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 24 V ±20% to 30% (a wide range of up to 17 V to 36 V, sometimes even wider) or lower voltages like 4.5 V to 6 V (for example, from the backplane or generated as an intermediate supply rail from the 24 V)
- Output voltages: typical voltages like 3.3 V, 5 V, 12 V, or even 24 V, but also split rails like ±5 V, ±15 V, ±18 V
- Output voltage accuracy: better than 3% to 5% desired, optocoupler-less designs preferred to reduce complexity and improve reliability
- Output power: up to 4 W to 5 W, sometimes up to 10 W or above
- Size: small size designs needed, height often limited to a range of 4 mm to 8 mm
- Type of isolation: in most cases, functional isolation for breaking ground loops (1 kV to 2.5 kV 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 2 W to 4 W 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<sub>IN</sub> controlled
- Quasi-regulated
- Regulated

The provided minimum and maximum input voltage values (V<sub>IN</sub> minimum, V<sub>IN</sub> maximum) of the devices represent the best-case values of all the listed devices supporting a specific topology. The 2.95 V given as
$V_{IN}$ minimum for the fly-buck topology is related to the minimum $V_{IN}$ of the TPS55010, whereas the 120 V 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.
Table 1. Usable Isolated Power Topologies and Proposed TI Devices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Open-Loop LLC (see Figure 1)</th>
<th>Open-Loop Push-Pull (see Figure 2)</th>
<th>Duty Control Push-Pull (see Figure 3)</th>
<th>Fly-Buck (see Figure 4)</th>
<th>Fly-Buck Boost (see Figure 5)</th>
<th>Primary-Side Regulated Flyback (see Figure 6)</th>
<th>Fully-Integrated Modules (see Figure 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{IN} (MIN, MAX)</td>
<td>9 V, 34 V</td>
<td>2.25 V, 36 V</td>
<td>3 V, 36 V</td>
<td>2.95 V, 120 V</td>
<td>2.95 V, 120 V – [Non-iso V_{OUT, NL}]</td>
<td>4.5 V, 65 V</td>
<td>4.5 V, 26.4 V</td>
</tr>
<tr>
<td>MAX P_{OUT}</td>
<td>Up to 9 W</td>
<td>Up to 10 W</td>
<td>Up to 5 W</td>
<td>Up to 15 W</td>
<td>Up to 10 W</td>
<td>Up to 15 W</td>
<td>Up to 2 W</td>
</tr>
<tr>
<td>V_{OUT} Regulation</td>
<td>Non-regulated</td>
<td>V_{IN} controlled</td>
<td>Quasi-regulated</td>
<td>Regulated</td>
<td>Regulated and non-regulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{ISO}</td>
<td>Depends on used transformer</td>
<td></td>
<td>Regulated</td>
<td></td>
<td></td>
<td>Up to 5 kV_{RMS}</td>
<td></td>
</tr>
<tr>
<td>Type of Isolation</td>
<td>Best</td>
<td>Good</td>
<td>Good</td>
<td>Better</td>
<td>Better</td>
<td>Good</td>
<td>(4)</td>
</tr>
<tr>
<td>Reference Designs (Examples)</td>
<td>PMP23061, PMP23216, PMP23209</td>
<td>TIDA-01576, PMP22992, PMP21561</td>
<td>SN6507DGQEV</td>
<td>TIDA-00688, TIDA-00889, PMP10545, PMP10571</td>
<td>TIDA-010048, TIDA-010069, TIDA-01535, PMP30750, PMP22760</td>
<td>TIDA-01434</td>
<td></td>
</tr>
<tr>
<td>Additional Collateral</td>
<td>SLUA977, SLLA553, SLYY202, SLLA561</td>
<td>SLLA587, SLLA436, SLLA566</td>
<td>SLLA587, SLLA566</td>
<td>SLYT615, SLPY004, SNVA900, FLYBUCK FLYBACK Design Calculator</td>
<td>E2E™ forum blog post, FLYBUCK FLYBACK Design Calculator</td>
<td>SNVAA28, SNVAA900, SLYT800 PSR Flyback Design Tool</td>
<td></td>
</tr>
</tbody>
</table>

(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) Basically any buck converter, even non-synchronous buck. Cross-check loop stability and consult collateral for inverting buck boost such as SNVA856, SLVA933, SLLA910, SLYT286, SLVAE10, SLLA317.

(3) Additional limitation of 65 V or 100 V 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.
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