability to transfer large amounts of data with high bandwidth between domains and the BMS is a key enabler of smart buildings. Consequently, having a capable and reliable information and communications technology (ICT) infrastructure is the backbone of any smart building.

Internet Protocol (IP)-based network connectivity is already well-established in both industrial and residential applications. It is easy to install and maintain, integrates well with existing platforms, and has an extensive implementation stack spanning both hardware and software. However, Ethernet has one disadvantage: Even though it provides connectivity to devices, power from the electrical grid still needs to be drawn from separate cabling.

With the introduction of the first-generation IEEE Power over Ethernet standard for Type 1 and 2 devices, this challenge was overcome for low-power devices like IP phones and conference systems. With PoE, power-sourcing equipment (PSE) such as a PoE switch is capable of providing power and connectivity along twisted-pair Ethernet cabling for multiple connected powered devices (PDs). As a result, only one physical connection, the Ethernet socket, is required, and it can be handled exclusively by IT experts. This approach also reduces wiring effort and simplifies device management, thereby lowering installation and operation costs.

Until recently, only devices up to 30 W could be powered by PoE, hampering its widespread adoption. With the release of the IEEE 802.3bt standard in September 2018, Type 3 and Type 4 PoE use all four pairs of the twisted-pair Ethernet cabling, increasing the available power per port to 100 W. This has opened the door for PoE in higher-power applications such as PoE-powered 5G small cells, LED luminaires, high-power Wi-Fi access points, and public announcement (PA) systems.

The amendment also addresses overall energy efficiency, with lower standby power consumption and a protocol to manage the available power in a more granular way with power classes. But those provisions pose new challenges in switched-mode power supply (SMPS) designs for PoE devices.

First, up to 100 W per port is added to the PoE switch power budget on the PSE side to fully support the latest standard. To avoid an increase in the form factor required for the SMPS, the power density of the SMPS needs to be scaled up. This means that efficiency, power density, and reliability are key requirements for the main SMPS in PSE designs.

Second, the right semiconductor solutions need to be matched to the respective SMPS topology (e.g., active clamp flyback [ACF] or LLC). Choosing efficient and reliable solutions like Infineon's superjunction CoolMOS™ MOSFETs maximizes available power and extends the lifetime of the devices. Thanks to their high efficiency, energy consumption is also reduced.

Efficiency, cost-effectiveness, and power density all play a crucial role on the isolated DC/DC SMPS converter stage for PDs. Every watt saved by increasing overall SMPS efficiency can be used by the PD itself.

When combined with reliable and efficient semiconductor solutions like Infineon's OptiMOS™ and StrongIRFET™ families for PD SMPS systems or CoolMOS™ for SMPS in PSE, Power over Ethernet plays a crucial role in creating a reliable ICT infrastructure in a smart building. It can also unlock additional cost savings.

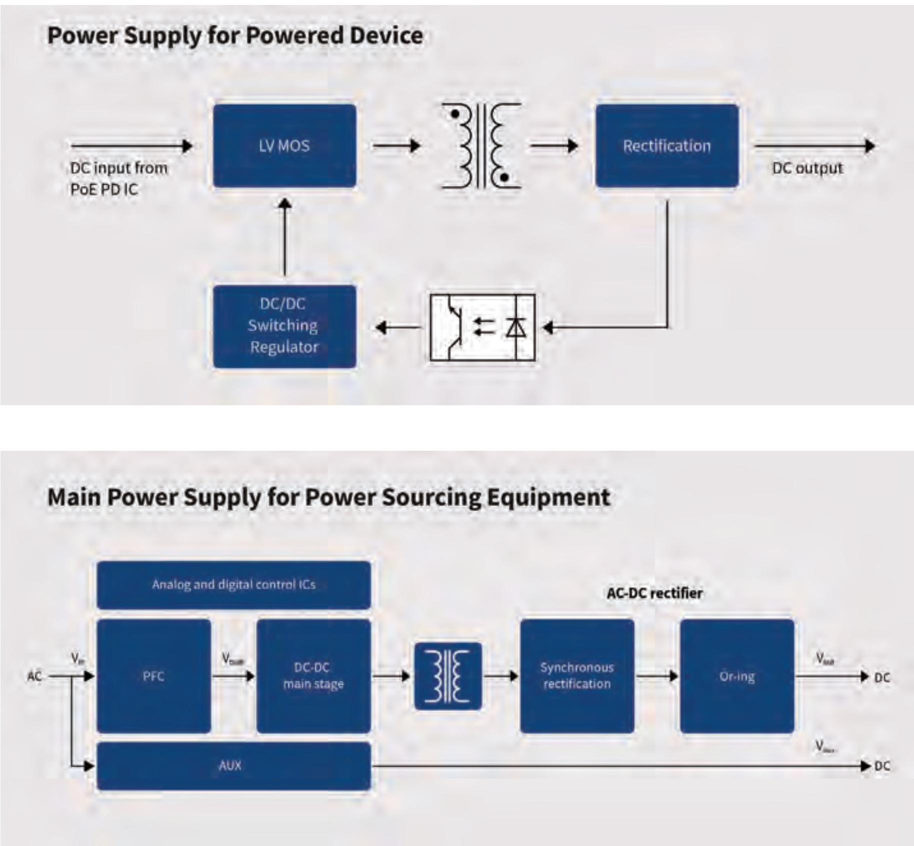


Figure 3: *PDs make use of a generic isolated DC/DC converter solution (top) unless targeting specific applications such as LED lighting. The PSE requires an efficient PFC and low-loss switches using an isolated topology (bottom).*

EXAMPLE 2: CONDITION MONITORING

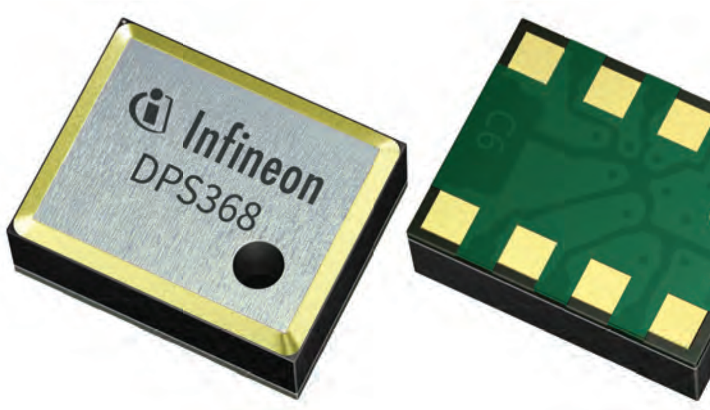
Device and system failures such as broken elevators and air-conditioning units are huge disturbances that can disrupt the smooth operation of a building. In interconnected smart buildings, even small problems can lead to significant disruptions in a building's operation. Building operators are therefore desperately looking for options to monitor the condition of the installed device base and predict failures before they happen.

Sensors play a decisive role in monitoring a device's condition. Placed inside or outside the device, they collect data on the various parameters that reflect its operational status. Examples include airflow monitoring in HVAC devices using barometric air pressure sensors, current flow measurement in motor drives using current sensors and sound anomalies, and vibration measurement using microelectromechanical system (MEMS) microphones. These sensors allow deviations from defined optimal states to be detected in real time.

Predictive maintenance is the next logical step after the implementation of condition monitoring. It can be used to estimate when a device is most likely to fail and trigger proactive maintenance in a timely manner.

This trend was evident at this year's AHR Expo in Orlando, Florida, and is likely to be in the spotlight at Light + Building in Frankfurt.

Having identified this trend, Infineon will showcase an end-to-end demonstrator for condition monitoring and predictive maintenance in HVAC systems at Light + Building. Developed in collaboration with end-to-end IoT and cloud solutions developer Klika Tech and powered by Amazon Web Services (AWS), the demonstrator illustrates the potential of sensors in condition monitoring and predictive



Infineon XENSIV™ DPS368 pressure sensor enables airflow monitoring in HVAC systems. Thanks to its waterproofness and robustness (IPx8), it is well-suited to collect data in rugged environments such as HVAC.

maintenance solutions for smart buildings.

The demonstrator focuses on the key problems of HVAC devices, including airflow measurement. It integrates multiple Infineon products, listed below, to ensure precise and reliable data recording.

Sense:
- XENSIV™ DPS368 barometric pressure sensor
- XENSIV™ TLI4970 current sensor
- XENSIV™ TLV493D-A1B6 3D magnetic sensor
- XENSIV™ BGT24LTR11 24-GHz radar sensor

Compute:
- XMC™ XMC4800 IoT Amazon FreeRTOS connectivity kit

Secure environment:
- OPTIGA™ Trust X

Using devices in Infineon's XENSIV™ sensor portfolio, critical components in an HVAC device such as the compressor, fans, motors, and filters are monitored together with overall system vibrations. The sensors collect data directly at component level. The collected data is pre-processed locally using the XMC™ microcontroller and sent to the AWS cloud for data intelligence and anomaly detection. Embedded hardware security safeguards the entire data flow from the edge to the cloud.

HVAC devices are just one example of a domain in which sensors can enable condition monitoring and predictive maintenance, unlocking added value for building operators, tenants, and device manufacturers. Elevators, valves, and lighting are other critical domains in which application-specific semiconductor solutions and advanced software intelligence can address maintenance problems and provide in-depth insights.

SUMMARY

Next-level building automation requires input from sensors in order to trigger actuators and automatize decisions across all domains. Semiconductor solutions provide the basis of smartification, with sensors, power management ICs, microcontrollers, and security ICs providing the crucial link between the real and the digital worlds. Thanks to advanced technologies and smart connectivity solutions, the buildings of today can be turned into the self-aware, green, intelligent buildings of tomorrow, helping to solve the challenges that urbanization and climate change pose to society. ■