48 V ground loss: 12 V CAN transceiver protection

Introduction

This application note presents a protection solution, which can be easily implemented in systems.

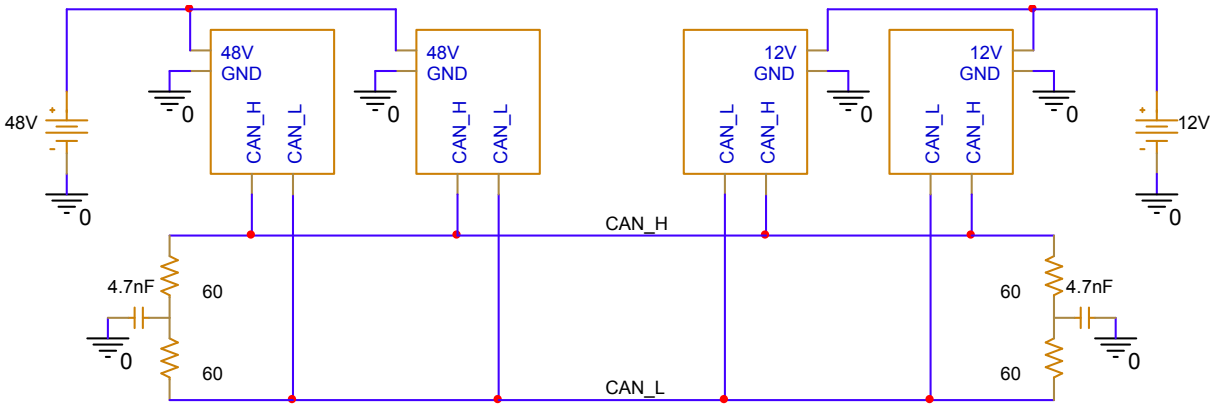
The 48 V automotive power supply is increasingly used by car makers and Tier 1 manufacturers.

The purpose of using a voltage higher than the usual 12 V is to reduce wire size, weight, and voltage drop losses.

Nevertheless, the 12 V system continues to be used with the 48 V system.

These systems can exchange data through the CAN bus. The CAN bus voltage is the same regardless of the system power supply, so no issue occurs during normal operation.

Figure 1. Communication on CAN bus between 12 V and 48 V power nets



However, when a 48 V system loses the GND connection, a high voltage appears on the CAN bus.

Two solutions can manage this overvoltage:

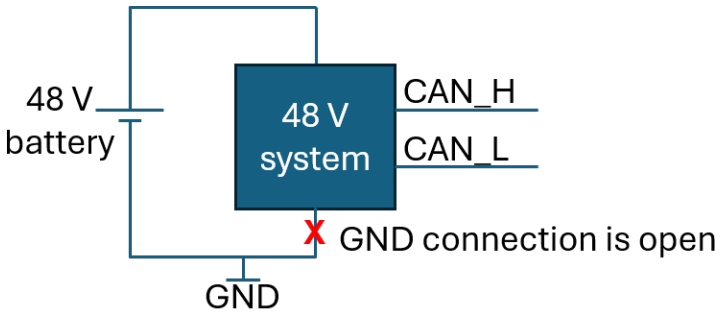
- Use a 48 V compliant CAN transceiver on a 12 V system:
  - However, existing chips with a 12 V CAN transceiver are no longer usable
  - 48 V CAN transceiver cost is higher than the 12 V CAN transceiver cost
- Implement a protection solution that limits the voltage on the CAN lines during a 48 V system ground loss. This solution allows the use of existing 12 V chips that are already qualified.

1 48 V system GND loss issue

The GND loss issue is part of the tests that the *ISO 21780* standard requires as *test 12*, ground loss.

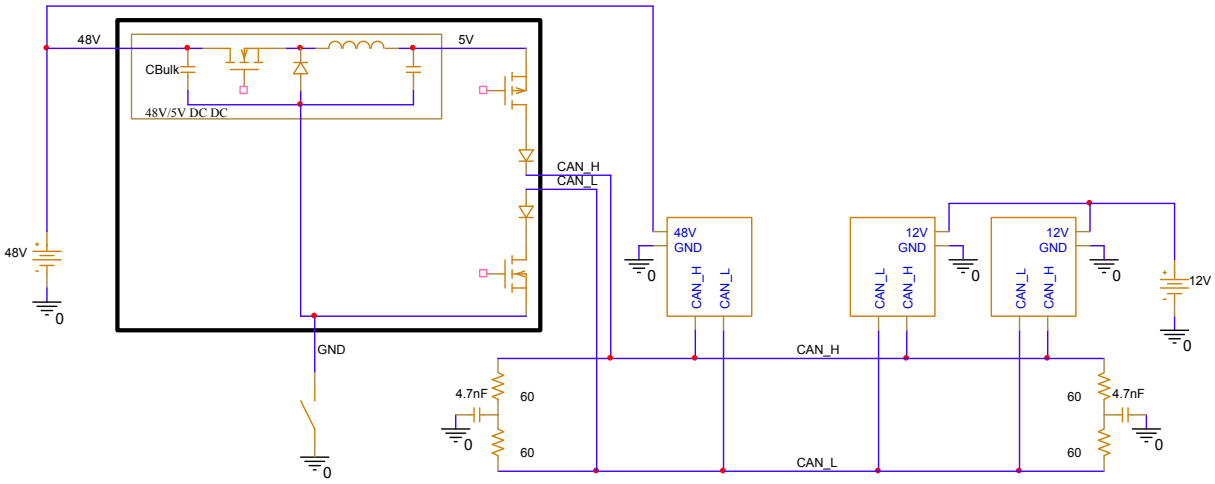
This issue appears when the GND connection of a 48 V system is cut, as shown in the following schematic Figure 2.

Figure 2. GND loss issue



A GND loss in the 48 V system induces a voltage on the CAN lines that rises up to the 48 V battery voltage, as explained below.

Figure 3. CAN network with simplified internal structure of 48 V module with CAN transceiver



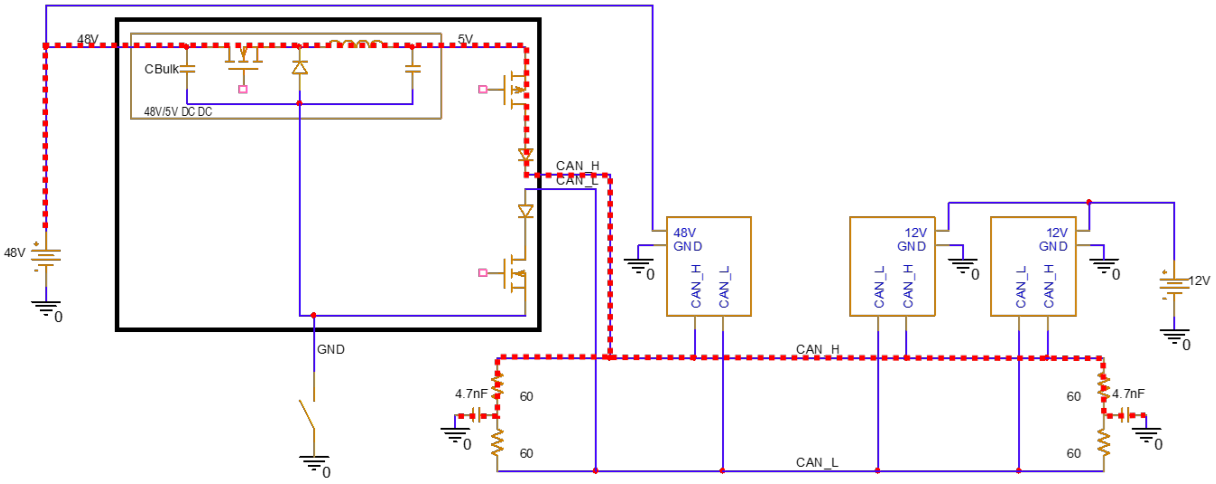
When GND is disconnected from 0 V, a current path is created between the 48 V battery and the 4.7 nF split capacitors.

The split capacitors then charge to the 48 V battery voltage, minus the voltage drop between the battery and the capacitors.

This situation creates a high voltage on the CAN_H and CAN_L lines.

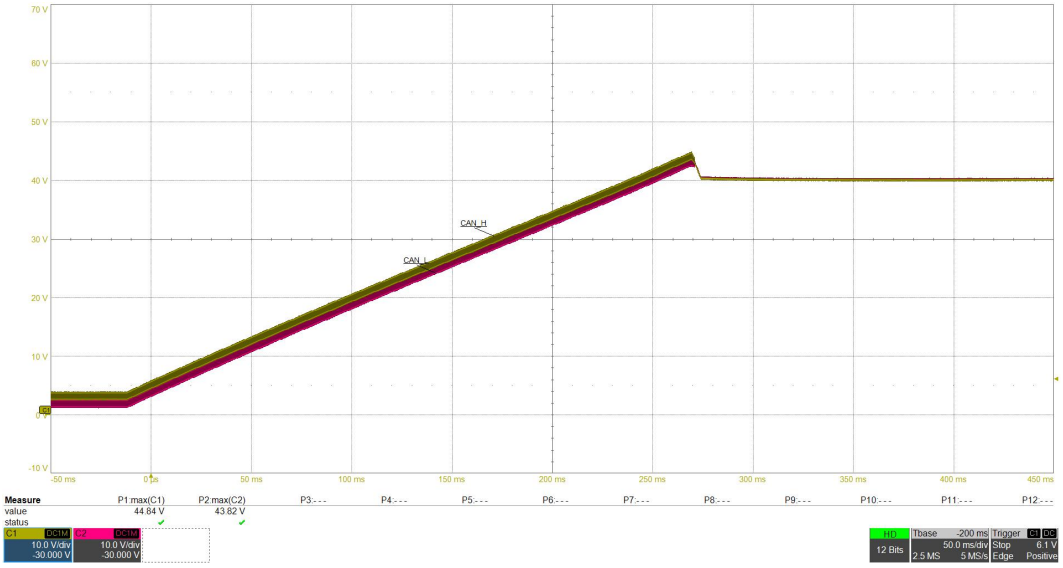
The following Figure 4 shows the current path between the 48 V battery and the split capacitors.

Figure 4. Current path between 48 V and 4.7 nF split capacitors during GND loss



Measurements show a high voltage on CAN_H and CAN_L.

Figure 5. CAN_H and CAN_L measurement during GND loss event (battery voltage = 48 V)



According to *ISO 11898-2*, the maximum voltage on CAN_H and CAN_L for a 12 V CAN transceiver is 40 V. Therefore, 12 V CAN transceivers require protection to prevent failure.

2 Solution to limit voltage on CAN lines during GND loss event

A simple solution to limit the CAN voltage during a GND loss event is to clamp the voltage on the 4.7 nF split capacitors.

This clamp is implemented by placing a TVS in parallel with the split capacitors.

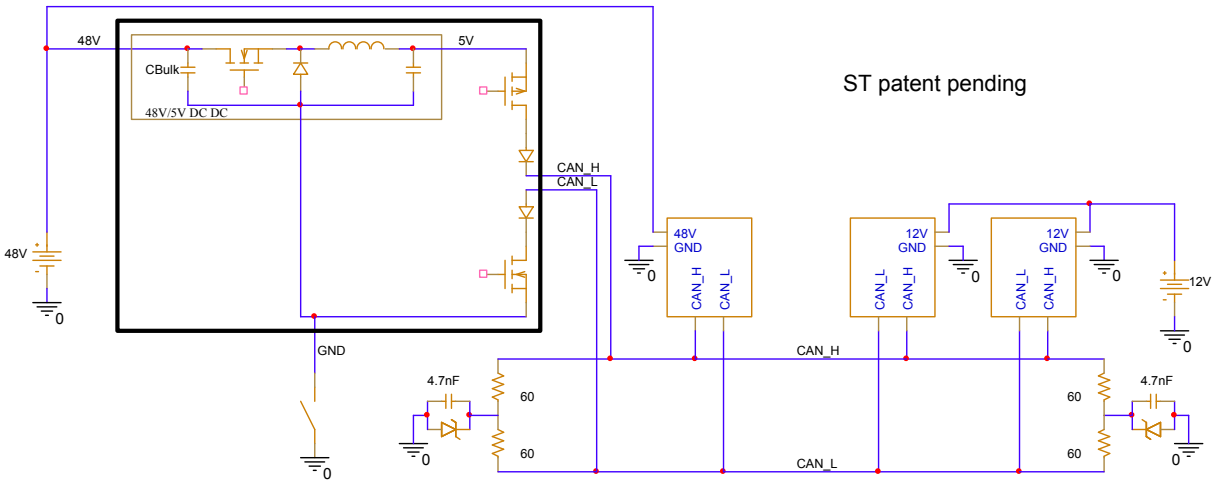
This solution is ST patent pending.

Power dissipation in the TVS is limited for the following reasons:

- CAN transceiver output current is limited: ISO 11898-2 specifies a maximum HS-PMA driver output current of 115 mA. In addition, the CAN transceiver datasheet specifies the short-circuit current on CAN_H and CAN_L.
- 48 V to 5 V DC-DC converter delivers 5 V for a limited time. The discharge time of the bulk capacitor on the 48 V side of the DC-DC converter defines this duration. When the bulk capacitor voltage decreases below the DC-DC undervoltage threshold, the converter stops operating.

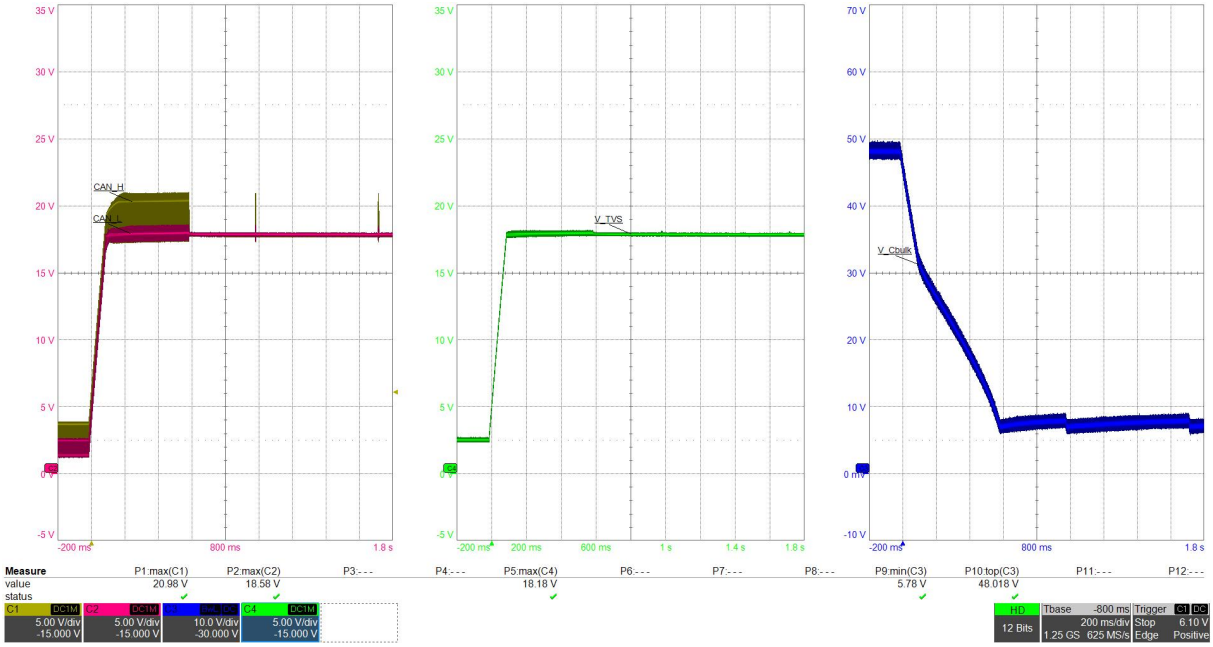
The following Figure 6 shows the schematic with a TVS to clamp the voltage on CAN_L and CAN_H during a GND loss event.

Figure 6. Solution with TVS to limit voltage on CAN lines during a GND loss event



Measurements were performed with the SM4T18AY TVS, as shown in the following oscillograms Figure 7.

Figure 7. CAN_H, CAN_L, TVS, and DC-DC C_{Bulk} voltage measurements during GND loss event



When the voltage exceeds the TVS clamping voltage, the TVS limits the voltage on the CAN lines.

The overvoltage is applied until the DC-DC converter stops operating because the DC-DC bulk capacitor discharges.

The 48 V bulk capacitor value and the current consumed on the 5 V side define this time.

This measurement was performed with only a CAN transceiver and an oscillator connected to 5 V, so the current consumption on the 5 V side is very low.

The bulk capacitor on the 48 V side is 330 µF.

3 TVS selection

The TVS voltage must be selected according to the CAN_H and CAN_L voltages during normal operation.

ISO 11898-2 defines the following values:

- Single-ended voltage on CAN_H = 4.5 V max
- Single-ended voltage on CAN_L = 2.25 V max.

Therefore, the minimum TVS V_{RM} is 4.5 V to comply with the CAN voltage during normal operation.

If compliance with *ISO 16750-2* is still required for the 12 V system, the CAN link must comply with 18 V_{DC} for 60 min. Therefore, the minimum TVS V_{BR} is 18 V.

On the 12 V system, ESDCAN protections are implemented on the CAN lines (see "AN5878: How to design a robust automotive CAN system" for more details). The TVS must limit the voltage to a value lower than the ESDCAN V_{BR} to avoid ESDCAN conduction.

STMicroelectronics proposes the following ESDCAN protection solutions.

Table 1. STMicroelectronics ESDCAN offer in SOT-23 package

Order code	I_{RM} max. at V_{RM}		V_{BR} at I_R			V_{CL} Pulse ISO7637-3		V_{CL} at I_{PP} (8/20 µs)		C		ΔC(1)	αT(2)
	-	-	Min.	Max.	-	3a at -150 V min.	3b at +150 V max.	Max.	-	Typ.	Max.	Typ.	Typ.
	µA	V	V		mA	V		V	A	pF		pF	10^{-4}/°C
ESDCAN24-2BLY	0.1	24	27	32	1	-40	40	43	5	-	30	0.1	9
ESDCAN01-2BLY	0.1	24	25	30	1	-35	35	40	5	-	30	0.1	9
ESDCAN04-2BLY	0.05	25.5	27.5	30.7	1	-35	35	43	3	17	19	0.1	9
ESDCAN06-2BLY	0.1	35	38	42.2	1	-44	44	59	3	13	15	0.1	9

1. *ΔC: capacitance variation between IO1 and IO2 versus GND*
2. *To calculate V_{BR} versus T_j: V_{BR} at T_j = V_{BR} at 25°C x (1 + αT x (T_j - 25))*

Table 2. STMicroelectronics ESDCAN offer in SOT-323 package

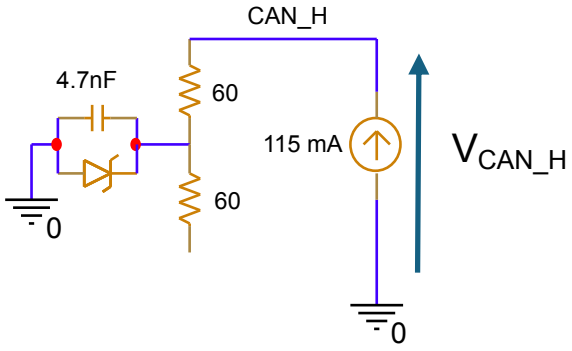
Order code	I_{RM} max. at V_{RM}		V_{BR} at I_R			V_{CL} Pulse ISO7637-3		V_{CL} at I_{PP} (8/20 µs)		C		ΔC	αT (1)
	-	-	Min.	Max.	-	3a at -150 V min.	3b at +100 V max.	Max.	-	Typ.	Max.	Typ.	Typ.
	µA	V	V		mA	V		V	A	pF		pF	10^{-4}/°C
ESDCAN02(2)	0.01	26.5	28.5	31.7	1	-36	36	37	1	3	3.5	0.01	9
								44	3				
ESDCAN03 (2)	0.01	24	26.5	29.7	1	-34	34	35	1	3	3.5	0.01	9
								41	3				
ESDCAN05 (2)	0.1	36	39	43.3	1	-45	45	52	1	3	3.5	0.01	9
								61	3				
ESDCAN06 (2)	0.1	35	38	42.2	1	-44	44	50	1	13	15	0.01	9
								59	3				

1. *V_{BR} at T_j = V_{BR} at 25°C x (1 + αT x (T_j – 25))*
2. *To include the suffix -2BWY to complete the RPN name*

For the 12 V system, ESDCAN V_{BR} min. is in the range of 25 V to 28.5 V. During a GND loss event, CAN_H and CAN_L must remain below this range.

Simple Figure 8 schematic is used to get voltage on CAN lines.

Figure 8. Schematic to calculate voltage on CAN line during GND loss with TVS



Using this worst-case calculation, the maximum voltage on the CAN line is as follows:

- Take 115 mA as the CAN transceiver short-circuit current
- Use a TVS with V_{BR} typ = 18 V ($V_{BR\ min.}$ = 17.1 V). Because the V_{BR} temperature coefficient is positive, V_{BR} increases to 18 V even if $V_{BR} = V_{BR\ min.}$
- For a first calculation, use TVS R_D = 3 Ω
- CAN line maximum voltage = $I \times R_{term} + V_{BR} + R_D \times I = 0.115 \times 60 + 18 + 3 \times 0.115 = 25.3$ V.

This worst-case calculation gives maximum CAN line values that comply with the ESDCAN protections presented above.

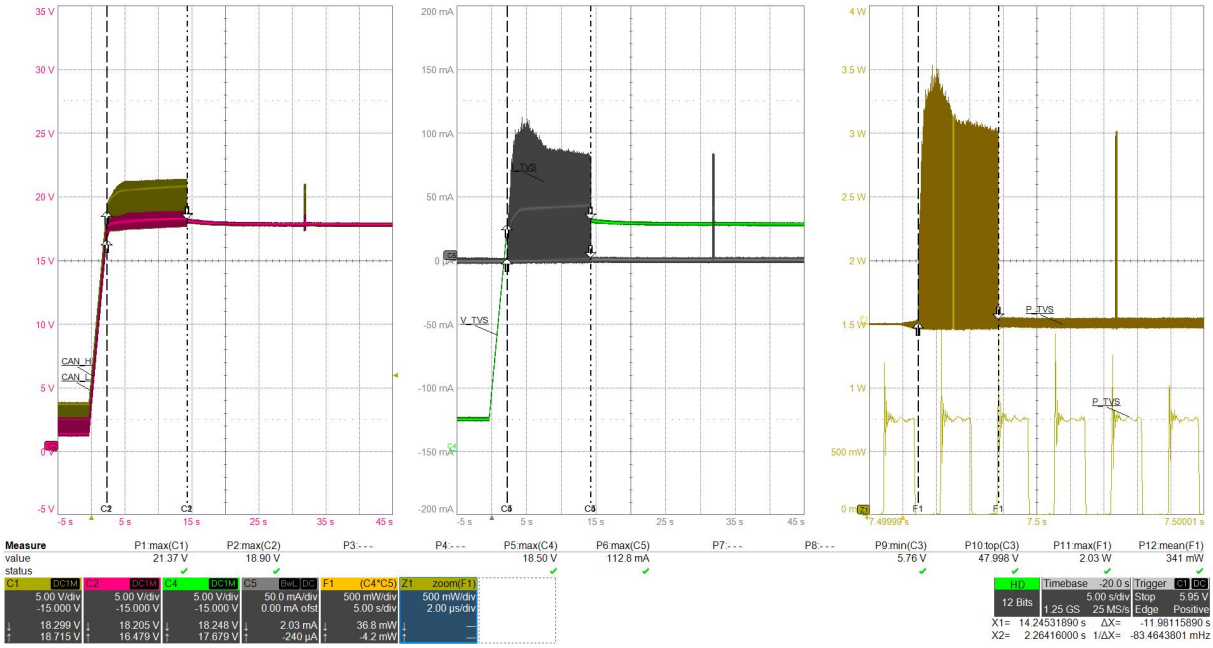
The second point is to define the TVS power capability. The DC-DC bulk capacitor value on the 48 V side and the DC-DC output current define the current duration. A higher output current makes the 48 V bulk capacitor discharge faster. This also causes the DC-DC converter to shut down more quickly. Therefore, the worst case occurs when the system draws the lowest current. This condition gives the maximum TVS conduction time.

A measurement was performed with a bulk capacitor of 10 000 µF, and the DC-DC load was only the CAN transceiver. This is a worst case because the current delivered by the DC-DC converter is very low. The TVS is SM4T18AY.

The following oscillograms in Figure 9 show:

- C1 and C2: CAN_H and CAN_L
- C4: TVS voltage
- C5: current on one TVS
- F1: power on one TVS
- Z1: zoom on power on one TVS.

Figure 9. GND loss event protected by TVS, with C_{Bulk} = 10000 µF and very low DC-DC output current



Because the bulk capacitance is high and the DC-DC output current is very low, the TVS clamping duration is high. A duration of 12 s was measured.

The average power in the TVS is 341 mW (CAN signal duty cycle = 50%).

The SM4T18AY datasheet gives $Z_{th(j-a)}$ = 80°C/W for a pulse duration of 12 s.

Therefore, the junction temperature increase is 80°C/W × 341 mW = 27.3°C.

This value is low and complies with an ambient temperature of 125°C (SM4T18AY $T_J$max. = 150°C).

Also, the maximum voltage on the CAN lines is 21.37 V, which is lower than the ESDCAN protection V_{BR}.

4 Conclusion

Protection against GND loss overvoltage can be implemented with a TVS in parallel with the split capacitors. SM4T18AY is suitable. If higher power is needed, SMA6T18AY, SM6T18AY, SM15T18AY, SM30T18AY and SM5018AY can be used.

This simple solution protects a 12 V CAN transceiver and allows the use of existing, already qualified 12 V devices.

This solution is covered by a pending ST patent application. Contact the local ST representative before implementation.

Revision history

Table 3. **Document revision history**

Date	Revision	Changes
18-Sep-2026	1	Initial release.

Contents

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