DESIGN SOLUTIONS

POWER

Pack More Punch in Your Small Sensor While Keeping It Cool

Introduction

Sensors have become ubiquitous in the industrial environment. As they increase in sophistication and shrink in size, sensors are enabling Industry 4.0. In turn, sensor electronics are becoming more complex, requiring on-board voltage regulators to deliver power more efficiently and with minimum 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 a simple solution to this challenge.

Industrial Sensor Applications

Industrial end equipment often operates in a harsh electronic environment. Sensors detect and diagnose many parameters and also make decisions. They must be durable and reliable, regardless of the environment. Proximity sensors, temperature sensors and pressure sensors are used in many industries, including food and beverage, chemical processing, oil and gas, pharmaceutical, manufacturing, construction, hydraulic and pneumatic applications, water and wastewater, HVAC, and refrigeration systems, to name just a few!

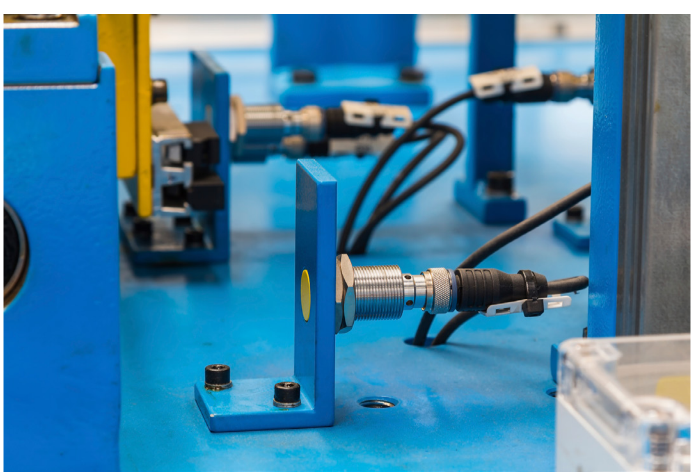


Figure 1. Proximity sensors in action

The Sensor System

Figure 2 illustrates a typical sensor system in a factory environment.

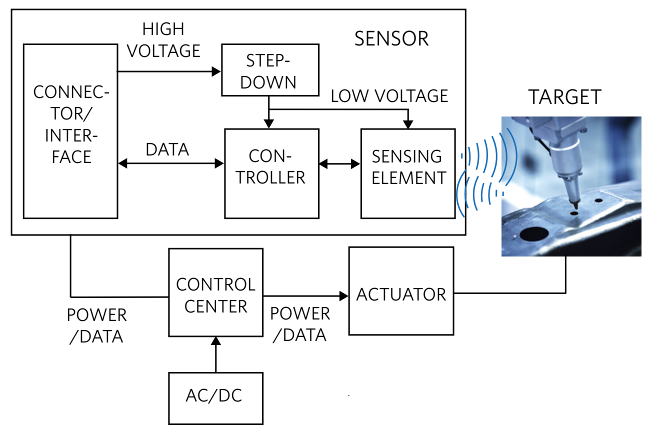


Figure 2. Typical industrial sensor system

Sensors may be located anywhere on the factory floor. The control center receives information from the sensor and sends the appropriate action to the actuator via a field bus. The sensor 'box' includes a front-end connector/interface handling data and routing the power to a step-down voltage regulator which delivers the appropriate voltage to the ASIC/microcontroller/FPGA and the sensing element.

Safe Low Voltage Operation

The sensor is typically powered by an isolated 24V DC power source. 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 of 42V or 60V that are much higher than the sensor operating voltage. According to SELV/FELV regulations, an isolated device handling up to 60V is considered safe to touch. Protection above 60V can be provided with the addition of dedicated TVS devices.

Sensor Current Consumption

Table 1 is a list of the most common sensors and motor encoders and their typical current consumption. Proximity sensors (Table 1a) are by far the most common and can be catagorized as optical, inductive, capacitive, photoelectric and ultrasonic.

Proximity Sensors	I (mA)
Optical	80
Amplified Inductive	100
Capacitive	100
Photoelectric	100
Ultrasonic	45

Table 1a. Proximity sensor typical current consumption

Pressure sensors (Table 1b) are based on the piezolelectric effect or on strain gauge. In piezoelectric sensors the crystal produces a voltage proportional to the pressure. In a strain gauge sensor the silicon resistance varies with pressure.

Pressure Sensors	I (mA)
Piezo-Resistive or Silicon Strain Gauge	20

Table 1b. Pressure sensor typical current consumption

Rotary or linear encoders (Table 1c) are widely used in sensing speed and position of electric motors.

Motor Encoders	I (mA)
Rotary Optical	20
Linear	10

Table 1c. Motor encoder typical current consumption

Temperature measurements are based on diodes, thermocoupleas or resistors depending on the application temperature range. As an example a typical resitor temperature detector (RTD) is a 100 Ohm platinum resistor.

FELV: Functional Extra Low Voltage. A non-isolated circuit below 60V.

Industry 4.0: The fourth industrial revolution. The current trend of automation and data exchange in manufacturing technologies to create the smart factory.

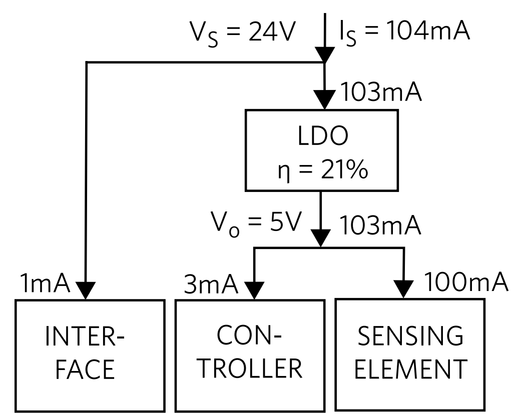
RTD: Resistance Temperature Detector.

SELV: Separated Extra Low Voltage. An isolated circuit below 60V. Such circuit is considered safe to the touch.

TVS: Transient Voltage Suppressor. Clips voltage transients, for example above 60V.

Powering the Sensing Element

Most industrial sensing elements need an input voltage significantly lower than that supplied by the system. Figure 3 shows the case in which an LDO is used to step-down a 24V system voltage to 5V to power the microcontroller and the sensing element. This is a lossy process (η = 21%) that ends up costing 2.5W of power dissipation.



$$P_S = I_S \times V_S = 104\text{mA} \times 24\text{V} = 2.5\text{W}$$

Figure 3. LDO powered sensor

In Figure 4 the voltage stepdown is performed by a buck switching regulator with 85% efficiency at 100mA.

Here the buck converter transfers power with high efficiency, resulting in a loss of only 624mW.

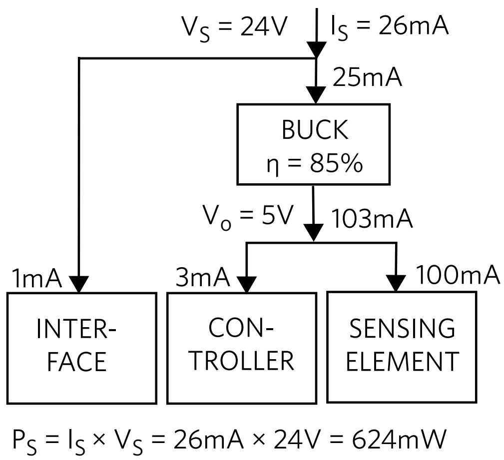


Figure 4. Buck powered sensor

Packing More Punch

As mentioned earlier, sensor electronics are becoming more complex while sensor housings are shrinking to enable intelligent factories. Hence, it is important that the on-board voltage regulator is small in size and delivers power with high efficiency and minimum heat generation. Figure 5 illustrates the size of a Himalaya switching regulator IC (MAX17552) and the companion inductor housed in a small, m8-sized proximity sensor . Clearly the MAX17552 consumes minimal space in this application

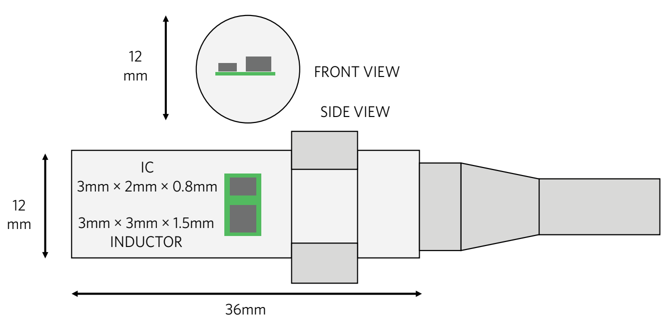


Figure 5. Buck IC, inductor and sensor size comparison

Digital Sensor System Architecture

Figure 6 illustrates a digital sensor system based on the popular IO-Link® point-to-point serial communication protocol. IO-Link, used for communicating with sensors and actuators, has been adopted as an international standard (IEC 61131-9). The IO-Link bus carries power (24V) and data.

The sensor may be located anywhere on the factory floor. The control center receives information from the sensor and sends the appropriate instruction to the actuator via the standard I/O field bus. The sensor 'box' includes an IO-Link transceiver interface which handles data and routes the 24V power to a step down voltage regulator. The regulator delivers 5V to the microcontroller and to the sensing element.

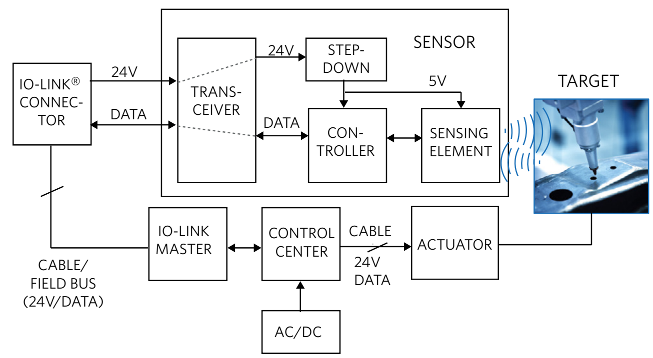


Figure 6. Digital sensor system

A Tailor-Made Buck Converter Family

The MAX17550, MAX177551–MAX17552 and MAX17530, MAX17531–MAX17532 families of high-efficiency, high-voltage, synchronous step-down DC-DC converters save space with integrated MOSFETs and operate over a 4V-to-60V and 4V-to-42V input voltage range, respectively. Delivering output current up to 25mA, 50mA or 100mA, the devices are ideal for sensor applications. The output voltage is accurate to within ±1.75% over the -40°C to +125°C temperature range. The converters consume only 22µA of no-load supply current in PFM mode. The low-resistance, on-chip MOSFETs ensure high efficiency at full load and simplify PCB layout. The devices offer programmable switching frequency to optimize solution size and efficiency, and are available in compact 10-pin (3mm × 2mm) TDFN and 10-pin (3mm × 3mm) µMAX® packages. Simulation models are also available to simplify design.

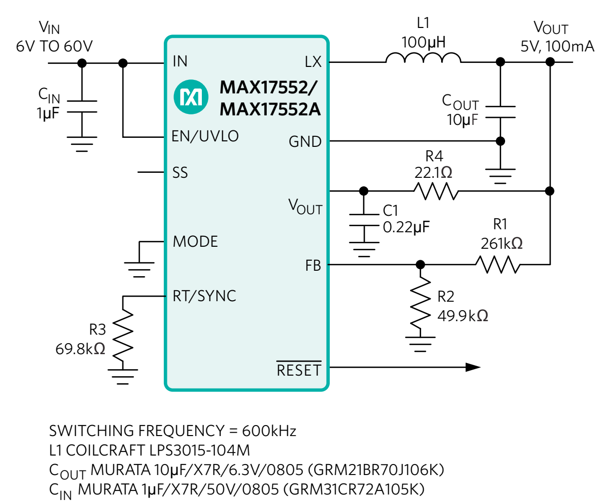


Figure 7a. MAX17552 typical application circuit

Figures 7a and 7b show typical application circuits for the 600kHz configurations—optimized for small size—delivering 5V to a load up to 100mA. This enables a total solution size of only 50mm^2.

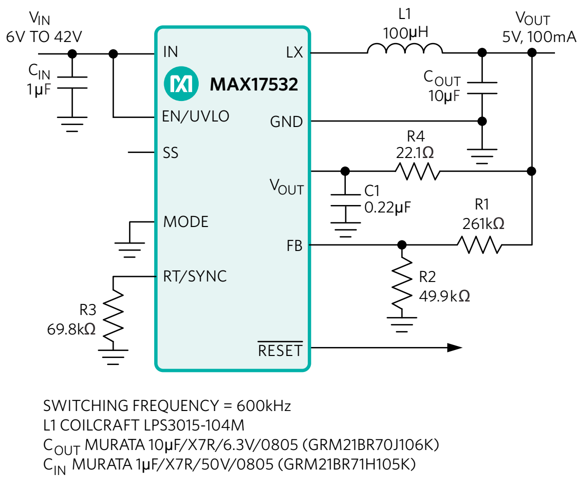


Figure 7b. MAX17532 typical application circuit

Figures 8a and 8b show the typical efficiency curves at various input voltages with 5V output. With a 24V input the peak efficiency is 87% for both device families. As shown earlier, these devices decisively outperform any LDO based solution in terms of power savings.

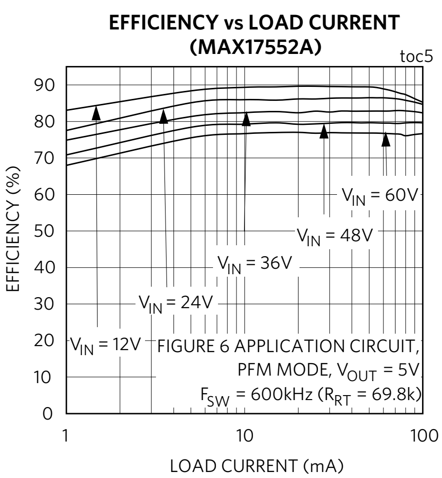


Figure 8a. MAX17552 typical efficiency curves

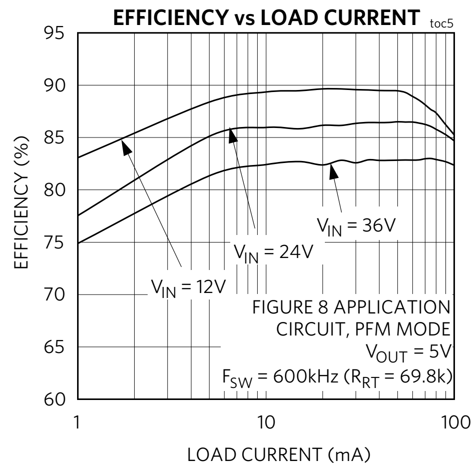


Figure 8b. MAX17532 typical efficiency curves

Conclusion

We reviewed common industrial sensor architectures and examined the power needs and challenges of various types of sensors. In addition, we provided a solution to efficiently and safely deliver power in a small form-factor using a switching regulator as an alternative to the lossy and thus, inadequate, LDO. Finally, we introduced a new family of Maxim Integrated switching regulators, the MAX17550–MAX17552 and MAX17530–MAX17532 high-efficiency, high-voltage, synchronous step-down DC-DC converters with integrated MOSFETs. These small buck regulators deliver an output current up to 25mA, 50mA, or 100mA and are tailored to the needs of industrial sensor applications.

Learn more:

MAX17530 42V, 25mA, High-Efficiency, Buck Converter

MAX17531, 42V, 50mA, High-Efficiency, Buck Converter

MAX17532, 42V, 100mA, High-Efficiency, Buck Converter

MAX17550, 60V, 25mA, High-Efficiency, Buck Converter

MAX17551, 60V, 50mA, High-Efficiency, Buck Converter

MAX17552, 60V, 100mA, High-Efficiency, Buck Converter

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