DESIGN SOLUTIONS
POWER

Iso-Buck Converter Enables Smaller, More Efficient Isolated Power Supplies

Introduction

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. This design solution discusses the reasons for isolation in low-voltage power conversion systems and reviews an isolated digital I/O module as an example. Finally, a novel isolated architecture, dubbed "Iso-Buck", is shown to be a better alternative to the classic flyback converter, yielding a more compact and more power-efficient solution.

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. 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, a phenomenon that degrades the equipment reliability. Accordingly, isolated power supplies are routinely utilized in industrial, consumer, and telecom applications concerned with the protection of sensitive loads and the long-term reliability of the equipment.

Digital I/O System Example

The I/O modules of automated factories (Figure 1) are at the heart of factory process control and are prime examples of low-voltage isolated systems.

Figure 2 illustrates a generic digital I/O module and factory system block diagram. A central hub takes the AC line power and converts it to 24V DC, delivered to the I/O module together with the corresponding digital input (DI) and digital output (DO) data. The factory environment is harsh, with electric and magnetic interferences and overvoltages, requiring protection

Figure 1. Digital I/O module

for sensitive electronics. Each module's programmable logic controller (PLC) is powered via an isolated step-down voltage regulator. At the digital input module (DIM), a rugged voltage level translator interface powers the sensor, receives its information, and passes it along to the PLC via a digital isolator or optocoupler. A similar power, signal, and isolation chain on the digital output module (DOM) leads to the on-board driver, interfacing to the external actuator. A power-efficient and compact implementation of the isolated step-down converter in the input and output modules is necessary for modern systems.

Traditional Implementation

The flyback converter (Figure 3) is the classic architecture that produces an isolated output. During the 'ON' time of the transistor T1, the voltage across the primary winding is positive (equal to V_{IN}) and the voltage across the secondary winding is negative. Consequently, the Shottky diode SD prevents energy from passing to the output, and the energy is stored in the gapped transformer. During the 'OFF' time of T1, the primary winding inverts its voltage, which allows the energy to be released to the output. The control loop is quite complex, requiring an additional voltage regulator (TL431A) to regulate the voltage at the output.

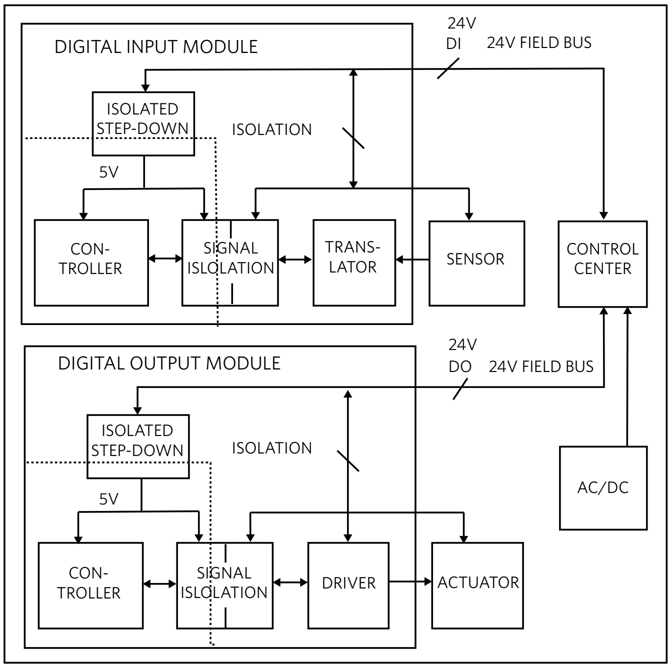


Figure 2. Digital I/O module and factory system block diagram

An optocoupler provides the isolated feedback needed to close the loop to the primary. This solution, which utilizes two ICs and many passive components, is typically expensive, inefficient, and space consuming.

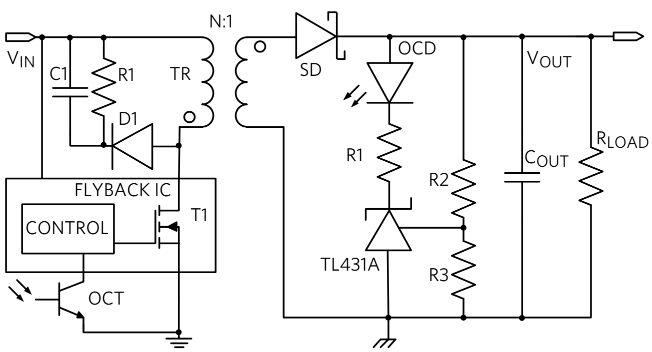


Figure 3. Flyback with optocoupler

Iso-Buck Implementation

The Iso-Buck converter uses a new and highly integrated architecture that greatly reduces the bill of materials (BOM). The block diagram in Figure 4 shows this architecture at a glance. It is essentially a synchronous buck converter driving a gapped transformer instead of an inductor.

When T1 is 'ON,' the voltage across the primary winding is negative (equal to minus V_{FB}), and the voltage across the secondary winding is positive, allowing the energy to be transferred to the output. The opposite is true during the T1 'OFF' time. The control loop is closed at the primary side, eliminating the need for the optocoupler while still remaining isolated.

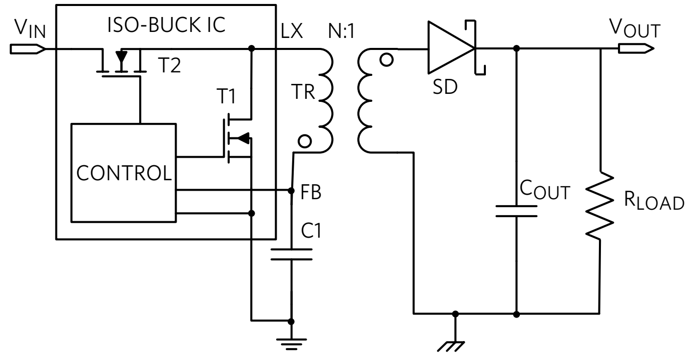
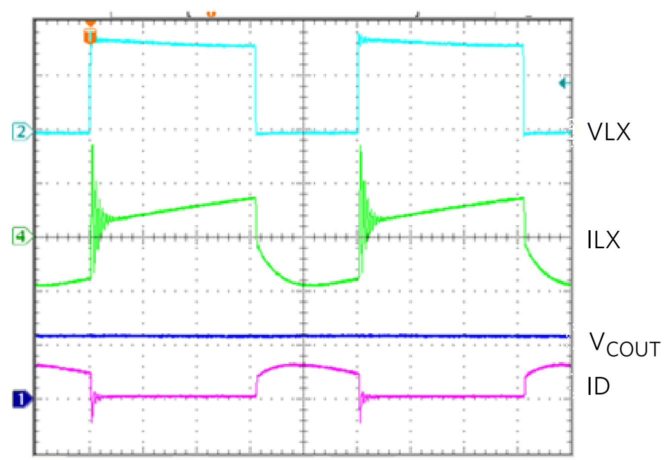


Figure 4. Iso-Buck converter

Using the MAX17681 Iso-Buck Converter

The Iso-Buck architecture is enabled by the MAX17681, a 4.5V to 42V input, high-efficiency, DC-DC converter. Figure 5 shows the main MAX17681 waveforms: V_{LX} and I_{LX} are the voltage and current at the LX node, V_{COUT} is the output voltage, and ID is the current in the Schottky diode.



CH2:LX VOLTAGE, CH4:LX CURRENT, CH3:SECONDARY CURRENT, CH1:V_{OUT}

Figure 5. Iso-Buck waveforms

The MAX17681 incorporates a few essential features that differentiate it from a standard buck converter. First, it implements proper internal blanking design to account for the primary current ringing due to the tranformer leakage inductance and capacitance, as exhibited in the I_{LX} waveform in Figure 5.

Second, it eliminates the customary pre-bias feature of standard buck converters. This feature inhibits negative current during soft-start. In the Iso-Buck architecture this would lead to a non-monotonic output voltage startup as illustrated in Figure 6.

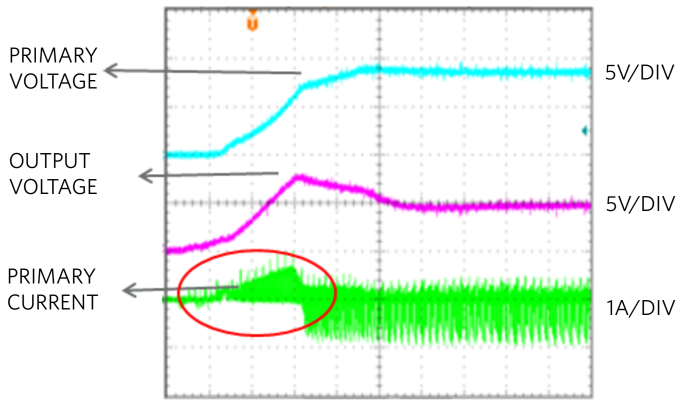


Figure 6. Standard buck non-monotonicity in Iso-Buck mode

Negative current capability is required since the T1 'ON' time is the only time that energy is transferred to the output in the Iso-Buck architecture.

Figure 7 shows the monotonic startup of the MAX17681 which is possible due to its ability to sink current in this phase.

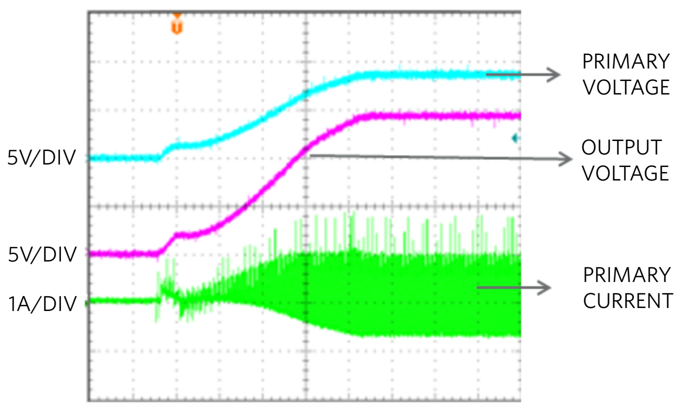


Figure 7. MAX17681 Iso-Buck monotonic startup

Iso-Buck vs. Flyback

The simpler Iso-Buck architecture, by eliminating many external components, results in a more power-efficient solution compared to the traditional flyback converter. The reduction of the number of BOM components by up to 50%, results also in board-space savings of up to 30%. Closing the feedback on the primary side leads to a more relaxed output voltage accuracy, in the range of ±10%.

Conclusion

In this design solution, we reviewed the reason for isolated power in the most diverse applications. We discussed a typical digital I/O system, highlighting its input and output isolated architecture and the necessity for compactness and efficiency. Finally, we showed how the MAX17681, by implementing a novel isolated architecture, yields a more compact and more power-efficient solution that provides a better alternative to the classic flyback converter.

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

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

Learn more:
MAX17681 4.5V to 42V Input, High-Efficiency, Iso-Buck DC-DC Converter.

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