DESIGN SOLUTIONS

POWER

Protect Your Small Sensor from the Harsh Industrial Environment

Sensors are ubiquitous in the electrically harsh industrial environment (Figure 1). As they increase in sophistication and shrink in size, they become more complex, requiring on-board switching regulators to deliver power more efficiently for minimal heat generation. How do you safely deliver low-voltage power to tiny sensors in high-voltage, industrial environments, while minimizing solution size and maximizing efficiency? In this design solution, we will review a typical industrial sensor architecture and provide an innovative solution to this challenge.

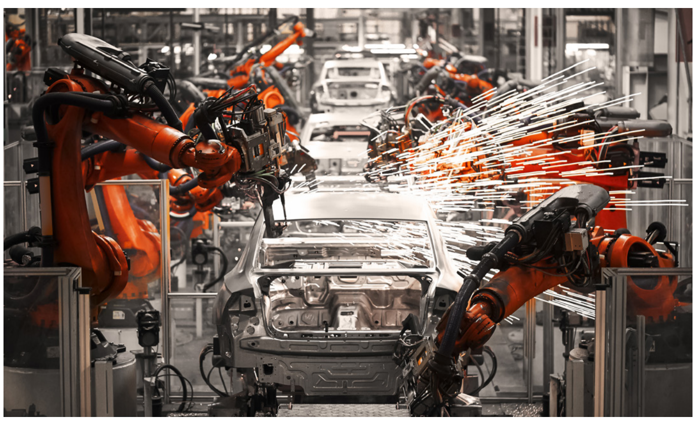

Figure 1. Welding in an Automotive Assembly Line

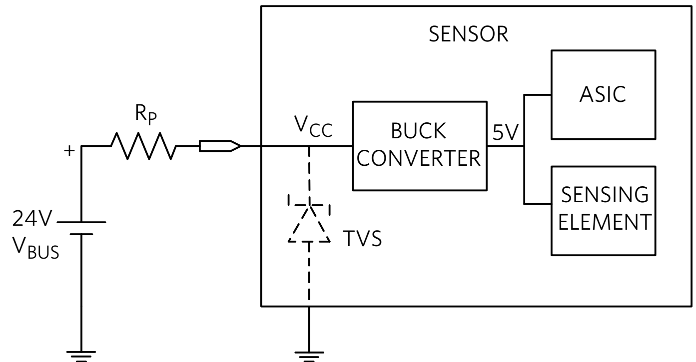

Figure 2. Sensor Power System

Safe Power Challenge

The sensor "box" includes a front-end transceiver that handles data and routes the power to a step-down buck converter, which delivers the appropriate voltage to the ASIC/microcontroller/FPGA and sensing element. The sensor is typically powered by a 24V DC power source (V_{BUS}). The power path is shown in Figure 2.

If the 24V bus is clean or has an electric noise level below the operating voltage of the front-end switching regulator, no protection is necessary (no TVS in Figure 2) and a buck converter with a typical max input voltage of 36V or 42V is sufficient for this sensor design.

However, the factory floor can be a very challenging environment, with long cables and strong electromagnetic interference resulting in high-voltage transients. Accordingly, the step-down converter inside the sensor must withstand voltage transients much higher than the sensor operating voltage.

A typical sensor power management solution utilizes transient voltage suppressors (TVS) to limit the input voltage (V_{CC}) of the front-end buck converter. The associated input current peaks are reduced by the resistor R_P, a parasitic or physical element in the electric path between the voltage transient's source (V_{BUS}) and the sensor.

Let's see how to select a TVS out of the Littelfuse™ catalog, as an example. The general characteristics of a TVS are shown in Figure 3.

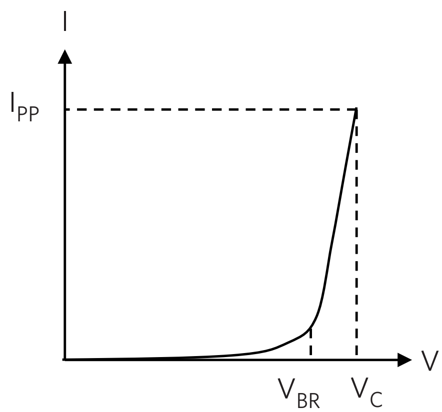

Figure 3. TVS V-I Characteristics

The TVS device is an open circuit until the voltage across it reaches V_{BR}. At this point, it starts to conduct current while its voltage rises slightly up to its maximum clamping voltage V_C, which corresponds to the maximum allowed peak pulse current I_{PP}. The product $V_C \times I_{PP}$ is the maximum peak power that the TVS can handle (400W for this TVS family).

For effective protection, the TVS V_{BR} must be chosen to be above $V_{CC(MAX)}$ while V_C must be below the switching regulator input voltage breakdown.

Our V_{BUS} supply is 24V ±10%, with 26.4V maximum ($V_{BUS(MAX)}$). The closest possible TVS choice from the catalog is the SMAJ28A, with a minimum 28V V_{BR} , a 45.4V maximum clamp voltage and a 8.8A maximum peak current (Figure 4). The delta between the TVS voltage and the voltage transient develops the current through the resistor, R_P, which has to be below the maximum-allowed I_{PP}.

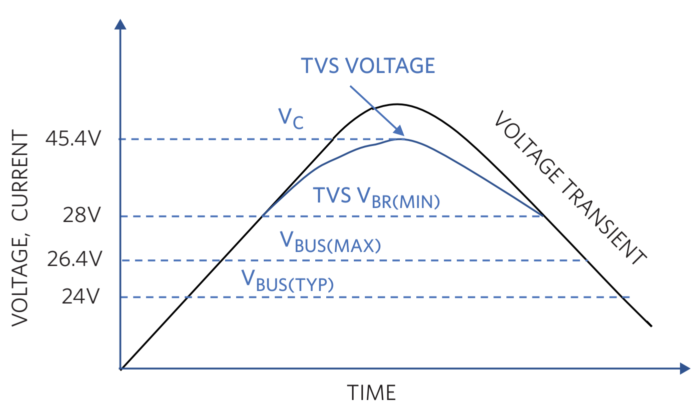

Figure 4. Minimum TVS Selection

The fact that our buck converter must withstand $24V_{DC}$ and at least a 45.4V transient removes a large group of buck converters from consideration.

Additionally, with the selection above, there is only a 1.6V margin between the maximum V_{BUS} and the minimum TVS voltage (V_{BR}). A higher margin requires a voltage rating for the buck converter (V_{CC}) well above 45.4V. Ideally, with a 60V-rated buck converter, a SMAJ33A with a minimum V_{BR} of 33V can be used (and a clamp voltageV_C of 53.3V, well below 60V). This gives an operating margin of 6.6V above $V_{BUS(MAX)}$ and 6.7V below 60V (Figure 5).

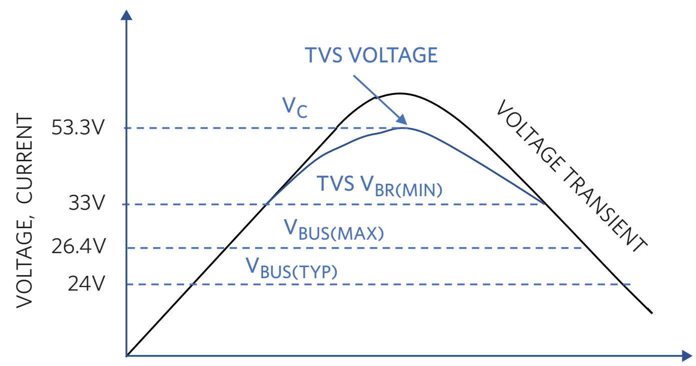

Figure 5. Ideal TVS Selection

Sensor Miniaturization Challenge

For sensor miniaturization, the typical PCB strategy of placing all the buck converter components on the same plane is not ideal. In Figure 6, a 300mA buck converter IC and passives (L,R,C) require a hefty PCB area ($29.3mm^2$ net area).

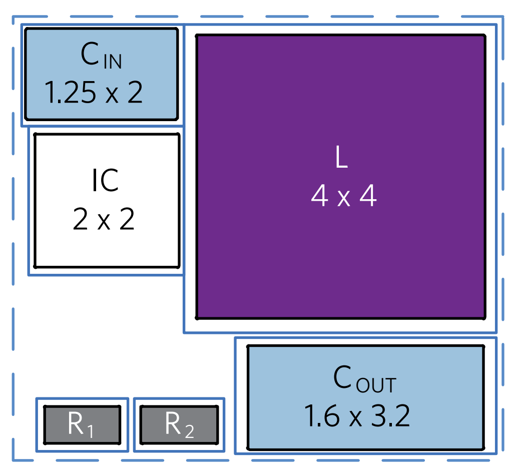

Figure 6. Typical Planar Buck Implementation ($29.3mm^2$ Net Area)

The Thermal Challenge

Sensors have sealed enclosures (without fans or cooling) due to the harsh environments they sit in. A small amount of heat generated inside this small enclosure can quickly raise the sensor temperature, compromising its reliability. The trend of sensor miniaturization makes their thermal management even more challenging. The solution to the thermal challenge is a buck converter with very high efficiency.

Recalling the above challeges: an efficient buck regulator that fits inside a small PCB area and has a 60V breakdown voltage is necessary to fit inside a small sensor.

The Solution: uSLIC Power Module

A novel way to solve the space problem is to vertically integrate the inductor on top of the IC. One example is the Himalaya uSLIC™ power module. It delivers more power in a smaller space than ever before, with high efficiency and ease of use. The uSLIC power module vertically integrates the inductor and the buck converter IC, dramatically reducing the PCB space occupied by the standard buck converter solution. This still meets expectations of high-voltage tolerance and high-temperature operation. The MAXM15064 module (Figure 7) is available in a low-profile, compact, 10-pin, 2.6mm × 3mm × 1.5mm uSLIC package. The device operates over a wide temperature range from -40°C to +125°C.

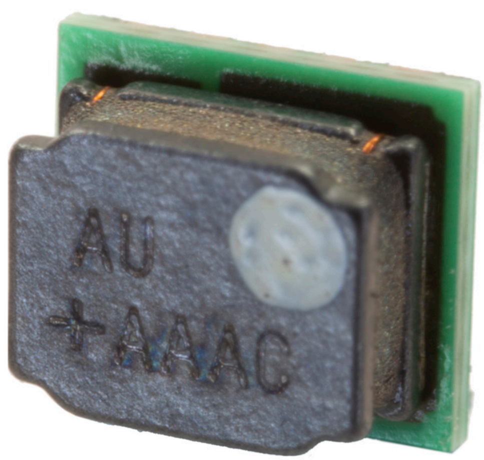

Figure 7. 60V, 300mA uSLIC (2.6mm × 3mm x 1.5mm)

Figure 8 shows the dramatic size reduction achieved with the MAXM15064 300mA, 60V buck converter uSLIC module. The ability to meet a 60V maximum operating voltage (not just the absolute maximum rating) and support output voltages below 1.8V (to support the latest digital ICs), are its distinguishing features. Thanks to the vertical integration of the inductor, the net component area is a mere 21mm^2.

Compared to the IC solution of Figure 6, the uSLIC module solution's net component area is 28% smaller.

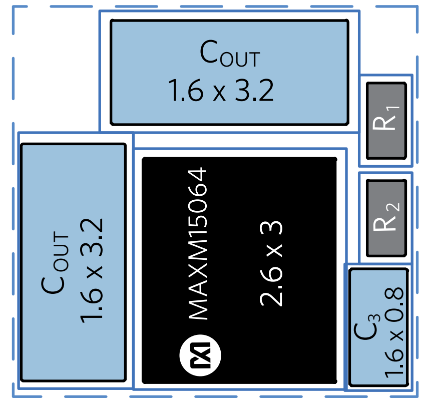

Figure 8. 60V, 300mA High-Voltage Module Implementation (21mm^2 Net Area)

Minimum Heat Generation

Figure 9 shows the efficiency of the MAXM15064 module-with 5V output and input voltages from 12V to 60V. Despite the small size, the buck converter delivers high efficiency with peaks up to 90%. For a 24V-powered application, the uSLIC provides an efficiency well above 80% across most of the operating range, assuring low-power losses and low heat generation.

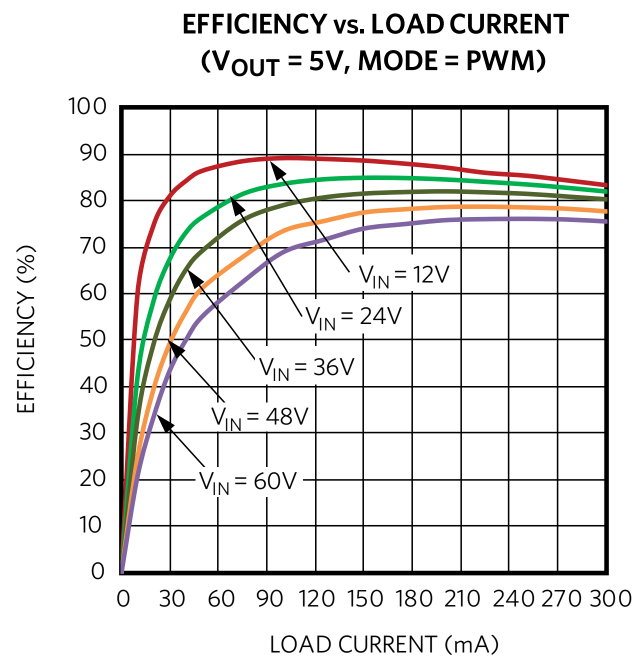

Figure 9. Minimum Heat Generation with uSLIC

Low Emissions

The module's PCB layout is designed to minimize trace lengths and eliminate ground loops for minimum radiated emissions. The use of high-frequency ceramic capacitors minimizes conducted emissions. Figure 10 shows that the MAXM15064 radiated emissions comfortably meet the CISPR22 CLASS B specification.

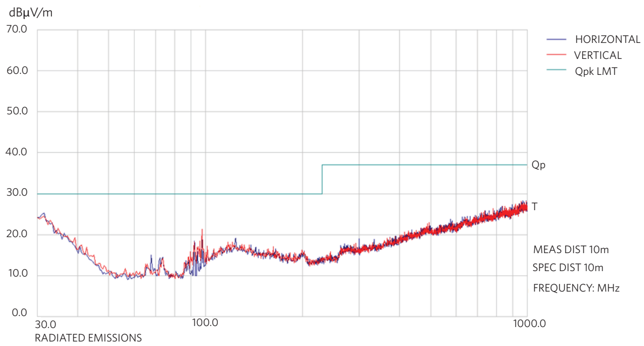

Figure 10. Radiated Emissions

Figure 11 shows that the MAXM15064 conducted emissions also comfortably meet the CISPR22 Class B specification.

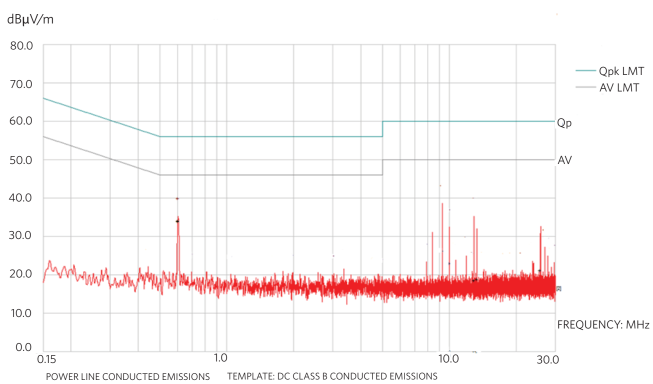

Figure 11. Conducted Emissions

Conclusion

We discussed the challenges of safely delivering higher power more efficiently with minimum heat generation for small industrial sensor applications. The proper protection of the 24V input power is best served by a buck converter that can withstand a 60V input. Finally, we introduced a disruptive approach that stretches the input voltage rating and the power density envelope with a novel, miniaturized, easy-to-design, high-performance buck converter module based on uSLIC technology. The MAXM15064 uSLIC power module is a high-efficiency, small-size, low-EMI buck converter ideal for powering tiny sensors in industrial applications.

Learn more:

MAXM15064 4.5V to 60V, 300mA Compact Step-Down Power Module

Pack More Power Than Ever in Your Small Sensor

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