

Isolated Power Topologies for PLC I/O Modules and Other Low-Power Applications



Designers of programmable logic controller (PLC) I/O modules or other industrial low-power applications have to find a reliable design for proper and safe operation of their designed circuits under the conditions of a harsh industrial environment. Isolated power converters are frequently found in such applications and help in the following:

- Avoiding or breaking potential ground loops
- Avoiding coupling between adjacent channels or modules
- Providing electrical safety

Common design requirements for such isolated power converters used specifically in PLC I/O module applications include the following, which are also similarly applicable to other industrial low-power applications:

- Input voltage: Field power voltages, often $24V \pm 20\%$ to 30% (a wide range of up to 17V to 36V, sometimes even wider) or lower voltages like 4.5V to 6V (for example, from the backplane or generated as an intermediate supply rail from the 24V)
- Output voltages: typical voltages like 3.3V, 5V, 12V, or even 24V, but also split rails like $\pm 5V$, $\pm 15V$, $\pm 18V$
- Output voltage accuracy: better than 3% to 5% desired, optocoupler-less designs preferred to reduce complexity and improve reliability
- Output power: up to 4W to 5W, sometimes up to 10W or above
- Size: small size designs needed, height often limited to a range of 4mm to 8mm
- Type of isolation: in most cases, functional isolation for breaking ground loops (1kV to 2.5kV for a 1-second to 1-minute test), but also more stringent ones ranging from basic, up to reinforced insulation in cases when electrical safety is required
- Power efficiency: needs usually to be very high (80 to 90% or higher desired) to provide the lowest full-power losses due to the following reasons:
 - Small plastic housing, no forced air flow
 - Maximum ambient temperature of application in the range of 50°C to 70°C , expected ambient board temperature level in the range of 85°C to 105°C
 - Total power consumption per PLC module is often limited to 2W to 4W due to thermal restrictions based on the previously-listed items. The majority of this power is targeted for the payload. Additional power losses in the isolated power converters; therefore, need to be minimized.

[Table 1](#) provides an overview of usable isolated power topologies and proposed TI devices addressing the aforementioned requirements.

All of the listed topologies are optocoupler-less approaches – although the underlying traditional topologies which are found in higher power designs are known to use optocoupler feedback.

The table groups the proposed topologies into the following categories:

- Non-regulated
- V_{IN} controlled
- Quasi-regulated
- Regulated

The provided minimum and maximum input voltage values (V_{IN} minimum, V_{IN} maximum) of the devices represent the best-case values of all the listed devices supporting a specific topology. The 2.95V given as V_{IN} minimum for the fly-buck topology is related to the minimum V_{IN} of the TPS55010, whereas the 120V given

as V_{IN} maximum for this topology represents the maximum V_{IN} of the LM5168 and LM5169. Specific topologies like fly-buck-boost and primary side regulated flyback require an additional margin to be applied.

The given maximum output power (maximum P_{OUT}) is representing the capability of the most powerful device given for a specific topology and depends furthermore on the ratio V_{OUT}/V_{IN} and the turns ratio of the used transformer.

V_{ISO} stands for the isolation voltage of the used transformer and is often related to specific technical standards.

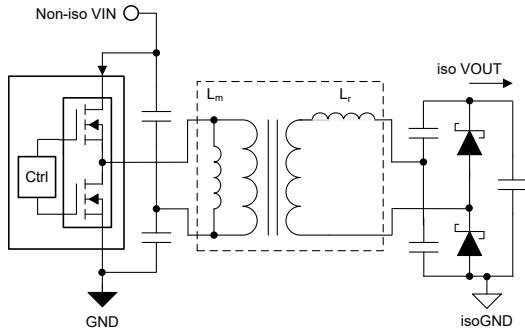


Figure 1. Open-Loop LLC

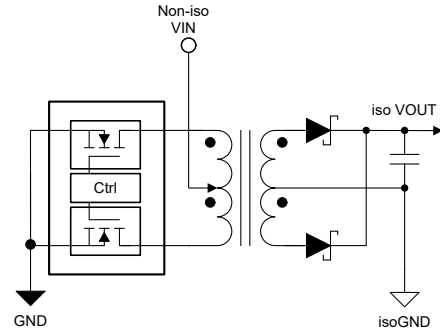


Figure 2. Open-Loop Push-Pull

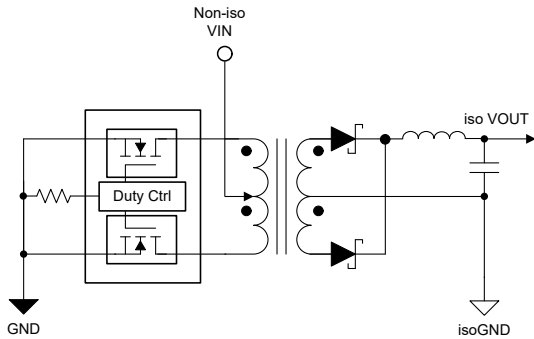


Figure 3. Duty Cycle Controlled Push-Pull

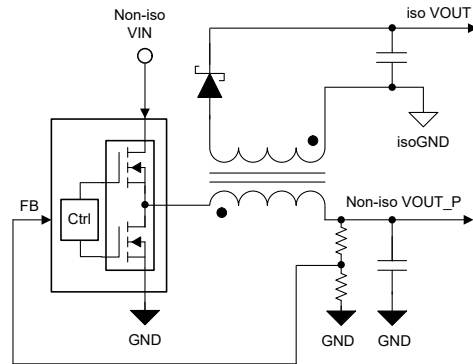


Figure 4. Fly-Buck

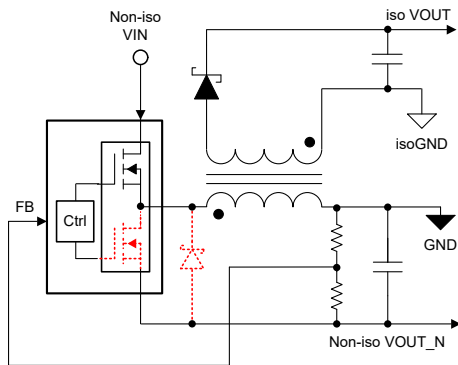


Figure 5. Fly-Buck- Boost

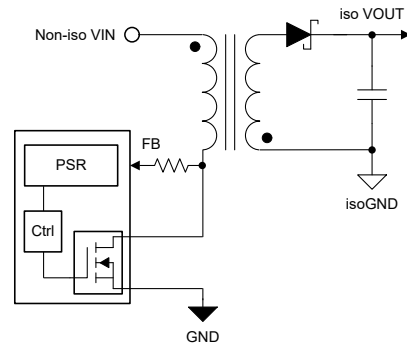


Figure 6. Primary Side Regulated Flyback

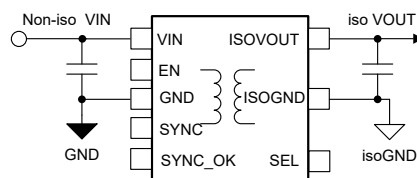


Figure 7. Fully-Integrated Modules

Table 1. Usable Isolated Power Topologies and Proposed TI Devices

Parameter	Open-Loop LLC (see Figure 1)	Open-Loop Push-Pull (see Figure 2)	Duty Control Push-Pull (see Figure 3)	Fly-Buck (see Figure 4)	Fly-Buck Boost (see Figure 5)	Primary-Side Regulated Flyback (see Figure 6)	Fully-Integrated Modules (see Figure 7)
V _{IN} (MIN, MAX)	9V, 34V	2.25V, 36V	3V, 36V	2.95V, 120V	2.95V, 120V – Non-iso V _{OUT_N}	4.5V, 65/100V ⁽³⁾	4.5V, 26.4V
MAX P _{OUT}	Up to 9W	Up to 10W	Up to 5W	Up to 15W	Up to 10W	Up to 15W/50W+ ⁽⁶⁾	Up to 2W
V _{OUT} Regulation	Non-regulated		V _{IN} controlled	Quasi-regulated		Regulated	Regulated and non-regulated
V _{OUT} setting ⁽⁵⁾	n, (L _r , C _r)	n	n, R _{DC}	n, resistor-divider for non-iso V _{OUT}		R _{FB} , n	⁽⁴⁾
V _{ISO}	Depends on used transformer					Up to 5kV _{RMS}	
Type of Isolation						Up to reinforced	
EMI	Best	Good	Good	Better	Better	Good	⁽⁴⁾
Supporting Devices	UCC25800-Q1 UCC25800B-Q1	SN6501, SN6505A, SN6505B SN6505D-Q1, SN6507	SN6507	TPS55010, LM5017, LM5018, LM5019, LM25017, LM25018, LM25019, LM5160, LM5160A, LM5161, LM5168, LM5169 ⁽¹⁾ LMR50410XF, TPS560430XF, TPS560430X3F, TPS560430YF, LMR23630F, LMR23630AF, LM73605, LM73606, LMR36015FB, LMR36500F, LMR36501F, LMR36502F, LMR36503RF, LMR36503MSC-Q1, LMR36506RF, LMR36520FA		Converters (integrated MOSFET): LM5180, LM5181, LM25180, LM25183, LM25184 Controllers (external MOSFET): LM5185, LM25185	Isolated Power UCC33410, UCC33420, UCC12050, UCC12040, UCC12051-Q1, UCC12041-Q1, UCC14xxx, UCC15xxx DCH01, DCPA1, DCP01B, DCR01, DCV01, DCP02, DCR02 Isolated data and power ISOW784x, ISOW7841A-Q1, ISOW774x
Reference Designs (Examples)	PMP23061, PMP23216, PMP23209, PMP40980, PMP40970, PMP23240	TIDA-01576, PMP22992, PMP21561	SN6507DGQEV	TIDA-00688, TIDA-00689, PMP15006, PMP10532	⁽²⁾ PMP10545, PMP10733, PMP10571	TIDA-010048, TIDA-010006, TIDA-010009, TIDA-01535, PMP31177, PMP30834, PMP30750, PMP22760	TIDA-01434
Additional Collateral	SLUAAB9 SSZTCX7	SLLA587, SLLA436, SLLA566	SLLA587, SLLA566	SLYT615, SLPY004, SNVA790, Design Calculator	SNVAA84, Design Calculator	SNVAA28, SNVA900, SLYT800	SSZTD18, SLUA977, SLLA553, SLYY202, SLLA561

- (1) Basically any synchronous buck which can be forced to operate in CCM or in forced PWM and for which a negative current limit is large enough and specified can work in low-power, fly-buck configuration. Select the appropriate device version out of a device family. Cross-check negative current limit and loop stability - see data sheets and additional collateral.
- (2) Cross-check loop stability and consult collateral for inverting buck boost such as [SNVA856](#), [SLVA933](#), [SLVA910](#), [SLYT286](#), [SLVAE10](#), [SLVA317](#).
- (3) Additional limitation of 65V (for converters with integrated MOSFET) or 100V (controllers with external MOSFET) exists for switch-node voltage; see the specific data sheet especially regarding the reflected output voltage and the needed clamp circuit.
- (4) Depends on specific module and used topology
- (5) n-Turns ratio of transformer
- (6) MAX POUT up to 15W for converters with integrated MOSFET, more than 50W for controllers plus external MOSFET

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