Meeting the Power Challenges of the Smart Building

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January 2019

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Abstract

The trend of automation and data exchange in the smart building continues unabated, relying on new technologies and approaches to achieve higher comfort, reduce carbon footprint, and improve cost. The adoption of these technologies introduces challenges in terms of energy efficiency, miniaturization, and system reliability.

This white paper reviews the challenges for smart building electronic components and presents a few examples of how power management can come to rescue.

Introduction

Smart buildings can have significant energy savings

Buildings—with a carbon footprint even greater than that of the transportation sector—account for a significant portion of the total energy consumption in the United States. The American Architecture 2030 standard recently issued a challenge for all existing buildings to cut energy use by 50% compared with 2005 levels, and for all new buildings to be completely carbon neutral by 2030. In other words, they should supply most of their energy needs using renewable sources. Many large- and medium-sized cities already require commercial building owners to disclose actual green building performance to tenants, buyers, and, in some cases, the public. By utilizing modern control and automation techniques, smart buildings can have significant energy savings, protect the environment, improve the health and safety of its occupants, and enhance quality of life.

Designing for building automation (Figure 1) introduces issues of energy efficiency, solution size, system safety, and reliability of the electronics used. This white paper will review the megatrends underlying the smart building revolution and their associated system challenges, from networking protocols all the way down to the hardware. It then examines new solutions for power management through several case studies.

Figure 1. Building automation.

Megatrends in Building Automation

Building operators increasingly manage larger buildings remotely, using the cloud. Their software platforms provide performance monitoring, data analytics, visualization, fault detection and diagnostics, and portfolio energy management. These automation systems can monitor several variables in real time and analyze historical data to adjust the devices to provide comfort to users while complying with government regulations and tariff policies. By networking the equipment data to the cloud, analytics can be run in real-time using advances in artificial intelligence (AI) to determine the action to be taken. The most prevalent use of automation in buildings is in HVAC (heating/ventilation/air conditioning), lighting, monitoring, access control, fire detection, and surveillance using CCTV (closed circuit television).

A building's energy is measured by energy use intensity (EUI) and is noted in kilo British thermal units per square foot (KBTU/SF). One KBTU equals 3.142kWh.

The Building Automation System

Building automation system architecture (Figure 2) includes different layers for management, control, and the field.

The management layer operates and controls the smart building from one central location, recording and optimizing data as necessary. Problems are spotted in real time and action can be taken immediately. This layer uses network protocols like BACnet and Modbus.

The control layer (the building automation block shown in Figure 2) deals specifically with the building's equipment control at the hardware level. Here decentralized protocols like KNX and LonWorks are used.

At the field layer, intelligent sensors and actuators collect data and perform tasks. For example, the lighting level is sensed and automatically adjusted to match the time of day. Shading is provided to ensure optimal use of natural light without glare.

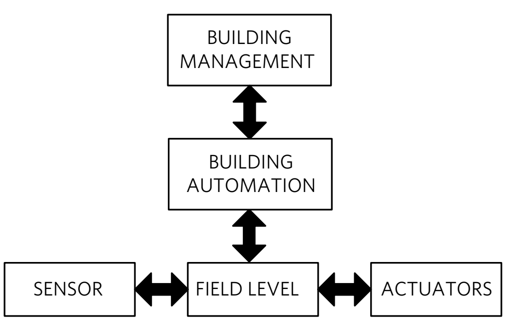

Figure 2. Smart building system.

The Technology Enablers

All this intelligence, networking, and control is enabled by phenomenal advances in hardware and software. At the field level, it is manifested through controllers, sensors, I/Os, and actuators. A controller can be a programmable logic controller (PLC), motor/motion controller, or a distributed control system (DCS) using advanced processors and microcontrollers. Sensors can be either digital or analog and used to measure temperature, humidity, ventilation, and occupancy. Actuators can be used in locks, window alarms, security camera positioning, solar panels, blinds, and other moving mechanisms. In a modern building, sensors and actuators can communicate on wire or wireless gateways to the control center. They are powered by batteries or wired DC voltages, typically in the 5V to 24V+ range. In Figure 3, the wireless sensors connect to the monitoring system via a gateway to detect the humidity, HVAC, and temperature.

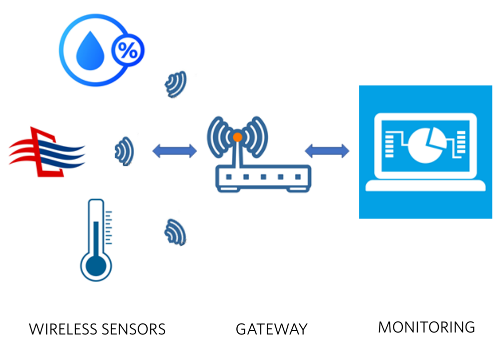

Figure 3. Wireless sensors at work.

Sensors and actuators can communicate on wire or wireless to the control center

It is crucial that the power-supply solution is extremely efficient while delivering higher power and occupying a smaller area than ever before

The controller receives inputs from sensors on the field, processes them, and drives the proper actuators. Today's sensors and actuators are equipped with internal processors that make simple decisions locally without the need to escalate to the controller, thereby improving throughput.

The Challenges

The proliferation of intelligent, internet-connected equipment in the smart building requires a proliferation of processors and connectivity interfaces into every controller, sensor, and actuator in the field. This, in turn, places new requirements on system hardware: reduced component size to fit additional electronics in the same chassis, improved energy efficiency to perform within the same or lower thermal budget and increased electrical/mechanical safety and reliability to reduce downtime. In summary, the challenges for the electronic components are:

1. Higher Energy Efficiency
2. Reduced Solution Size
3. Increased Safety and Reliability

In the following sections, we will present a few examples of how power management electronics can come to the rescue in each case.

The Solutions

High Energy Efficiency

The smaller PCB size that results from miniaturization presents a challenge for thermal dissipation. Thermal management options, such as heatsinks, are ruled out since board space is at a premium. Fans for forced airflow cannot be used due to sealed enclosures that prevent ingress of dust and pollutants. Therefore, it is crucial that the power-supply solution is extremely efficient, while delivering higher power and occupying a smaller area than ever before.

Often sensor and actuator applications are characterized by a 24V nominal DC voltage bus that has its history in old analog relays and remains the de-facto industry standard. However, the maximum operating voltage for industrial applications is expected to be 36V to 40V for non-critical equipment, while critical equipment, such as controllers, actuators, and safety modules, must support 60V (IEC 60664-1 insulation and 61508 SIL standards). Popular output voltages are 3.3V and 5V with currents varying from 10mA in small sensors to tens of amps in motion control, CNC, and PLC applications. Thus, the obvious choice for building and industrial control applications is a step-down (buck) voltage regulator (Figure 4).

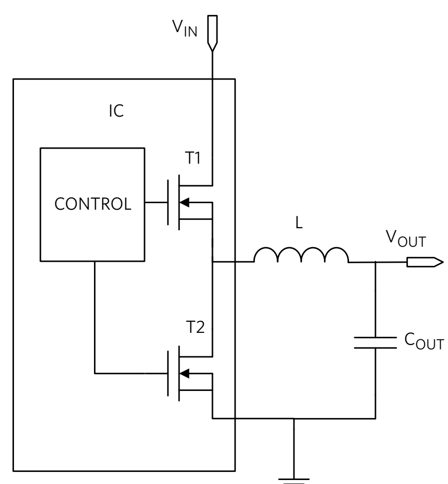

Figure 4. Fully integrated synchronous buck converter.

Buck converters that achieve high efficiency for high-performance systems include the **MAX17574** and **MAX17506** (from the Himalaya IC family) and the **MAX17504** power module (from the Himalaya SiP power family).

A Word of Caution on Maximum Input Voltage

While 24V is the nominal rail for many applications, carefully consider the maximum operating voltage. Select from 28V, 36V, 42V, or 60V input power management solutions that are available on the market today. With a margin of only 4V, clearly 28V is too close to 24V to provide a reliable margin. Many standards require 60V tolerance, removing the need to make a choice. It is tempting for many designers to choose a device with a 36V maximum input. However, using a 36V input is a high-risk approach for sensors and encoders that work on a 24V rail. Even if TVS (transient voltage suppressor) diodes are used for surge protection, they have a wide tolerance and could still expose equipment to excessive voltages. Unless you are certain and have modeled every possible surge scenario resulting from long cables and PCB traces, use devices with a 42V or 60V maximum operating voltage even if the standard does not require it.

Reduced Solution Size

Sensors have become ubiquitous in the smart home environment. In turn, sensor electronics are becoming more complex, requiring on-board voltage regulators to deliver power more efficiently with minimal heat generation. How do you safely deliver low-voltage power to tiny sensors, while minimizing solution size and maximizing efficiency? In this section, we will review a typical sensor architecture and provide a simple solution to this challenge.

Smart Home Sensor Applications

Sensors (Figure 5) detect and diagnose many parameters and make decisions. They must be durable and reliable regardless of the environment.

Figure 5. Temperature and humidity sensor.

Sensors may be located anywhere in the building. The sensor “box” is powered by a voltage regulator, which delivers the appropriate voltage to the ASIC/micro-controller/FPGA, AFE, and the sensing element.

Sensors have become ubiquitous in the smart home environment

Isolation improves functional safety and reliability

Safe Low-Voltage Operation

The sensor is typically powered by a 24V DC power source. However, a building can be a very challenging environment to install sensors, which require long cable connections to the power source that result in high-voltage transients. Accordingly, the step-down converter inside the sensor must withstand voltage transients of 42V or 60V, which are much higher than the sensor operating voltage. As discussed before, for 24V rails, it is best to rely on devices that have an operating maximum of 42V.

Examples of power solutions which meet the requirements of building automation sensors are the **MAX15062** and **MAX15462** (from the Himalaya IC family) and the **MAXM17532** and **MAXM15462** (from the Himalaya uSLIC™ module family).

For higher input voltage operation and/or higher input voltage bus electric noise immunity, use the 60V-rated **MAXM15064** (300mA) or **MAXM17552** (100mA). For lower input voltage operation and/or low electric noise environment, use the 24V-rated **MAXM17903** (300mA) or **MAXM17900** (100mA).

Increased Safety and Reliability: Isolation

Isolated DC-DC voltage regulators are found in the most diverse applications. Although an isolated solution is more complex than a non-isolated one, there is still an expectation for it to fit in a small space and be highly efficient. In this case study, we discuss the reasons for isolation in low-voltage power conversion systems.

Low-Voltage Isolated Systems

According to SELV/FELV regulations, input voltages below 60V are considered inherently safe to touch, but the need for isolation in this operating range is still pervasive for functional safety and reliability reasons. In this voltage range, the power-supply electronic load, typically a very delicate and expensive microcontroller, needs protection. It could readily self-destruct if accidentally exposed to high voltage.

Isolation also prevents ground loops, which occur when two or more circuits share a common return path. Ground loops produce parasitic currents that can disrupt the output-voltage regulation as well as introduce galvanic corrosion of the conducting traces. This is a phenomenon that degrades equipment reliability.

As an example, the patented **MAX17690** (Figure 6) is a peak current-mode, fixed-frequency switching controller, part of our Rainier family of isolated "Bye Bye Optocoupler" solutions. It is specifically designed for the isolated flyback topology operating in discontinuous conduction mode (DCM).

Increased Safety and Reliability: Protection

Protection circuits are the unsung heroes of today's electronics. The long electrical chain, from the AC line to the digital load, no matter the application, is interspersed with fuses and transient voltage suppressors of all sizes and shapes. While common issues like ESD protection and pin-to-pin short circuits are handled within ICs, there are additional aspects to

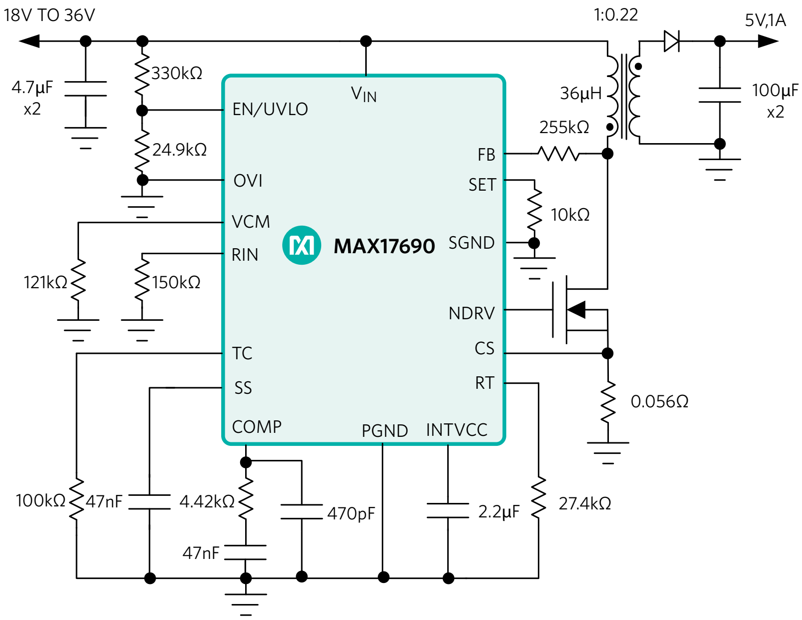

Figure 6. No-opto flyback controller.

Protection electronics must handle fault conditions

consider for safety and reliability. Along the electrical path, electrical stressors—such as inrush currents due to storage capacitors, reverse currents due to power outages, overvoltages, and undervoltages induced by inductive load switching or lightning—can damage precious electronic loads.

This is true for microprocessors and memories, which are built with fragile sub-micron, low-voltage technologies. Layers of protection are necessary to handle these potentially catastrophic events (Figure 7).

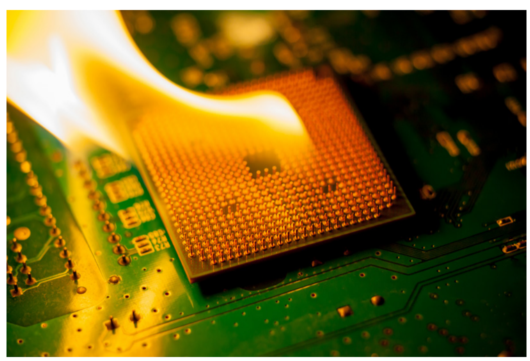

Figure 7. Unprotected CPU on fire.

Protection electronics must handle fault conditions such as overvoltage/undervoltage, overcurrent, and reverse-current flow within the limits of its voltage and current rating. If the expected voltage surge exceeds the protection electronics ratings, additional layers of protection are added, in the form of filters and TVS devices.

Integrated Solution

Figure 8 shows an integrated protection circuit that addresses overvoltage, reverse polarity, current limiting, reverse current, and short-circuit protection with all the benefits of an e-fuse and surge stopper. Designers can easily implement robust protection in their smart building equipment and pass compliance with configurable pins to set UVLO/OVLO, current limit, real-time voltage, and current monitoring, current thermal foldback, thermal shutdown, and other features.

The highly integrated protection IC **MAX17523** from the Olympus protection family is a candidate for this application.

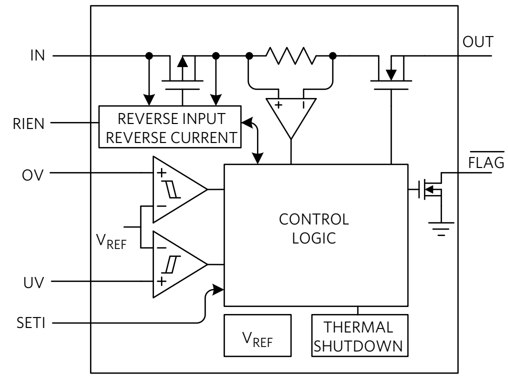

Figure 8. Integrated protection in a single IC.

Summary

As the current trend of automation and data exchange in the smart building continues unabated, it will rely on new technologies and approaches to achieve higher comfort, lower carbon footprint, and improved cost. The adoption of these technologies introduces challenges in terms of energy efficiency, miniaturization, and system reliability. For each challenge discussed, a few power management ICs were presented to help designers realize better building automation systems. These power management solutions overcome the critical challenges faced by today's smart buildings.

Related Resource

Power Management for the Smart Building Design Guide

Learn more

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www.maximintegrated.com/smartbuilding