AN-PJ2001

TVS Diode Power Rating Evaluation

Using 1.5KExA series as an example

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1. Revision History

Rev.	Revision Description	Edit by	Date
Rev.00	Document Release	Rino Ho	2023/03/10

2. Introduction

A transient voltage suppressor (TVS) is a P-N junction of an avalanche diode designed to clamp overvoltage and dissipate high transient power surge. TVS diodes are designed to protect sensitive semiconductors from damages caused by transient voltage that comes from power source. During a voltage spike, the TVS diode junction avalanches to provide a low-impedance path for the transient current. Thus, the transient current is diverted away from the protected component and shunted through the TVS diode to the ground.
TVS devices offer more advantages than metal-oxide varistors (MOV) since there are no ageing effects for TVS, which ensures stability over time for better reliability.

3. TVS Electrical Characteristics

3.1 Basic Principles of TVS

Figure 1. shows that TVS diodes are connected in parallel with a device under protection (DUP) on circuit boards. Whenever the transient voltage exceeds the operating voltage, a breakdown occurs, which allows transient current to flow through a low resistance path. This is when the TVS diodes function immediately to shunt the current and keep the DUP at cut-off voltage until the voltage reverts to operating voltage. The TVS automatically reverts to high impedance state after the pulse passes, thus allowing the circuit returns to operating voltage.

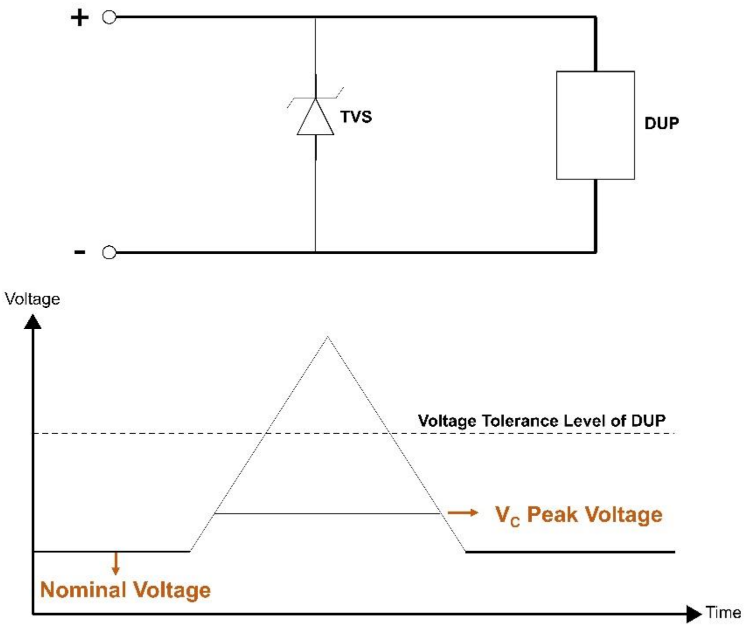


Figure 1. TVS Application

3.2 TVS Terms

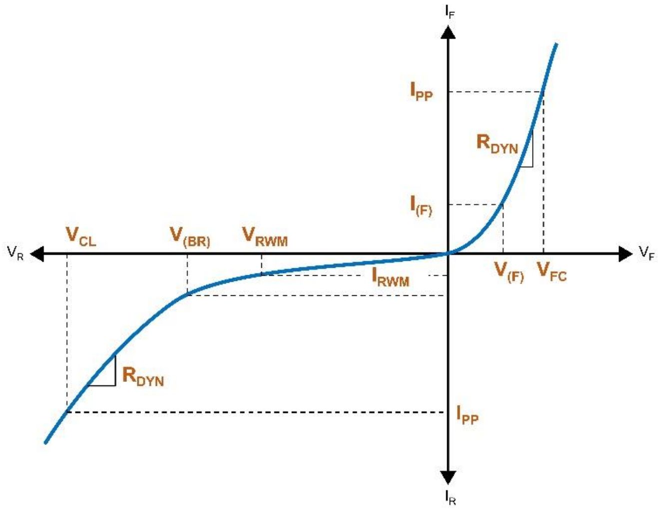


Figure 2. TVS Characteristic Curve Definition (Bidirectional TVS as An Example)

1. V_{RWM}

V_{RWM} stands for reverse working maximum voltage, which is the voltage that can be applied to a TVS diode at which the diode will not conduct enough current for operation. The defined V_{RWM} is used for testing for leakage while in operation.

2. V_{BR}

V_{BR} stands for breakdown voltage, which is the voltage that the TVS diode begins to break down, which is commonly defined at 1mA or 10 mA. V_{BR} is defined as the voltage that when exceeded, the leakage begins to increase exponentially.

3. I_R

I_R is the reverse leakage current that is defined at V_{RWM} to ensure the TVS works properly.

4. V_C

V_C is the maximum clamping voltage, which is the voltage that a TVS diode can withstand under a 10/1000μs surge waveform in figure 3. The product of V_C and peak pulse current is the power rating of TVS at 10/1000μs ($P_P = V_C \times I_{PP}$)

5. I_{PP}

I_{PP} stands for the peak pulse current, which is the maximum current that a TVS can sustain for a 10/1000μs waveform. The I_{PP} multiplied by V_{CL} is the TVS rated power (10/1000μs)

6. P_{PP}

P_{PP} is the maximum power rating that a TVS can sustain for a 10/1000μs waveform

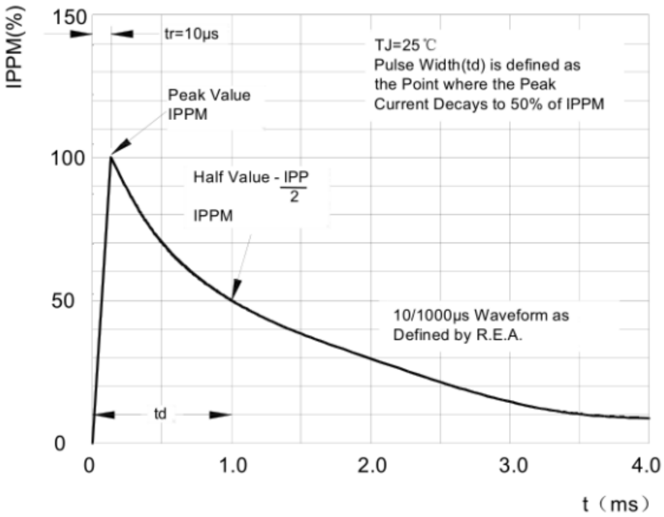


Figure 3. Test Pulse Waveform

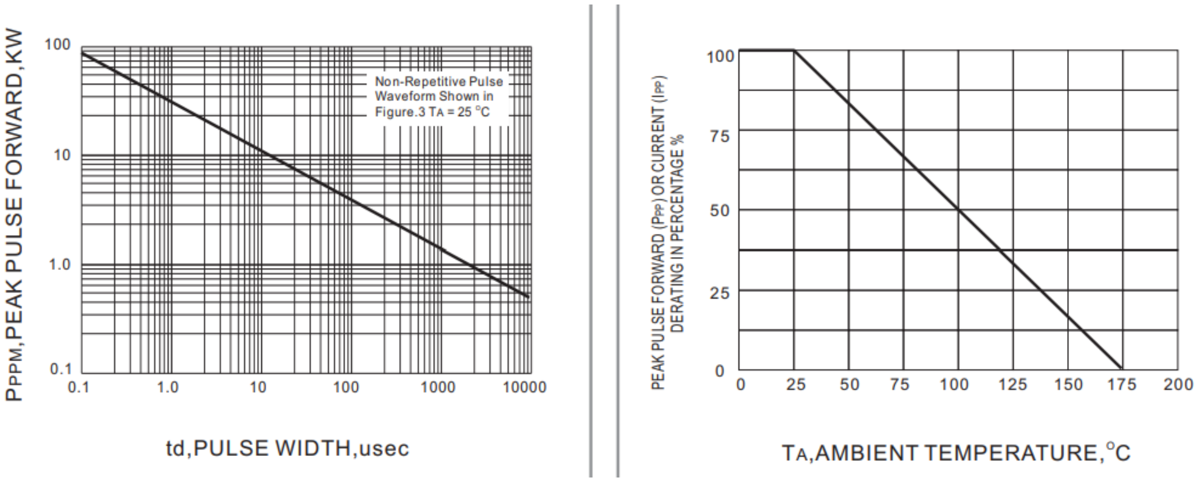
4. Power Rating Evaluation of TVS

For general applications, TVS diodes are used for absorbing transient surge energy to evaluate if the transient surge energy has exceeded P_{PP} standard. Extended applications for TVS include absorbing repetitive spike energy to evaluate whether the combination of the average rated power and thermal resistance exceeds T_J standard or not.

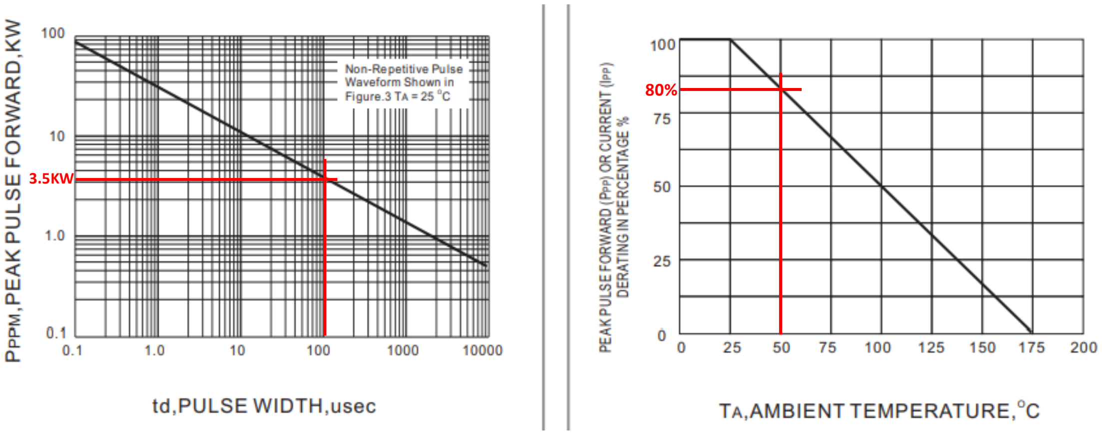
4.1 Transient Surge Energy Evaluation (Single pulse)

When the surge occurs in single pulse, the pulse width derating and thermal derating values can be used to determine if the transient surge energy has surpassed the operating values.
TVS instantaneous power < P_{PP} by Pulse Width Derating x Temperature Derating.

Evaluation Method Example:
We take a 1.5KEXXXA series TVS as an example, the instantaneous peak power of TVS is 2KW:
td = 100us, T_A = 50°C
P_{PP} = 3.5KW x 80% = 2.8KW (reference to figure 4. (c) and (d))
Since 2KW < 2.8KW, we can rule the TVS as “Pass”



(a) (b)

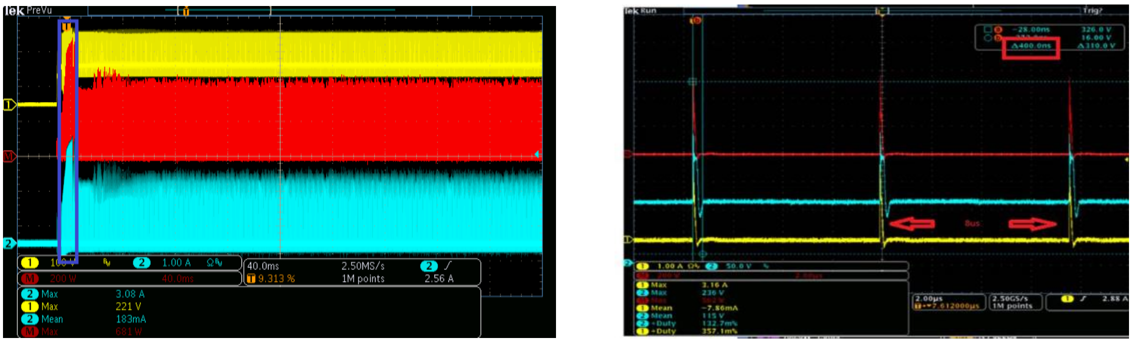


(c) (d)

Figure 4. 1.5KExA Series Derating Curve

4.2 Transient Surge Energy Evaluation (Repetitive Pulse within a short period)

In another scenario, the surge waveform can occur in a repetitive pulse within a short period instead of a single pulse, as shown in the blue-boxed area below for reference.



(a) (b)

Figure 5. Waveform Measurement Example

Evaluation Method:

As highlighted in the blue marked area in figure 5. (a), the total pulse width is shorter than 10ms (figure 5. (b)).

If, Peak Power < P_{PP} by Pulse Width Derating x Temperature Derating.

Then, we can rule the TVS as "Pass"

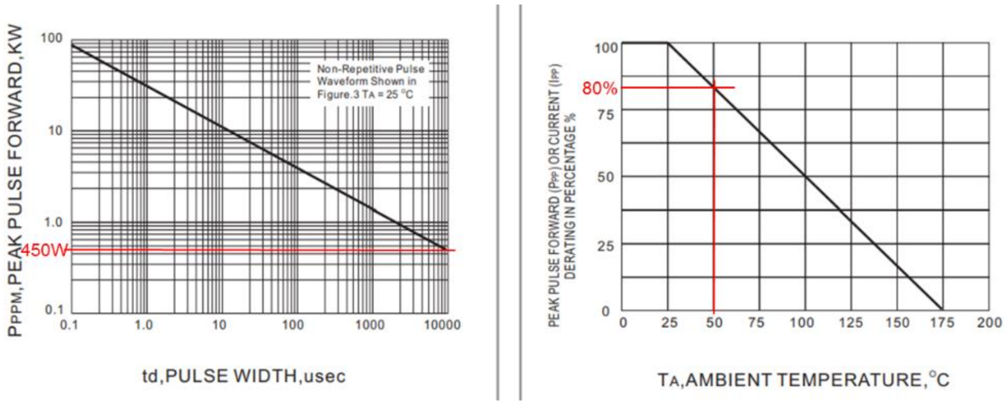
Example:

We take a 1.5KEXXXA series TVS as an example, the instantaneous peak power of TVS is 300W:

Total Pulse width = 10ms, T_A = 50°C

P_{PP} = 450W x 80% = 360W (Reference to figure 6. (a) and (b)).

300W < 360W ➔ we can rule the TVS as "Pass"



(a) (b)

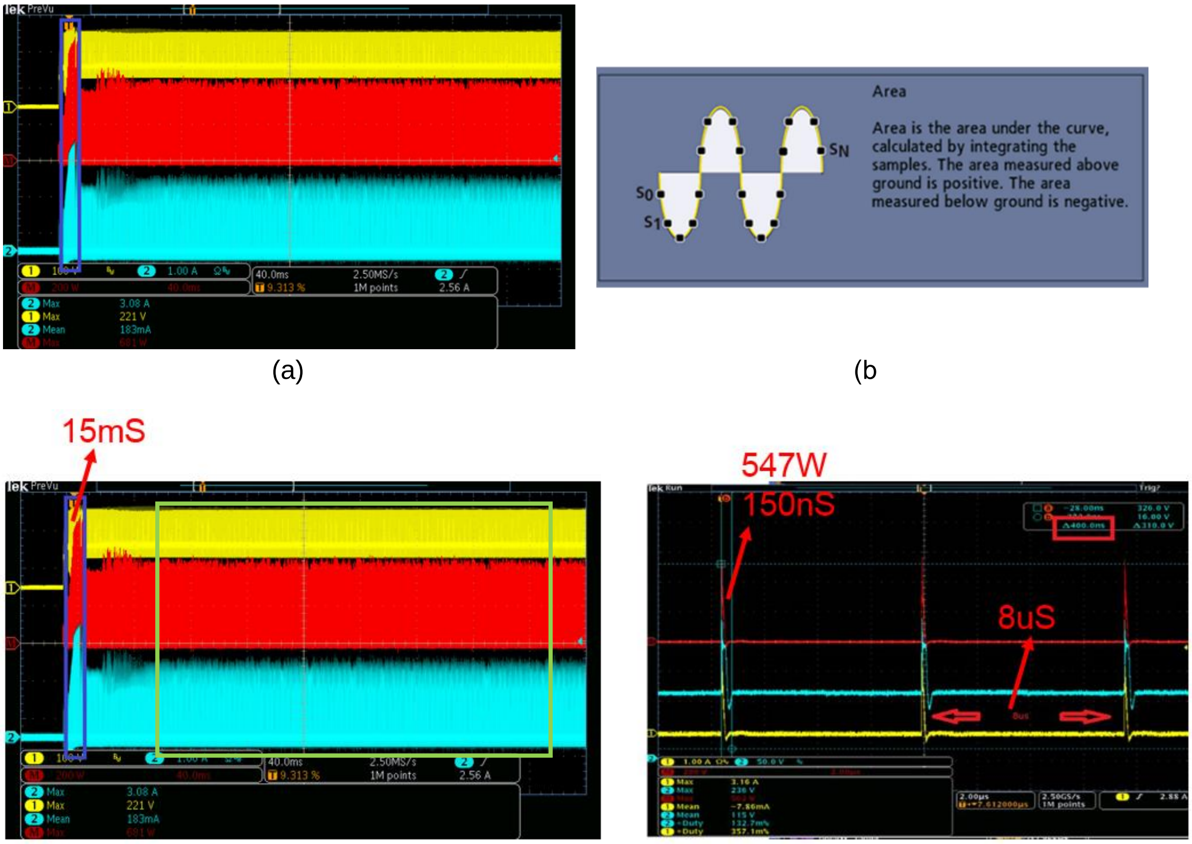
Figure 6. 1.5KExA series Derating Curve

If the data resulted from the evaluation methods above exceeds the operating voltage or if the total pulse width time is over 10ms, the accumulated energy from discrete pulse power can be used to determine if the surge energy has exceeded the operating voltage.
The use of an oscilloscope is recommended for receiving a more accurate result, providing that the oscilloscope is built with an accumulator function.
The calculation results from using peak power, total pulse width, and pulse duty are not as accurate since it might represents a worse result than the actual data.

How to read the data from an oscilloscope (take Tektronix as an example):
Using the “Gating” function on “Measure” to set the measuring range to the scope in the blue mark shown in figure 7. (a). When setting the scope, the portion of the blue-boxed area is suggested to be more than 80% of the entire screen. To get the energy result of the accumulator, simply increase the “Area” measuring range on “Measure” as figure 7. (b).
Energy < 1.5KW x 1ms x Temparatiure Derating.

Calculation Method:
Total pulse time (highlighted in the blue marked area in figure 7. (a)) divided by pulse cycles = total number of cycles
The energy of each cycle= peak power x pulse width
Total energy= number of cycles x energy of each cycle < 1.5KW x 1ms x Temperature derating.

Example:
@T_A=50°C
15mS/ 8uS = 1875 cycles
547W x 150nS = 8.2uJ
Total Energy = 8.2uJ x 1875 = 0.154J
0.154J < 1.2J (1.5KW x 1mS x 80%) ➔ We can rule the TVS as “Pass”



(a) (b

(c) (d)

Figure 7. Waveform Measurement Example

4.3 Steady State Power Evaluation

The evaluation of pulse occurs in steady state (highlighted in the green marked area in figure 7. (c)) can be calculated by average power.

4.3.1 Using an oscilloscope to calculate average power

The green marked area in figure 7. (c) shows the number of cycles for each pulse is about 10-20 cycles. Then use the measurement formula to calculate the mean value of the power waveform.
If (Power X R_{THJA}) + T_A < T_J standard , then we can rule the result as "Pass"

Example:
We take a 1.5KEXXXA series TVS as an example:
R_{THJA} = 30°C/W, T_J = 175°C
The average power result is P_{AVG} = 3W, T_A = 50°C.
T_J = 3W x 30°C/W +50°C = 140°C
Since 140°C < T_J standard of 175°C, we can rule the result as "Pass"

4.3.2 Calculate average power with pulse power and duty

Example:
We take a 1.5KEXXXA series TVS as an example:
R_{THJA} = 30°C/W, T_J = 175°C.

TVS instantaneous peak power = 100W, T_P=150ns, T=8us T_A = 50°C.

P_{AVG} = 100W x 150ns/8us = 1.875W

T_J = 1.875W x 30°C/W +50°C = 106.25°C

Since 106.25°C < T_J standard of 175°C, we can rule the result as "Pass"