

Output Power Port Protection in PLC Systems

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ABSTRACT

The Programmable Logic Controller system can face a number of system faults like reverse polarity, short-circuit, higher voltage and surge on output power ports. This document describes the protection provided by traditional schemes and by TPS2662 devices for output power ports.

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1 Introduction

The Programmable Logic Controller (PLC) system usually has field transmitters powered from analog input modules, Digital IO modules or mixed modules through long cables. The Programmable Logic Controller system can face a number of system faults that require protection. An example of such fault events include miswiring events, transients (EFT, surge) on the output power port causing damage to sensitive module components. [Figure 1](#) shows a block diagram of analog input module with output power port for field transmitters. E-fuse A provides protection to module from faults and transients on field power bus whereas E-fuse B provides protection to module from faults and transients on power backplane. For protection from faults and transients on output power port, an additional E-fuse or protection is required. [Section 2](#) and [Section 3](#) describe the protection provided by traditional protection schemes and protection provided by TPS2662 devices for output power ports.

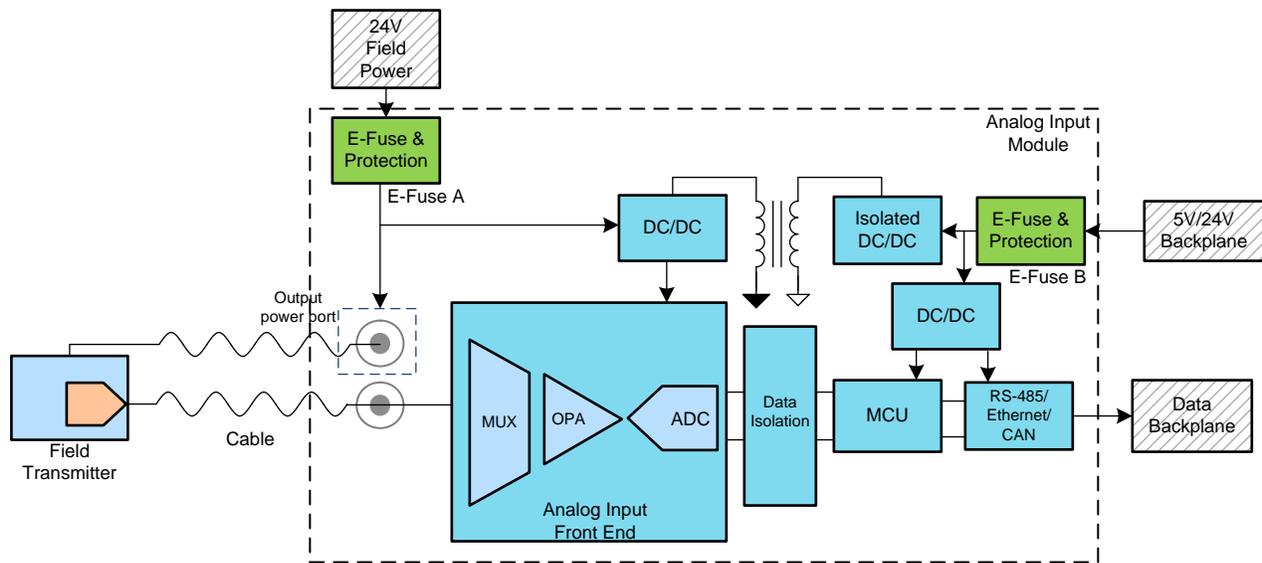


Figure 1. Analog Input Module with Output Power Port

2 Traditional Protection Schemes for Output Power Port

A traditional protection scheme is illustrated in Figure 2. To offer power protection to the output power module, a few external components are typically needed. A diode (D1) is used in series to prevent reverse flow of current. A PTC is used to limit the current in the event of a short circuit. A second diode (D2) is used to protect from reverse polarity. Lastly, a TVS diode (D3) is used for surge protection to clamp the voltage coming into the module. The power ports share the same power bus with other components on modules. The field power is also used to provide power to output drivers and other components in Analog IO modules, Digital IO modules and Mixed modules.

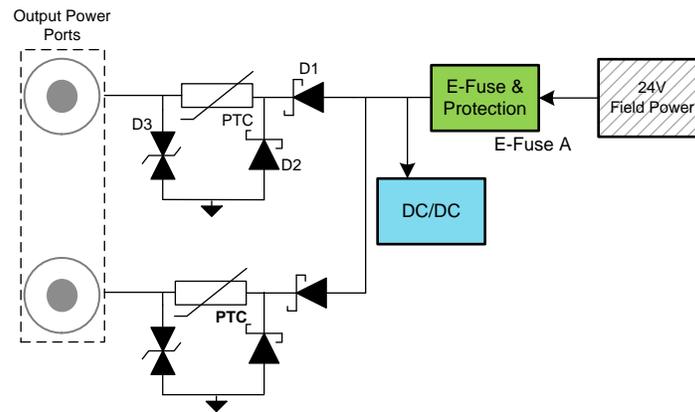


Figure 2. Traditional Protection Scheme

Miswiring at Output power port can lead to reverse polarity and cause flow of excess current through Diode (D2). The current through D2 is limited to holding current by PTC. Prolonged reverse polarity at output port can lead to heating of D2 and subsequent damage and failure of the output port. To prevent heating of D2, a PTC with lower current rating is used. Figure 3 shows a reverse polarity fault at output power port. During a reverse polarity fault, the current from the output port reaches up-to trip current (I_{TRIP}) of the PTC, PTC brings the down the current slowly to a lower current value. The slow response time at approximately (30 ms) of the PTC causes the E-Fuse A to disable the output to protect the field power bus and it leads to shutdown of the module during this fault. Figure 4 provides the response of a traditional protection scheme on reverse polarity. The current through output port reaches 1.45 A, PTC brings the current slowly down to 135 mA.

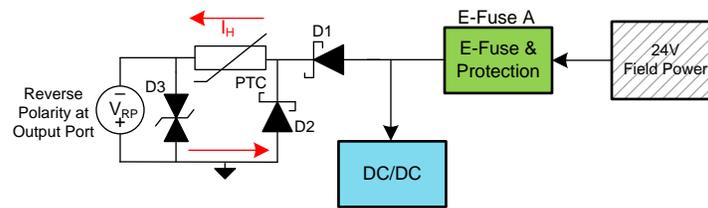


Figure 3. Reverse Polarity at Output Power Port

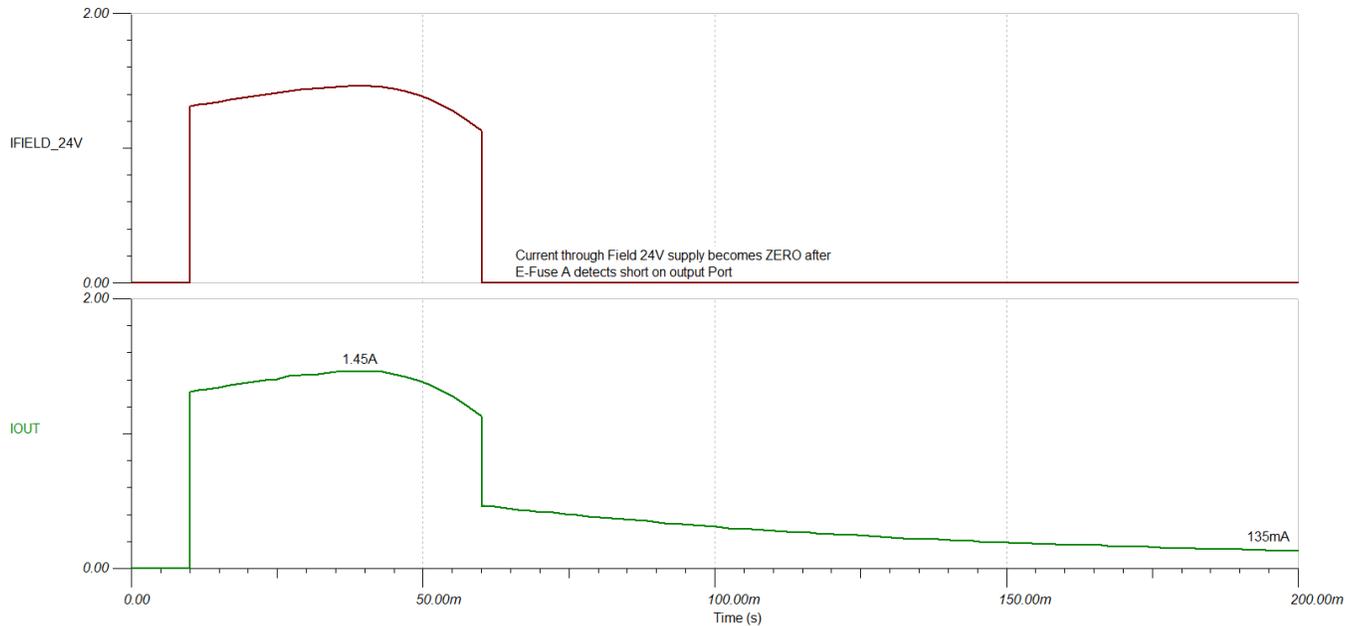


Figure 4. Response on Reverse Polarity

In case of short, the PTC limits the current Output Power Port, but the current limited by PTC varies significantly with temperature. The holding current (I_H) of PTC reduce with temperature and a PTC with higher holding current needs to be selected for entire operating temperature range. With higher current limiting, the cables for powering field transmitter have to be thicker and more expensive.

During a surge, TVS diode D3 clamps the voltage at Output Power Port. In case of positive surge, the positive clamping voltage during surge is blocked by diode D1. But during a negative surge the negative clamping voltage is not blocked by D1 and it can lead to shutdown of internal power bus by E-fuse A or damage the components connected on power bus of the module from output of E-Fuse A.

3 Output Power Port Protection with TPS2662 Devices

As described in [Section 2](#), traditional protection schemes provide limited protection to Output Power Port. [Figure 5](#) illustrates the protection scheme for Output Power Port with TPS2662 devices and [Table 1](#) lists the protection features in TPS2662 devices. [Section 3.1](#), [Section 3.2](#), [Section 3.3](#) and [Section 3.4](#) describe the protection offered by TPS2662 device for output power port.

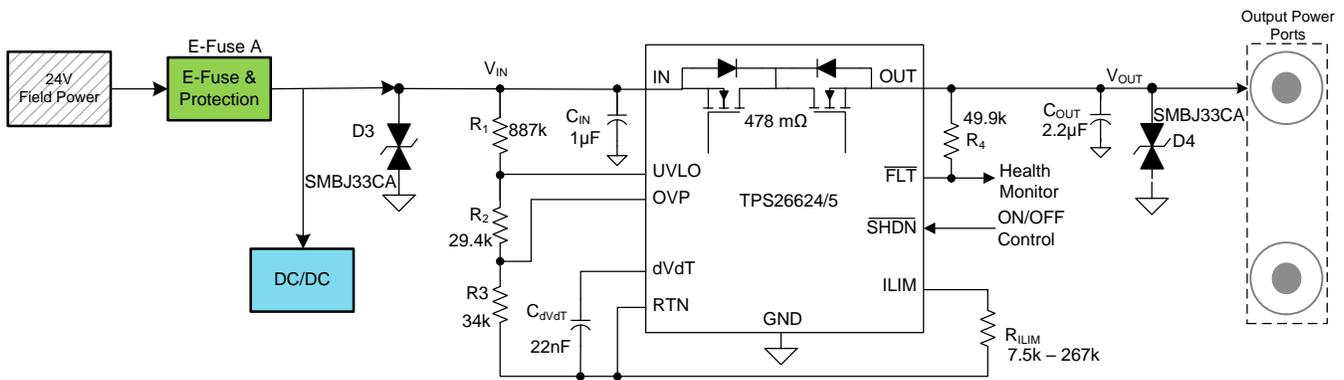


Figure 5. Output Power Port Protection with TPS2662

Table 1. Protection Features with TPS2662 Devices

Device	Oversvoltage Protection	Undersvoltage Protection	Input Reverse Polarity Protection	Output Reverse Voltage Protection	Short-circuit and Current Limit Protection	Overcurrent and Thermal Fault Response
TPS26620	Adjustable cut-off	Adjustable cut-off	Y	N	Y	Latch Off
TPS26621	Adjustable cut-off	Adjustable cut-off	Y	N	Y	Auto-retry
TPS26622	Fixed Clamp (38V)	Adjustable cut-off	Y	N	Y	Latch Off
TPS26623	Fixed Clamp (38V)	Adjustable cut-off	Y	N	Y	Auto-retry
TPS26624	Adjustable cut-off	Adjustable cut-off	Y	Y	Y	Latch Off
TPS26625	Adjustable cut-off	Adjustable cut-off	Y	Y	Y	Auto-retry

3.1 Protection From Reverse Polarity on Output Due to Miswiring

As the output power port terminals are similar to input power terminals, there are always chances of connecting another power supply to output power port with reverse polarity. With traditional protection scheme illustrated in Figure 2, if output power port is subjected to reverse polarity, it can lead to shutdown of module and a failure of output port during prolonged faults. TPS26624 and TPS26625 devices have integrated output reverse polarity protection; the internal FETs are turned off during reverse polarity on output and prevent the flow of excessive current and the subsequent heating. Figure 6 illustrates the operation of TPS26624 device during reverse polarity on output. For this test, an output voltage of -24 V is applied on OUT with input as 24 V, the device turns off the internal FETs and prevents the excessive flow of current from IN to OUT pins .

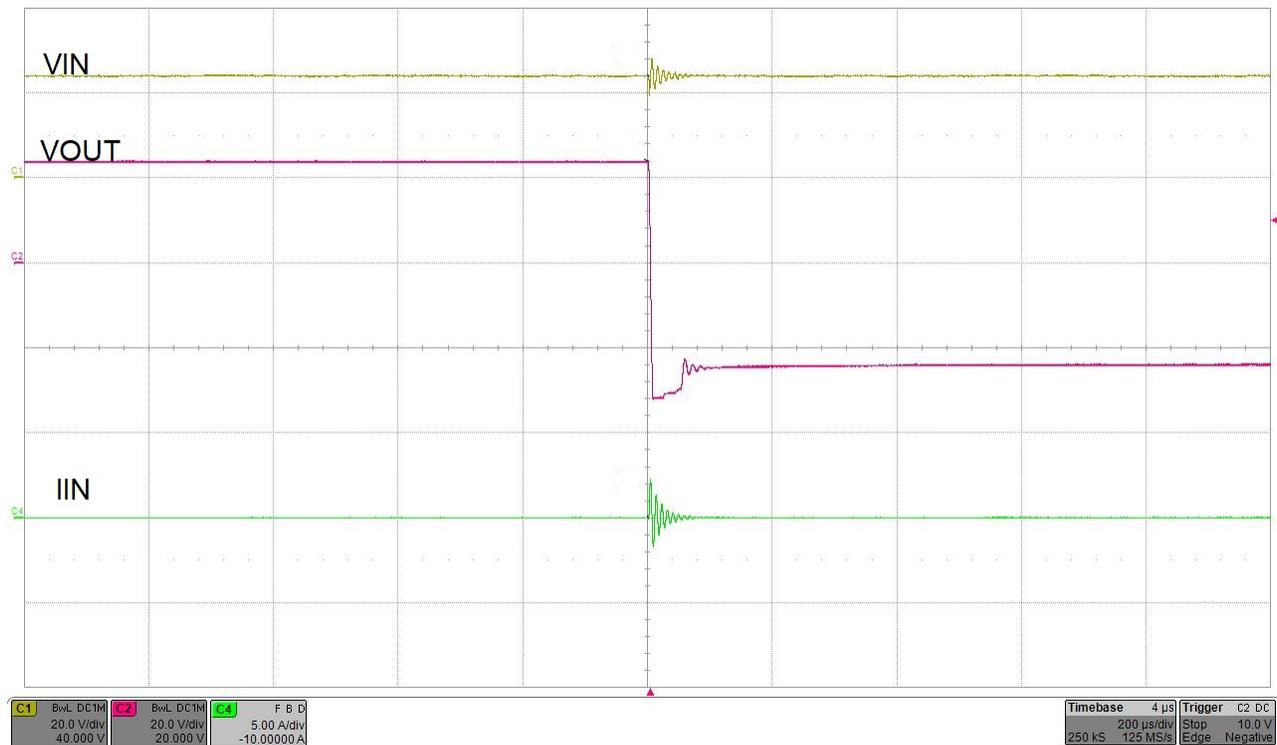


Figure 6. Output Reverse Polarity Protection with TPS26624 and TPS26625

3.2 Protection from Short on Output

A short can occur on output power port either due to miswiring or due to short on the field transmitter. In case of short circuit, a large current flows through the cables. With traditional protection schemes illustrated in Figure 2, the PTC has a slower response time and can lead to shutdown of internal power bus and the module. TPS2662 devices have a fast trip comparator to limit the current in the event of short circuit. Figure 7 provides the response of TPS2662 device in event short circuit. For this test, a short is applied on output, the fast trip comparator turns off the internal FETs and the input current is limited to less than 2.7 A for a duration of 1-μs during short circuit

TPS2662 also offer a current limiting accuracy of 5% over temperature at a current of 0.88 A. With better current limiting, thinner and less expensive cables can be used for powering the field transmitter.

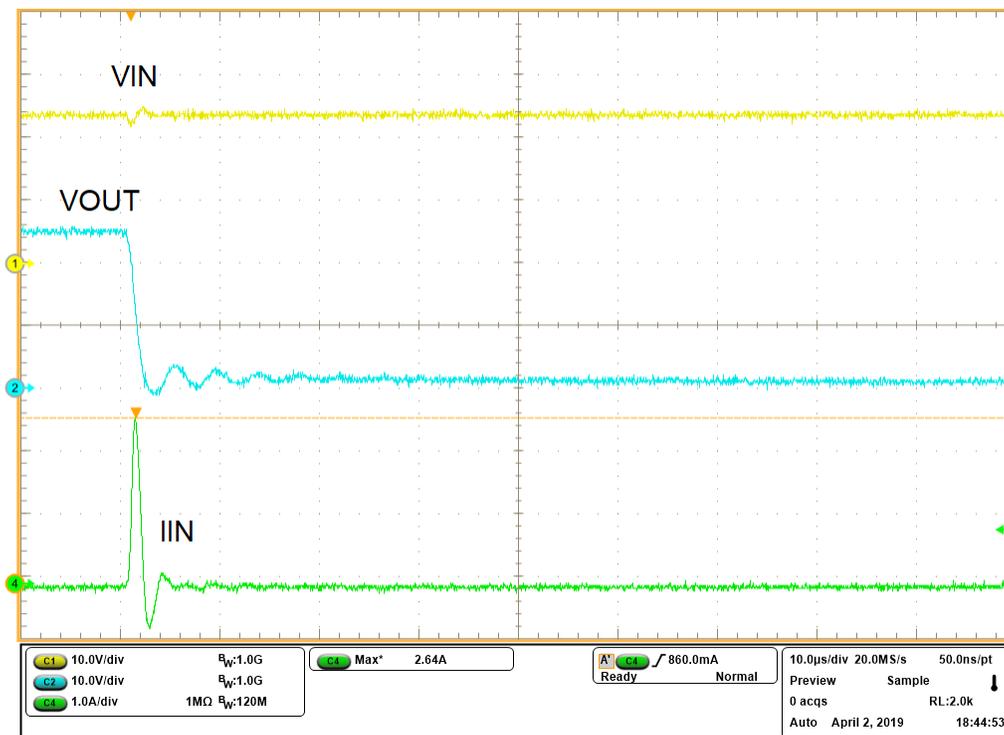


Figure 7. Short Circuit Protection with TPS2662 Devices

3.3 Protection from Higher Voltage on Output

In case of miswiring the output power port could be connected to source of higher voltage, the low voltage devices on the modules can get damaged. In case of voltage higher than input on output, a reverse current flow from output port. TPS2662 devices have reverse blocking comparator to prevent the flow of current from output to input. [Figure 8](#) illustrates the overvoltage protection with TPS2662 devices. For this test, the output voltage is increased from 24 to 32 V, the device turns off the internal FETs and reverse current is blocked within 10 μ s by the device .

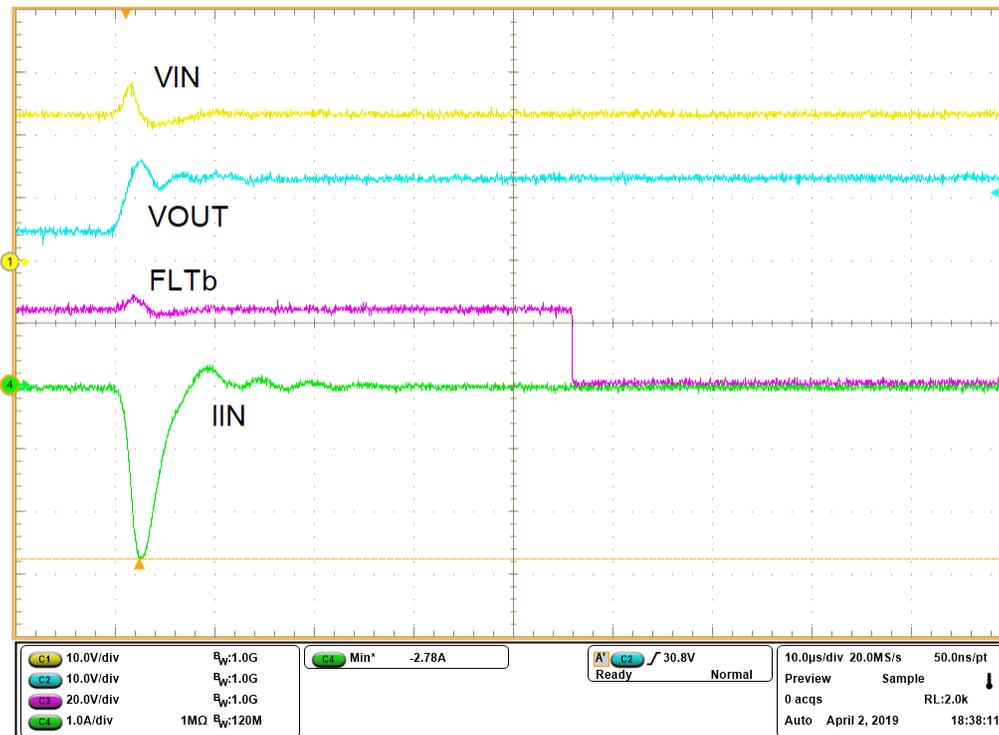


Figure 8. Protection from Higher Voltage on Output with TPS2662 Devices

3.4 Protection from Surge on Output

A surge on output port can occur due to long cabling, lightning event or frequent load changes. During the surge event, the voltage can either swing positive or negative. A positive surge can lead to flow of reverse current from output to input whereas a negative surge can lead to flow of excessive current from input to output. With traditional protections schemes illustrated in Section 2 and Figure 2, the TVS diode can clamp the voltage on output port but during negative surge event, the diode D1 conducts and can lead to shutdown of the module. With reverse current blocking and reverse polarity protection in TPS26624 and TPS26625 devices, these devices disconnect the output during surge events. Figure 9 and Figure 10 show the response of TPS26624 device during the positive surge and negative surge respectively. The device turns-on the internal FETs after the surge event.

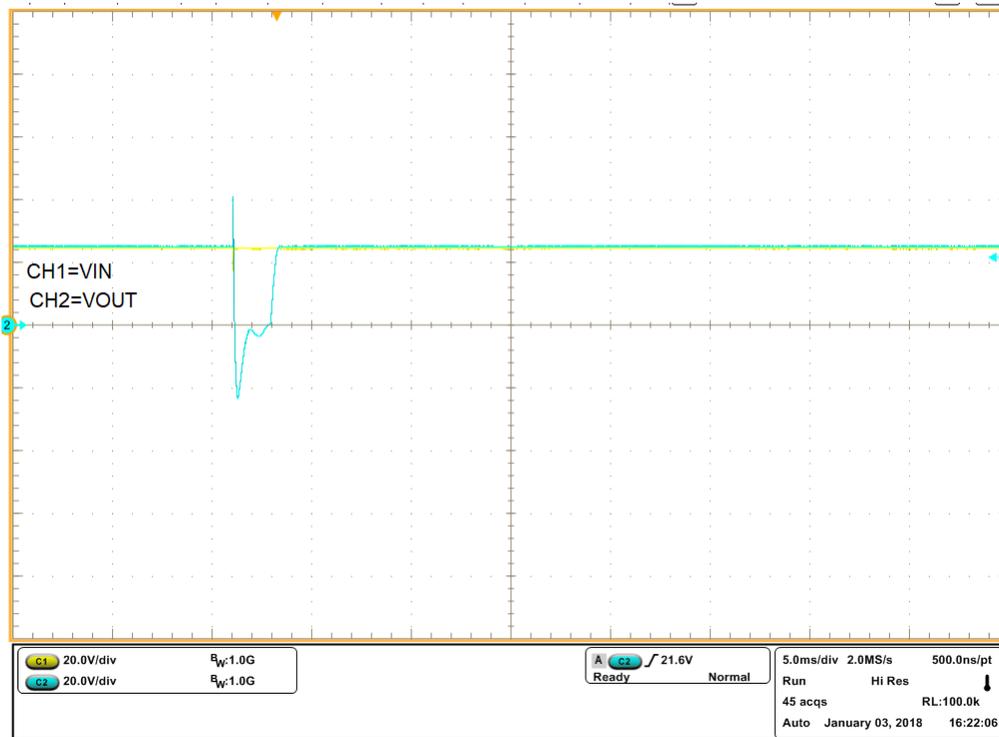


Figure 9. Protection from Positive Surge [500 V, $Z_i = 42 \Omega$]

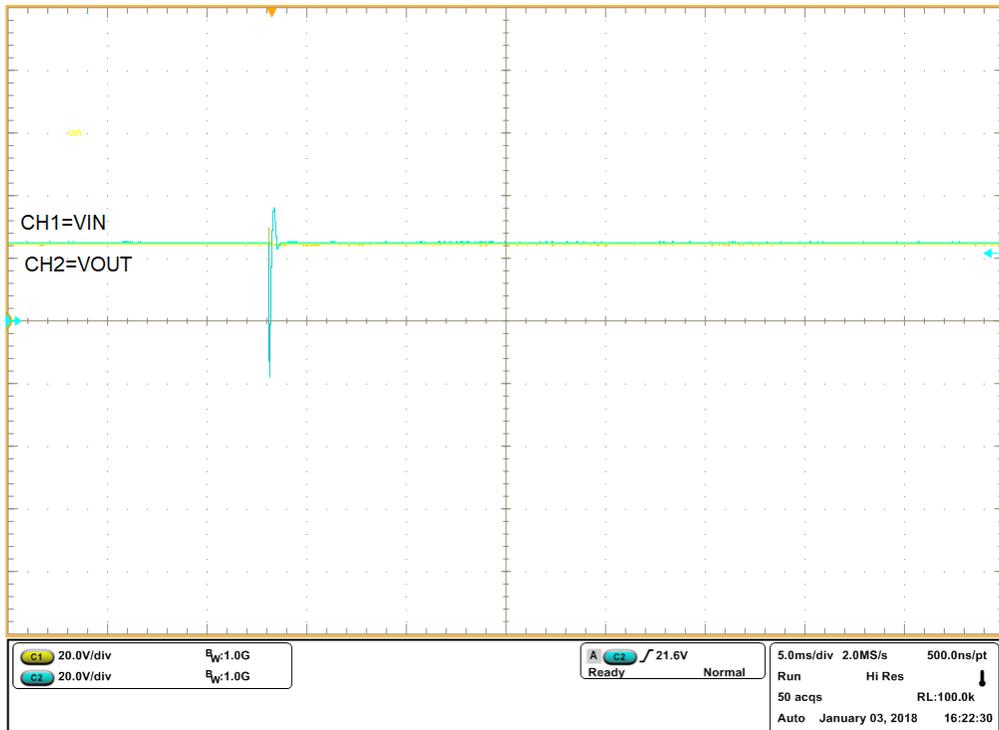


Figure 10. Protection from Negative Surge [-500 V, $Z_i = 42 \Omega$]

Table 2 provides performance with TPS26624 and TPS26625 devices for EFT protection. For more details on Surge and EFT tests in PLC systems, see [Simplifying EFT, Surge and Power-Fail Protection Circuits in PLC Systems](#).

Table 2. Performance with TPS26624 and TPS26625 for EFT protection

EFT Level	Voltage (kV)	Pass/Fail on output (VOUT)
1	± 0.5	Pass with Criteria-A performance
2	± 1	Pass with Criteria-A performance
3	± 2	Pass with Criteria-A performance

4 Conclusion

Traditional power scheme provide limited protection to output power ports during surge events, reverse polarity and short circuit. With traditional protection, the module can shutdown during these faults and transients on output power port or failure of output power port during prolonged faults.

TPS26624 and TPS26625 offer complete protection for Output Power Port from reverse polarity, short circuit, higher voltage and surge events by isolating the power bus of the module and prevent the shutdown and failure of the module during these faults and transients.

5 References

- [TPS2662x 60-V, 800-mA Industrial eFuse with Integrated Input and Output Reverse Polarity Protection](#)
- [TPS2662 Design Calculator](#)
- [TPS2662 Pspice Model](#)
- [Simplifying EFT, Surge and Power-Fail Protection Circuits in PLC Systems.](#)

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