

## Power Your Isolated System Effortlessly from 2W to 40W

### Introduction

Automated factories employ many sensors and I/O modules to control industrial processes (Figure 1). Designing the power circuit for ever shrinking modules that operate in harsh industrial environments is challenging, due to the variety of module applications and the requirements for electrical isolation, small size, and low-power consumption. For each module, designers often scramble to find the right voltage regulator controller, the right transformer, inductor, and discrete transistors to fit their application. In this article, we take a look at a new power methodology that accelerates isolated power supply design, as highlighted by six readily available reference designs that support applications from 2W to 40W.



Figure 1. 24V Programmable Logic Controller Input/Output Module

### The Need for Isolation

In general, isolation between a high-voltage input and a low-voltage output is needed for safety-reasons. In offline applications where the input voltage is the powerline, isolation

offers protection from accidental electrocution. According to SELV/FELV regulations, input voltages below 60V are considered inherently safe to touch. Yet, the need for isolation in this operating range is still pervasive. In this case, the element to protect is the power-supply electronic load, typically a very delicate and expensive microcontroller that would 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 long-term reliability of the equipment.

### The Digital I/O Module System

A single module can have up to 64 channels and a factory floor may utilize several modules. Figure 2 illustrates a generic digital I/O module system block diagram. A central hub takes the AC line power and converts it to 24V DC, delivered to the I/O modules together with the corresponding input (DI) and output (DO) data. The factory environment is harsh, with electric and magnetic interference and over-voltages, requiring protection 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.

### Isolated Step-Down Architectures

Flyback and forward-converter topologies are commonly used in industrial, switch-mode power-supply, isolated, step-down designs below 40W. The flyback converter utilizes a gapped transformer to both transfer and store energy, thereby minimizing the number of output components. However, the high peak

currents inherent in its discontinuous operation relegate its use to low-power applications. As power increases, the forward converter becomes preferable, since the inductor following the transformer provides a smoother secondary side current. Both architectures are discussed in more detail in the following sections.

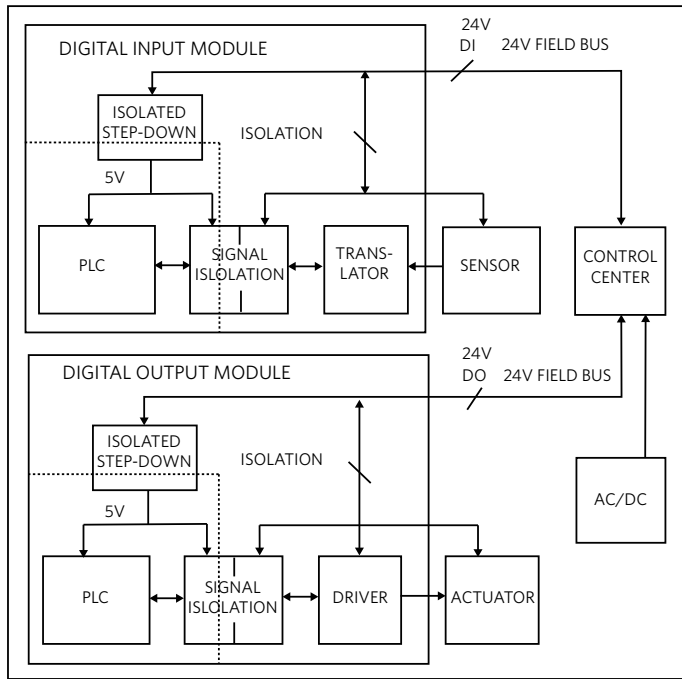


Figure 2. Digital I/O Module System Block Diagram

### Flyback Converter Architecture

The flyback converter (Figure 3) is a simple, accurate, and cost-effective isolated architecture. 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 Schottky diode SD prevents the energy from passing to the output and is stored in the gapped transformer. The capacitor  $C_{OUT}$  assures continuous feed to the output load. During the 'OFF' time of T1, the primary winding inverts its voltage, allowing the energy to be released to the output, feeding the load and recharging  $C_{OUT}$ . In this phase, the primary winding is reset via the R1/C1/D1 passive network, while an optocoupler provides the necessary isolated feedback to close the loop with the primary side with good accuracy ( $\pm 5\%$ ). To minimize power loss, the system designer should select a Schottky diode with a very low forward-drop voltage and a low-leakage gapped transformer. If the transistor T1 is not integrated, then it needs to be selected for very low 'ON' resistance and low switching losses.

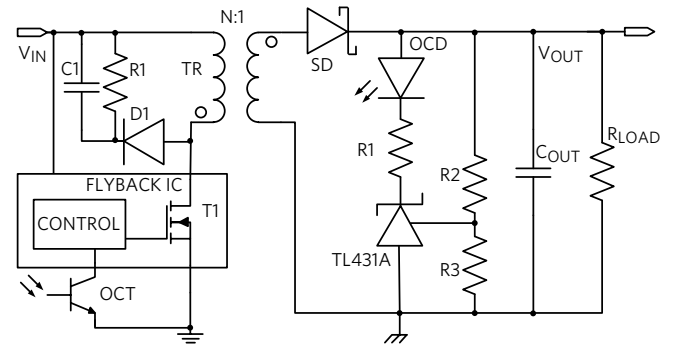


Figure 3. Flyback with Integrated Power Transistor

### Active-Clamp Forward Converter Architecture

The forward converter (Figure 4) architecture is more complex and more efficient than the flyback converter, and is preferred for higher current and higher power.

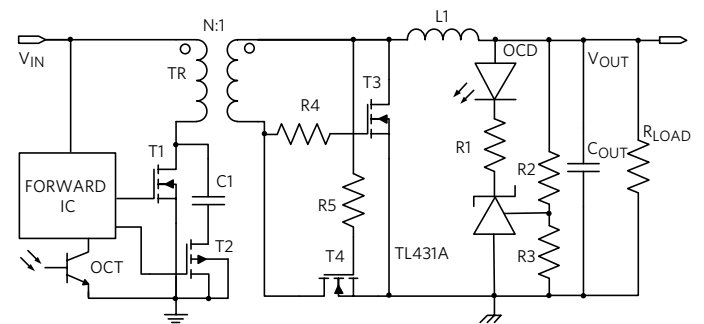


Figure 4. Active-Clamp Forward Block Diagram

In Figure 4, the current is continuously maintained on the secondary side. During the 'ON' time of the transistor T1, the current on the secondary side circulates via the transistor T4, and the inductor L1. During the 'OFF' time, the current is held via T3 and L1. Instead of diodes, the use of transistors T3 and T4 on the secondary side enhances the efficiency of this architecture. An active-clamp reset via T2 and C1 also enhances efficiency, as the energy stored in the primary leakage inductance during the 'ON' time of T1 is subsequently stored in C1 rather than being dissipated in a passive network. Here again, if external transistors are used, they need to be chosen for low on-resistance and low switching losses. The transformer should have low leakage and the inductor should have minimal ohmic losses.

In all cases, the PCB layout should be done with great care to avoid noise pickup and coupling of the traces, which can result in parasitic oscillations.

## The Family of Six Reference Designs

Six 24V input reference designs have been developed that greatly simplify the task of the system designer. These designs are 'ready to go', and cover a wide range of industrial applications from 2W to 40W. Every power rail is isolated with a readily available transformer from multiple global vendors, providing quick, convenient transformer selection. All the reference design BOMs, schematics, layout files and Gerber files are available and most reference design boards feature through-hole pins for immediate board placement and accelerated prototyping.

Three of the reference designs are implemented with a flyback architecture and provide low current output. The lowest current design (2W/400mA) integrates the power switch within the IC, while the other two (10W/800mA and 20W/1.6A) utilize an external power switch. The active-clamp forward architecture is adopted for the three higher power reference designs (10W/2A, 20W/4A, and 40W/8A), all of which utilize external power switches. Table 1 shows the entire family.

$V_{IN} = 24V$	Output Current	Flyback Power/ $V_{OUT}$	Forward Active Clamp Power/ $V_{OUT}$
MAXREFDES111#	400mA	2W/5V	
MAXREFDES112#	800mA	10W/12V	
MAXREFDES113#	1.6A	20W/12V	
MAXREFDES114#	2A		10W/5V
MAXREFDES115#	4A		20W/5V
MAXREFDES116#	8A		40W/5V

Table 1. The MAXREFDES111#-MAXREFDES116# Family

This new family of tested, proven, compact, and readily available reference designs puts to rest the designer's concerns about proper selection of discrete transistors, transformers, inductors, and proper PCB layout.

Let's take a closer look at the efficiency of two of these designs.

### MAXREFDES112# Flyback Power Supply

The MAXREFDES112# 10W, 24V input, 12V output, 0.8A flyback reference design board (2cm × 6cm), which uses the MAX17596, peak-current-mode PWM controller, is shown in Figure 5.

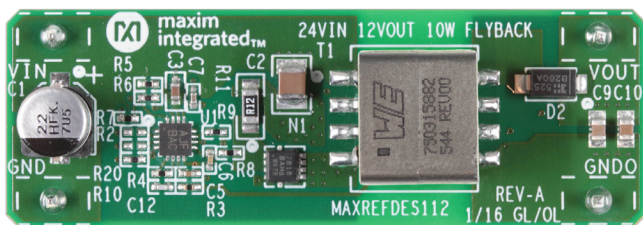


Figure 5. MAXREFDES112# Flyback Power Supply

Figure 6 shows the efficiency over a wide range of input voltages and load currents. In all cases the peak efficiency is well above 85%.

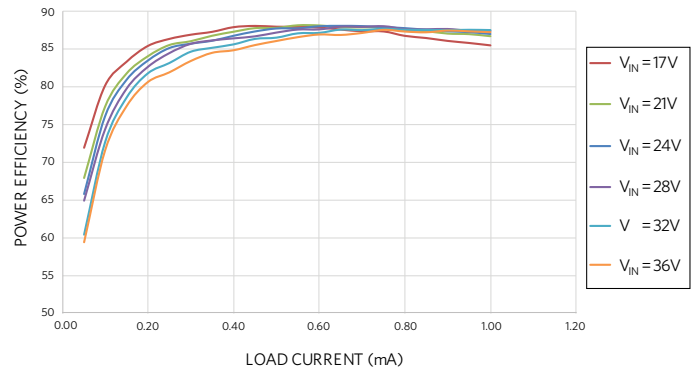


Figure 6. MAXREFDES112# Efficiency

### MAXREFDES115# Active Clamp Forward Power Supply

The MAXREFDES115# 20W, 24V input, 5V output, 4A reference design board (2cm × 6cm), which uses the MAX17599, active clamp, current-mode PWM controller, is shown in Figure 7.

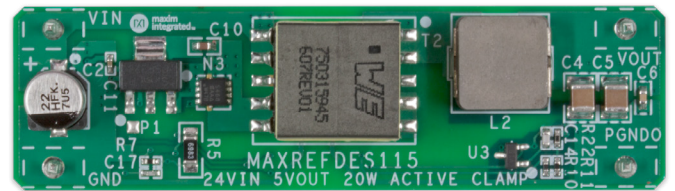


Figure 7. MAXREFDES115# Active Clamp Forward Power Supply

Figure 8 shows the efficiency over a wide range of input voltages and load currents. In all cases the peak efficiency is above 90%.

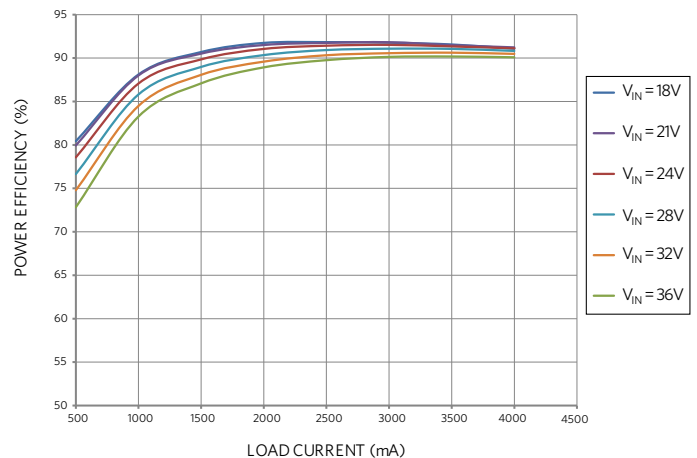


Figure 8. MAXREFDES115# Efficiency

As expected the active clamp forward converter yields higher efficiency when compared to the flyback.

## Conclusion

We discussed the need for accelerated design of isolated power supplies in the most diverse applications. We focused on an industrial system, from the sensor to the actuator, highlighting the digital input and digital output module architectures and their need for isolated, efficient power. Finally, we presented six reference designs covering a wide range of power options. System designers can effortlessly power their systems with these reference designs, available as a PCB for prototyping and as a Gerber file for full production on-board integration. Particular care has also been put into offering a choice of transformers from multiple global vendors, providing quick, convenient transformer selection to further simplify and accelerate the design of isolated power supplies.

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

**SELV:** Separated Extra Low Voltage. An isolated circuit below 60V.

### Learn more:

[MAXREFDES111# Isolated, 24V to 5V, 2W Flyback Power Supply.](#)

[MAXREFDES112# Isolated, 24V to 12V, 10W Flyback Power Supply.](#)

[MAXREFDES113# Isolated, 24V to 12V, 20W Flyback Power Supply.](#)

[MAXREFDES114# Isolated, 24V to 5V, 10W Active-Clamp Forward Power Supply.](#)

[MAXREFDES115# Isolated, 24V to 5V, 20W Active-Clamp Forward Power Supply.](#)

[MAXREFDES116# Isolated, 24V to 5V, 40W Active-Clamp Forward Power Supply.](#)

Design Solutions No. 21

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