Optimizing the Power Supply for Digital I/O modules With Smart High-Side Switches

Paul Kundmueller

The digital output module in PLC systems is one end equipment that heavily uses high-side switches to source power and provide current limiting protection to another system. There could be upwards of eight or more digital output channels per module where the current needs to be sourced through high-side switches. Depending on the current levels per channel, this can lead to some very large and expensive power supplies. Understanding the optimal power supply required for the system is important to ensure the module functions as it is supposed to, and that the total system cost remains low.

Choosing a power supply without considering the corner case of a short circuit on one or more of the channels is often done. Not accounting for a short circuit event when choosing a supply can cause the whole power supply to shut down, which can cause all the channels to turn off instead of only the channels that exhibited the fault.

This document examines how TI's high-side switches can help to optimize the power supply in digital output modules by providing adjustable, accurate current limiting in the case of a short-circuit event, which helps save on the overall cost of a PLC system.

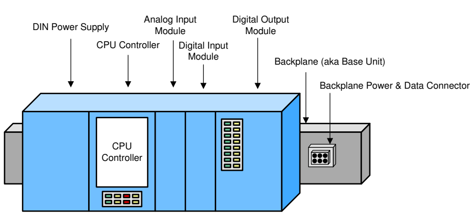

Figure 1. Example of a Typical PLC System

Choosing a Power Supply for Digital Output Modules

There are often many different requirements that must be considered when selecting the appropriate power supply for a digital output, such as operating temperature range, voltage range, SELV compliance, and so on and so forth. This section focuses on examining how a power supply must be selected based on the technical specifications of a digital output module. As a reference, an example digital output module is analyzed with the following specifications.

Table 1. Technical Specifications for an Example 16-CH Digital Output Module

Parameter	Value	Unit
Voltage (typ)	24	V
# of Channels	16	-
IOUT, per CH	0.5	A
Short-circuit threshold (typ)	1	A

Looking at the module specifications again, the pertinent information is given in terms of the nominal voltage level (24 V), as well as the number of channels the module can source (16 CH), the output current per channel (0.5 A), and when the protection features are enabled (1 A).

Many times, the power supply capability is incorrectly determined by multiplying the channel count (16 CH) by the output current per channel (0.5 A), which comes out at 8 A. Determining the power supply capability with this number can cause issues when the system is operating in the factory since short circuits and overload conditions have not been taken into account.

Taking a second look at the technical specification of the module, the short-circuit protection of each channel is not enabled until an individual channel reaches 1 A, which is double the current rating of the channel. The actual maximum current, which can be sourced per channel until the short-circuit protection is enabled, is 1 A. Output currents above 0.5 A can arise in situations where there is a slow creep in current levels or short-circuits. This ultimately leads to an increase in downtime for the factory.

Multiplying the maximum current per channel by the number of channels leads to 16 A, which is two times the previous number that was considered. Table 2 shows the results of the two different methods for choosing the power supply capability.

Table 2. Power Supply Selection Based on Current Levels

Power Supply Output Current Requirements at 24 VDC			
Use Cases	**Number of Channels**	**IOUT, per CH (A)**	**Total IOUT (A)**
Case 1 – Nominal Current	16	0.5	8
Case 2 – Fault Case	16	1	16

As seen in the table, there is quite a bit of difference between the two methods in terms of defining the required power supply capability. Optimization of the short-circuit trip level is important in ensuring that the power supply does not become too large and too expensive. In the next section, the adjustable current limit of TI's high-side switches is analyzed on how the short-circuit level of the digital output module can be adjusted such that the power supply capability is optimized.

Optimizing the Power Supply With the Accurate, Adjustable Current Limit of TI's High-Side Switches

To help optimize the power supply, TI's high-side switches offer an accurate, adjustable current limit that can help reduce the short-circuit level that is specified in the digital output module. The current limit of TI's high-side switches can be adjusted by way of an external resistor on the ILIM pin of the device.

Figure 2 shows an example of this scheme with the block diagram of the TPS27S100, and some of the internal circuitry of the device that enables the adjustable current limit with an external resistor.

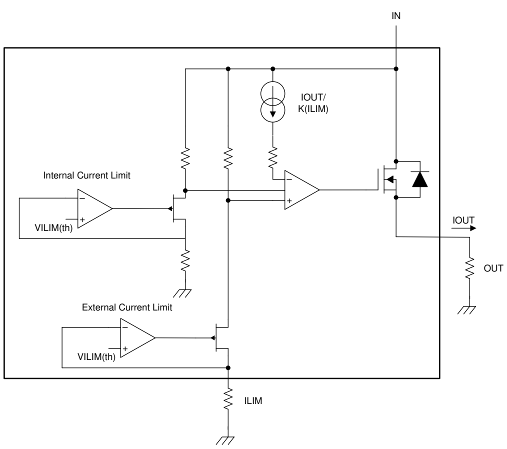

Figure 2. TPS27S100 Adjustable Current Limit Functional Block Diagram

Applying this to the digital output module example in the previous section, the current limit on TPS27S100 can be adjusted such that the threshold is just above the 500 mA output current. To do this, the accuracy of the current limit needs to be taken into account. TPS27S100 offers accurate current limiting at ± 20% when the current limit is set to greater than 500 mA. To account for the resistor variation and to give some headroom on the 500 mA output current, the minimum current limit can be set to 600 mA.

Equations for calculating the resistor value for the ILIM pin can be found in the *Applications* section of the corresponding high-side switch data sheet. The equations for the TPS27S100 can be found here.

Figure 3 showcases the performance of the adjustable current limit of TPS27S100 when set to 750 mA. The overload condition in the waveform is 5 Ω load, which is applied to the output of the device.

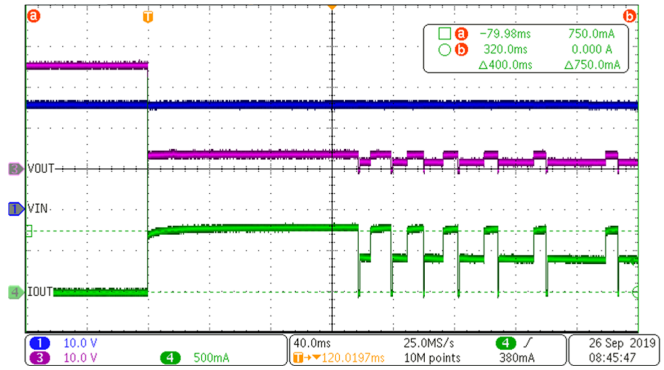

Figure 3. Waveform of the TPS27S100 During an Overload Condition (5-Ω / 4.2-A Load)

Now that the typical current limit value has been determined for the TPS27S100, this report can now analyze how using the device can help to reduce the short-circuit protection in the digital output module, and thus optimize the power supply. Table 3 compares the approach with TPS27S100 versus the existing solution.

Table 3. Power Supply Selection Based on Current Levels With TPS27S100 Use Case Added

Power Supply Output Current Requirements at 24 VDC			
Use Cases	Number of Channels	IOUT, per CH (A)	Total IOUT (A)
Case 1 – Nominal Current	16	0.5	8
Case 2 – Fault Case	16	1	16
Case 2 – Fault Case With TPS27S100	16	0.75	12

The TPS27S100 approach helps to ensure the system is fully protected against overload events and reduce the required power supply capability by 25%, which can offer some pretty big cost savings on the power supply. This can ultimately lead to a cheaper system cost for a PLC solution.

Conclusion

TI offers many high-side switches that can be used in digital output modules to help optimize the short-circuit protection of the module, fully protect the system, and provide cost reductions in the power supply. TI's portfolio also offers a wide range of devices with different RON values and channel counts to fit any digital output module requirement. To learn more about TI's high-side switch portfolio offering, please visit TI's high-side switch portal page.