Application Report

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Does BAV99 Really Protect My System from ESD?

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ABSTRACT

This document provides in-depth analysis of one of the most widely used devices for electrostatic discharge (ESD) protection, the BAV99, while also comparing these results to that of ICs designed particularly for ESD event protection. This application note describes the use case of the BAV99 and its limitations.

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1 Introduction

In most, if not all, electronic devices developed today, there is a risk of electro-static discharge or ESD at interfaces with metal contacts. For many companies, protection against these risks are not seen as high-priority concerns; therefore, many engineers may not invest time thinking about devices they can use to mitigate the risk, but rather follow poor ESD-protection methods. The BAV99 device has been around for quite a long time and people have found creative ways to implement it in ESD areas. Although not described in the data sheet as an ESD protection device, there are many instances in which this device is selected for its very low cost and simplicity. It is important to know the actual functionality and limitations of the device to make sure that the ESD protection is being handled properly. The ensuing sections describe the BAV99 functionality, its response to a transient event, its limitation in fail-safe mode, and its size drawbacks all in comparison to Texas Instrument devices specifically designed for ESD protection.

2 BAV99 Overview

The BAV99 device is a 3-pin steering diode that has small forward voltage, large breakdown voltage, and low capacitance. The device consists of stacking two diodes by connecting the cathode of one to the anode of another and provides pins to the cathode, anode, and in between the two diodes. Figure 1 shows an internal top-view diagram of the device.

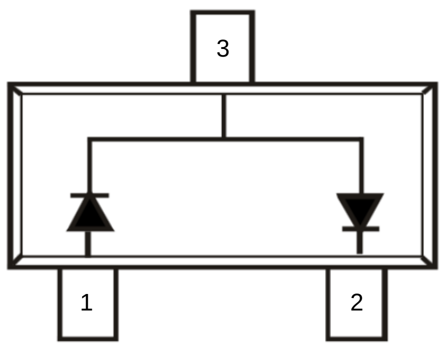

Figure 1. BAV99 Internal Top Down View

The typical use case is to have the center tap, pin 3, connected to an input/output (I/O) digital line with the top pin cathode, pin 2, connected to some supply (V_{CC}) and the bottom anode, pin 1, connected to ground (GND). The BAV99 is essentially one half of the structure of TI's unidirectional devices, as is discussed in Section 3.

2.1 Device Characterization

The following section outlines the characterization testing for the BAV99. These results show the behavior of the internal diodes (I-V Curve) as well as the insertion loss. Designers should pay attention to this important information when selecting an ESD protection device.

Figure 2 shows the I-V curve of the BAV99. Note that this device is just two diodes with a forward bias of 0.7 V; therefore, if a bias, V_{CC}, is applied to the cathode (pin 2) this I-V curve will shift to V_{CC} + 0.7 V, as shown in Figure 2.

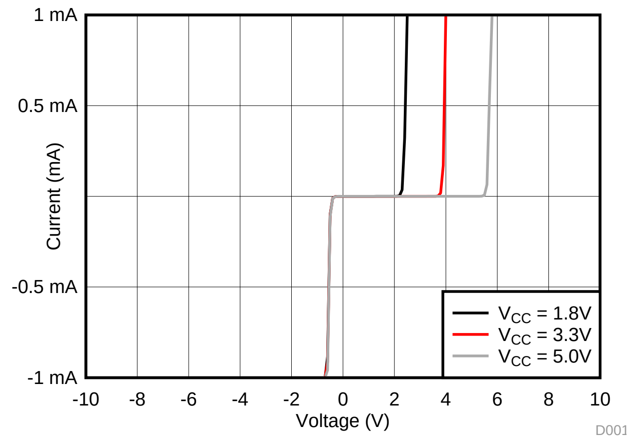

Figure 2. BAV99 I-V Curve (Multiple V_{CC}s)

The BAV99 device is also tested with respect to insertion loss and –3-dB bandwidth. This parameter is important because it is a limiting factor regarding the bandwidth of a system. The –3-dB bandwidth of the device is determined by . the total capacitance present in the BAV99 device. This is important because signals that are higher frequency than the –3-dB point will experience a significant amount of loss and should not be put through the device.

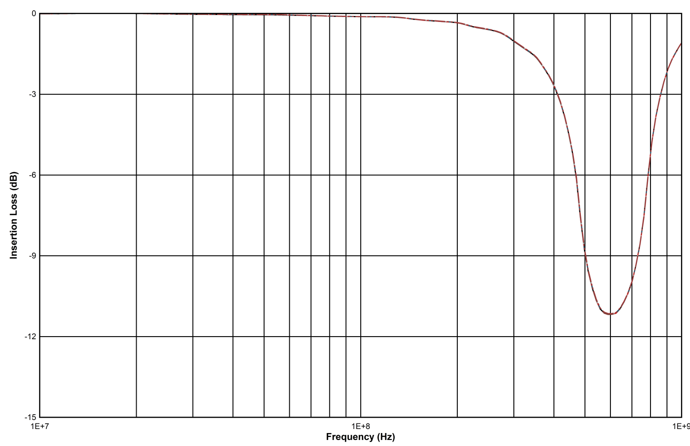

Figure 3. BAV99 Insertion Loss

3 BAV99 Transient Event Reaction

Since this device is just two diodes stacked on top of each other, it is natural to wonder how this device could be used for something like ESD or surge. The key to the BAV99 is that it does not have to take much of the transient events. The IEC 61000-4-2 is the international ESD standard that models an ESD event to look like Figure 4. When that is applied to the I/O (pin 3) of BAV99 with pin 1 connected to GND and pin 2 connected to V_{CC}, the diode from I/O to V_{CC} becomes forward biased and "steers" the current to the V_{CC} plane shown in Figure 5.

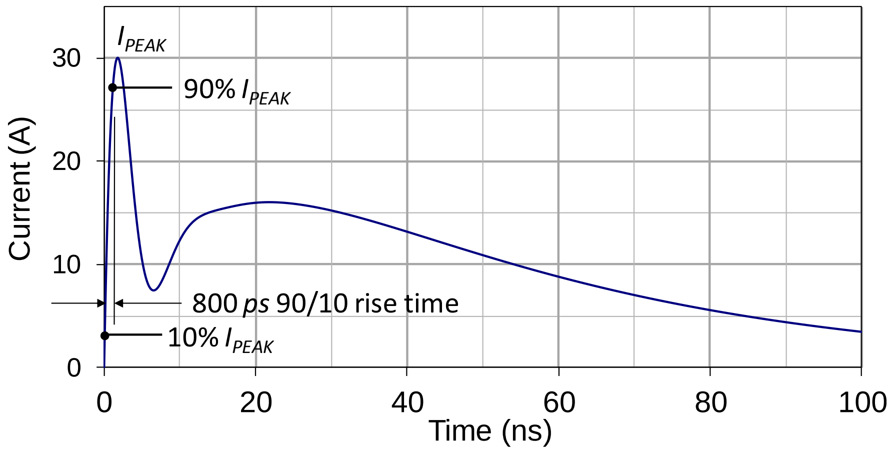

Figure 4. IEC 61000-4-2 ESD Waveform

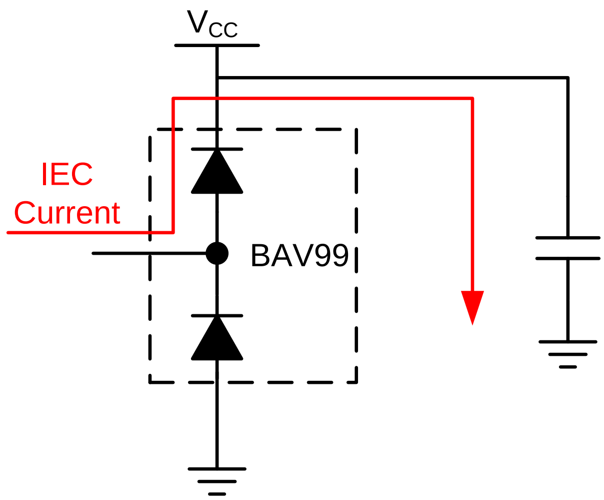

Figure 5. BAV99 During ESD Event

This means that the BAV99 itself is not providing the ESD protection, but rather whatever capacitor or clamps on V_{CC} provide the ESD protection. Therefore, without some sort of clamping circuit on the V_{CC} rail, this ESD pulse could break whatever is providing the rail.

In comparison, all TI ESD devices, such as the TPD1E05U06 shown in Figure 6, have an internal clamp so that when an ESD event occurs, the pulse is clamped by the internal clamping diode and the current is dispersed through the ground plane.

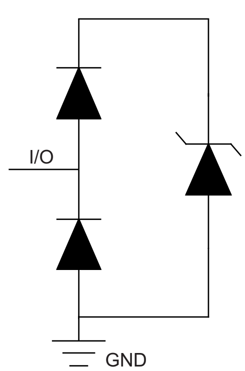

Figure 6. TPD1E05U06 Functional Block Diagram

Another transient event the BAV99 is subject to is surge. This transient event is characterized by IEC 61000-4-5 which outlines a pulse with a rise time of 1.2 µs and decays to 50% at 50 µs for the voltage waveform. This pulse is much longer than the ESD pulse and therefore will have much more energy. As with the ESD pulse, the BAV99 does not actually protect what is connected to the center tap, but rather steers this transient event through the forward diode to the power plane it is connected to, forcing some other protection device to take the brunt of the energy. Just as with the ESD event, the BAV99 is limited by the power dissipated through its diodes. If the ESD strike or surge event is too high, instead of steering the transient pulse away, the internal diodes will break and cause either an open or a short on that diode path.

NOTE: The BAV99 is **not** the protection device for any transient event such as ESD or surge.

When the BAV99 is placed in a system, the passing level of IEC 61000-4-2 or IEC 61000-4-5 will be almost exclusively dependent on what is connected to the rail to which the BAV99 is connected. The only role that the BAV99 plays is if it becomes too hot from thermal dissipation, the diode could be broken. The BAV99 is not specified to pass any level of IEC 61000 since it has to be part of a bigger system to be tested.

4 Fail-Safe Limitations of BAV99

In modern end equipment it is not uncommon to have multiple different power supplies even for the same voltage node. For this reason, it is reasonable to assume that sometimes what is on the I/O pin of BAV99 might not be derived from the same V_{CC} as connected to BAV99. This setup is shown in Figure 7.

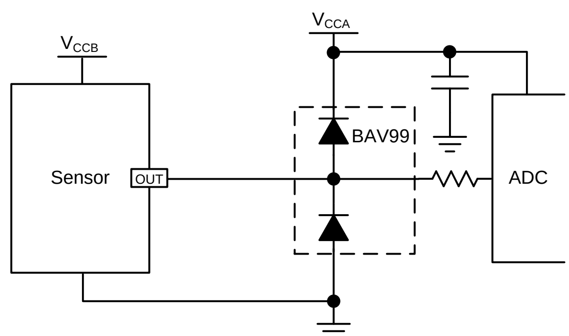

Figure 7. Typical BAV99 Setup

This means that V_{CCA} were ever to lose power (0 V) when V_{CCB} was still active and the sensor was outputting, the BAV99 would be forward biased from pin 3 to pin 2. Current is then flowing into the V_{CCA} rail which could damage that power supply during a power supply sequence event.

5 Form Factor

The most obvious drawback of the BAV99 is its size. The big purpose of having ESD devices are that they should be invisible in normal application and should not impede the normal operation of the circuit it is trying to protect. While having the BAV99 on a schematic may make it look inconspicuous, when trying to layout all components it can be extremely frustrating to place because of how big it is. The BAV99 for the most part is in the SOT23 package pictured below with dimensions and only a one channel device. In comparison the TPD1E04U04 is in the DPL (0201) and DPY (0402) package that provides a space savings of 3.17 mm^2 because it only requires two pins for one channel protection.

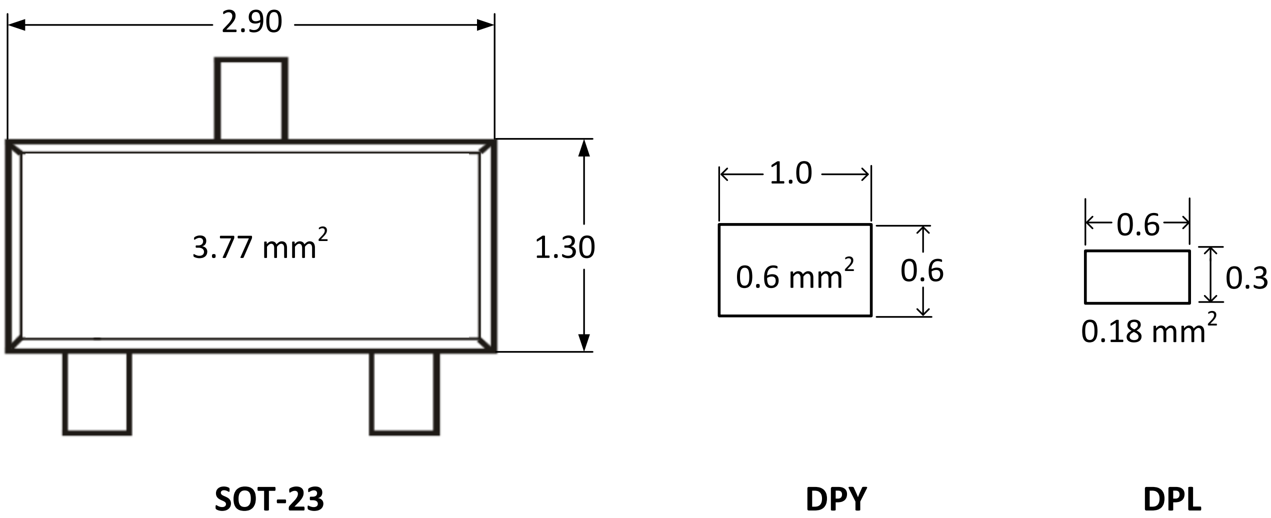

Figure 8. SOT23 Package vs DPY and DPL Package

6 Summary

In conclusion, the BAV99 is two diodes stacked on top of each other with a pin in between. This device is useful in applications where current needs to be steered away from the middle pin. However, it is extremely important to recognize that the BAV99 itself does not actually provide the protection from transients such as electrostatic discharge or surge events. Therefore, it is difficult to be sure that your system is protected against certain levels of the standard because the BAV99 or the device somewhere else that is actually taking all of this current could break without knowing where the problem stems from. Also in fail-safe applications, where the driving signal is powered off another rail than the receiving end, the receiving end rail could be damaged since the top diode would steer the current to that supply. Finally the form factor of the BAV99 is so large for one channel applications when compared to TI's portfolio of ESD protection that it can become a pain for board layout. As it can be seen the BAV99 device itself is not providing protection, therefore a more complete solution with fixed protection limits would be to use Texas Instruments selection of discrete ESD diodes. Suggestions for Texas Instrument devices that can replace the BAV99 by providing robust protection against ESD events is found in Table 1

Table 1. ESD Protection Suggestion Devices

Parameter	ESD401		TPD1E05U06		TPD1E04U04		TPD1E10B06		TPD1E6B06	
IEC 61000-4-2 Contact Rating	±24 kV		±12 kV		±16 kV		±30 kV		±15 kV	
Breakdown Voltage	–7.5 V and 7.5 V		–0.7 V and 6.5 V		–0.7 V and 6.2 V		–7.8 V and 8.4 V		–8.25 V and 7.25 V	
Clamping Voltage (TLP)	11 V at 1 A	24 V at 16 A	10 V at 1 A	14 V at 5 A	5.3 V at 1 A	8.9 V at 16 A	8 V at 1 A	12.5 V at 5 A	8 V	13.5 V
Line Capacitance	0.77 pF		0.42 pF		0.5 pF		12 pF		6 pF	
Dynamic Resistance	0.7 Ω		0.8 Ω		0.25 Ω		0.32 Ω		0.55 Ω	
Surge Clamping Voltage	14.8 V at 4.5 A		16 V at 2.5 A		15 V at 3 A		15.82 V at 6.75 A		14.7 V at 4.45 A	
Surge Max Power	67 W		40 W		19 W		106 W		65 W	
Package Size	1.0 mm × 0.6 mm		1.0 mm × 0.6 mm		1.0 mm × 0.6 mm		0.6 mm × 1.00 mm		0.6 mm × 0.3 mm	

7 References

- ESD401 product folder
- TPD1E05U05 product folder
- TPD1E04U04 product folder
- TPD1E10B06 product folder
- TPD1E6B06 product folder