Flat-Clamp surge protection technology for efficient system protection

Zhao Fang
Design Engineer

Padmanabhan Gopalakrishnan [GP]
Systems and Applications Manager

Cameron Phillips
Applications Engineer
Texas Instruments

Transient voltage suppression (TVS) diodes are popular choices for surge protection. Although their low cost and simplicity make them an easy choice, several inherent drawbacks pose challenges for system design. The wide temperature variation and inefficient clamping of TVS diodes, coupled with large package footprints, often require the overdesigning of protected circuits.

Texas Instruments (TI) has designed a new clamp technology to protect against transient surge events. This Flat-Clamp technology provides a robust solution to dissipate surge transients while simultaneously providing a precise, flat and temperature-independent clamping voltage that minimizes residual voltage to the protected system.

The package area of a Flat-Clamp device is as much as 90 percent smaller than industry-standard subminiature version A (SMA)/subminiature version B (SMB) packages, with much lower capacitance and as much as 50 percent lower leakage than conventional TVS-based solutions.

This paper provides a brief overview of surge protection standards, explains Flat-Clamp technology and illustrates through examples how this technology optimizes system designs.

The need for surge protection

The demand for more robust and space-efficient circuit protection has increased as more industrial equipment includes advanced integrated circuits (ICs). The evolution of IC technology has driven more functionality into smaller semiconductor components such that the dimension of building-block transistors has shrunk to mere nanometers.

Although these ICs give industrial equipment more horsepower than ever before, smaller geometries are inherently less immune to transient stresses common in industrial environments. Unlike consumer electronic devices, most industrial systems must meet international standards for surge immunity, such as International Electrotechnical Commission (IEC) 61000-4-5 surge protection and IEC 61000-4-2 electrostatic discharge (ESD) protection. Industrial systems also have longer product lifetimes and operate in harsh environments. A robust surge protection solution is a necessity for industrial equipment.

For many years, the industry's primary choice for surge protection has been discrete TVS diodes (**Figure 1**). Although TVS diodes are robust and low cost, their wide temperature variation and inefficient clamping can result in a higher overall system cost and size. To accommodate these weaknesses but still ensure a robust, reliable system, designers often use higher-voltage-tolerant components. These components are more costly, consume higher power and take up more board space.

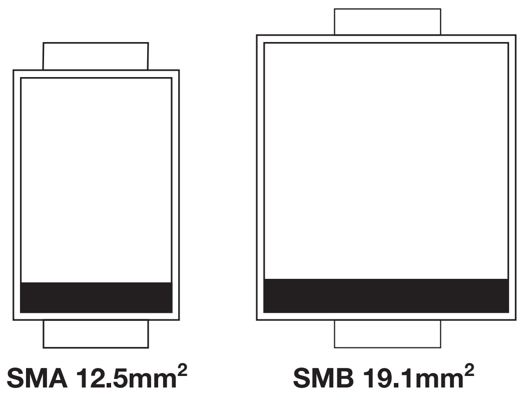

Figure 1. *Standard packages for discrete TVS surge protection diodes.*

Surge immunity standards

Engineers design their systems to pass IEC 61000-4-5, a strict standard for system-level surge immunity. This standard defines the test setup and procedures for surge immunity testing. Unlike ESD events covered by the IEC 61000-4-2 standard, surge events (which usually occur during power system switching transients or lightning discharge scenarios) have a longer pulse duration and much higher energy.

The IEC 61000-4-5 standard specifies different levels, or classifications, depending on where the equipment will be installed. For example, Class 1 is for partly protected environments, while Class 3 is for environments where cables run in parallel. The level of surge voltage, together with the equivalent impedance (R_{eq}) from the surge strike, determines how much surge current the protection device will need to handle (**Table 1**).

	Class 1	Class 2	Class 3	Class 4
	500 V	1kV	2 kV	4 kV
R_{eq} = 42 Ω	12 A	24 A	48 A	96 A
R_{eq} = 12 Ω	42 A	84 A	167 A	334 A
R_{eq} = 2 Ω	250 A	500 A	1000 A	2000 A

Table 1. *Maximum peak current values depending on voltage level and R_{eq}.*

To provide a consistent test method to gauge surge robustness, the IEC 61000-4-5 standard defines a combinational waveform generator (CWG) to generate surge pulses. **Figure 2** shows a simplified CWG, which has a power supply that charges the coupling capacitor (C_C) . Upon closing switch S1, C_C discharges through the pulse-shaping network formed by R_{s1}, R_m, L_r and R_{s2}. Adjusting the values of these components produces a waveform that meets the compliance waveforms of the short- and open-circuit conditions according to the IEC 61000-4-5 standard.

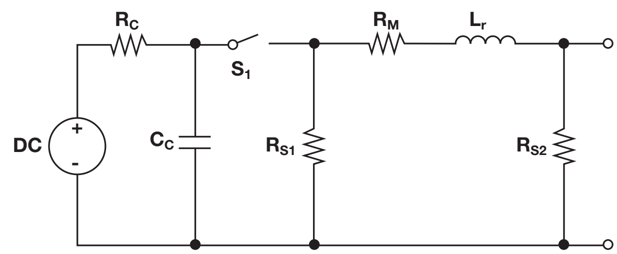

Figure 2. *Simplified circuit diagram of the CWG.*

Referring back to **Table 1**, a 2Ω equivalent impedance is the CWG's inherent source impedance, which by itself is a good model of the source impedance of a low-voltage power supply. A 12Ω equivalent impedance (2Ω from the CWG source and 10Ω from the coupling network) models the impedance of the power source and ground network and is used when a surge happens between the mains and ground. A 42Ω equivalent impedance (2Ω from the CWG source and 40Ω from the coupling network) models the impedance between all other lines and ground. Data or signal lines use this impedance level.

The IEC 61000-4-5 standard defines surge pulses based on the waveform shape when the CWG discharges into a short circuit. The short-circuit waveform has an 8µs front time (similar to rise time) and a 20µs time-to-half-value of the pulse waveform, as shown in **Figure 3**. The peak pulse current (I_{PP}) value related to the 8/20µs surge is larger than that related to the 10/1,000µs standard that is used to specify many TVS diodes, since its pulse duration is much shorter. During shorter surge periods, a protection device must be able to handle more peak power without sustaining damage.

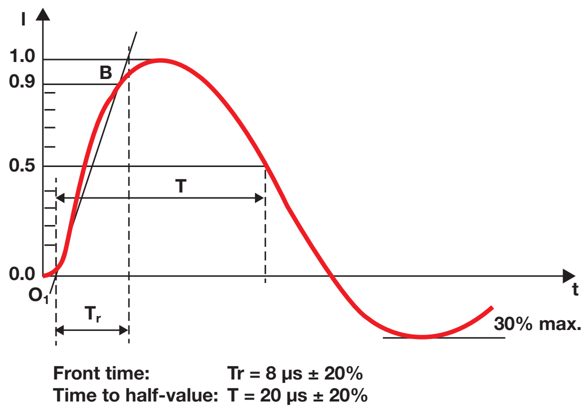

Figure 3. *Waveform of a short-circuit current at the output of the CWG.*

Surge protection design using conventional TVS diodes

A wide range of applications use conventional TVS diodes as surge clamps. **Figure 4** shows the I-V characteristics of a TVS in the positive quadrant. The reverse working voltage (V_{RWM}), also known as standoff voltage, describes the voltage level up to which the TVS presents no significant influence to the protected circuitry (other than the device's parasitic capacitance, leakage, etc.). In a system design, V_{RWM} should be at or above the upper limit of the system's operating voltage, since any higher voltage causes unwanted leakage through the TVS diode clamp.

The breakdown voltage (V_{BR}) defines the reverse voltage at which the TVS diode starts to actively conduct current to clamp a transient event. As more current flows through the diode, the voltage across the diode will rise according to its dynamic resistance (R_{DYN}). During a transient event, currents in the multiple-ampere range are forced to flow through the protection device. This transient current through the diode's R_{DYN} will cause an additional voltage rise above the V_{BR} of the TVS.

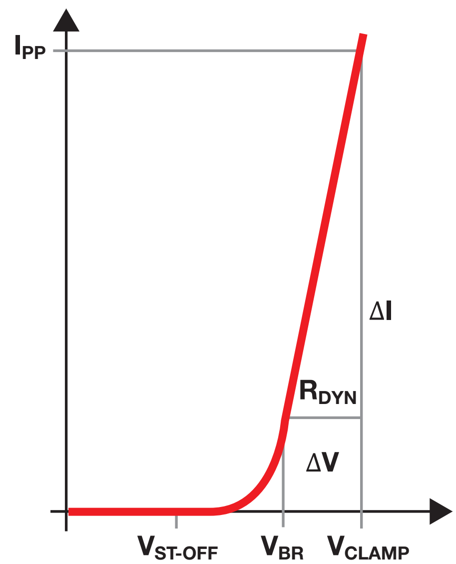

Figure 4. *Standoff, breakdown and clamp voltage.*

The combined voltage across the TVS diode at the rated surge current (I_{PP}) is defined as the clamping voltage (V_{CLAMP}) of the TVS. For conventional TVS diodes, R_{DYN} is fixed and Vclamp depends directly on the current level (**Figure 5**). V_{CLAMP} at the specified transient-surge current level must be low enough to protect all downstream components.

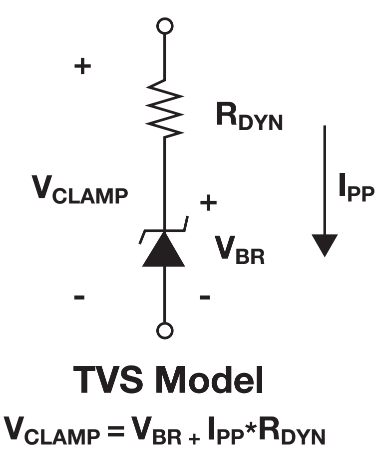

Figure 5. *Electrical model of conventional TVS clamps.*

The physical properties of the silicon and junction area of the diode limit the R_{DYN} of TVS diodes. Even with very large diode areas, an 8/20µs surge R_{DYN} can be in the hundreds of milliohms. Thus, TVS diodes usually have high V_{CLAMP} relative to their V_{RWM}, and designers must take additional steps to design a robust system.

To prevent system failures during a surge event, one approach is to overdesign downstream circuits with devices capable of tolerating high surge-clamping voltages. Although this can produce a robust system, it results in higher system costs, higher power consumption and an increase in IC footprint sizes.

A second option is to select TVS diodes with much lower R_{DYN}, but this leads to difficult trade-offs such as higher input/output (I/O) capacitance, higher I/O leakage and larger TVS package sizes.

TI's Flat-Clamp technology

TI's Flat-Clamp family of surge clamps helps designers by providing a device that removes the difficulties of designing with traditional TVS diodes. **Figure 6** is a functional block diagram of the TI Flat-Clamp family of surge clamps, which integrate a voltage-sensing circuit, a gate-drive circuit and a power field effect transistor (FET), which acts as the active clamp. The voltage-sensing circuit determines the triggering voltage (V_{BR}) of the clamp. When the input voltage to the clamp is lower than the triggering voltage, the gate driver and power FET are off, and no active current flows in the clamp. Once the input voltage (V_{IN}) is higher than the triggering voltage, the gate driver and power FET turn on to clamp the voltage at the IN pin. The gate-drive circuit is designed such that a regulation loop keeps the IN pin V_{CLAMP} very close to the V_{BR} even as more transient surge current flows through the device from the protected pin.

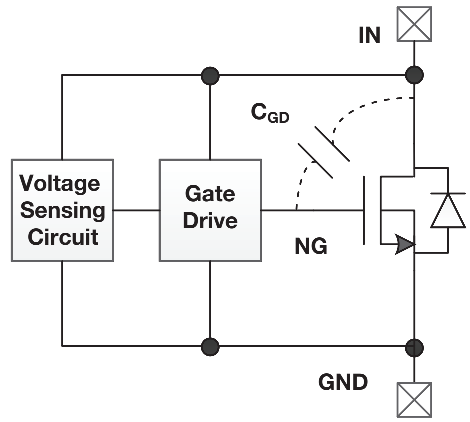

Figure 6. *Flat-Clamp technology functional block diagram.*

Looking at the functionality of the surge clamp in more detail, a small voltage change (ΔV_{IN}) on the IN pin causes a voltage change (ΔV_{NG}) on the NG node through the voltage-sensing circuit and gate driver. **Equation 1** defines the gain (A_G):

$$AG = \frac{dV_{NG}}{dV_{IN}} \tag{1}$$

Equation 2 expresses the gain looking into the IN pin:

$$g = \frac{dI_{IN}}{dV_{IN}} = g_m \bullet A_G \tag{2}$$

where $g_m = \dfrac{dI_{IN}}{dV_{NG}}$ is the gain of the power FET, which is a high value due to the large size of the main power FET.

Because of the high values of A_G and g_m, the overall gain (g) is high and ΔV_{IN} on the IN pin will cause a large current change (ΔI_{IN}) after triggering. In this way, the feedback mechanism controls the dynamic resistance of the surge clamp to a very low value. The behavior of the Flat-Clamp circuit enables a transient surge-protection solution with unique advantages over conventional TVS diodes [1].

Flat-Clamp protection vs. conventional TVS diodes: Key parameters

A Flat-Clamp diode is an alternative to a conventional discrete TVS diode that offers several advantages.

R_{DYN} and clamping

Recall that the R_{DYN} of a transient clamp is defined as the slope of the I-V curve after triggering. **Figures 7** and **8** compare the R_{DYN} and clamping behavior of a Flat-Clamp diode versus conventional TVS diodes. As mentioned in the previous section, because the gain values of A_G and g_m are high for a Flat-Clamp implementation, **Equation 3** shows that R_{DYN} can be near zero:

$$R_{DYN} = \frac{dV_{IN}}{dI_{IN}} = \frac{1}{g_m \cdot A_G} \tag{3}$$

The near zero R_{DYN} provides a precise, flat V_{CLAMP} over the duration of the surge event. Also, unlike TVS diodes, it's possible to compensate V_{CLAMP} over temperature and process.

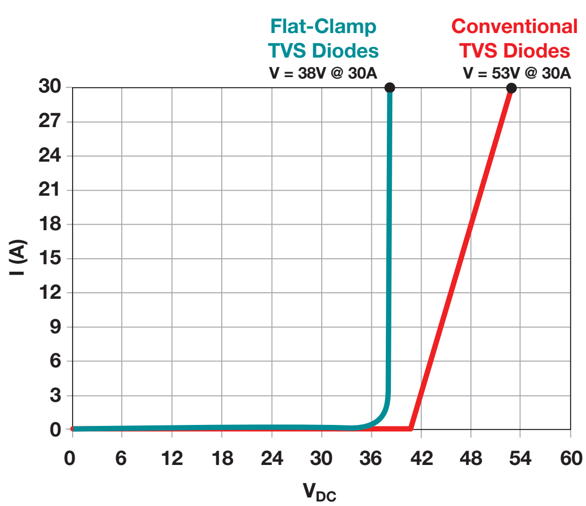

Figure 7. *DC I_{IN}-V_{IN} curves of a Flat-Clamp diode vs. conventional TVS diodes.*

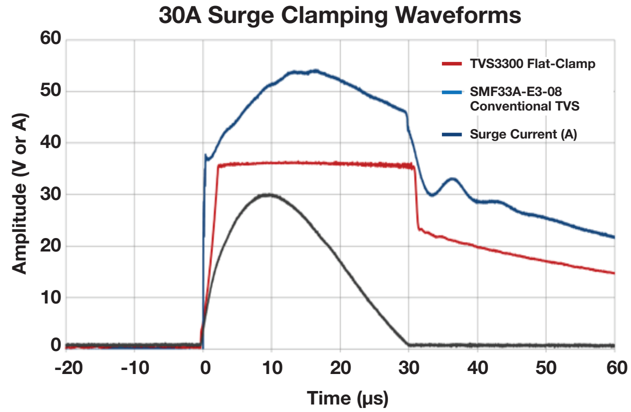

Figure 8. *8/20µs surge clamping of a Flat-Clamp diode vs. a conventional TVS diode.*

Package size and thermal considerations

Due to the clamping efficiency of the Flat-Clamp technology, much less power dissipates during a surge event versus a conventional TVS solution. Consider a 30A 8/20µs surge pulse with the TVS3300 device, the peak pulse power (P_{PP}) is 38V * 30A = 1,140W; for a comparable TVS device in a small outline diode (SOD)-123 package, P_{PP} is 54V * 30A = 1,620W, over 40 percent higher.

With that in mind, you can see in **Figure 9** that the package size of the TVS3300 is as much as 5x smaller than the conventional TVS in the SOD-123 package.

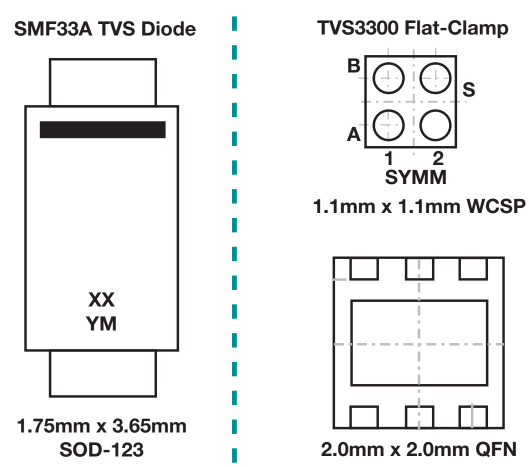

Figure 9. *Package size comparison.*

Given the lower power dissipation, it makes sense that the Flat-Clamp diodes could have a smaller package, but how is a ~5x reduction possible? We accomplish this by placing our Flat-Clamp devices in compact packages that lower the footprint without compromising thermal performance.

To better understand why the package doesn't compromise the device performance (and the role of packages for surge clamp devices in general), let's introduce the concept of thermal diffusion length (L_θ) for a material. L_θ describes the distance that the thermal energy can propagate in a material over a period of time (**Equation 4**).

$$L_\theta(t) = \sqrt{D_\theta \cdot t} \quad (4)$$

where $D_\theta \approx 0.5 cm^2/s$ for silicon.

During an 8/20µs IEC 61000-4-5 event, the thermal diffusion length is around 32µm. Since 32µm is much less than the thickness of a typical silicon chip (~120µm-280µm, see **Figure 10**), all of the thermal energy from an 8/20µs surge pulse must dissipate within the silicon chip itself. Thus, package size and thermal properties are not relevant for dissipating the power in nonrepetitive 8/20µs surge events.

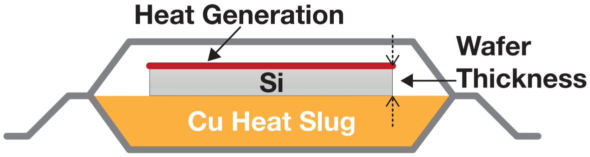

Figure 10. *Illustration of a packaged chip with a copper heat slug underneath.*

During a 10/1,000µs surge event, the thermal diffusion length is around 224µm, which is close to the thickness of a typical silicon chip. For a 10/1000µs surge event, the heat can start to reach the silicon-to-package boundary, and the thermal resistance of the package begins to play a role in surge performance. You can see this in the difference between the surge specs of the package options for the TVS3300. Both the 1.2mm² wafer chip scale package (WCSP) and the 4mm² SON package options have identical performance for the 8/20µs waveform, but thanks to it's improved thermal performance the SON package sees slightly better performance during the longer 10/1000µs waveform. This optimization allows us to provide robust protection in a much smaller package than traditional TVS diodes as the Flat-Clamp family of devices is primarily targeted at 8/20µs surge applications.

Capacitance

To prevent unwanted signal distortion, a protection solution should be as invisible as possible to the protected system. Diodes and protection circuits do have inherent capacitance that impact system performance, so the lower the capacitance, the less chance that the protection solution will impact signal integrity negatively.

Figure 11 shows the capacitance value at different working voltages of the Flat-Clamp family compared to conventional TVS diodes. Discrete TVS diodes can add significant capacitance, especially at lower working voltages. The capacitance introduced by the Flat-Clamp TVS diodes is significantly lower than conventional TVS diode solutions.

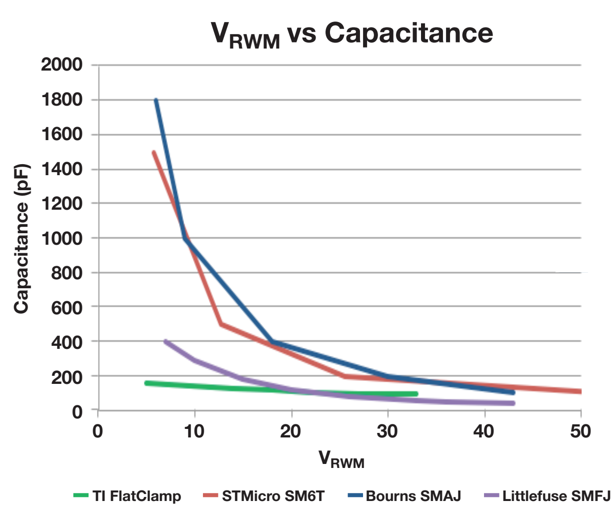

Figure 11. *Capacitance of the TI Flat-Clamp family vs. conventional TVS diodes.*

Leakage

A typical complementary metal-oxide semiconductor (CMOS) amplifier input stage will have an input bias current in the picoampere (pA) range, while bipolar amplifiers are in the nanoampere (nA) range. Conventional TVS diodes have microamperes (µA) of reverse leakage current. This leakage current can generate significant errors when flowing through input-protection resistors or source impedance.

Flat-Clamp technology has very low static leakage current and offers a significant advantage over conventional TVS diodes for applications such as industrial 4-20mA loop networks, where leakage can impact accuracy. **Figure 12** compares the V_{RWM} versus the maximum leakage current for conventional TVS diodes relative to the TI Flat-Clamp family. TI's Flat-Clamp devices can guarantee low leakage because there are minimal process variations, while conventional TVS diodes cannot guarantee less than 1µA of leakage. At low working voltages, conventional TVS diodes can have leakages that approach 1mA, which can significantly impact signal integrity and cause lower efficiency in low powered systems.

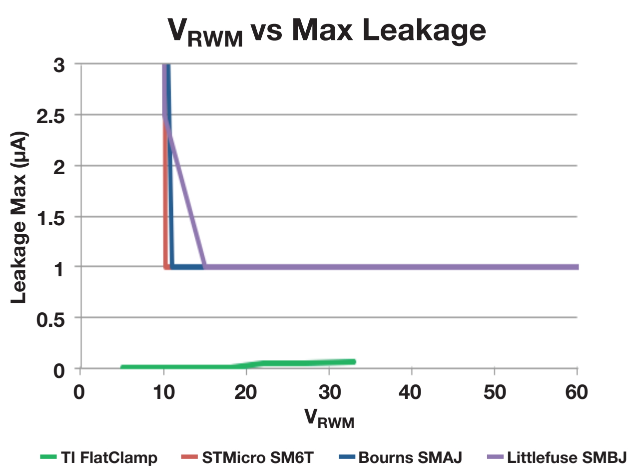

Figure 12. *V_{RWM} vs. maximum leakage current for the TI Flat-Clamp family vs. conventional TVS diodes.*

Flat-Clamp diodes, being active devices, have a second form of leakage that you must consider during system design. The second type of leakage is dynamic leakage, caused by a fast signal on the protected pin. The recommended operating table of the Flat-Clamp diode data sheet describes the acceptable slew rates for the protected pin. When the slew rate of the AC signal is low, the displacement current dominates the static leakage current due to the parasitic capacitance of the surge clamp (just like a standard TVS diode). Once the slew rate is above the recommended level, the main clamp FET could turn on due to the coupling of the I/O pin to the gate of the clamped FET, causing high dynamic leakage and unwanted signal distortion.

Power vs. temperature derating

Conventional TVS diodes are designed (and expected to work) over a wide temperature range. At elevated temperatures, you'll need to consider the TVS diode's maximum allowable junction temperature in order to make sure that it is not exceeded during a surge event. As the ambient temperature increases, the power dissipation capability decreases. A power derating curve in the data sheet normally shows this performance limitation.

In TI Flat-Clamp diodes, the closed-loop regulation of the clamp voltage ensures a fixed voltage across temperature. This means that there is minimal derating over temperature compared to a conventional TVS diode, thus improving overall system robustness. **Figure 13** shows the derating curve for the 8/20µs P_{PP} across ambient temperature for the TVS3300 and for the SMAJ33A.

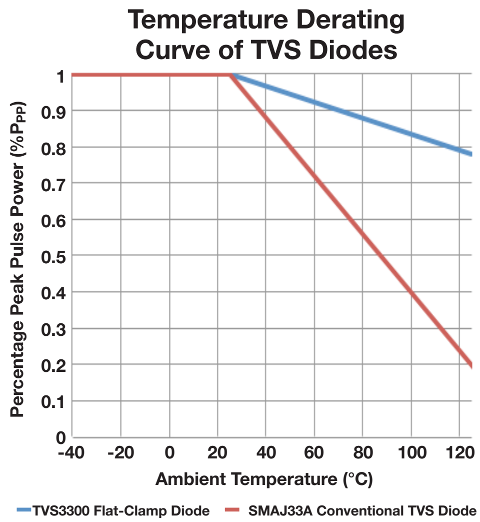

Figure 13. *Temperature derating curve of the TI Flat-Clamp family.*

Reliability

One concern with any new technology replacing what has been a staple in the surge-protection area is reliability. With such a small package, striking the Flat-Clamp diodes multiple times seems as though it could heat up the device enough to cause a failure. To test for that case, TI ran the TVS3300 with 4,000 repetitive 30A 8/20µs surge pulses, with less than 15s in between pulses at an ambient temperature of 125°C. **Figure 14** shows the V_{CLAMP}, I_{PP} and leakage

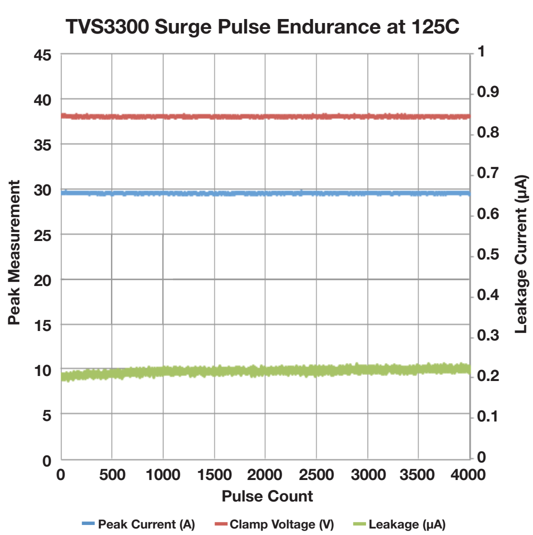

Figure 14. *TVS3300 8/20µs surge pulse 4,000 times.*

for each of the 4,000 pulses. Notice how there is no shift in either V_{CLAMP} or L_{leak} even after the full endurance test.

Design example No. 1 – 40V vs. 60V system design

As an example of how Flat-Clamp diodes can improve system design, let's look at the design difficulties in accomodating the poor clamping performance of conventional TVS diodes on a general industrial system. Assume that the system needs to support 33V normal operating voltages. To protect this system using a standard TVS diode, you must select a device with a V_{RWM} across temperature that is greater than 33V to account for variations.

Many standard TVS diodes only spec V_{BR} at 25°C, which can make selection difficult because the V_{BR} is typically lowest at -40°C. To support 33V at -40°C, you will need to choose a TVS with a V_{BR} of nearly 39V. A typical SMF series TVS will have a surge V_{CLAMP} at I_{PP} = 30A of ~55V. The components downstream of the surge-protection diode must be rated higher than V_{CLAMP} (>55V) in order to avoid any damage during a surge event, increasing system cost and complexity.

Now consider the same 33V system design using the TI TVS3300 Flat-Clamp diode. For I_{PP} = 30A, the TVS3300 will clamp the protected bus to 38V. Closed-loop regulation of the clamp voltage ensures minimal voltage change across process and temperature. You can design protected components to a lower voltage tolerance, which means less device variation and smaller component size.

Table 2 compares the performance and cost for a 60V-tolerant low dropout (LDO) regulator and a 40V-tolerant LDO. It is clear that the 40V LDO offers lower cost and better performance. The LDO also has associated external components and a higher system voltage that would require larger external components (see **Table 3**).

LDO	TPS7A16	TPS7A19
V_{IN}	3 V to 60 V	4 V to 40 V
Quiescent Current	5 µA @ 10 µA	15 µA @ 200 mA
Output Current	100 mA	450 mA
Accuracy	2%	2%
Package (Area)	HVSSOP (9mm2)	SOP (9mm2)
Dropout	60 mV @ 20 mA	50 mV @ 50 mA
Features	Enable, Power Good	Enable, Power Good
Price @ 1ku	$1.39	$0.59

Table 2. *60V vs. 40V LDO comparison.*

Capacitor	C1608X7R2A103	GRM155R71H103
Cap	0.01 µF	0.01 µF
Temp Coeff	X7R	X7R
Tolerance	±10%	±10%
Voltage Rating	100V	50V
Package (Area)	0603	0402
Price @ 1ku	$0.01739	$0.00233

Table 3. *100V vs. 50V capacitor comparison.*

Tables 4 and **5** show additional performance and cost comparisons for common system components, bipolar junction transistors (BJTs) and series-protection Schottky diodes. You must make similar performance and cost trade-offs for all other downstream components (multiplexers, relays, etc.). As a system designer, your system is more robust and reliable (and your job is easier) if you can select lower-voltage-tolerant components. In addition to less stress on the system during a surge event, Flat-Clamp diodes allow you to reap benefits on cost, component size and performance.

It's not just the cost of a conventional TVS diode but its impact on the overall system cost that must be assessed. Designers often overlook this factor when assessing the total system cost for a protection solution.

Transistor	BC55-16PA, 115	DSS4240T-7
Type	NPN	NPN
Voltage CE	60 V	40 V
Current C	1A	2A
Power	650 mW	600 mW
Package (Area)	3-UDFN (4mm2)	SOT23-3 (3.77m2)
Price @ 1ku	$0.11	$0.09166

Table 4. *60V vs. 40V BJT comparison.*

Diode	BAT46WJ, 115	SDM20U40-7	NSR0340HT1G
Diode	Schottky	Schottky	Schottky
Voltage	100 V	40 V	40 V
Current	250 mA	250 mA	250 mA
Forward Voltage	850 mA@ 250 mA	600 mA@ 200 mA	590 mA@ 200 mA
Leakage Current	9 µA @ 100 V	5 µA @ 30 V	6 µA @ 40 V
Package (Area)	SOD-323 (1.92mm2)	SOD-523 (0.96mm2)	SOD-323 (1.92mm2)
Price @ 1ku	$0.08860	$0.07223	$0.05020

Table 5. *100V vs. 40V Schottky diode comparison.*

Design example No. 2 – Node on 4-20mA industrial network

The second example is an application found in a 4-20mA loop industrial network. Factory automation endpoints or transmitter nodes require protection for several downstream components, including multiplexers, analog-to-digital converters (ADCs), 4-20mA transceivers and LDO regulators. Unfortunately, data sheets for most ICs generally do not provide a transient voltage immunity rating, which makes it challenging to select the right components to robustly protect your system.

In order to understand the technical advantages of the TI Flat-Clamp devices for protection in a system, consider the 4-20mA Current Loop Transmitter Reference Design. Let's compare the surge protection implementation of a discrete TVS diode to one using a Flat-Clamp device.

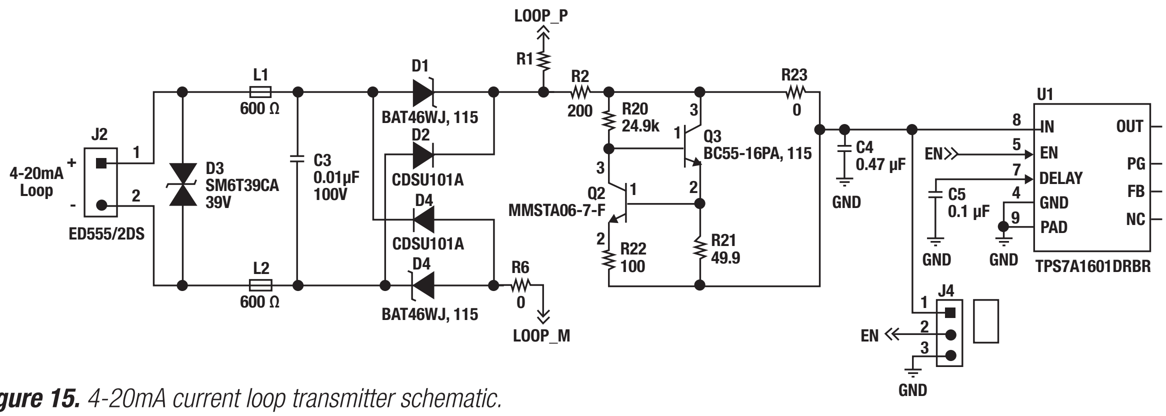

Figure 15. *4-20mA current loop transmitter schematic.*

Figure 15 is a schematic of the reference design, which currently uses an SM6T39CA for surge protection. At the output of this conventional TVS diode are additional diodes and a BJT, in order to protect the LDO from exposure to higher voltages.

The protected parts that are downstream of the TVS are the LDO (TPS7A1601-U1), the BJT controlled by the 4-20mA, the digital-to-analog converter (DAC), the diodes in reverse-polarity protection and the input capacitor (C3). Each of these components must be rated higher than the maximum clamping voltage of the surge protection TVS diode in order to prevent system damage. For an I_{PP} = 35A 8/20µs surge event, the SM6T39CA would be expected to clamp at about 50V. In this same application, the TVS3300 would clamp at 38V, and could enable a smaller and cheaper system solution.

Design example No. 3 – Small-form-factor system design

Although the small-form-factor systems trend is hardly new for personal electronics like cellphones or wearables, more industrial and automotive systems are also pushing for smaller solution sizes. Industrial networks and process control systems use sensors and field transmitters that may be no larger than a pencil. This level of integration forces designers to compress more circuitry into a smaller space.

Conventional discrete TVS diodes come in industry-standard package footprints (such as SMA or SMB packages) that range from 12-19mm^2. The active circuit implementation of the TI Flat-Clamp family offers the ability to implement signal-line surge protection in a much smaller footprint.

For example, the TI TVS3300 is available in a 1.1mm x 1.1mm wafer chip-scale (WCSP) package specified to support a P_{PP} of 1.3kW at a 90 percent smaller footprint than the SMA package of a conventional TVS diode. The TI TVS3300 is also available in a 2mm x 2mm small outline no-lead (SON) package specified to support a P_{PP} of 1.3kW at an almost 70 percent smaller footprint than a typical SMA package common for discrete TVS diodes. This is a sizable advantage for very space-constrained systems like industrial sensors and transmitters.

Figure 16 shows a typical industrial sensor. You can see that two conventional TVS diodes at the input occupy a large portion of the system board space. The industry-standard SMA package takes up 12.5mm^2 of board space, while the larger SMB package would occupy up to 19.1mm^2 of board space.

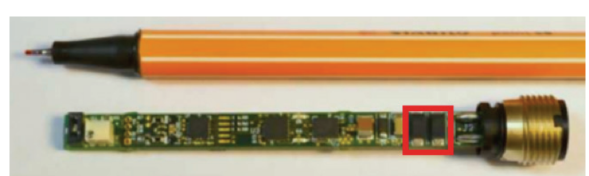

Figure 16. *Sensor transmitter reference design board.*

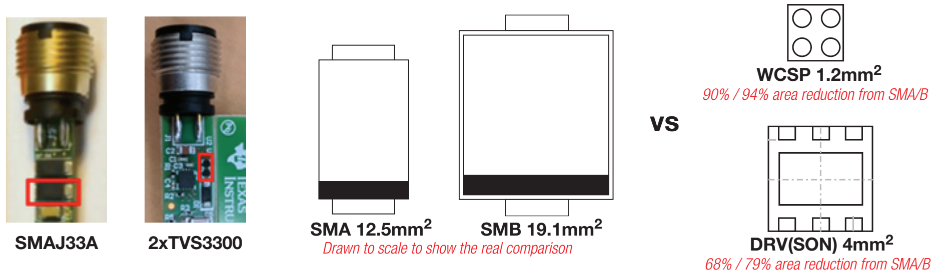

Figure 17. *Component footprint size comparison between conventional TVS diodes in SMA and SMB packages and TI packages offered for precision surge clamp devices.*

Adopting a small-form-factor Flat-Clamp diode saves board space and enables a much closer placement of the surge protection to the connector, which also helps reduce potential electromagnetic interference (EMI) in the circuit **(Figure 17**).

Conclusion

The TI Flat-Clamp family of protection diodes gives designers a new choice to optimize system voltage, size and cost without comprising surge immunity. The technology's ability to dissipate surge transients while simultaneously providing a precise, flat and temperature-independent clamping voltage minimizes residual voltage to the protected system. This enables tighter budgets on voltage tolerance for protected downstream components, which can save significant space and cost. Also, since the protection solution is a fraction of the size of conventional TVS diodes, with much lower capacitance and leakage current, the possibility of new applications with smaller form factors opens up.

References

1. Wang, Dening and Roland Son. Precision surge clamp with constant clamping voltage and near-zero dynamic resistance under various thermal, power and current levels. U.S. Patent 20,150,303,678 A1 filed April 22, 2015.

Additional resources

- Download the TVS0500 data sheet.
- Order SMA/SMB TVS drop-in replacement adapter boards.
- Start designing now with the TVS3300 evaluation module.
- Check out the "TVS3300 Configurations Characterization" application note.
- Read the "Protecting field transmitters from surge transients" blog post.
- Check out the Surge Protection Reference Design for PLC Analog Input Module.
- Watch the precision surge product training video.
- Check out the "IEC 61000-4-x Tests for TI's Protection Devices" application note.

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265