


Meeting the Efficiency and Power Dissipation Needs of Space-Constrained Applications

Tiny Himalaya uSLIC™ Power Modules Enable a New Frontier of Component Miniaturization

By Thong "Anthony" Huynh, Principal MTS, Industrial Power Applications, and Anil Telikepalli, Executive Director, Industrial & Healthcare Business Unit

March 2018

Abstract

Electronic equipment used in our factories, buildings, and an array of other applications is getting smarter and also smaller. Shrinking space and thermal budgets are driving the miniaturization of components. This presents a challenge for analog ICs and, in particular, the power management components that are challenging to shrink. This paper examines a new type of power solution that consumes little board space and provides low power dissipation while delivering high efficiency.

Introduction

New Breed of Power Solutions Addresses Shrinking System Size

Electronic equipment increasingly needs miniaturized components

Artificial intelligence, IoT, and machine learning are already influencing our everyday lives and are expected to make a remarkable impact on electronics used in applications ranging from industrial and defense to communications, medical, and consumer. Electronic equipment needs to collect, synthesize, and act upon data – this intelligence requires more power in a reduced space and thermal budget, making conventional solutions unviable and complicated. With dramatic advances in sensing, connectivity, and cloud computing, miniaturization of components is the next frontier. While digital ICs have moved to increasingly smaller process nodes to shrink the size, it is not easy to shrink analog ICs, especially power management components that take up a significant area of the PCB. Thanks to recent advances in architecture, process, and packaging technology, a new breed of power solutions has emerged to address this. This paper will discuss how these power solutions provide high efficiency and low power dissipation in a tiny form factor without compromising reliability.

Market Trends

Let us consider the latest developments in popular applications.

Factory Automation

Take the example of factory automation and the trend toward smart factories (also called Industry 4.0). Operators make money when the factory has high utilization and throughput. This translates to reducing downtime by minimizing failures, eliminating manufacturing inefficiencies by streamlining processes, and enhancing utilization by reconfiguring equipment to build diverse products on the same line.

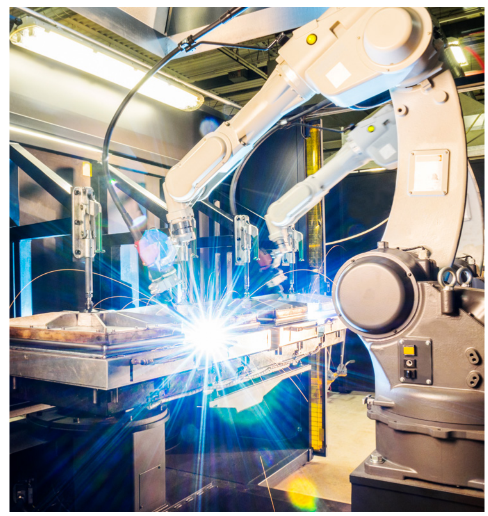

Figure 1. Factory automation

A smart factory requires sophisticated real-time data–this means every intelligent system has high-performance ICs that demand more power. These include sensors and I/O, motors, encoders, actuators, CNC, and PLC controllers, all of which need to be very small and power efficient. Power ICs used in these systems need to be small, efficient, and robust, not to mention tolerant of drops, shock, and vibration.

Smart Cities - Building Automation and Electrification

Cities are seeing a phenomenal population migration—some Asian cities grew 2x in five years! With high-density dwellings and offices resulting in high energy usage, policymakers have established incentives and penalties to encourage energy conservation and efficient delivery. According to the American Council for an Energy-Efficient Economy, smart building automation can save up to 18% in energy. By deploying temperature, light, occupancy, and air quality sensors, operators can control optimal airflow dynamically and make heating, ventilation, and air conditioning (HVAC) more efficient. Cameras, access control, parking, and elevators help rapidly move people in and out of buildings, while sensors help respond to fire and safety hazards.

Automated lighting and fans provide comfort. Increasingly, IoT sensors, I/O, and controllers that demand small-size power solutions are used.

Consider electrification–including the steps of generation, transmission, and distribution. A significant amount of energy is lost due to faults, load shedding, and inefficient grid operation. This has led to distributed control systems (DCS), remote terminal units (RTUs), arc fault detectors (AFDs), circuit breakers, contacts, etc. Additional deployment of sensors and increased intelligence across the grid can help make the electrification process more efficient. This approach has led to the addition of microcontrollers and signal chain components to existing equipment. Requirements for small size and efficient power management are creating demand for power management ICs that are not only small and efficient but compliant to electromagnetic interference (EMI) standards.

Communications, Cloud, and Data Center

Advances in processing and network infrastructure have led to more and more enterprises using centralized data centers on a subscription model rather than

Figure 2. Building automation and electrification

captive servers. This has paved the way to new business models and new data center architectures that not only include dynamic monitoring and classification of traffic but also real-time analytics. This requires advanced processing engines and, on average, a 10x increase in power density. When you look at the power architecture, not only are new intermediate rails like 48V being deployed, but numerous "tiny" housekeeping supplies and a plethora of sensors and data converters are being used in highly space-constrained boards. In addition, meeting EMC compliance testing is critical.

Consumer Devices

Most people can readily associate with smartphones that have led the revolution to thin-profile electronics. Driven by this, other audio/video equipment like headphones and virtual reality devices, gaming, and entertainment gadgets have become at least 2x smaller while still being packed with Bluetooth® (BLE) functionality, Li-ion rechargeable batteries, and miniature power supplies. Other examples include fitness electronics like wrist bands, watches, rings, belts, and others that all use optical or other sensors and need ultra-small power management solutions that can even be mounted on flexible PCBs. Beyond size, immunity to drop and shock is critical for power management ICs.

Medical: Clinical and Wearables

Beyond clinical and hospital environments, untethering patients from wires and bulky diagnostic and monitoring equipment has led to the adoption of modern electronics that leverage the size revolution of consumer devices combined with the reliability and robustness of industrial equipment. Today, a cardiac or diabetic patient can be remotely monitored with minimally invasive wearables. Invisible assisted devices like hearing aids and vision rectifiers along with diagnostic devices like SpO2, hydration, and blood pressure monitors are all driving the need for ultra-small power management solutions. With several of these wearables used in $20mm^2$ or smaller casing area, it is indeed critical to have small sizes without sacrificing efficiency and battery life.

Powering all of the above devices requires small size and high-efficiency power management solutions. To fit these solutions into small enclosures that are deployed in harsh mechanical, electrical, and thermal environments, designers also need shock and vibration tolerance, EMI compliance, and high temperature operation–a multidimensional challenge.

Intelligent Sensors

Since sensors are key to many of the market trends above, let's discuss why everyone is clamoring for intelligence in IoT sensors. Goals of reducing downtime, improving efficiency, and gathering data to enable new business models are driving the intelligence being added to sensors.

Figure 3. Intelligent sensors

Reduce Equipment Downtime

When there is an abnormal operating situation, the system reports an error because the equipment has stopped working, but it does not deliver detailed analysis. Equipment downtime can last several hours to days until the maintenance crew figures out where the problem lies, which can be costly. With an intelligent sensor, on the other hand, the abnormal area can be identified in real time and fixed. The maintenance person can resolve the failure much faster.

Improve Setup and Changeover Efficiency

During system startup or changeover, operators must perform I/O check for each of the thousands of sensors installed on the line. Checking for individual sensor IDs and status one-by-one will take an enormous amount of time and reduce system changeover efficiency. With smart, connected sensors, the operator can check individual sensor identification code in batches remotely, resulting in a sharp reduction of commissioning time.

Design Requirements/ Challenges

As previously discussed, smart equipment comes with many benefits, but they also pose some hardware design challenges. More intelligence means more circuitry, thus requiring more power, higher integration, and increased complexity to fit everything into a limited device space. Small space requirements also mean tougher thermal management, requiring a power solution that is highly efficient.

Increased complexity requires more design time. Traditional discrete solutions lead to complicated and less efficient designs. The high temperature rise and large solution size of a traditional power supply limits how system designers can build more innovation and integration into their products. Products, as a result, face a longer time to market.

New Power Modules Meet the Demands

Maxim's new high-efficiency Himalaya uSLIC power module family with integrated inductor significantly reduces solution size, temperature rise, and time to market.

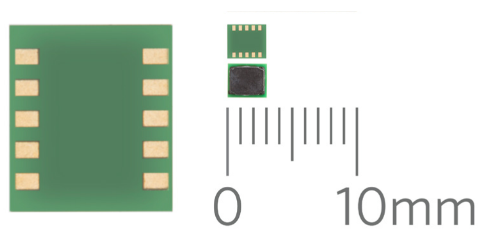

Figure 4. MAXM17532 Himalaya uSLIC power module

The MAXM17532 is a 4V to 42V input step-down DC-DC power module which integrates a controller, MOSFETs, an inductor, as well as the compensation components. It supports an adjustable output voltage from 0.9V to 5.5V and supplies up to 100mA of load current. The high level of integration significantly reduces size, design complexity, and manufacturing risks and offers a true "plug-and-play" power supply solution packed in a thermally enhanced, tiny 10-pin 2.6mm x 3mm x 1.5mm package. MAXM15462 is another member of the

Traditional power supplies limit innovation and integration

Himalaya uSLIC family that operates from 4.5V to 42V input and supports output voltage from 0.9V to 5V, supplying up to 300mA in the same tiny package. More members are expected to be added to this family.

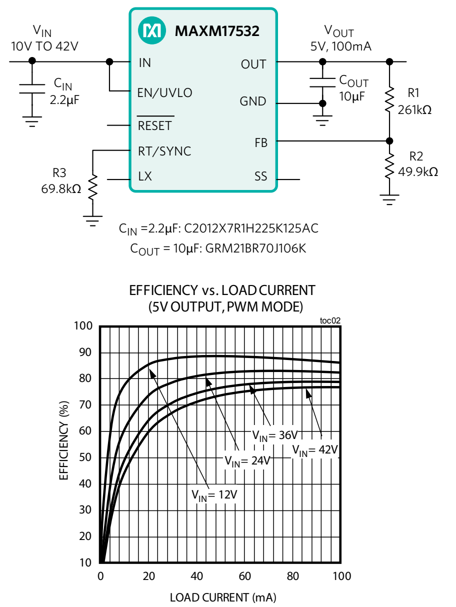

Figure 5. Typical application circuit for MAXM17532 Himalaya uSLIC module

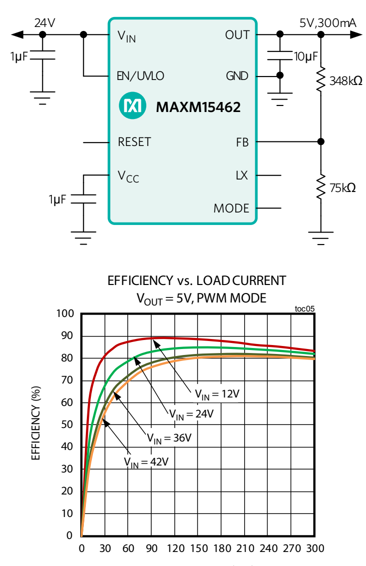

Figure 6. Typical application circuit for MAXM15462 Himalaya uSLIC module

Note that for industrial applications, 42V maximum operating voltage is critical as it supports not only noisy 12V nominal applications, but also popular 24V nominal applications. 36V maximum operating options available in the market with 42V absolute maximum fall short, resulting in system failures and product recalls.

Compared to other available solutions, these power modules carry various key advantages:

- Popular rails: Enable multiple applications with wide-input support across nominal input voltages of 5V, 12V, 24V, and 36V
- Smallest solution size: 2.25x smaller solution size compared to competitive solutions
- High efficiency: 90% peak efficiency in less than $15mm^2$ solution size; superior thermal performance
- Simplified design: Fully synchronous buck regulator with built-in compensation; integrated inductor for ease of design and faster time to market
- Rugged: Compliant to CISPR 22 (EN 55022) Class B EMC emission standards, as well as JESD22-B103/B104/B111 drop, shock, and vibration standards. For more details, refer to the application note "Assembly Guidelines for (uSLIC) Packages (AN6417)" and the design solution "Pack More Power Than Ever in Your Small Sensor (DS69)."

Factory Automation Application Example: Optical Proximity Sensor

Let's take an optical proximity sensor with an IO-Link® interface as an example of the efficacy of the Himalaya uSLIC power modules.

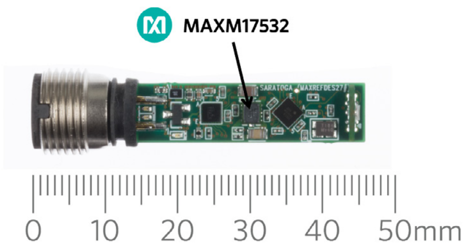

Figure 7. MAXM17532 in a tiny proximity sensor

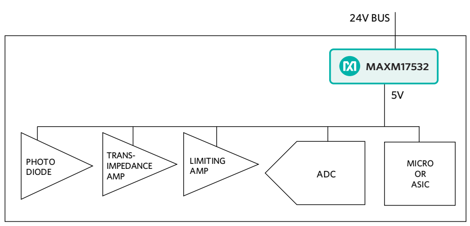

Figure 8. Typical optical proximity sensor system block diagram

This sensor's entire circuitry has to fit on a 6.5mm x 30mm PCB, and it consumes 80mA from the 24V input (19.2VDC to 30VDC). In this example, the MAXM17532 uSLIC power module converts the 24V bus voltage down to 5V to power a microprocessor or ASIC as well as various other mixed-signal blocks.

Its high efficiency, small solution size, and few external components makes this device ideal for this space-constrained application. At 24V input, 5V/80mA output, and conversion efficiency of 83%, the total power consumed from the input is:

$P_{IN} = P_{OUT}$/efficiency = $(V_{OUT} \times I_{OUT})$/efficiency = (5V x 80mA)/83% = 482mW; and the power dissipation in the MAXM17532 power solution is:

$(P_{IN} - P_{OUT})$ = 482mW – (5V x 80mA) = 82mW

If an LDO is used here, the input power dissipation would be:

$P_{IN} = V_{IN} \times I_{OUT}$ = 24V x 80mA = 1920mW, and the power loss in the LDO would be:

$(P_{IN} - P_{OUT})$ = 1920mW – (5V x 80mA) = 1520mW

LDO efficiency = P_{OUT}/P_{IN} = (5V x 80mA) / 1920mW = 21%

Table 1 summarizes the results: V_{IN} = 24V, V_{OUT} = 5V, I_{OUT} = 80mA, output power = 400mW.

In other words, the tiny uSLIC power solution is 4x more efficient than the LDO and reduces the power dissipation to 1/19.

The tiny uSLIC power solution is 4x more efficient than the LDO and reduces the power dissipation to 1/19

Device	Efficiency	Input Power	Power Dissipation
MAXM17532	83%	482mW	82mW
LDO	21%	1920mW	1520mW
MAXM17532/LDO Ratio	395%	25%	1/19

Table 1. MAXM17532 performance versus LDO

Industrial Application Example: Motor Encoder

Here is an example of a motor encoder, along with its system block diagram.

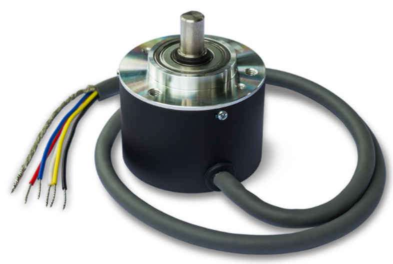

Figure 9. Motor with encoder

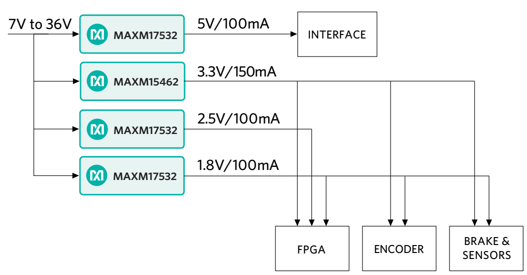

Figure 10. Encoder and digital rating plate system power diagram

The encoder and digital rating plate are powered by the industrial 24VDC input (19.2VDC to 30VDC). Motor inductive ringing ads an extra guard band requirement to the 7VDC to 36VDC operating range for the power converter.

Let's take the 3.3V/150mA rail as an example. We'll use MAXM15462, which has an efficiency of 85% at 150mA at 24V, in this case. Performing a similar analysis, we get P_{IN} = 583mW and power dissipation = 88mW.

Now, let's compare this with a traditional solution using LDOs. In this system, using LDOs directly from the power source at these high currents would generate a large amount of heat and be unviable. It would make sense to add a DC-DC converter to create an intermediate rail of 5.5V from which the LDOs draw power. Assuming a state-of-the-art intermediate DC-DC converter efficiency of 90%, we can analyze this design performance as follows:

3.3V LDO output power = 3.3V x 150mA = 495mW

3.3V LDO input power = 5.5V x 150mA = 825mW

Input supply power associated with 3.3V output at 24V = 825W / 90% = 917mW

Total power loss associated with 3.3V output = 917mW - 495mW = 422mW

Total system efficiency = 495mW / 917mW = 54%

Table 2 summarizes the results: V_{IN} = 24V, V_{OUT} = 3.3V, I_{OUT} = 150mA, output power = 495mW

Device	Efficiency	Input Power	Power Dissipation
MAXM15462	85%	583mW	88mW
LDO	54%	917mW	422mW
MAXM15462/LDO Ratio	158%	64%	1/4.8

Table 2. MAXM15462 performance versus LDO

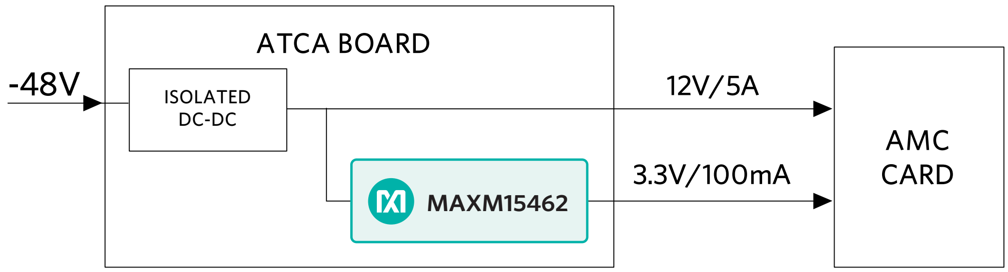

Figure 11. An ATCA board powering an AMC card

Designing for space-constrained PCBs

In other words, the tiny uSLIC power solution is 1.6x more efficient than the LDO and reduces the total device power dissipation to less than 1/4, a significant power dissipation reduction in an already elevated temperature motor environment (especially when we add the power dissipation of all four voltage rails together). It's also worth noting that the LDO solution requires an additional intermediate DC-DC converter, which adds cost and consumes extra space.

Communication Application Example: ATCA Housekeeping

Advanced Mezzanine Card (AMC) is a modular add-on that extends the functionality of an Advanced Telecom Computing Architecture (ATCA) board. The AMC card needs +3.3V housekeeping power for card management with a maximum current of 100mA. A uSLIC power module would serve this +3.3V requirement very well while taking very little space, saving room for other circuitries.

Consumer Application Example: Smart Digital Assistant

Voice-controlled countertop digital assistants and many other consumer household electronics like refrigerators, microwaves, coffee machines, and others typically plug into a 5V USB or $15V_{OUT}$ wall adaptor and need low current power supplies in a highly space-constrained chassis. While audio amplifiers and processors need higher currents, the wireless module needs 100mA to 300mA. The uSLIC power modules work directly with the 5V/15V input, delivering 90% efficiency, and their tiny size satisfies the continuing desire for the equipment to squeeze into the space-constrained PCB.

Figure 12. Digital assistant

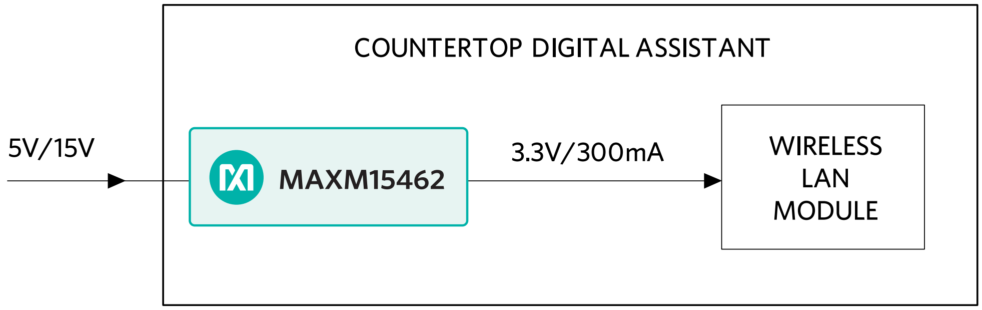

Figure 13. MAXM15462 uSLIC powering wireless LAN module

Passing CISPR 22 EMI for conducted and radiated emissions

EMI Compliance

Finally, equipment must meet EMI requirements. The Himalaya uSLIC power module family passes CISPR 22 (EN55022) EMI for both conducted and radiated emissions. Below are EMI test results for MAXM17532. For more details, refer to the design solution "Pack More Power Than Ever in Your Small Sensor (DS69)."

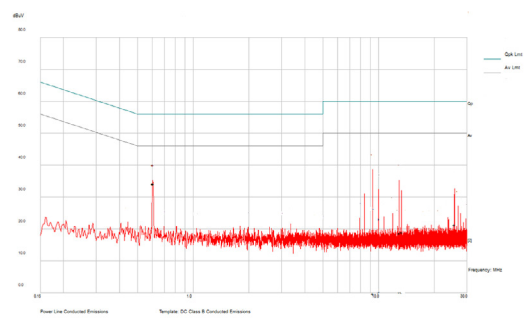

Figure 14. MAXM17532 conducted EMI test result – PASS CISPR 22 Class B

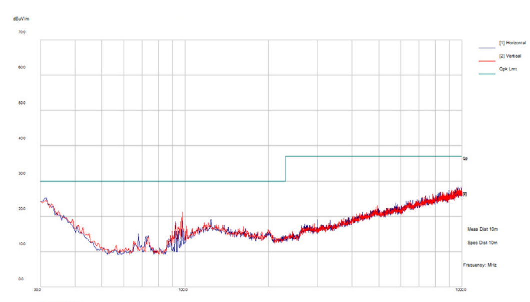

Figure 15. MAXM17532 radiated EMI test result – PASS CISPR 22 Class B

Summary

Thanks to recent advances in architecture, process, and packaging technology, a new breed of power solutions has emerged to address the efficiency, power dissipation, and size requirements of highly space-constrained applications. Maxim's uSLIC power module family is part of a new frontier of component miniaturization, providing solutions enabling applications in artificial intelligence, IoT, machine learning, connectivity, cloud computing, communications, medical, and consumer.

Additional Resources

For more information about Maxim's uSLIC Himalaya Power Modules, visit:
www.maximintegrated.com/uSLIC

For more information about Maxim's Himalaya Step-Down Switching Regulators, visit: www.maximintegrated.com/himalaya

Learn more

For more information, visit:
www.maximintegrated.com