AN-1013

SUPER CLAMP TVS feature and comparison with conventional TVS

Content

1. SUPER CLAMP TVS introduction……………………………………………………...………..2

1.1 SUPER CLAMP TVS feature……………………………………………...…......………… 2

1.2 SUPER CLAMP TVS structure…………………………………….…………………………3

2. SUPER CLAMP TVS characteristics……………………………………………………………4

3. SUPER CLAMP TVS I-V curve, V_C, V_{BR} compare with conventional TVS……….5

3.1 8/20us I-V curve comparison…………………………………………………………………5

3.2 V_C tested by 8/20us IPP comparison…………………………………………………5

3.3 10/1000us I-V curve comparison……………………………………………………………6

3.4 V_C level by 10/1000us IPP comparison……………………………………………...……7

3.5 Breakdown voltage (V_{BR}) temperature deviation comparison…….…..…...8

4. Automotive protection……..……………………..…………………………..……………………9

4.1 ISO 16750 test…..………………………………………………………………..…………………9

4.2 ISO 7637 test….……………………………………………………………….………………….10

5. Protection power system…………………………………………………...…………………….11

6. Summary……………………………………………………………………………………………….13

1. SUPER CLAMP TVS introduction

SUPER CLAMP series TVS diodes with snapback characteristics feature a superior optimized clamping ratio between the designated breakdown voltage and clamping voltage. This optimized clamping ratio provides a lower clamping voltage to protect the circuit at a much higher peak pulse current than conventional TVS diodes, which enables the circuit designer to choose lower working voltage of capacitors, switching devices, polarity protection diodes, load switch MOSFETs and so as well the regulator ICs. In addition, SUPER CLAMP TVS diodes provide the flexibility to combine with other conventional TVS diodes in series to meet different working voltage requirements with high peak surge current.

1.1 SUPER CLAMP TVS feature

SUPER CLAMP TVS diodes breakdown voltage (V_{BR}) difference of temperature deviation is lower than conventional TVS, this V_{BR} stability by temperature variation helps the designer anticipate voltage range when temperature is added consideration. The snapback characteristics are shown below in Figure 1.

TSC high power DO-218AB package SUPER CLAMP TVS diodes specification:

ELECTRICAL SPECIFICATIONS (T_A = 25°C unless otherwise noted)

Part number	Device marking	Breakdown voltage V_{BR}@I_T (V) (Note 1)		Test current I_T (mA)	Working stand-off voltage V_{WM} (V)	Maximum blocking leakage current I_R@V_{WM} (µA) (Note 1)	Maximum blocking leakage current I_R@V_{WM} T_J=175ºC (µA) (Note 1)	Maximum peak impulse current I_{PPM} (A) tp =10/1000 (µs)	Typical clamping voltage V_C at I_{PPM} (V)	Typical temp. coefficient of V_{BR} αT (%/°C) (Note 2)
		Min.	Max.							
LTD7S24CAH	LTD7S24	26.7	29.5	5	24	1	150	300	24	0.081

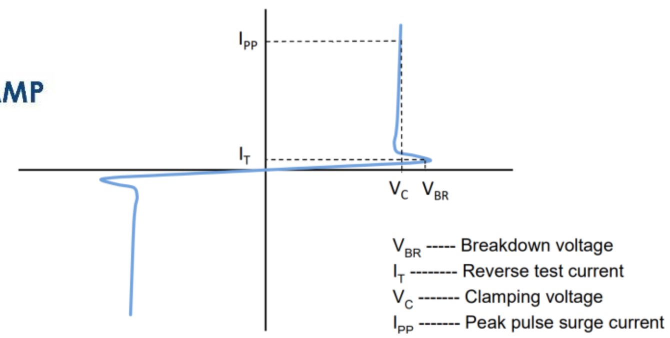


Figure 1: SUPER CLAMP TVS Vc- I_{pp} curve characteristics

1.2 SUPER CLAMP TVS structure

SUPER CLAMP TVS adopt BJT (Bipolar junction transistor) different from conventional TVS in Figure 2 SUPER CLAMP TVS instinctive snapback characteristics breakdown voltage occurs then returns and breakdown again. This SUPER CLAMP ratio provides lower V_C (clamping voltage) at high I_{PP} (peak impulse current), its following protected discrete components could sustain lower voltage stress, and the designer could use lower working voltage specification components like a capacitor, MOSFET…etc.

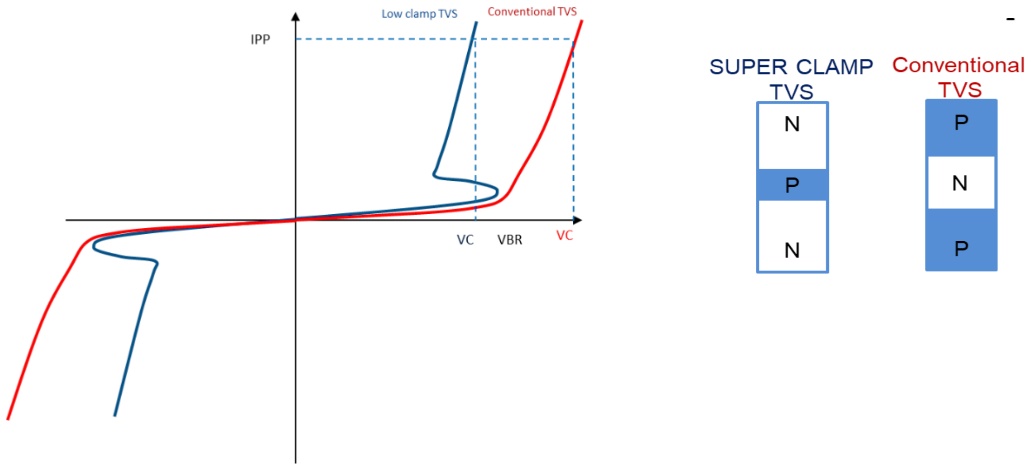


Figure 2: Conventional and SUPER CLAMP TVS structure, V_C – I_{PP} curve

2. SUPER CLAMP TVS characteristics

V_{WM} (Working stand-off voltage):
Normal voltage TVS can withstand system normal operation, TVS will not breakdown with very low leakage current flow only.

V_{BR} (Breakdown voltage):
The voltage slightly increased at the specific test current (I_T) condition.

V_C (Clamping voltage):
The maximum voltage for a peak pulse I_{PP}, the SUPER CLAMP TVS clamping voltage is lower than the breakdown voltage at transient surge.

I_{PP} (Peak impulse current):
The transient current at the clamping voltage represents the capability of the product. SUPER CLAMP TVS I_{PP} capability is higher than conventional TVS.

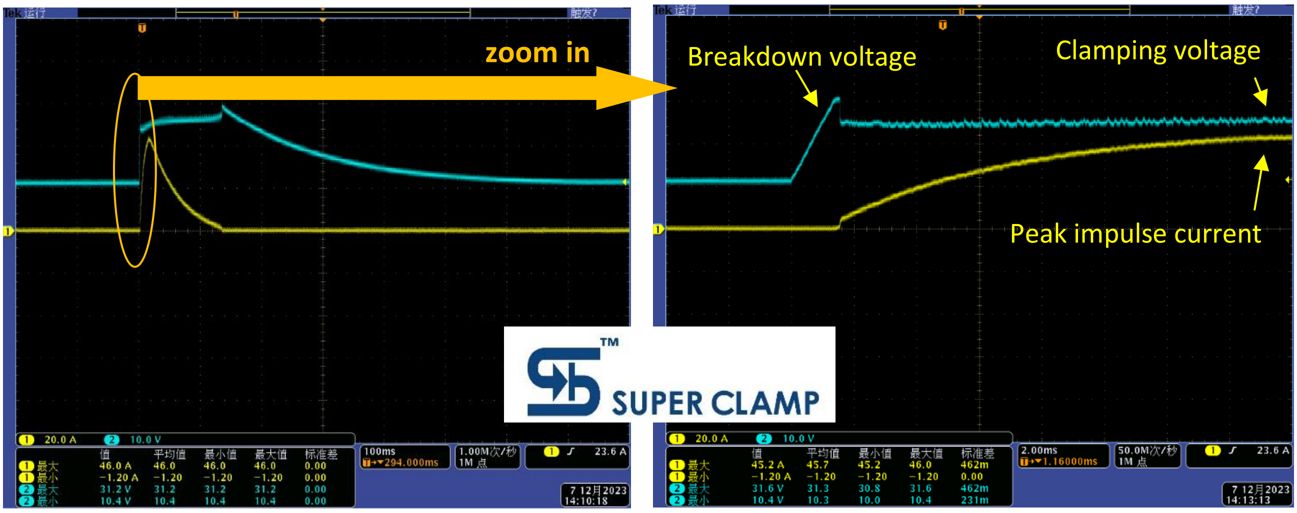


Figure 3: SUPER CLAMP TVS LTD7S24CAH I_{PP} and V_C waveform

3. SUPER CLAMP TVS I-V curve, V_C, V_{BR} compare with conventional TVS

To understand SUPER CLAMP TVS's characteristics and advantages over conventional TVS, compare the DO-218AB package bi-directional SUPER CLAMP TVS LTD7S24CAH and conventional TVS TLD8S24CAH in the 8/20 us and 10/1000 us surge pulse test.

3.1 V_C tested by 8/20us I_{PP} comparison

Take SUPER CLAMP TVS LTD7S24CAH and conventional TVS TLD8S24CAH to test 8/20us transient surge. Applying 8/20us I_{PP}=500A to these two TVS and record V_C results as in Figure 4. LTD7S24CAH V_C=22.5V which is 63.38% of TLD8S24CAH V_C=35.5V.

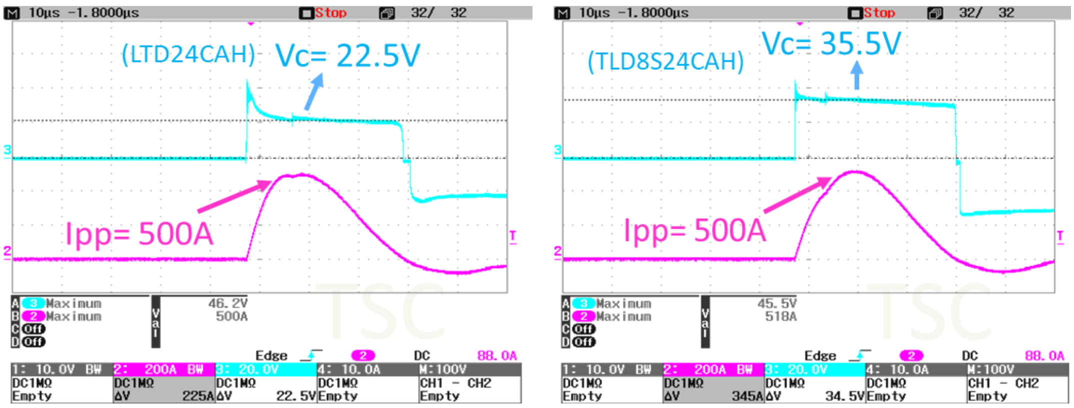


Figure 4: SUPER CLAMP and conventional TVS tested 8/20u I_{PP}=500A

3.2 8/20us I-V curve comparison

Take SUPER CLAMP TVS LTD7S24CAH and conventional TVS TLD8S24CAH to test 8/20us transient surge and record V_C – I_{PP} waveform (Figure 5). LTD7S24CAH curve shows snapback characteristics whose V_C clamping ratio=1.63 (V_C/V_{WM}) and Rdny=0.005 ohm is lower than TLD8S24CAH curve shows exponential characteristics whose V_C clamping ratio=2.54 (V_C/V_{WM}) and Rdny=0.017 ohm. SUPER CLAMP TVS can suppress transient surge closer to V_{BR} than conventional TVS.

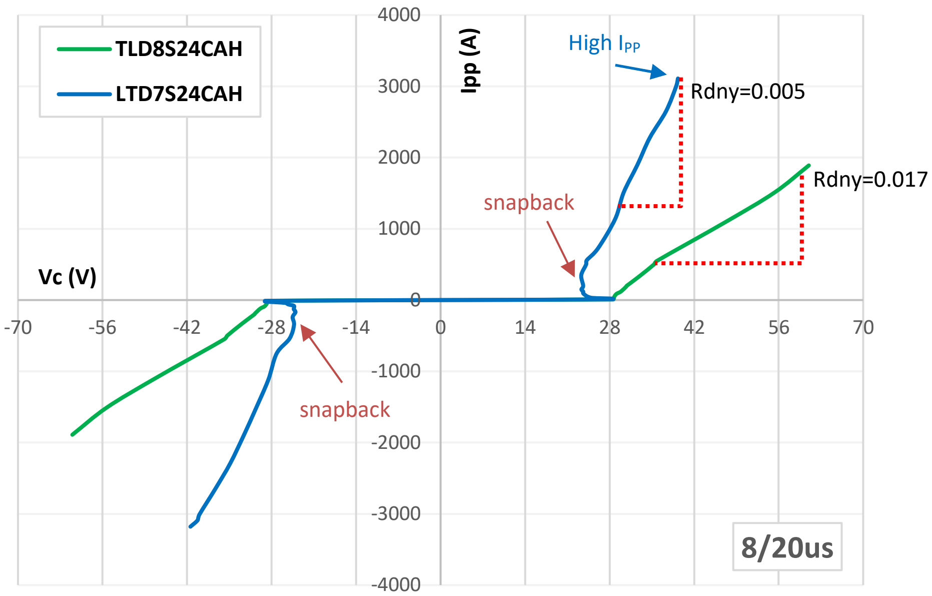


Figure 5: SUPER CLAMP and conventional TVS in 8/20us I-V curve

3.3 V_C level by 10/1000us I_{PP} comparison

A wider TVS V_{WM} allows the system to operate within a broader working voltage range, based on the specific V_C. To see the SUPER CLAMP TVS V_{WM} level compared to conventional TVS by the same V_C effect, take SUPER CLAMP TVS and a series of conventional TVS to test 10/1000us surge as Figure 6(a). LTD7S24CAH V_C=25.15V which is similar to TLD8S20CAH V_C=25.4V at I_{PP}=204A. LTD7S24CAH snapback characteristic helps V_C clamping lower ratio, which lets LTD7S24CAH own the same V_C level as TLD8S20CAH. But LTD7S24CAH has a higher current and allowable working voltage V_{WM}=24V than TLD8S20CAH based on the same V_C level.

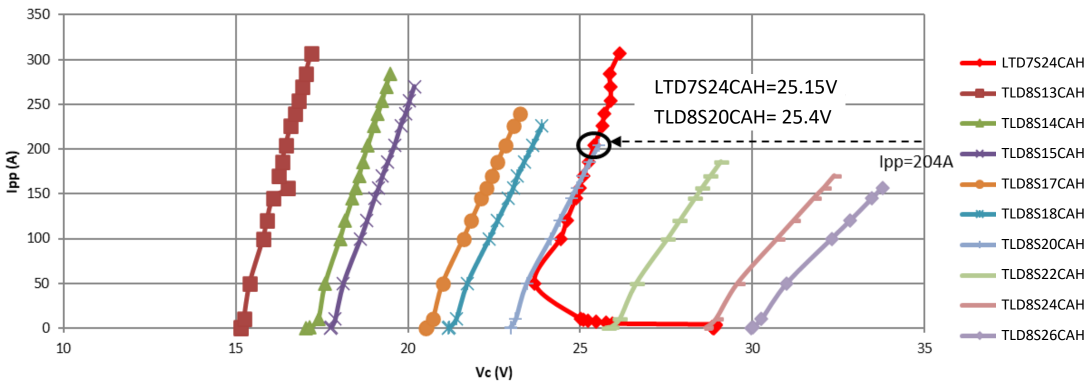


Figure 6(a): V_C comparison of LTD7S24CAH and TLD8SxxCAH by 10/1000us I_{PP} tested

Compared to the peak pulse currents of 170A and 300A, even with a current increase of 70.45%, the variation in clamping voltage is only 3.2%, which is significantly smaller, as illustrated in the waveform in Figure 6(b).

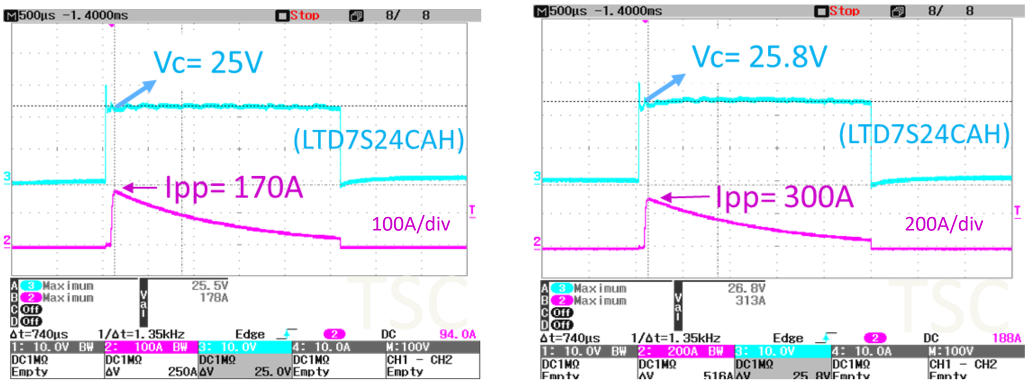


Figure 6(b): V_C comparison of LTD7S24CAH in 10/1000us I_{PP} tested

3.4 10/1000us I-V curve comparison

Take SUPER CLAMP TVS LTD7S24CAH and conventional TVS TLD8S24CAH to test 10/1000us transient surge and record V_C – I_{PP} waveform in Figure 7. LTD7S24CAH curve shows snapback characteristics whose V_C clamping ratio=1.075 (V_C/V_{WM}) and Rdny=1.05 ohm is lower than TLD8S24CAH curve shows exponential characteristics whose V_C clamping ratio=1.35 (V_C/V_{WM}) and Rdny=1.16 ohm. SUPER CLAMP TVS can suppress transient surges closer to V_{BR} than conventional TVS.

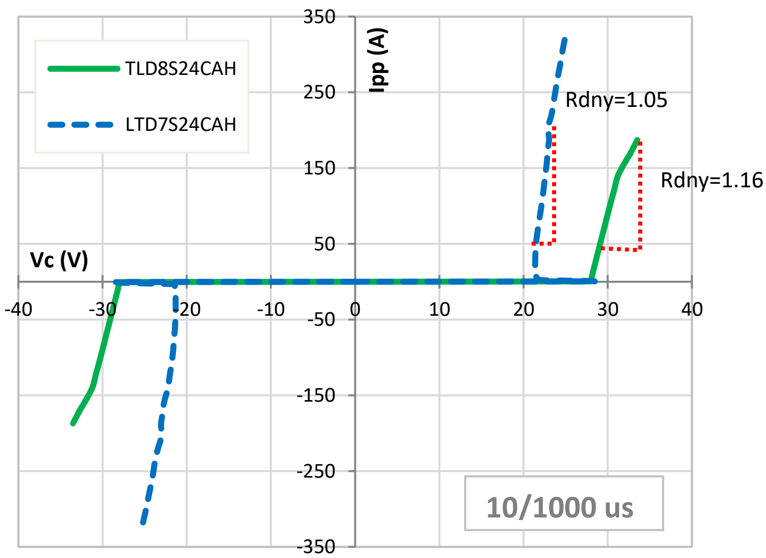


Figure 7: SUPER CLAMP and conventional TVS 10/1000us I-V curve

3.5 Breakdown voltage (V_{BR}) temperature deviation comparison

V_{BR} will be a concentration of designers examining if TVS is adequately turned on when the temperature increases. Take SUPER CLAMP TVS LTD7S24CAH and conventional TVS TLD8S24CAH to test V_{BR} in temperatures from -55ºC to 175ºC (Figure 8). LTD7S24CAH operates in the temperature range -55ºC to 175ºC, V_{BR} deviation difference is 4.1V; TLD8S24CAH operates with a V_{BR} deviation difference is 5.2V. So LTD7S24CAH V_{BR} difference of temperature deviation is more stable than TLD8S24CAH. The competition in a wide temperature range variation is 0.17V/10℃ versus 0.22V/10 ℃, the normalized curve is shown below.

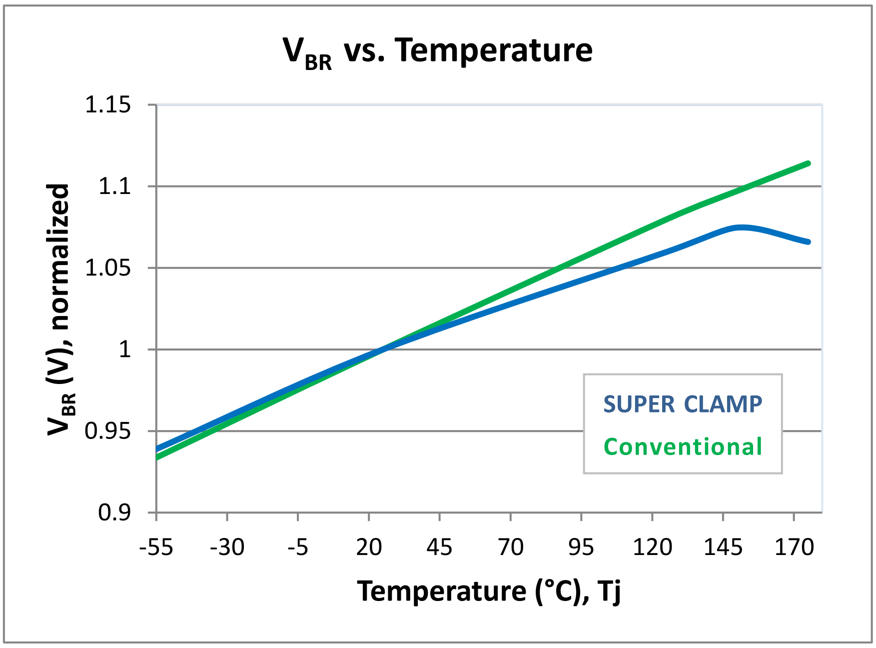


Figure 8: SUPER CLAMP and Conventional TVS V_{BR} temperature variation

4. Automotive protection

The hazards indicated are described by several standards bodies, including the Society of Automobile Engineers (SAE), the Automotive Electronics Council (AEC), and the International Organization for Standardization (ISO). One important standard, ISO 16750-2, outlines the load dump test, which is the most demanding in terms of energy and rigorous verification for automotive systems.

4.1 ISO 16750 test

According to ISO 16750-2, the test simulates a load dump event without centralized load-dump suppression. These pulses mimic the surge caused when the alternator loses its centralized load dump protection. SUPER CLAMP TVS can be utilized in various automotive applications, including protection against power surges and as freewheel diodes, among other functions. Load dump transients are among the most severe power surges and can cause serious damage to a vehicle's electronic systems. SUPER CLAMP TVS is the ideal solution for mitigating this risk, as it provides low and stable clamping voltage, preventing damage to downstream components. Figure 9 illustrates how to protect your subsystem from a load dump pulse in these systems.

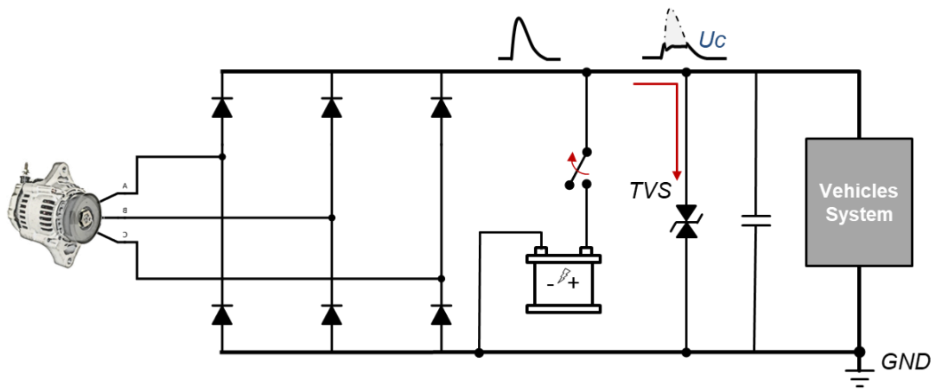


Figure 9: Load dump generation in the vehicle system

Figure 10 shows the waveforms of the LTD7S24CAH at a load dump test condition of 101 V U_S with a 400 ms pulse width, 1.75-ohm Ri, and 10 pulses. Comparing V_C and I_{PPM} waveforms, the SUPER CLAMP TVS LTD7S24CAH provides a lower clamping voltage (73.5%) and delivers a higher pulse current (115%) than conventional TVS.

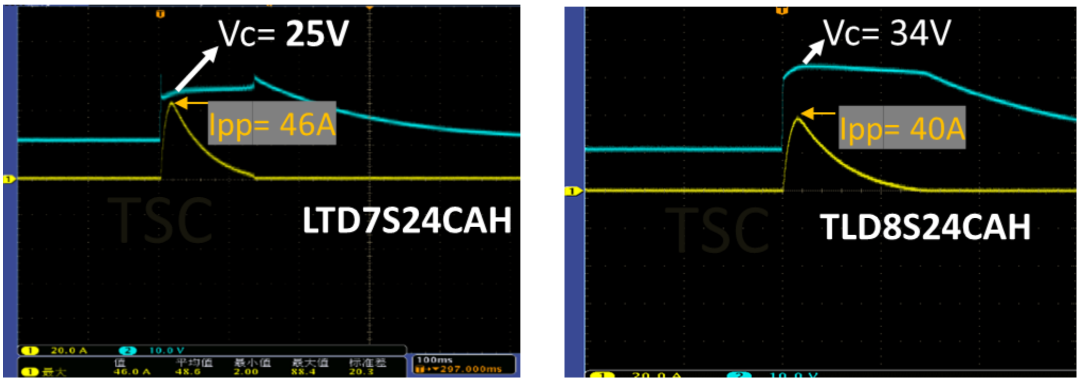


Figure 10: Waveforms of the LTD7S24CAH and TLD8S24CAH at TEST A

4.2 ISO 7637 test

ISO 7637 applies to all types of road vehicles, regardless of the propulsion system—whether powered by spark ignition, diesel engines, or electric motors. The standard ensures that equipment installed in passenger cars and commercial vehicles with 12V or 24V electrical systems is compatible with electrical transients.

ISO 7637 specifies the methods and procedures for testing, including bench tests for injecting and measuring transients. Additionally, it provides a classification for functional performance status, indicating the level of immunity to these electrical transients. Figure 11 (a) & (b) show the waveform in the LTD7S24CAH at the different levels that are passed. All test conditions are listed in table 1 below.

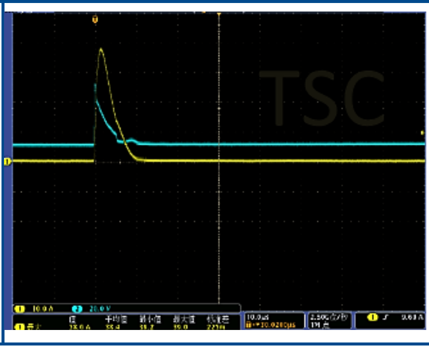
Pulse 1 Level IV	Pulse 2a Level IV
	

Figure 11(a): Waveforms of the LTD7S24CAH Load 4.2 in ISO 7637 test

Pulse 3a Level IV	Pulse 3b Level IV

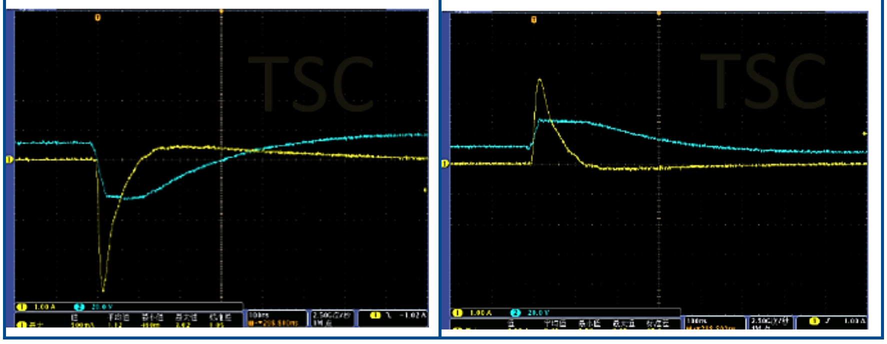


Figure 11(b): Waveforms of the LTD7S24CAH Load 4.2 in ISO 7637 test

Table 1: LTD7S24CAH in ISO 7637 test conditions

Condition	Pulse 1 Level IV		Pulse 2a Level IV		Pulse 3a Level IV		Pulse 3b Level IV	
	Ua=12V	Ri=10Ω	Ua=12V	Ri=2Ω	Ua=12V	Ri=50Ω	Ua=12V	Ri=50Ω
Us	-150V		+112V		-220V		+150V	
Clamping voltage (V)								
LTD7S24CAH	-24		27		-26		30	

5. Protection for power system

The primary function of a TVS is to clamp transient voltages and allow current to flow through the TVS at the clamping voltage. Various power systems experience different transient surges in applications. Figure 12(a) illustrates a simplified circuit without a TVS, showing a transient voltage in the system. In an electrical installation, disruptive surges can appear on a power line. These sources include abrupt load switching, faults in the power system, and induced lightning transients from indirect lightning strikes. Additionally, transient voltages from back EMF generated by motor systems can cause voltage spikes illustrated in Figure 12(b).

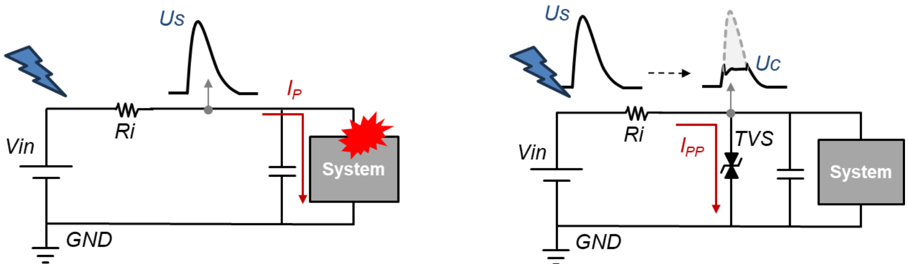


Figure 12(a): TVS transient clamping operation

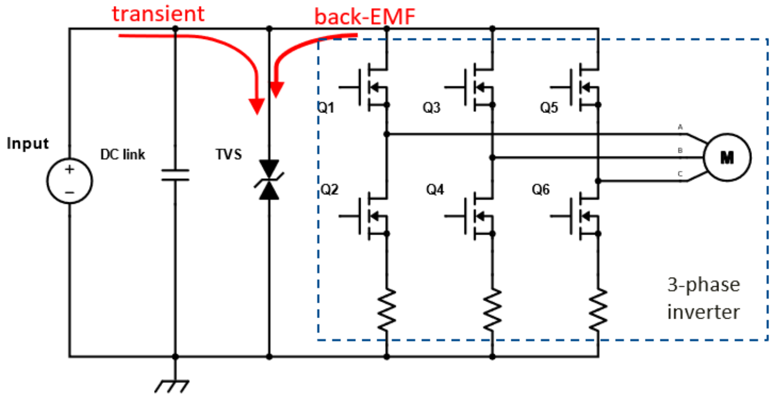


Figure 12(b): TVS transient clamping operation in motor system

However, as shown in Figure 13, a SUPER CLAMP TVS can suppress this high voltage down to 32V (Fig 13 right) compared to without TVS conditions (Fig 13 left). The high transient-handling capability of the SUPER CLAMP TVS makes it well-suited for meeting the demanding requirements of most power and industrial systems.

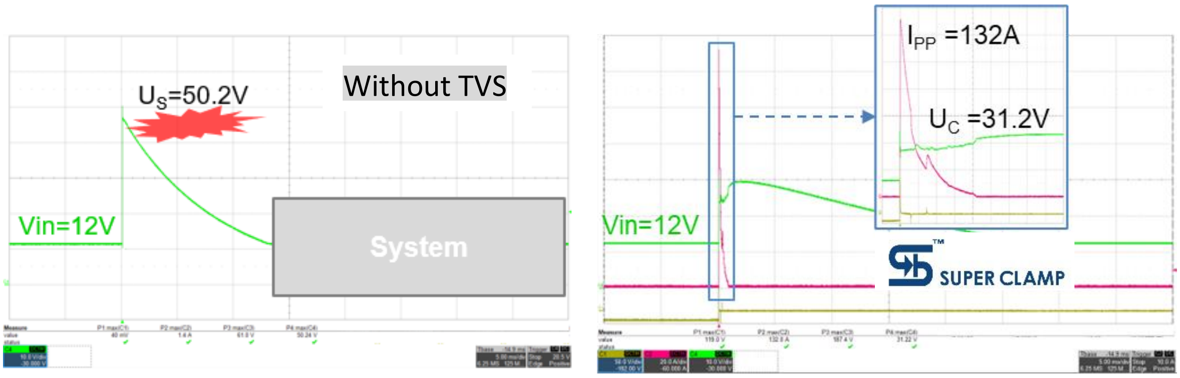


Figure 13: TVS transient clamping operation in 12V power system

6. Summary

SUPER CLAMP series of TVS diodes deliver significantly lower clamping voltage compared to conventional TVS under the same pulse current conditions, reducing voltage stress on discrete components. Additionally, the SUPER CLAMP series can handle much higher pulse currents within the same package size-300A in DO-218AB versus 170A for traditional models that support PCB downsizing. With an operational temperature range of -55°C to 175°C and compliance with automotive qualifications and the ISO 7637 standard, these advantages make the SUPER CLAMP series an ideal choice for high-performance applications.

Authors

Ken Kan : Field Application Engineer Assistant Manager: ken_kan@ts.com.tw

Hank Kuo : Application Engineer Manager: Hank_kuo@ts.com.tw

Notice

Notice This application note information is for reference only based on this experiment and the limited quantity of samples, please follow the datasheet specification or inquire about contact windows before you use in application.

Taiwan Semiconductor Co., Ltd.

Headquarters

Address: 11F. No. 25 Sec. 3, Beishin Rd, Shindian District, New Taipei City, Taiwan R.O.C.

Telephone: +886-2-8913-1588

E-mail: marketing@ts.com.tw

Website: www.taiwansemi.com