MicroNote™ 132

AIRCRAFT LIGHTNING PROTECTION

A Shortcut to Selecting Transient Voltage Suppressors for RTCA/DO-160 Threats

Featuring Microsemi's New

DIRECTselect™ Method

by

Mel Clark and Kent Walters

Microsemi
Power Matters.™

Micronote 132

Table of Contents

Background	3
Abnormal Voltage Characteristics	4
Definitions for Graphs 1-18	5
Using *DIRECTselect* – Examples for Waveform 5A	6
Clamping Voltage Significance	7
Selecting Lightning Protection for Waveform 5A	8
Protecting Across Power Distribution Lines	9
Multiple Surge Events	11
Summary and Conclusions	11
Acknowledgments and References	12
Index of *DIRECTselect* Graphs	13
DIRECTselect Graphs and Data Tables	14-31

BACKGROUND

Within the thin metal and composite shell of every jetliner, tens of thousands of sensitive semiconductor components are performing critical functions from navigation to engine control. Since aircraft are struck by lightning twice a year on average, protection of sensitive electronic devices providing a myriad of functions is essential to ensuring the safety of both passengers and crew.

Although aircraft lightning threats are well defined in RTCA/DO-160, there are very few off-the-shelf transient voltage suppressors (TVSs) that are direct "plug-ins" rated for operating voltage and surge protection from the three waveforms and five levels of lightning threats defined in this document.

Lengthy calculations must often be made to convert TVS surge ratings at standard 10/1000 µs to their equivalent values for specified aircraft lightning threats. In addition, matching a device with the threat can be cumbersome. Our MicroNotes 126, 127 and 130 illustrate these computations, providing a path from defined aircraft surge requirements to the parameters of available TVS products suitable for a given application. With those many resources, there is also **Now a better way using Microsemi's *DIRECTselect*™** to quickly guide the designer to a suitable solution **including considerations for elevated temperature deratings where applicable.**

DIRECTselect Method

Here is how it works: Define your surge requirements as specified in DO-160F in **Section 22, Induced Transient Susceptibility** per waveform, **3, 4, or 5A and Threat Levels 1 through 5** as specified in **Table 22-2**. Herein are the threat levels for **Pin Injection** that define the most severe threats to your circuit. Most requirements combine Waveforms 3 and 4. Since Waveform 4 (6.4/69 µs) is more severe, by a factor of 3.8 [1], we have included only Waveform 4 on our charts for simplicity. Values of Waveform 3 only, when required, are easily calculated using the guidance in MicroNote 127 [2].

For reference, Waveforms 3, 4, and 5A are illustrated in Figures 1, 2 and 3 respectively

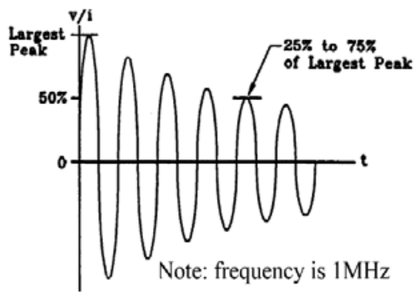


Figure 1. Waveform 3

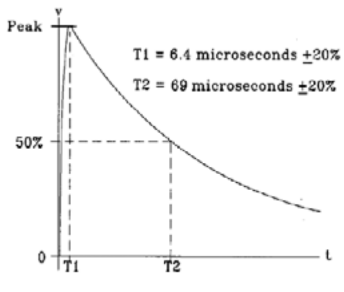


Figure 2. Waveform 4

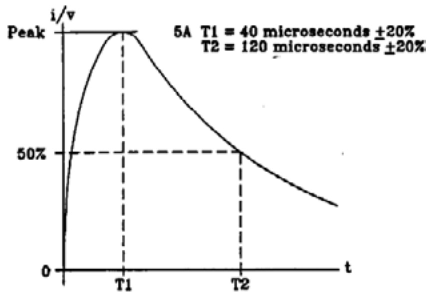


Figure 3. Waveform 5A

LEVEL	Waveforms		
	3	4	5A
	Voc/Isc	Voc/Isc	Voc/Isc
1	100/4	50/10	50/50
2	250/10	125/25	125/125
3	600/24	300/60	300/300
4	1500/60	750/150	750/750
5	3200/128	1600/320	1600/1600

Figure 4. Matrix of Threat Levels 1 through 5 from Table 22-2 in RTCA/DO-160.

This table defines the peak open circuit voltage (Voc) and peak short circuit current (Isc) for each of the waveforms listed. In making your TVS selection, maximum **Working Standoff Voltage (V_{WM})** values are required along with the **Peak Pulse Current (I_P)** threat, where the **graphs shown on pages 14 thru 31** are plotted with **I_P** vertically and **V_{WM}** horizontally. The **I_P** as displayed on the graph must exceed the curve depicting the current limit of the Threat Level. Examples will lead you through the selection process.

Individual graphs exist for each **TVS product family** and are arranged in **ascending order of power rating and surge current from 500 W up through 30,000 W.** These graphs are also a further extension of information in Tables 1 and 2 of MicroNote 130 [3] with added consideration for 70°C and 100°C. **Graphs 1 through 9** are associated with Waveform 4 and Graphs 10 through 18 are associated with **Waveform 5A**. Each graph is accompanied by a supplemental table containing multiple data points **from which each curve was derived**, plus a list of the applicable **Microsemi products** for use with **these specific surge current threat levels.** This presentation provides direction for TVS selection for a broad distribution, from low voltage, low level lightning threats on data lines up through high levels for power distribution lines.

ABNORMAL VOLTAGE CHARACTERISTICS

Other critical voltage parameters for selecting TVS products may sometimes include extended **Surge Limits** associated with abnormal voltage. These are maximum excursions above the nominal operating voltage. Surges differ from transient voltage in that they are long term **Abnormal Voltage Characteristics** with high-line voltages extending for durations of tens, up to hundreds of **milliseconds that can destroy TVSs.**

These voltage anomalies are caused by normal generator functions and must be considered in TVS selection. An example of the **ac abnormal voltage surge curve**, displaying voltage vs time is shown in **Figure 16-5 of the RTCA/DO-160, Section 16 specification** as illustrated below in Figure 5:

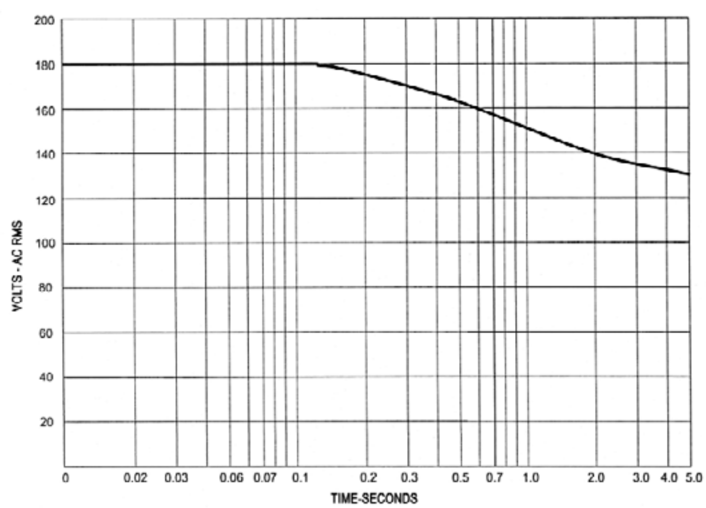


Figure 5. Envelope of AC Abnormal Voltage Surges from Figure 16-5 in RTCA/DO-160

The normal operating voltage values in this graph are for 115 V rms. The rms values must be converted to peak ac values for comparing TVS parameters since the TVSs are characterized for peak, not rms values. **A TVS will not withstand the long surge durations of abnormal voltage surge.** They must be selected so that the maximum Peak Working Voltage, V_{WM}, is equal to or greater than the peak abnormal voltage. Higher magnitude short transients well beyond these voltages such as found in Waveform 3, 4 and 5A are still clamped after exceeding the V_{BR} of the properly selected TVS. For 230 V rms lines, double the values shown in the graph above [4].

DC power lines are also plagued with the same anomaly, **abnormal dc voltage surge**, resulting from voltage excursions produced by the generators. For dc power, there are three categories of surge voltage as shown in RTCA/DO-160, Section 16, Figure 16-6 as also shown below in Figure 6.

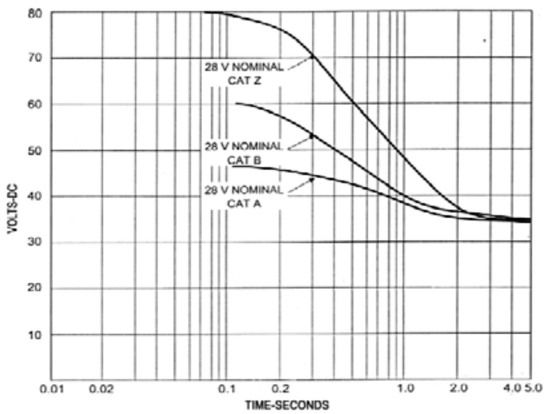


Figure 6. Typical Abnormal DC Voltage Surges per Figure 16-6 in RTCA/DO-160.

Note that there are **3 categories of abnormal voltages** for 28 V nominal and **with 100 ms worst case surge**, similar to the ac power lines. Three levels of abnormal voltages are listed; **Category A, B and Z** with the most common requirement being **Category B**. **For 14 V dc requirements, divide these upper voltage limits by 2 for the applicable values [5].**

As with the envelope for the ac voltages, **the V_{WM} of the TVS must be equal to or greater than the abnormal voltage limit.** For exceptions, consult factory.

DEFINITIONS FOR GRAPHS 1 THROUGH 18

The green, blue and yellow curves represent the ratings of the TVS device in terms of rated Peak Pulse Current (I_P) at ambient temperatures. The I_P is shown in the vertical axis and Working Voltage (V_{WM}) in the horizontal axis. The **green curve** on each graph depicts the peak surge current rating versus working voltage at **25°C** along with additional curves for derating to **70°C (blue curve)** and **100°C (yellow curve)**. The **red Curves**, represent the **Pin Injection current threat levels** as defined by the **RTCA/DO-160 specification** and are labeled accordingly. If the curve for the applicable ambient operating temperature is above the red curve designating the maximum threat level, the TVS device will perform at that threat level. Only those levels that are applicable for the associated device families are included on the graph.

The eighteen individual graphs in this document cover the entire DO-160 threat range. **Nine of these graphs display surge threats and surge capability of the TVSs for Waveform 4 (6.4/69 µs) and nine display this same information for the more severe Waveform 5A (40/120 µs). Values shown on the graph include the +20% high side tolerance of the pulse widths.**

Based on requests from the aerospace industry, Microsemi devices meet the vast majority of needs. If no part exists for a given voltage and surge current rating, custom components can be designed. Consult the factory for these options.

GRAPH OVERVIEW

Each graph is derived from the peak pulse current (I_{PP}) levels at 10/1000 µs ratings of the product data sheet. For the shorter aircraft transients, the power levels are higher, by a factor of 3.33x for the 6.4/69 µs waveform and 2.33x for the 40/120 µs waveform and are labeled as I_P. These multiplication factors include the +20% tolerance of the threat duration [6]. **For Waveform 4**, the graph numbers and associated TVS power levels with part types are listed on the following page. **Except for 1Nxxxx part numbers shown that already have military qualifications, add M prefix for source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in MicroNote 129.**

Graph Number	TVS Power Level @ 10/1000 µs	Product Series (more details on graphs)
1	500 W	1N6103A-1N6137A, 1N6461-1N6468, 1N8073-1N8109, P5KE, SMBJSAC
2	600 W	P6KE, SMB
3	1500 W	1N5629A-1N5665A, 1N5907, 1N5908, 1N6036A-1N6072A, 1N6138A-1N6173A 1N6469-1N6476, 1N8110-1N8146, 1.5KE, SMC, SMCJLCE
4	3000 W	SML
5	5000 W	5KP
6	6500 W	PLAD6.5KP
7	7500 W	PLAD7.5KP
8	15,000 W	15KP, PLAD15KP
9	30,000 W	PLAD30KP

A more complete listing of each product series is shown on its associated graph. NOTE: A **second series of graphs (10 through 18)** are also included for **Waveform 5A** and contains equivalent information on the product series as waveform 4 above with **threat levels** increased to the magnitude of waveform 5A.

USING *DIRECTselect* - EXAMPLES FOR WAVEFORM 4

For our **first example**, let's consider a low level transient voltage threat to an **ARINC - 429, +/- 5 V** data line. For this illustration, the **lightning threat** requires protection from **Waveform 4, (6.9/69 µs) Level 3** (300Voc/60Isc). Applications with voltages going in both positive and negative directions require bidirectional TVS devices.

We know the selection will be within the **first few** of the **seven graphs** because of the relatively low current rating requirement. Since the **lowest voltage** devices have the **highest current ratings**, the device would most likely be found on the first one or two graphs.

In reviewing **Graph 1**, **the 500 W TVS at 5 V working voltage (V_{WM}) has a peak current rating of 180 A.** This is well above the necessary **requirement of 60A** for **Level 3** with margin for **temperature derating up to 100^{O}C.** In the supplementary table, data points for these graphs are provided that include the major parameters: Peak Pulse Current (I_{PP}), Clamping Voltage (V_C), and $V_{WM.}$ Exact values not shown can be extrapolated from this data.

Device selection for the **ARINC - 429, Slow Data rate** signals, **10-11 kHz**, would be the SMBJ5.0C **or SMBJ5.0CA**. For the **Fast Data** rate signals at **100 kHz**, the selection would be the **SMBJSAC5.0 with low capacitance of 30 pf or less. Two of these devices are required in anti-parallel to achieve bidirectional protection**. Refer to the data sheet on Microsemi's web site for complete information on installing this part. The selection shown is a surface mount device; however these parts are also available in axial-leaded configurations.

In our **second example**, a TVS is required for performance to **Waveform 4** (6.4/69 µs)**, Level 3** (Voc300V/Isc60A) for **+/-48V ac.** This application also requires a bidirectional device and must have a higher power rating than in the previous example because its operating voltage is significantly greater. **Since silicon TVSs provide the same power rating within a series ($P_{PP} = I_{PP} \times V_C$), the current rating will be about one-tenth of the value for a 48 V TVS compared to a 5.0 V device in the same series.** However, the **peak pulse power requirement is greater for this application**, so we continue our search among the graphs for a higher power device. In **Graph 3, for the 1500 W series,** we find that the current withstand (I_P) of a 48 V device @ 25°C is **64 A while the requirement is 45 A at 48 V.** It is interesting to note that the specified requirement of **60 A per Table 22-2 is reduced significantly** by the clamping voltage subtracting from the driving voltage [7], thus proportionally reducing the surge current. This is reflected in the downward slope of the **Level 3 Curve**. The SMCJ48CA, (CA suffix denoting bidirectional performance for ac) or equivalent will meet the surge requirements at 25°C and 70°C but is marginal at 100°C. The next level up, the 3000 W series is recommended for 100°C performance if required (see Graph 4).

Why are the “driving” current threats (I_S) of Levels 1 through 5 reduced with increasing voltage? Because the clamping voltage of the TVS subtracts from the open circuit driving voltage, thus lowering the driving current as illustrated in the following equation:

$$Is = (Voc - Vc) / Zs \quad \textbf{(Eq. 1.)}$$
$$= (300\ V - 77.4\ V) / 5\ ohm$$
$$= 44.5\ A$$

Where: Is = peak driving current of surge through the TVS Voc = open circuit voltage - 300 V
Vc = Max clamping voltage of SMCJ48CA
Zs = Source impedance of driving voltage - Voc / Isc

In this equation, we see the Voc open circuit voltage of 300 V is reduced to 222.6 V, with a corresponding reduction of surge current to 44.5 A, or about 25% below the value of 60 A for the Isc specified for Level 3.

CLAMPING VOLTAGE SIGNIFICANCE

The purpose of the TVS is to clamp the voltage spike to a level below the failure threshold of the components it is protecting. The **failure threshold voltage is not the operating voltage of the protected device. All components have a margin between rated value and transient failure threshold which is usually not specified by the manufacturer**.

Maximum operating voltage levels specified on data sheets for ICs and power transistors are for steady state conditions while most components can tolerate short term voltage spikes of less than 150 µs up to 50% greater values than the operating voltages. Normally the higher the voltage of the protected device, **the more narrow the margin in percentage** between maximum **operating voltage level and voltage spike failure level**. For example, a 400V rated switching transistor can usually tolerate a clamping level of 420 V or more, which is about 5% greater than its steady state operating level. In comparison, a 5 V to 15 V UART (universal asynchronous receiver transmitter) can normally withstand a 50% or greater voltage clamp above its maximum operating level. Manufacturers are reluctant to provide any other than the maximum operating voltage. The above failure threshold values are based on the writer's experience, including test measurements.

Our third example of protection is for a 48 V signal line monitoring status of voltage across a relay. The threat is **Waveform 4, Level 4** (750Voc/150Isc). This takes us to a higher power level device requirement that we find is the **5000 W** rated TVS shown in **Graph 5**. The peak current protection is more than twice that for our previous example, so we look for a TVS with higher power that will withstand this higher peak current surge.

Observing the V_{WM} of 48 V at Level 4 in graph 5 for 5000 W devices, we see that the maximum peak current rating for this voltage is approximately 210A @ 25°C. The derating graphs indicate that this part will operate safely at 70°C but marginal at 100°C. For 100°C performance, the higher power **PLAD6.5KP48A surface mount TVS in Graph 6** or the **PLAD7.5KP48A in graph 7 is recommended**. A unipolar device was selected because this is a dc application. Clamping of the negative transients is through the diode in the forward direction that can withstand higher surge currents than in the avalanche mode.

A fourth example of protection continues when ascending to a higher threat level protecting from a transient surge per **Waveform 4, Level 5 (1600Voc/320Isc)**. Operating conditions are on a **28 V dc power distribution line** that must withstand an **abnormal voltage condition of 60 V maximum, Category B [4].**

Continue working your way further into the pages noting that in **Graph 8 the 15,000 W TVS series** will withstand surge currents of **greater than 320 A at a voltage level of 60 V and 100°C. Above 60 V, a TVS will not conduct during the abnormal condition but will withstand a surge > 320 A for this Waveform 4, Level 5 threat.** A good selection for this application in Graph 8 would be a **15KP64A or PLAD15KP64A.** Verify that the clamping voltage is **compatible** with the maximum **failure threshold voltage** of the protected circuit / component. This device is rated for approximately 500 A at 25°C. It has a clamping voltage of 104 V at its rated peak pulse current (Ipp) as extrapolated from the graph/data table. This device has a significant margin of about 60% at 25°C that can be derated to 100°C with a margin of safety.

The 15,000 W axial-leaded devices are often made using 3-stacked chips that have been considered the most economical method for higher power surge suppressors. The PLAD15KP series is made up of a single larger chip in a surface mount package for the same power rating as well as two stacked chips for twice the P_{PP} rating at 30,000 W with the PLAD30KP series. With fewer internal chips stacked in series, it also allows lower voltages in these PLAD product series families where they start at 7 V and 14 V respectively. This can also be very useful for generating higher peak pulse power options as we shall observe in further examples for the severe Waveform 5A.

Our fifth example is one in which a 125 V dc status monitoring signal line must be protected from conditions of **Waveform 4, Level 5** (1600Voc/300Isc) in a 70°C ambient.

Continue on to **Graph 9** and locate the coordinates for the required performance. At 130V, the **PLAD30KP130A** device has a 6.4/69 μs rating of 470 A at 25°C and 380 A at 70°C; and 330A for 100°C. This selection should perform well for the application.

SELECTING LIGHTNING PROTECTION FOR WAVEFORM 5A

Waveform 5A is defined as having a waveform, of 40/120 μs +/- 20%. Calculations in the following examples are based on the +20% worst case, increasing the pulse duration from 120 μs to 144 μs maximum. **Graphs 10 through 18 depict curves for Waveform 5A**. These protection levels are developed in the same manner as those for Waveform 4 but with lower I_{PP} device ratings attributed to the longer Waveform 5A. The **increase in surge current / power for Waveform 5A is only 2.33** times the peak current value for a given device @10/1000 μs found in Microsemi data sheets as stated earlier.

Referring to **Figure 4 on page 3** and the column for **Waveform 5A**, note that the voltage spike amplitudes are identical to those for **Waveform 4**. However, the Isc current is higher by a factor of 5 because of the lower source impedance of only 1 ohm compared to 5 ohms for Waveform 4. Another component of the increased threat for Waveform 5A is its 74% longer duration compared to Waveform 4.

The more severe conditions of Waveform 5A are attributed to applications involving closer proximity of lightning source including those conductors close to the skin of the aircraft, areas containing a higher density of composite materials, long power distribution lines, and long signal line runs within the airframe plus a myriad of others.

From the writer's experience, ac and dc power distribution systems may be located in areas requiring protection from Waveform 5A surges, depending on the airframe structure. With the large amounts of composite materials used in construction of newer aircraft, both power and data lines are subjected to more severe lightning threats. Most threats presented by **Waveform 5A** appear to be **Level 4** (750Voc/750Isc) based on the writers experience.

Typical Waveform 5A Level 4 threats require the higher 30 kW product ratings for protection. Multiple 30 kW devices are often wired in series or parallel to provide the surge current withstand capability for Level 4, Waveform 5A threats. Although there have been no requests, TVS devices for Level 5 threats can be designed to also meet these requirements.

Example 1 protecting from **Waveform 5A threats** is that of a **125 V dc status signal line** subjected to **Level 2** (125Voc/125Isc). This is an easy one to solve since the operating voltage and threat are at the same level. There will be zero voltage impressed on the line because it is of the same value as the threat, hence no current is driven into the 125 V signal line and no protection is required (see EQ.1). For this same threat at lower operating voltages, protection will be required as shown in the following example.

Example 2 protection from **Waveform 5A** is one where a low speed **32 V bidirectional signal line** is exposed to a **Level 2** (125Voc/125Isc) threat. ARINC-429 and most other signals are run through shielded wiring that provides significant lightning protection, also the line impedances are quite high, further reducing lightning threats. This issue was discussed earlier in the section on protecting from Waveform 4 threats.

For this requirement, the solution is found on **Graph 13 for the 3000 W device**. The closest fit is the **SMLJ33CA** (33V V_{WM}) that can be derated for 100°C performance. This is a compact surface mount device in the DO-214AB with J bend tabs. The SMLJ series is a frequent choice for signal line protection from harsh lightning conditions.

Example 3 for a Waveform 5A threat **from Level 3** (300Voc/300Isc) lightning exposure, is for a **12 V power supply**. The **3000 W device in Graph 13** will protect up to **70°C** as observed on the coordinates; however, for protection at **100°C** ambient levels, the **5000 W** device depicted in **Graph 14 is required** where the **5KP12A axial leaded** device is recommended. **For surface mount, the PLAD6.5KP12A is recommended in Graph 15.**

Example 4 is more challenging protecting a **48 V off-line switching** power supply with a 100 V rated transistor and **Waveform 5A, threat Level 4** (750Voc/750Isc). Ambient operating temperature is 100°C and the power is

Category B with a maximum abnormal voltage surge of **60 V for 100 ms** previously described in Figure 6. Since a TVS will not withstand the power delivered by a 100 ms surge, 60 V becomes our defacto operating voltage. From **Graph 18 for the 30,000 W TVS**, our highest powered device for this voltage (PLAD30KP60A) will withstand a peak current of 727 A at 40/120 µs, (with V_C of 96.8 V) only 74 A above the threat level of 653 A at 25°C (see Eq.1). This is a close margin, but more than adequate to meet this requirement. A further level of creativity is required to meet higher temperature requirements.

One option to increase surge current capability is to use two devices of the same voltage type matched in parallel, providing twice the current capability of a single device to meet the often required 100°C ambient. They must be matched under surge conditions to ensure near equal voltage for sharing the current evenly. Two each of a 30KPA60A matched in parallel will provide the necessary protection up to 100°C with an approximate 50% safety margin. Special selected matched devices can be avoided by using two of the PLAD30KP30A in series for surface mount applications. The clamping voltage for the two devices in series is conservatively estimated to be 100 V maximum, the same value as the maximum rated operating voltage of the protected device [8]. Using two or more of the same lower voltage TVS devices in series (if available) where the voltage adds up to the desired V_{WM} value is recommended when surge currents are beyond the capability of a single TVS of a higher selected V_{WM} value. Multiple devices can be used as long as they are of the same type or of higher current rating when an equally divisible required number is not available.

PROTECTING ACROSS POWER DISTRIBUTION LINES

For protection across high voltage ac power distribution lines, there is the option of stacking lower voltage, higher current rated devices in series to compensate for the inherently lower surge current ratings of high voltage TVSs. This is particularly applicable for high V_{WM} applications requiring high surge current protection across ac distribution from a **Waveform 5A Level 4 threat (750Voc/750Isc)**.

Example 5 is for an application across a **115V ac distribution line** having an **Abnormal Voltage of 255 V** peak from 180 V rms (see Figure 5) feeding a switching power supply. A maximum clamping of 420 V is required for protection of the 400 V rated transistor within the supply. A few well chosen parts can be stacked in series which have a clamping voltage of 420 V maximum and still meet the surge current and a working voltage level equal to or slightly above the 255 V, 100 ms abnormal high voltage condition.

When reviewing the selection of available PLAD30KPxxx series devices and comparing the listed I_{PP}, remember that the current rating in the data sheet is for a 10/1000 µs waveform and Waveform 5A is 40/120 µs. Per the section on Graph Overview herein (page 5), the 10/1000 µs surge current rating is multiplied by 2.33x to obtain its higher value for the shorter 40/120 µs pulse width.

For example, we first calculate the true surge current (Is) of the Level 4 threat to the power supply using 400 V switching transistors with 420 V transient capability.

$$I_S = (Voc - Vc) / Zs \quad \textbf{(Eq. 2)}$$
$$= (750V - 420V) / 1\ ohm$$
$$= 330\ A$$

From this simple calculation, we find the threat @ 25°C is 330 A at 40/120 µs. Next we review the TVS devices available from the 30 kW ratings at 10/1000 µs such as the PLAD30KPxxx data sheet to select TVSs that provide the desired electrical parameters with surge capability of 330 A plus derating for high temperature performance.

Our target working voltage is 255 V peak, the worse case abnormal high voltage condition, or slightly higher, but still meeting conditions of maximum surge current and clamp voltage. For a trial fit on this severe requirement, we divide the working voltage by two, with a resulting value of 127.5 V which is closely rounded up to 130 V providing a PLAD30KP130CA option. Total clamping voltage of these parts in series is 2 x Vc, (Vc is 209 V) resulting in 418 V. The peak pulse current of the PLAD30KP130CA for the 40/120 µs Waveform 5A is:

$$I_P \text{ at } 40/120\ \mu s = 2.33 \times I_{PP} \text{ at } 10/1000\ \mu s \quad \textbf{(Eq. 3)}$$
$$= 2.33 \times 142\ A$$
$$= 331 \text{ Amps max } I_{PP}$$

Just a reminder that I_P is used to denote peak current rating at a waveform other than 10/1000 µs while I_{PP} is the 10/1000 µs data sheet rated peak pulse current. This limit of 331 A for the TVS is approximately equal to that calculated for this surge event of 330 A in Eq. 2, and is only suitable for 25ºC ambient temperatures, with no margin for derating to higher temperatures. When using multiple TVS devices in series resulting in higher V_C values, the calculations in Eq. 2 indicate the red threat level curves decline in value or effectively shift to the left with respect to the individual V_{WM} voltages for each TVS device used in series. This also results in improved margin of the green, blue and yellow performance curves relative to the I_S calculations for threat level curves where the 18 graphs only show I_S relations for individual TVS devices.

Three devices in series will provide a greater surge protection level. Dividing 255 V by three provides a PLAD30KP85CA for a surface mount package option with a clamp voltage of 137 V each. Total clamp voltage for the three parts in series is the additive values or 137 V x 3 yielding 411 Volts on the PLAD example where V_C is still conservative for the 420 V minimum requirement.

The peak surge current (I_P) rating for these three devices rated for a 4/120 µs, Waveform 5A is derived in the same manner as in the previous example yielding 508 A for I_P that provides a 54% increased margin from 330 A in Eq 2 and can also be conservatively derated to 100°C. In this example, the stacked devices were all the same voltage without fractional values remaining. If this is not the case, use a lower voltage device which matches closest when added together but is still above the system operating voltage.

Example 6 is for protection across **230 V ac lines** requires performance at an abnormal voltage surges up to 360 V rms or 509 V peak for 100 ms that is twice the value in figure 5, shown on page 4. TVS protection voltage levels are double the values previously illustrated for 115V. The same techniques are used for selecting lightning protection devices. In some applications where narrow margins exist between operating voltage and clamping voltage, the designer is encouraged to consult the factory for assistance.

Example 7: For protection across **28 V, Category B dc bus lines, threat Level 4 of Waveform 5A**, the net surge current is higher resulting from the lower clamp voltage as shown with a PLAD30KP60A selected for protection. This 66.7 V minimum breakdown device will adequately meet the 60 V for 100 ms, “Abnormal Voltage” condition.

$$
\begin{aligned}
I_S &= (Voc - Vc) / Zs \\
&= (750V - 96.8V) / 1\ \text{ohm} \\
&= 653\ \text{A}
\end{aligned}
\qquad \textbf{(Eq. 4)}
$$

The Level 4 surge current threat for a 28 V dc line is almost double that for the 115 V ac requirement previously shown since the clamping voltage of 96.8 V is far less across the ac power line in equation 4 above. The I_P of the PLAD30KP60A for a 40/120 µs pulse is 312 x 2.33 = 727 Amps providing a margin of 11% above the I_P requirement of 653 A for a 25°C ambient.

Many applications require the lowest clamping voltage that can be attained. Since the abnormal surge voltage does not exceed 60 V, using a device with a breakdown voltage equal to this value has been acceptable for most applications. Lower voltage TVSs providing lower clamping voltage than the PLAD30KP60A described above include the PLAD30KP58A and PLAD30KP54A. Minimum breakdown voltages at 25°C are 64.4 V and 60.0 V respectively on the PLAD products with minimum clamping voltages of 93.6 V and 87.1 V respectively. Maximum I_P for the PLAD30KP54A is 797 A at 40/120 µs or 2.33 x 342. Let's also compare this to the Waveform 5 Level 4 threat limit calculation.

$$
\begin{aligned}
I_S &= (Voc - Vc) / Zs \\
&= (750V - 87.1V) / 1\ \text{ohm} \\
&= 662.9\ \text{A}
\end{aligned}
\qquad \textbf{(Eq. 5)}
$$

Compared to the PLAD30KP60A, the PLAD30KP54A offers 9.9 Amps of additional current protection and a lower clamping voltage by 9.7 V for protecting more sensitive components. Although the lower end of the breakdown voltage (V_{BR}), is identical to the maximum Abnormal Voltage (60.0 V), the TVS will draw current when the temperature drops below 25°C for example, since TVS devices have a positive temperature coefficient of voltage. However the current drawn by the TVS will be minimal and only sufficient to maintain a breakdown voltage equal to the maximum Abnormal Voltage during this brief time period of 100 ms. For a power line, this small amount of extra current drawn for heating the TVS should present no problem.

When comparing this analysis of a 54 Volt V_{WM} in **Graph 18** for Level 4 protection, it is apparent this is sufficient for 25°C but not for 70°C or above. For higher ambient temperatures as in earlier examples, the easiest practice is to place two devices in series of one-half the voltage of the PLAD30KP54A. This is available in the surface mount series with the PLAD30KP28A to almost double the surge current or three devices with the PLAD30KP18A to triple the surge current capabilities. In those TVS series where these lower voltage selections have not been previously available (such as in the older 30KPxxx axial-leaded series), the alternative for increasing surge current capability is with matched parallel devices. Voltage matching is performed under surge conditions to ensure a very close match, typically within the range of +/- 0.5%, for even load sharing between devices. This is normally performed by the manufacturer. Parallel matched TVSs for aircraft lightning protection and general heavy duty surge protection have been in use for several decades and have a record of proven performance. This method has also been thoroughly tested in battle performance in military ships and aircraft.

For higher current applications using single components beyond the limitations of Microsemi's 30,000 watt devices, there is the RT130KP275CV thru 295CV or CA series, which is rated at 40,000 W for 10/1000 µs. They are characterized for Waveform 4, 6.4/69 µs and available in voltages intended for protection across 115 ac lines including abnormal high voltage conditions. Using the conversion equations reviewed in MicroNote No. 127, they may be applicable for other protection requirements confronted by the designer.

Copies of the RT130KP275CV thru 295CV or CA series data sheets can be downloaded from our web site at www.microsemi.com .

MULTIPLE SURGE EVENTS

Further inquiries have been made for devices to withstand multiple surge events as also defined by RTCA/DO-160. The profile of the surge consists of a maximum value followed by multiple strokes. Since there is cumulative heating effects from these multiple surges, the lower thermal resistance junction to case (bottom) of the PLAD designs make them a better choice. Also reference MicroNote 133 on our web site [9].

SUMMARY / CONCLUSIONS

This document is the fifth in our series of MicroNotes providing selection guidance specifically for the avionics design engineer (the others include MicroNotes Nos. 126. 127, 130, and 133). It translates the data sheet peak pulse current ratings of the 10/1000 µs waveform into the surge rating equivalents to meet the Waveform 3, 4 and Waveform 5A threats described in RTCA/DO-160.

A matrix of graphs for each device family from 500 W peak pulse power up through 30,000 W has been derived for surge ratings of each device family at 25°C, 70°C, and 100°C for the above threats. Each graph is supported with a table listing the data sheet electrical parameters for the individual components listed along with calculated data points for the curves.

Using the examples and guidelines in the text, the designer is able to select directly from the graph of a device to fit his requirement with minimal calculating and guesswork. We expect those using this document to save valuable design time by more rapidly selecting a TVS correctly rated for a given application.

This is our second issue at presenting this information in graph selection format. We expect other revisions to keep up with the emerging technologies and updates of the RTCA/DO-160 specification and its latest revision. We also still recognize there is room for modifications to make this document more user friendly. To help achieve this goal, constructive comments from the user are welcome. It is Microsemi's desire to provide the design engineer with the most up to date design information to assist in achieving his/her goal more efficiently.

For additional technical information, please contact Design Support at:

http://www.microsemi.com/designsupport

or

Kent Walters (kwalters@microsemi.com) at 602-458-3212

REFERENCES

[1] Clark, O. M., MicroNote™ No. 127, Microsemi Corp., pg. 6
[2] Clark, O. M., MicroNote No. 127, Microsemi Corp., pg. 6
[3] Walters, K., MicroNote No. 130, Microsemi Corp.,
[4] RTCA/DO-160E, Section 16, Figure 16-5, pgs. 16-37
[5] RTCA/DO-160E, Section 16, Figure 16-6, pgs. 16-38
[6] Clark, O. M., MicroNote No. 127, Microsemi Corp., pg. 10
[7] Clark, O. M., MicroNote No. 127, Microsemi Corp., pg. 17
[8] Clark, O. M. and Walters, K. MicroNote No. 112, Microsemi Corp.
[9] Walters, K., MicroNote No. 133, Microsemi Corp.

Index to
DIRECTselect Graphs and Datapoints

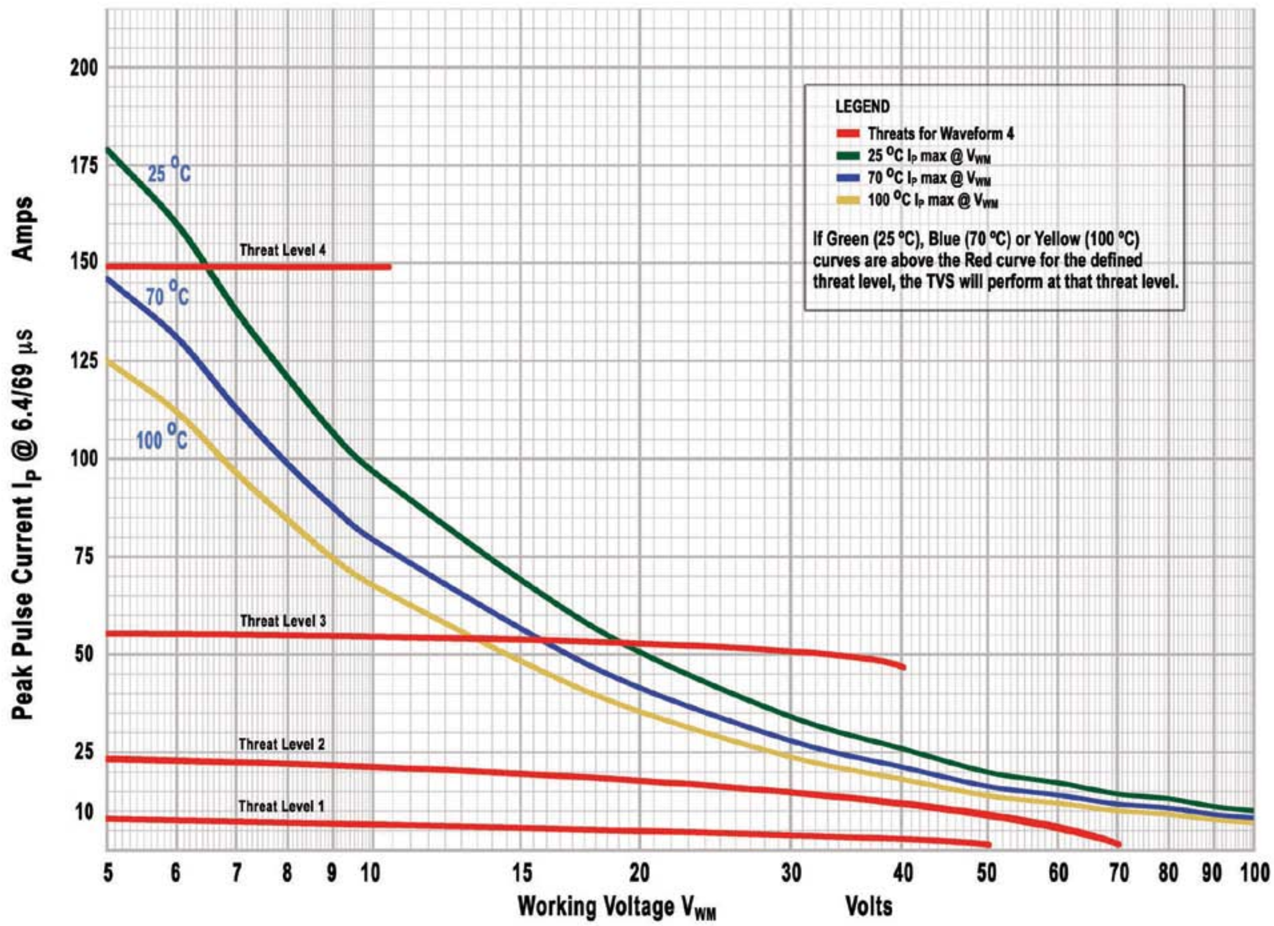
Graph #	Waveform Rating	Power*	Pg #
Graph 1	Waveform 4	500 W	14
Graph 2	Waveform 4	600 W	15
Graph 3	Waveform 4	1500 W	16
Graph 4	Waveform 4	3000 W	17
Graph 5	Waveform 4	5000 W	18
Graph 6	Waveform 4	6500 W	19
Graph 7	Waveform 4	7500 W	20
Graph 8	Waveform 4	15,000W	21
Graph 9	Waveform 4	30,000W	22
Graph 10	Waveform 5A	500W	23
Graph 11	Waveform 5A	600W	24
Graph 12	Waveform 5A	1500W	25
Graph 13	Waveform 5A	3000W	26
Graph 14	Waveform 5A	5000W	27
Graph 15	Waveform 5A	6500W	28
Graph 16	Waveform 5A	7500W	29
Graph 17	Waveform 5A	15,000W	30
Graph 18	Waveform 5A	30,000W	31

* Power rating at 10/1000 μs

Index

www.Microsemi.com

Graph 1: RTCA/DO-160, Waveform 4, Levels 1 through 4, 500 W TVS Series



Data Points for Curves in Graph 1

Waveform 4 RTCA/DO-160 using 500 W TVS Diodes

500 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_s Threat for Levels shown on graph Threat Levels 1-4			
V_{WM} V	V_C V	I_{PP} 500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	1 50V/10A A	2 125V/25A A	3 300V/60A A	4 750V/150A A
5	9.2	54.3	179	146	125	8.2	23.1	58.2	148.2
6	10.3	48.5	160	131	112	7.9	22.9	57.9	147.9
7	12.0	41.7	138	113	96.6	7.6	22.6	57.6	Over limit 25 °C
8	13.6	36.7	121	99	84.7	7.2	22.8	57.2	
9	15.4	32.5	107	88	74.9	7.0	21.9	56.9	
10	17.0	29.4	97	79.5	67.9	6.6	21.6	56.6	
12	19.9	25.1	83	68.0	58.1	6.0	21.0	56.0	
15	24.4	20.6	68	55.8	47.6	5.1	20.1	55.1	
18	29.2	17.2	57	46.7	39.9	4.0	19.2	54.2	
20	32.4	15.4	51	41.8	35.7	3.5	18.5	53.5	
28	45.4	11.0	36	29.5	25.2	0.9	15.9	50.9	
30	48.4	10.3	34	27.9	23.8		15.3	50.3	
36	58.1	8.6	29	23.7	20.3		13.4	Over limit 25 °C	
40	64.5	7.8	26	21.3	18.2		12.1		
48	77.4	6.5	22	18.0	15.4		9.5		
50	80	6.0	20	16.4	14.0				
60	96.8	5.2	17.3	14.2	12.1				
70	113	4.4	14.5	11.9	10.2				
80	126	4.0	13.3	10.9	9.3				
90	146	3.4	11.3	9.3	7.9				
100	162	3.1	10.2	8.4	7.1				

Microsemi TVs Part Numbers compliant to RTCA/DO-160

Standard Capacitance

- Axial Lead
  P5KE5.0A-170A, CA
  1N6103A-6137A
  1N6461-6468

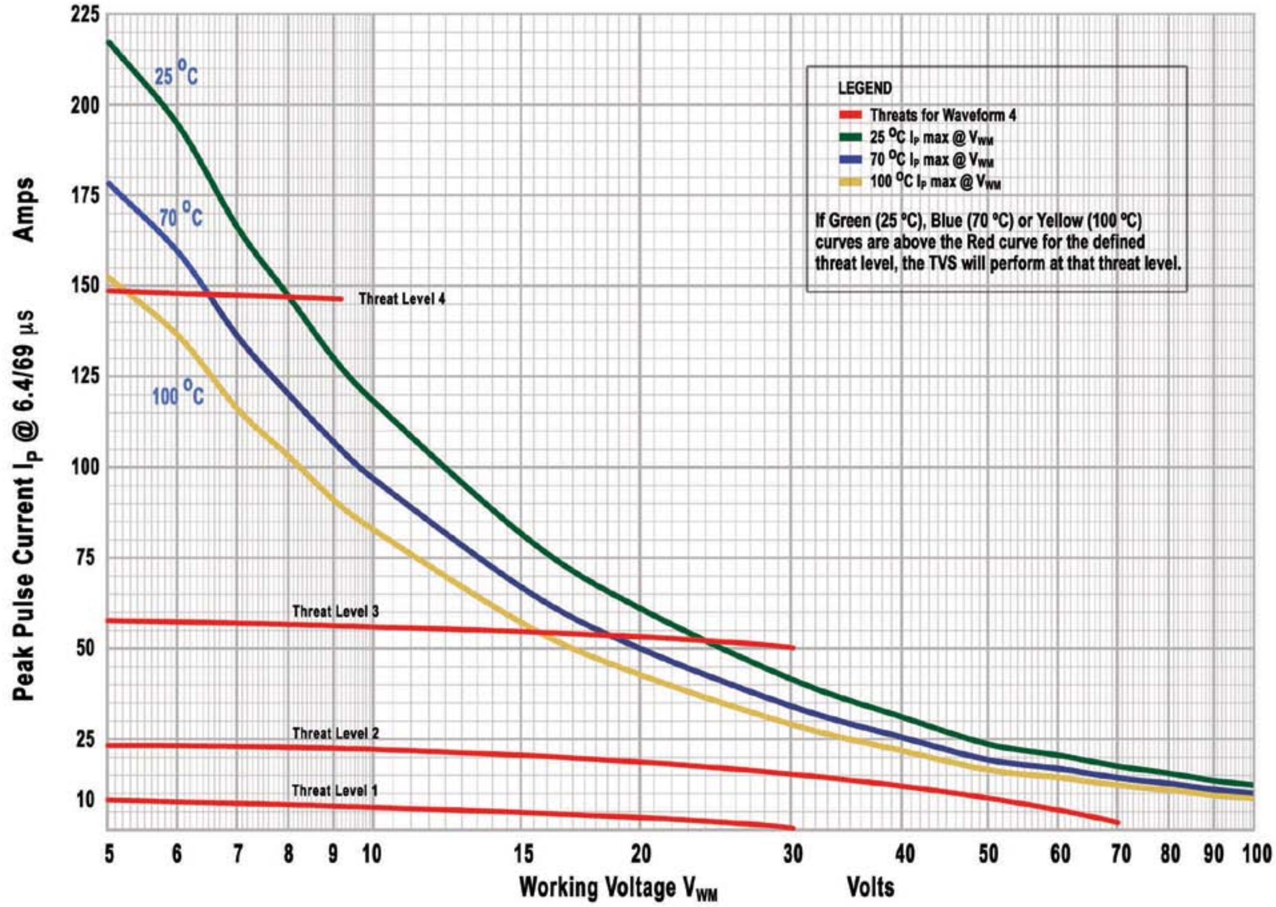
Low Capacitance

- Axial Lead
  SAC5.0-50
- Surface Mount
  SMBJSAC5.0-50

Except for 1Nxxxx part numbers shown that already have military qualifications, add M prefix for source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq. 1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 500 W are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 2: RTCA/DO-160, Waveform 4, Levels 1 through 4, 600 W TVS Series



Data Points for Curves in Graph 2 — Waveform 4 RTCA/DO-160 using 600 W TVS Diodes

600 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 1-4			
V_{WM} V	V_C V	I_{PP} 600 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	1 50V/10A A	2 125V/25A A	3 300V/60A A	4 750V/150A A
5	9.2	65.2	217	178	152	8.2	23.1	58.2	148.2
6	10.3	58.3	194	159	136	7.9	22.9	57.9	147.9
7	12.0	50.0	166	136	116	7.6	22.6	57.6	147.6
8	13.6	44.1	147	120	103	7.2	22.2	57.2	147.2
9	15.4	39.0	130	107	91.0	7.0	21.9	56.9	Over limit 25 °C
10	17.0	35.3	118	96.7	82.6	6.6	21.6	56.6	
12	19.9	30.2	101	82.8	77.7	6.0	21.0	56.0	
15	24.4	24.0	80.0	65.6	56.0	5.2	20.1	55.1	
18	29.2	20.5	68.2	55.9	47.7	4.0	19.2	54.2	
20	32.4	18.5	61.3	50.2	42.9	3.5	18.5	53.5	
28	45.4	13.2	43.9	35.9	30.7	0.9	15.9	50.9	
30	48.4	12.4	41.3	33.9	28.9	0.3	15.3	Over limit 25 °C	
36	58.1	10.3	34.3	28.1	24.0	0	13.4		
40	64.5	9.3	31.0	25.4	21.7		12.1		
48	77.4	7.7	25.6	20.9	17.9		9.5		
50	80.0	7.1	23.6	19.3	16.5		9.0		
60	96.8	5.6	20.6	16.9	14.4		5.6		
70	113	5.3	17.6	14.4	12.3		2.4		
80	126	4.7	15.6	12.8	10.9				
90	146	4.1	13.6	11.2	9.52				
100	162	3.7	12.3	10.1	8.61				

Microsemi TVS Part Numbers compliant to RTCA/DO-160

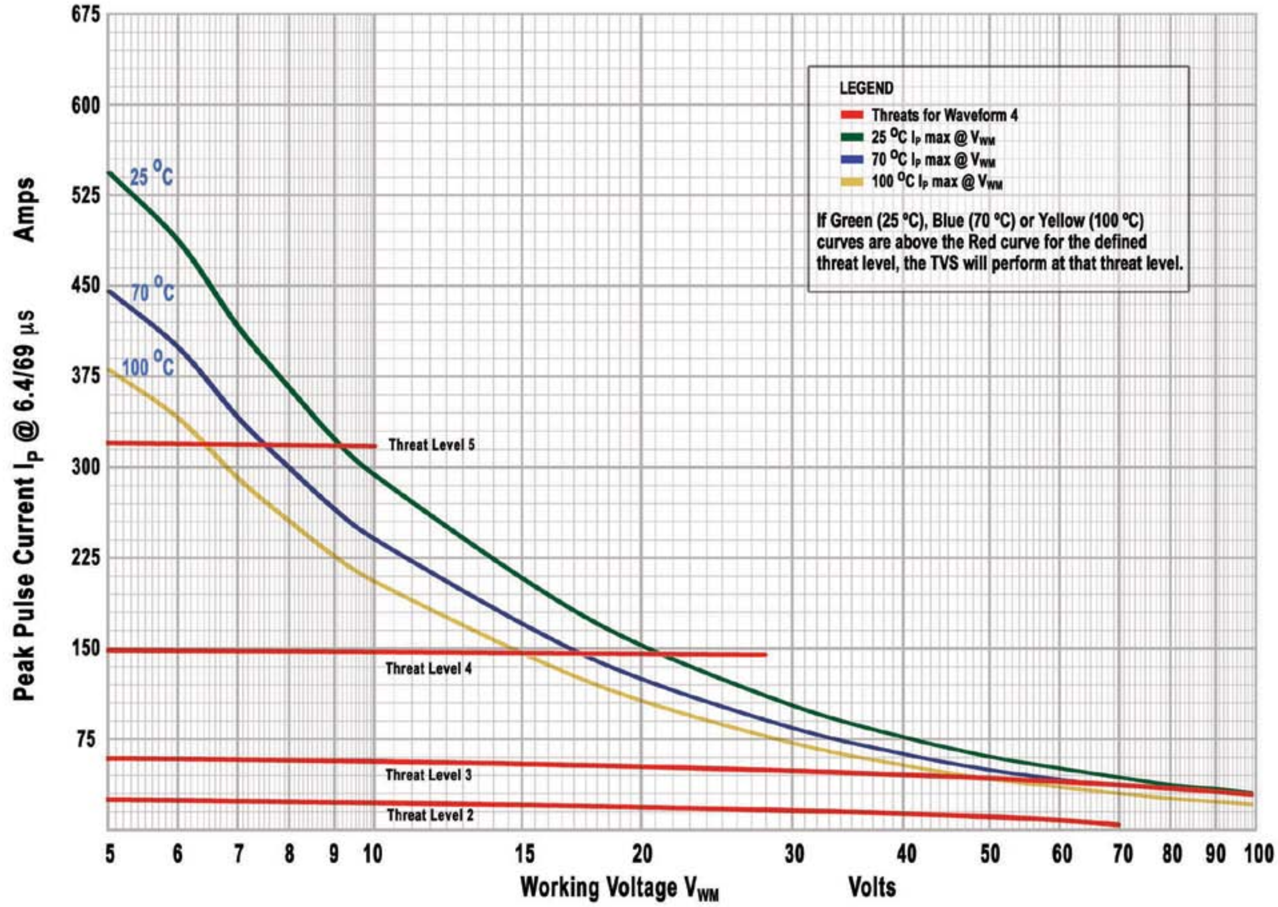
Standard Capacitance

- Axial Lead
  P6KE6.8A-200A, CA
- Surface Mount
  SMBJ5.0A-170A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 600 W are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 3: RTCA/DO-160, Waveform 4, Levels 2 through 5, 1500 W TVS Series



Data Points for Curves in Graph 3

Waveform 4 RTCA/DO-160 using 1500 W TVS Diodes

1500 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 2-5			
V_{WM} V	V_C V	I_{PP} 1500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	2 125V/10A A	3 300V/60A A	4 750V/150A A	5 1600V/320A A
5	9.2	163	543	445	380	23.1	58.2	148.2	318.2
6	10.3	146	486	398	340	22.9	57.9	147.9	317.9
7	12.0	125	416	341	291	22.6	57.6	147.6	317.6
8	13.6	110	366	300	256	22.8	57.2	147.2	317.3
9	15.4	97.4	324	266	227	21.9	56.9	146.9	316.9
10	17.0	88.2	294	241	206	21.6	56.6	146.6	316.6
12	19.9	75.3	251	206	176	21.0	56.0	146.0	316.0
15	24.4	61.5	205	168	144	20.1	55.1	145.1	Over limit 25 °C ↓
18	29.2	51.4	171	140	120	19.2	54.2	144.2	
20	32.4	46.3	154	126	108	18.5	53.5	143.5	
28	45.4	33.0	110	90.2	77.0	15.9	50.9	140.9	
30	48.4	31.0	103	84.5	72.1	15.3	50.3	Over limit 25 °C ↓	
33	53.3	28.1	93.6	76.7	65.5	14.3	49.3		
40	64.5	23.2	77.2	63.3	54.0	12.1	47.1		
48	77.4	19.4	64.6	52.0	45.2	9.5	44.5		
50	80.0	18.2	60.6	49.6	42.4	9.0	44.0		
60	96.8	15.5	51.6	42.3	36.1	5.6	40.6		
70	113	13.3	44.2	36.2	30.9	2.4	37.4		
80	126	11.4	38.0	31.2	26.6	0	34.8		
90	146	10.3	34.7	28.1	24.0	↓	30.8		
100	162	9.3	31.0	25.4	21.7		27.6		

Microsemi TVs Part Numbers compliant to RTCA/DO-160

Standard Capacitance

- Axial Lead
  - 1.5KE6.8A-400A, CA
  - 1N5629A-1N5665A
  - 1N5907, 1N5908
  - 1N6036A-1N6072A
  - 1N6138A-1N6073A
  - 1N6469-1N6476
  - 1N8110-1N8146
- Surface Mount
  - SMCJ5.0A-170A, CA

Low Capacitance

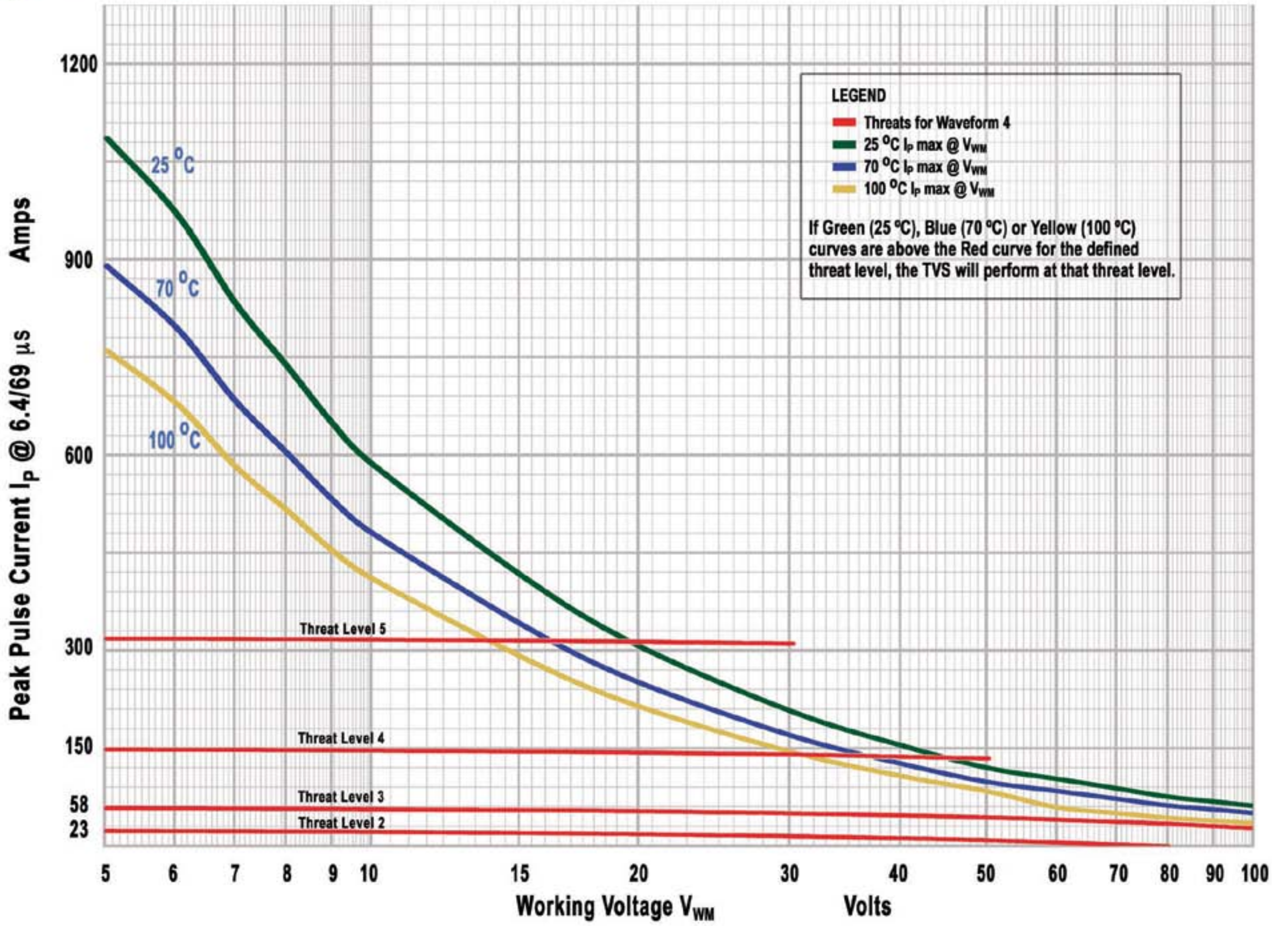
- Axial Lead
  - LC6.5-170A
  - LCE6.5-170A
- Surface Mount
  - SMCJLCE6.5-170A

Except for 1Nxxxx part numbers shown that already have military qualifications, add M prefix for source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 1500 W are taken from the data sheet while the subsequent three columns of 6.4/69 μs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 3

Graph 4: RTCA/DO-160, Waveform 4, Levels 2 through 5, 3000 W TVS Series



Data Points for Curves in Graph 4 — Waveform 4 RTCA/DO-160 using 3000 W TVS Diodes

3000 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 2-5			
V_{WM} V	V_C V	I_{PP} 3000 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	2 125V/10A A	3 300V/60A A	4 750V/150A A	5 1600V/320A A
5	9.2	326	1085	889	759	23.2	58.1	148.2	318.1
6	10.3	291	969	794	678	22.9	57.9	147.9	317.9
7	12.0	250	832	682	582	22.6	57.6	147.6	317.6
8	13.6	221	736	603	515	22.8	57.2	147.2	317.3
9	15.4	195	649	532	454	21.9	56.9	146.9	317.0
10	17.0	176	586	480	410	21.6	56.6	146.6	316.6
12	19.9	151	502	412	351	21.0	56.0	146.0	316.0
15	24.4	123	409	335	286	20.1	55.1	145.1	315.1
18	29.2	103	343	281	240	19.2	54.2	144.1	314.1
20	32.4	92.6	308	252	215	18.5	53.5	143.5	313.5
28	45.4	66.0	220	180	154	15.9	50.3	140.9	310.9
30	48.4	62.0	206	169	144	15.3	50.3	140.3	310.3
33	53.3	56.2	187	153	130	14.3	49.3	139.3	Over limit 25 °C
40	64.5	46.4	154	126	107	12.1	47.1	137.1	
48	77.4	38.8	129	105	90.3	9.5	44.5	138.5	
50	82.4	36.4	120	98.4	84.0	8.5	43.5	134.2	
60	96.8	31.0	103	84.5	72.1	5.6	40.6	Over limit 25 °C	
70	113	26.6	88.6	72.6	62.0	2.4	37.4		
80	126	22.8	75.9	62.2	53.1	0	34.8		
90	146	20.6	68.6	56.2	48.0		30.8		
100	162	18.6	61.9	50.7	43.3		27.6		

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

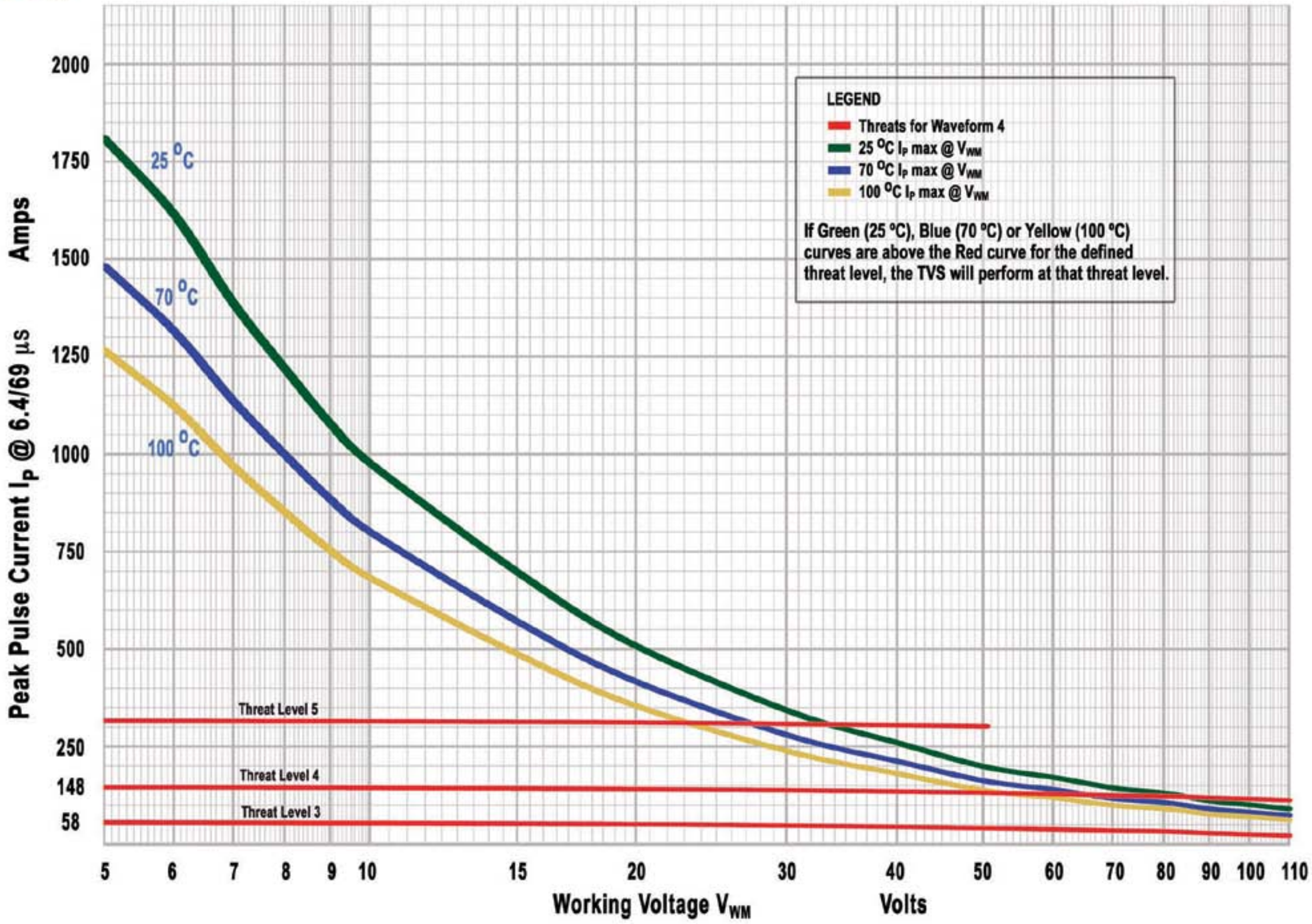
- **Surface Mount** SMLJ5.0A-170A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 3000 W are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 4

Graph 5: RTCA/DO-160, Waveform 4, Levels 3 through 5, 5000 W TVS Series



Data Points for Curves in Graph 5

Waveform 4 RTCA/DO-160 using 5000 W TVS Diodes

5000 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 3-5		
V_{WM} V	V_C V	I_{PP} 5000 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	3 300V/60A A	4 750V/150A A	5 1600V/320A A
5	9.2	543	1808	1482	1266	58.2	148.2	318.2
6	10.3	485	1615	1316	1124	57.9	147.9	317.9
7	12.0	417	1389	1138	972	57.6	147.6	317.6
8	13.6	367	1222	1002	855	57.2	147.2	317.3
9	15.4	325	1082	889	757	56.9	146.9	317.0
10	17.0	294	979	803	685	56.6	146.6	316.6
12	19.9	251	835	684	584	56.0	146.0	316.0
15	24.4	206	686	562	480	55.1	145.1	315.1
18	29.2	172	572	469	400	54.2	144.2	314.0
20	32.4	154	512	420	358	53.5	143.5	313.5
28	45.4	110	366	300	256	50.9	140.9	310.9
30	48.4	103	342	280	239	50.3	140.3	310.3
36	58.1	86	286	234	200	48.3	138.4	308.3
40	64.5	78	260	213	182	47.1	137.1	307.1
50	80.0	60	200	164	140	44.0	134	304.0
60	96.8	52	173	142	121	40.6	131	Over limit 25 °C ↓
70	113	44	146	119	102	37.4	127	
80	126	40	133	109	93.1	34.8	124	
90	146	113	34	92.7	79.1	30.8	121	
100	162	31	103	84.5	72.1	27.6	118	
110	177	28	93.2	76.4	65.2	24.6	115	

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

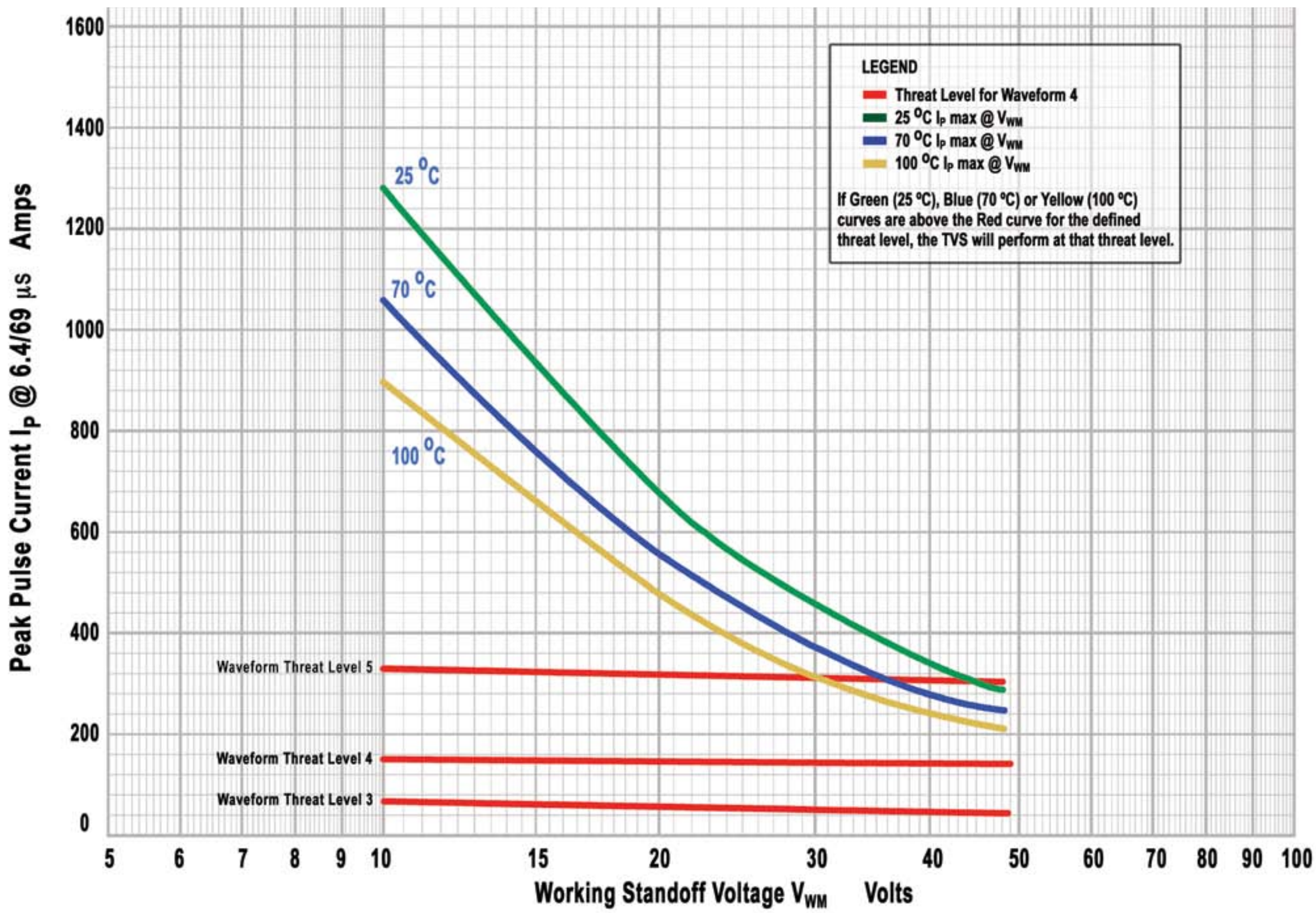
- **Axial Lead**
  5KP5.0A - 110, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 5000 W are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 5

Graph 6: RTCA/DO-160, Waveform 4, Levels 3 through 5, 6500 W TVS Series



Data Points for Curves in Graph 6

Waveform 4 RTCA/DO-160 using 6500 W TVS Diodes

6500 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 3-5		
V_{WM} V	V_C V	I_{PP} 6500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	3 300V/60A A	4 750V/150A A	5 1600V/320A A
10	17.0	383	1275	1045	892	56.6	146.6	316.6
11	18.2	358	1192	977	834	56.4	146.4	316.4
12	19.9	327	1089	893	762	56.0	146.0	316.0
13	21.5	302	1006	825	704	55.7	145.7	315.7
14	23.2	280	932	764	652	55.4	145.4	315.4
15	24.4	267	889	729	622	55.1	145.1	315.1
16	26.0	250	833	683	583	54.8	144.8	314.8
17	27.6	236	786	645	550	54.5	144.5	314.5
18	29.2	223	743	609	520	54.2	144.2	314.0
20	32.4	202	673	552	471	53.5	143.5	313.5
22	35.5	183	609	499	426	52.9	142.9	312.9
24	38.9	167	556	456	389	52.2	142.2	312.2
26	42.1	154	513	421	359	51.6	141.6	311.6
28	45.5	143	476	390	333	50.9	140.9	310.9
30	48.4	135	450	369	315	50.3	140.3	310.3
33	53.3	123	410	336	287	49.3	139.3	309.3
36	58.1	111	370	303	259	48.3	138.4	308.3
40	64.5	101	336	276	235	47.1	137.1	307.1
43	69.4	93	310	254	217	46.1	136.1	306.1
45	72.7	89	296	243	207	45.5	135.5	**Over Limit**
48	77.4	85	283	232	198	44.5	134.5	**25°C**

Microsemi TVS Part Numbers compliant to RTCA/DO-160

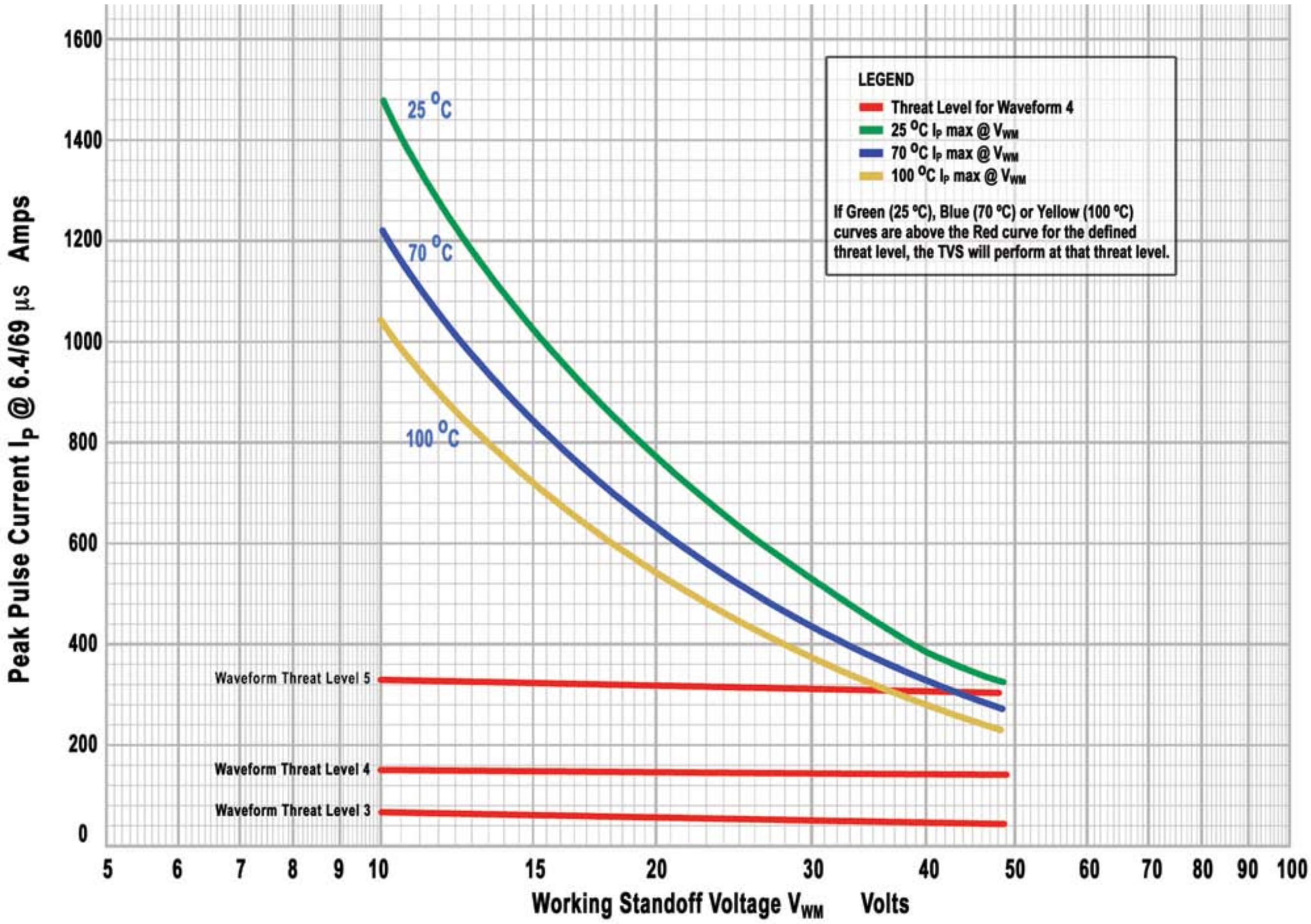
Standard Capacitance

- **Surface Mount**
  PLAD6.5KP10A – 48A, CA

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 6.4/69 μs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 6

Graph 7: RTCA/DO-160, Waveform 4, Levels 3 through 5, 7500 W TVS Series



Data Points for Curves in Graph 7 — Waveform 4 RTCA/DO-160 using 7500 W TVS Diodes

7500 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 3-5		
V_{WM} V	V_C V	I_{PP} 7500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	3 300V/60A A	4 750V/150A A	5 1600V/320A A
10	17.0	441	1469	1205	1028	56.6	146.6	316.6
11	18.2	412	1372	1125	960	56.4	146.4	316.4
12	19.9	377	1255	1029	878	56.0	146.0	316.0
13	21.5	349	1162	953	813	55.7	145.7	315.7
14	23.2	323	1076	882	753	55.4	145.4	315.4
15	24.4	307	1022	838	715	55.1	145.1	315.1
16	26.0	288	959	786	671	54.8	144.8	314.8
17	27.6	272	906	743	634	54.5	144.5	314.5
18	29.2	257	856	702	599	54.2	144.2	314.0
20	32.4	231	769	631	538	53.5	143.5	313.5
22	35.5	211	703	576	492	52.9	142.9	312.9
24	38.9	193	643	527	450	52.2	142.2	312.2
26	42.1	178	593	486	415	51.6	141.6	311.6
28	45.5	165	549	450	384	50.9	140.9	310.9
30	48.4	155	516	423	361	50.3	140.3	310.3
33	53.3	141	470	385	329	49.3	139.3	309.3
36	58.1	129	430	353	301	48.3	138.4	308.3
40	64.5	116	386	317	270	47.1	137.1	307.1
43	69.4	108	360	295	252	46.1	136.1	306.1
45	72.7	103	343	281	240	45.5	135.5	305.5
48	77.4	97	323	265	226	44.5	134.5	304.5

Microsemi TVS Part Numbers compliant to RTCA/DO-160

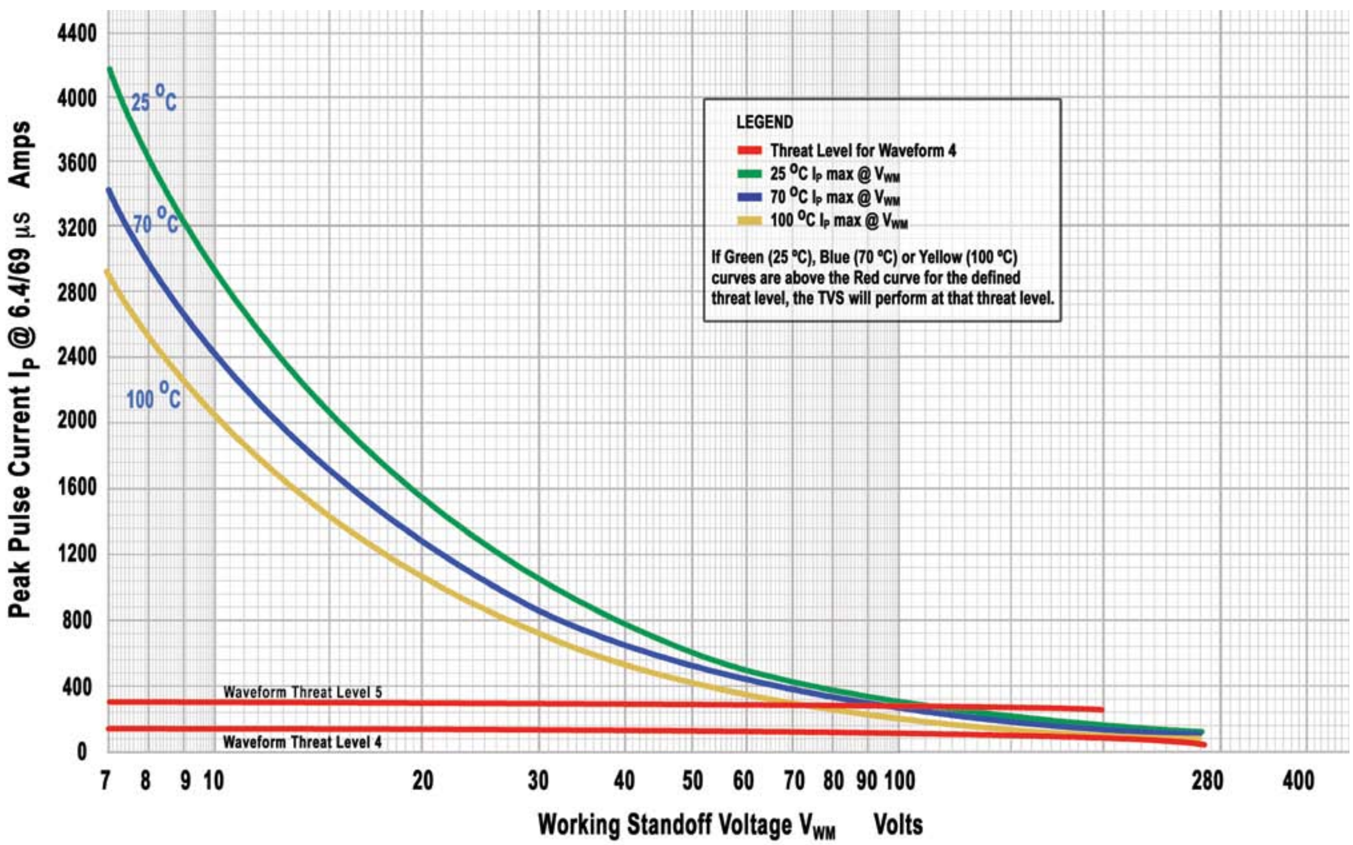
Standard Capacitance

- **Surface Mount**
  PLAD7.5KP10A – 48A, CA

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 7

Graph 8: RTCA/DO-160, Waveform 4, Levels 4 through 5, 15,000 W TVS Series



Data Points for Curves in Graph 8

Waveform 4 RTCA/DO-160 using 15,000 W TVS Diodes

15,000 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 4-5	
V_{WM} V	V_C V	I_{PP} 15,500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	4 750V/150A A	5 1600V/320A A
7.0	12.0	1251	4166	3416	2916	148	318
9.0	15.4	975	3247	2663	2273	147	317
10	17.0	882	2937	2408	2056	147	317
12	19.9	753	2507	2055	1755	146	316
14	23.2	645	2148	1761	1504	145	315
16	26.0	576	1918	1573	1343	145	315
18	29.2	516	1718	1409	1207	144	314
22	35.5	423	1409	1155	986	143	313
26	42.1	357	1189	975	823	142	312
30	48.4	309	1029	844	720	140	310
36	58.1	258	859	704	601	138	308
43	69.4	216	719	590	503	136	306
48	77.4	195	649	532	454	135	305
54	87.1	171	569	467	398	133	303
60	96.8	156	519	426	363	131	301
70	113	132	440	361	308	127	297
90	146	102	340	279	238	121	291
130	209	71	236	194	165	108	Over Limit 25°C
160	259	58	193	158	135	98.2	↓
200	322	47	157	129	110	85.6	
280	452	33	110	90.0	77.0	59.6	

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

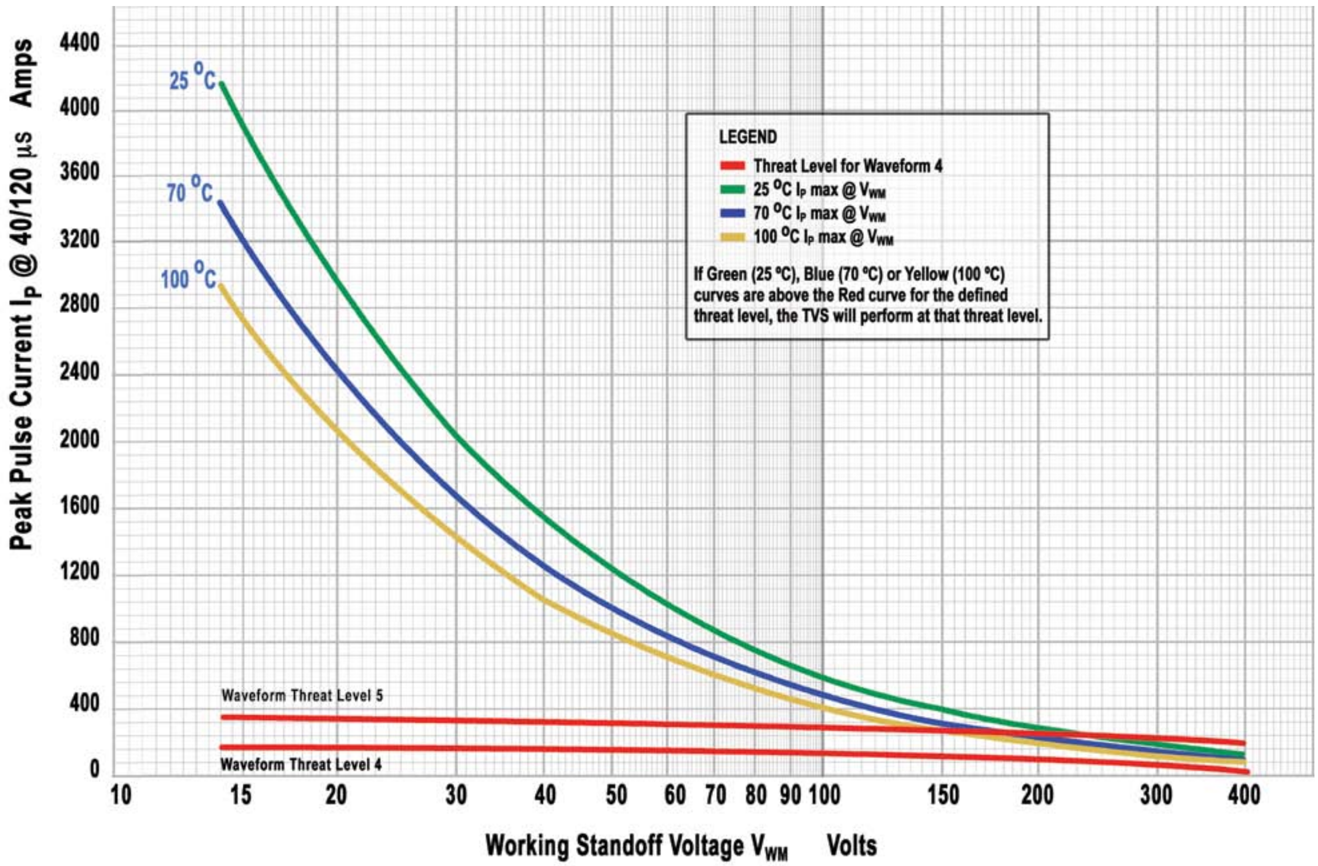
- Axial Lead
  15KP22A – 280A, CA
- Surface Mount
  PLAD15KP7.0A – 200A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 8

Graph 9: RTCA/DO-160, Waveform 4, Levels 4 through 5, 30,000 W TVS Series



Data Points for Curves in Graph 9

Waveform 4 RTCA/DO-160 using 30,000 W TVS Diodes

30,000 W TVS @10/1000 µs			Conversion to 6.4/69 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 4-5	
V_{WM} V	V_C V	I_{PP} 30,000 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	4 750V/150A A	5 1600V/320A A
14	24.0	1251	4166	3416	2916	145.2	315.2
16	27.2	1101	3666	3006	2566	144.6	314.6
18	30.8	975	3247	2663	2273	143.8	313.8
22	36.4	822	2737	2244	1916	142.7	312.7
26	43.0	696	2318	1901	1623	141.4	311.4
30	48.8	618	2058	1688	1441	140.2	310.2
36	58.1	516	1718	1409	1203	138.3	308.4
43	69.4	432	1439	1180	1007	136.1	306.1
48	77.4	390	1299	1065	909	134.5	304.5
54	87.1	342	1139	934	797	132.6	302.6
60	96.8	312	1039	852	727	130.6	300.6
70	113	264	879	721	615	127.4	297.4
78	126	240	799	655	559	124.8	294.8
90	146	204	679	557	475	120.8	290.8
110	177	168	559	458	391	114.6	284.6
130	209	142	473	388	331	108.2	278.2
160	259	116	386	317	270	98.2	268.2
180	291	104	346	284	242	91.8	261.8
220	356	84	280	230	196	78.8	248.8
300	483	62	206	169	144	53.4	Over Limit 25°C
400	644	46	153	125	107	21.2	

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

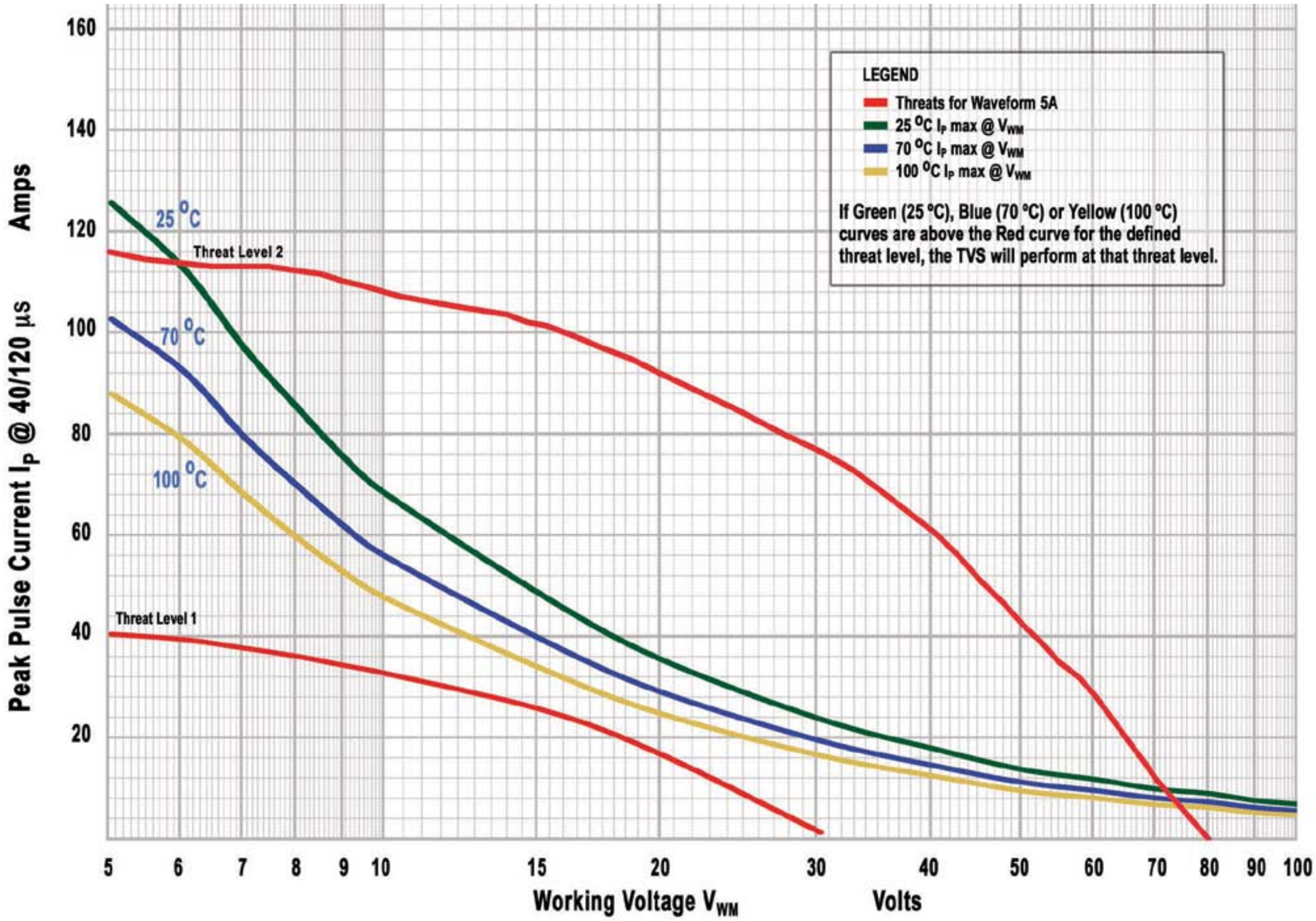
- **Surface Mount**
  PLAD30KP14A – 400A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 6.4/69 µs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 9

Graph 10: RTCA/DO-160, Waveform 5A, Levels 1 through 2, 500 W TVS Series



Data Points for Curves in Graph 10 — Waveform 5A RTCA/DO-160 using 500 W TVS Diodes

500 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 1-2	
V_{WM} V	V_C V	I_{PP} 500 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	1 50V/50A A	2 125V/125A A
5	9.2	54.3	126	103	88.2	40.8	116
6	10.3	48.5	113	92.7	79.1	39.7	114
7	12.0	41.7	97.2	79.7	68.3	38.0	113
8	13.6	36.7	85.5	70.1	59.8	36.4	112
9	15.4	32.5	75.7	62.1	53.0	34.6	110
10	17.0	29.4	68.5	56.1	47.9	33.0	108
12	19.9	25.1	58.5	48.0	41.0	30.1	105
15	24.4	20.6	48.0	39.3	33.6	25.6	101
18	29.2	17.2	40.1	32.9	28.1	20.8	96.8
20	32.4	15.4	35.9	29.4	25.1	17.1	91.6
28	45.4	11.0	25.6	21.0	17.9	4.6	79.0
30	48.4	10.3	24.0	19.7	16.8	1.6	76.6
36	53.3	8.6	20.0	16.4	14.0		71.7
40	64.5	7.8	18.1	14.8	12.7		60.5
48	77.4	6.5	15.1	12.4	10.6		47.6
50	82.4	6.0	14.0	11.5	9.8		42.6
60	96.8	5.2	12.1	9.9	8.4		28.2
70	113	4.4	10.2	8.4	7.1		12.0
80	126	4.0	9.3	7.6	6.5	Devices > 78 V_{WM} within limits	
90	146	3.4	7.9	6.5	5.5		
100	162	3.1	7.2	5.9	5.0		

Over limit 25 °C

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

- Axial Lead
  P5KE5.0A-170A, CA
  1N6103A-1N6137A
  1N6461-1N6468
  1N8073-1N8109

Low Capacitance

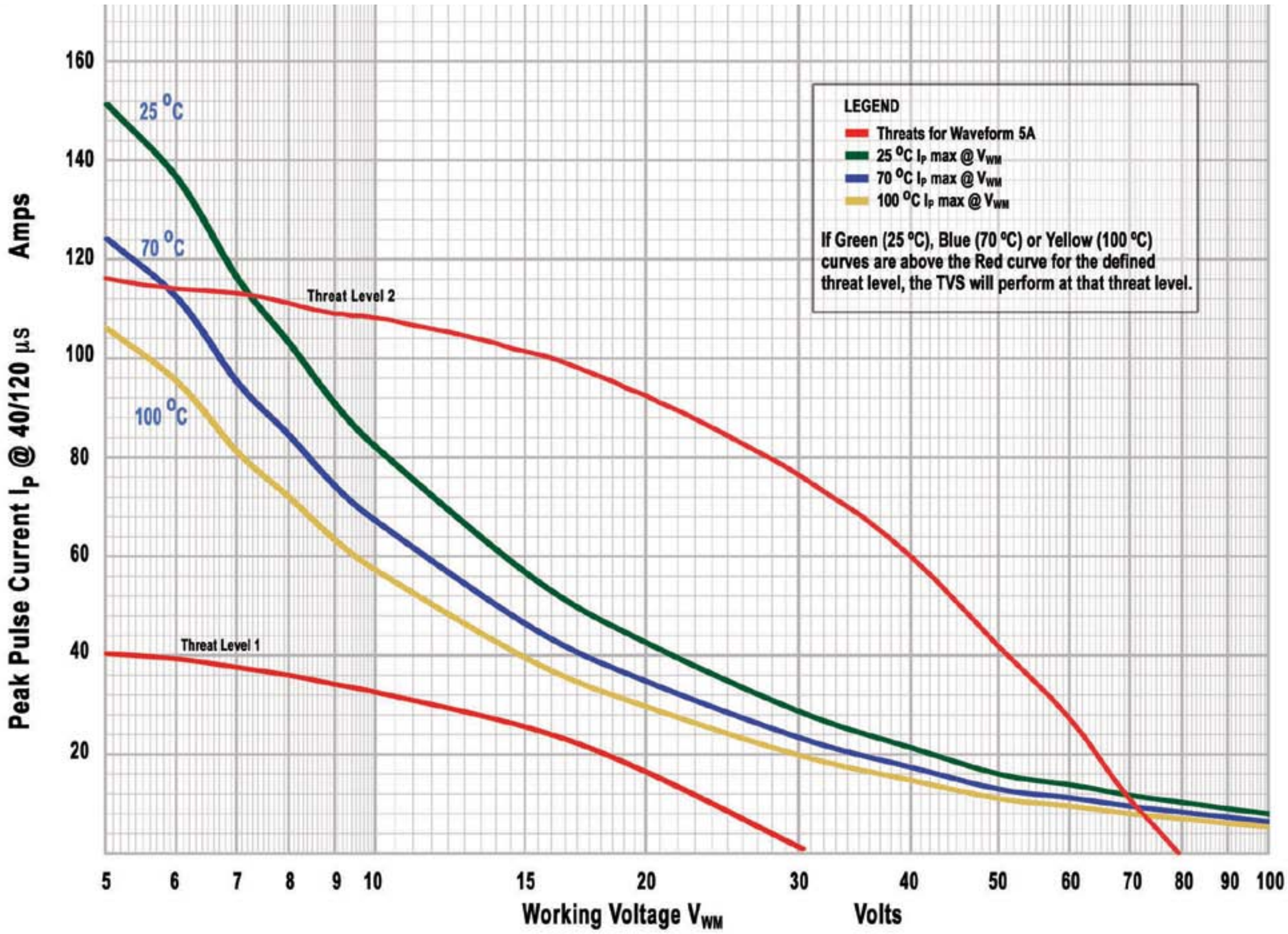
- Axial Lead
  SAC5.0-50
- Surface Mount
  SMBJSAC5.0-50

Except for 1Nxxxx part numbers shown that already have military qualifications, add M prefix for source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

Graph 10

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 500 W are taken from the data sheet while the subsequent three columns of 40/120 μs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 11: RTCA/DO-160, Waveform 5A, Levels 1 through 2, 600 W TVS Series



Data Points for Curves in Graph 11

Waveform 5A RTCA/DO-160 using 600 W TVS Diodes

600 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 1-2	
V_{WM} V	V_C V	I_{PP} 600 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	1 50V/50A A	2 125V/125A A
5	9.2	62.2	151	124	106	40.8	116
6	10.3	58.3	136	112	95.2	39.7	114
7	12.0	50.0	116	95.1	81.2	38.0	113
8	13.6	44.1	103	84.5	72.1	36.4	111
9	15.4	39.0	90.8	74.4	63.6	34.6	109
10	17.0	35.3	82.2	67.4	57.5	33.0	108
12	19.9	30.2	70.4	57.7	49.3	30.1	105
15	24.4	24.0	55.9	45.8	39.1	25.6	101
18	29.2	20.5	47.8	39.2	33.4	20.8	95.8
20	32.4	18.5	43.1	35.3	30.2	17.1	92.6
28	45.4	13.2	30.7	25.2	21.5	4.6	79.6
30	48.4	12.4	28.9	23.7	20.2	1.6	76.6
36	58.1	10.3	24.0	19.7	16.8		66.9
40	64.5	9.3	21.7	17.8	15.2		60.5
48	77.4	7.7	17.9	14.7	12.5		47.6
50	82.4	7.1	16.5	13.5	11.6		42.6
60	96.8	6.2	14.4	11.8	10.1		28.2
70	113	5.3	12.3	10.1	8.6		12.0
80	126	4.7	10.9	8.9	7.6	Devices > 75 V_{WM} within limits	
90	146	4.1	9.6	7.9	6.7		
100	162	3.7	8.6	7.0	6.0		

Over limit 25 °C

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

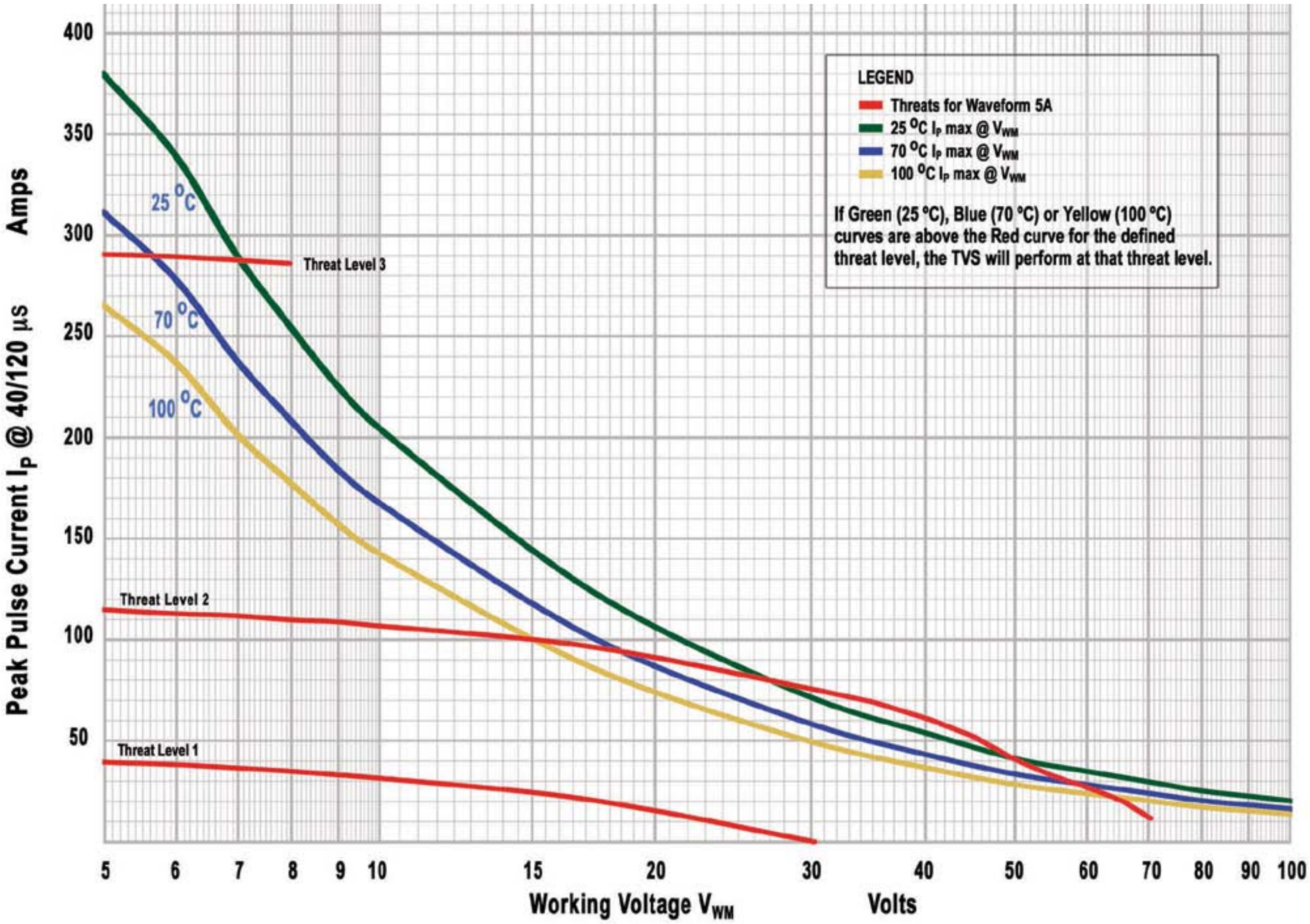
- Axial Lead
  P6KE6.8A-200A, CA
- Surface Mount
  SMBJ5.0A-170A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

Graph 11

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 600 W are taken from the data sheet while the subsequent three columns of 40/120 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 12: RTCA/DO-160, Waveform 5A, Levels 1 through 3, 1500 W TVS Series



Data Points for Curves in Graph 12

Waveform 5A RTCA/DO-160 using 1500 W TVS Diodes

1500 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 1-3		
V_{WM} V	V_C V	I_{PP} 1500 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	1 50V/50A A	2 125V/125A A	3 300/300 A
5	9.2	163	380	312	266	40.8	116	291
6	10.3	146	340	279	238	39.7	114	290
7	12.0	125	291	239	203	38.0	113	288
8	13.6	110	256	210	179	36.4	111	Over limit 25 °C ↓
9	15.4	97.4	227	186	159	34.6	110	
10	17.0	88.2	206	169	144	33.0	108	
12	19.9	75.3	175	144	122	30.1	105	
15	24.4	61.5	143	117	100	25.6	101	
18	29.2	51.4	120	98.4	84.0	20.8	95.8	
20	32.4	46.3	108	88.6	75.6	17.1	92.6	
28	45.4	33.0	76.9	63.0	53.8	4.6	79.6	
30	48.4	31.0	72.2	59.2	50.5	1.6	76.6	
36	58.1	28.1	65.5	53.7	45.8	↓	66.9 (Over limit 25 °C)	
40	64.5	23.2	54.0	44.3	37.8		60.5	
48	77.4	19.4	45.2	37.1	31.6		47.6	
50	82.4	18.2	42.4	34.8	29.7		42.6	
60	96.8	15.5	36.1	29.6	25.2		28.2	
70	113	13.3	31.0	25.4	21.7		12.0	
80	126	11.4	26.6	21.8	18.6		Devices >60 V_{WM} within limits	
90	146	10.3	24.0	19.7	16.8			
100	162	9.3	21.7	17.8	15.2			

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

- Axial Lead
  1.5KE6.8A-400A, CA
  1N5629A-1N5665A
  1N5907, 1N5908
  1N6036A-1N6072A
  1N6138A-1N6173A
  1N6469-1N6476
  1N8110-1N8146
- Surface Mount
  SMCJ5.0A-170A, CA

Low capacitance

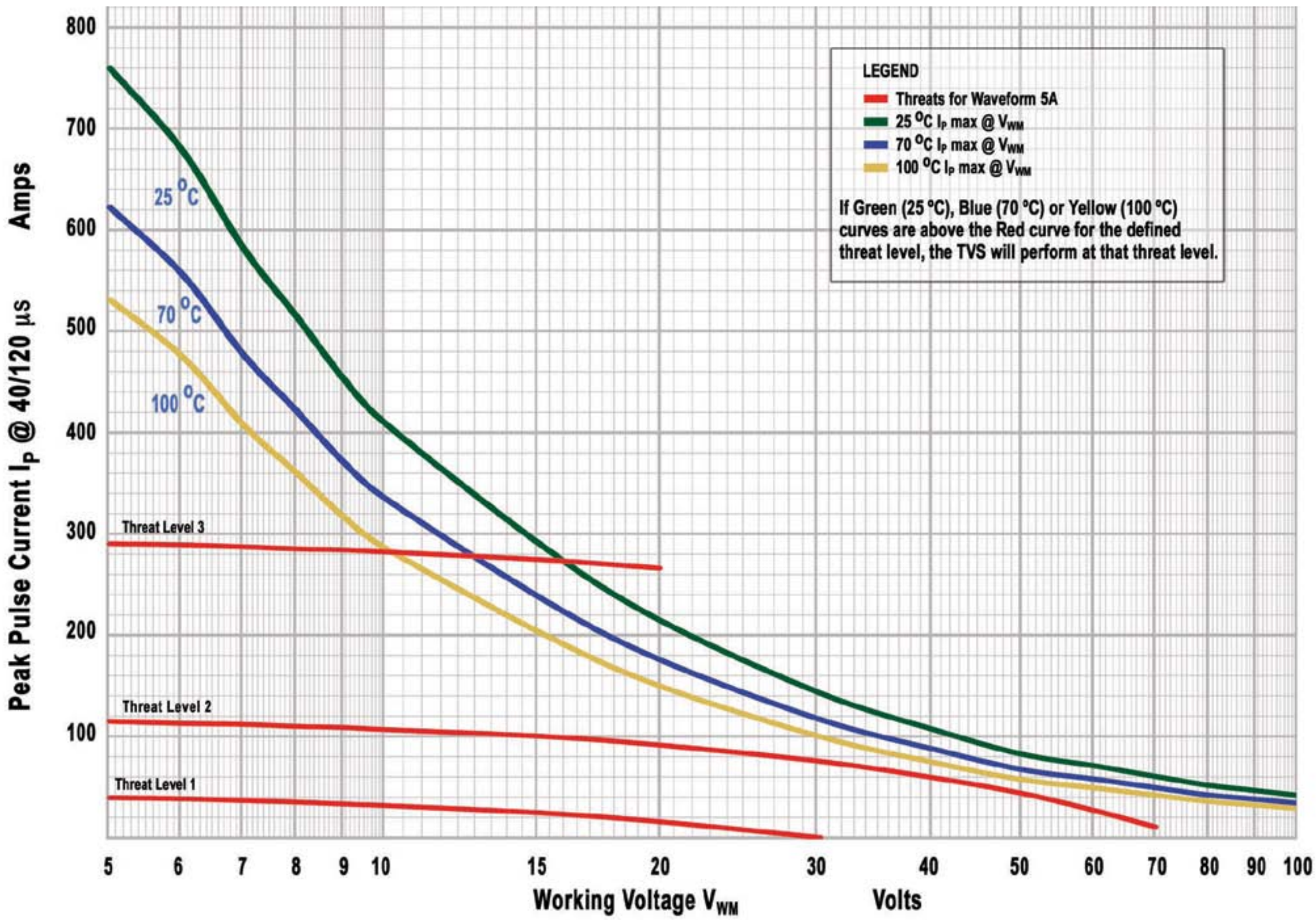
- Axial Lead
  LC6.5-170A
  LCE6.5-170A
- Surface Mount
  SMCJLCE6.5-170A

Except for 1Nxxxx part numbers shown that already have military qualifications, add M prefix for source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

Graph 12

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 1500 W are taken from the data sheet while the subsequent three columns of 40/120 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 13: RTCA/DO-160, Waveform 5A, Levels 1 through 3, 3000 W TVS Series



Data Points for Curves in Graph 13

Waveform 5A RTCA/DO-160 using 3000 W TVS Diodes

3000 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 1-3		
V_{WM} V	V_C V	I_{PP} 3000 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	1 50V/50A A	2 125V/125A A	3 300V/300A A
5	9.2	326	759	622	531	40.8	116	290.8
6	10.3	291	678	556	475	39.7	114	289.7
7	12.0	250	582	477	408	38.0	113	288
8	13.6	221	515	422	361	36.4	111	286.4
9	15.4	195	454	372	318	34.6	110	285
10	17.0	176	410	336	287	33.0	108	283
12	19.9	151	352	289	246	30.1	105	280
15	24.4	123	287	235	201	25.6	101	275
18	29.2	103	240	197	168	20.8	95.8	Over limit 25 °C
20	32.4	92.6	216	177	151	17.1	92.6	
28	45.4	66.0	154	126	108	4.6	79.6	
30	48.4	62.0	144	118	101	1.6	76.6	
36	58.1	51.6	120	98.4	84.0	0	66.9	
40	64.5	46.4	108	88.6	75.6		60.5	
48	77.4	38.8	90.4	74.1	63.3		47.6	
50	82.4	35.9	83.6	68.5	58.5		45.0	
60	96.8	31.0	72.2	59.2	50.5		28.2	
70	113	26.6	61.9	50.7	43.3		12.0	
80	126	22.8	53.1	43.5	37.2		0	
90	146	20.6	48.0	39.4	33.6			
100	162	18.6	43.3	35.5	30.3			

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

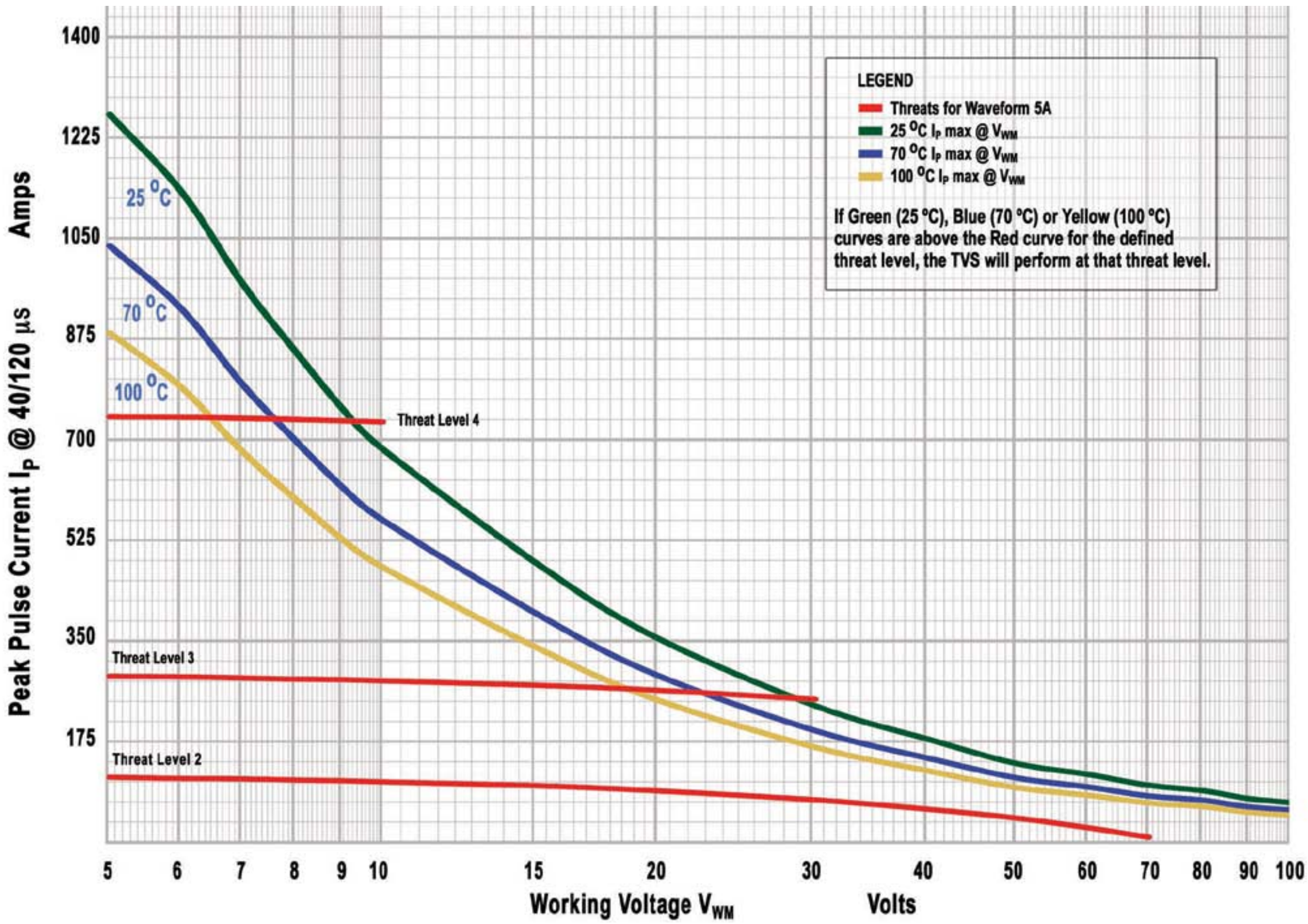
- Surface Mount
  SMLJ5.0A-170A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 3000 W are taken from the data sheet while the subsequent three columns of 40/120 µs data were derived as illustrated earlier in this document and also MicroNote™ 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 13

Graph 14: RTCA/DO-160, Waveform 5A, Levels 2 through 4, 5000 W TVS Series



Data Points for Curves in Graph 14 — Waveform 5A RTCA/DO-160 using 5000 W TVS Diodes

5000 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 2-4		
V_{WM} V	V_C V	I_{PP} 5000 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	2 125V/125A A	3 300V/300A A	4 750V/750A A
5	9.2	543	1265	1037	886	116	291	741
6	10.3	485	1130	927	791	114	290	740
7	12.0	417	972	797	681	113	288	738
8	13.6	367	855	701	599	111	286	736
9	15.4	325	757	621	530	110	285	734
10	17.0	294	685	562	480	108	283	Over limit 25 °C ↓
12	19.9	251	585	480	410	105	280	
15	24.4	206	480	394	336	101	275	
18	29.2	172	401	329	281	95.8	270	
20	32.4	154	359	294	251	92.6	267	
28	45.4	110	256	210	179	79.6	254	
30	48.4	103	240	197	168	76.6	Over limit 25 °C ↓	
36	58.1	86	200	164	140	66.9		
40	64.5	78.0	182	149	127	60.5		
48	77.4	65.0	151	124	106	47.6		
50	82.4	60.0	140	115	98.0	45.0		
60	96.8	47.0	109	89.4	76.3	28.2		
70	113	44.0	102	83.6	71.4	12.0		
80	126	49.0	95.5	78.3	66.9	0		
90	146	34.0	79.2	64.9	55.4	↓		
100	162	31.0	72.2	59.2	50.6			

Microsemi TVS Part Numbers compliant to RTCA/DO-160

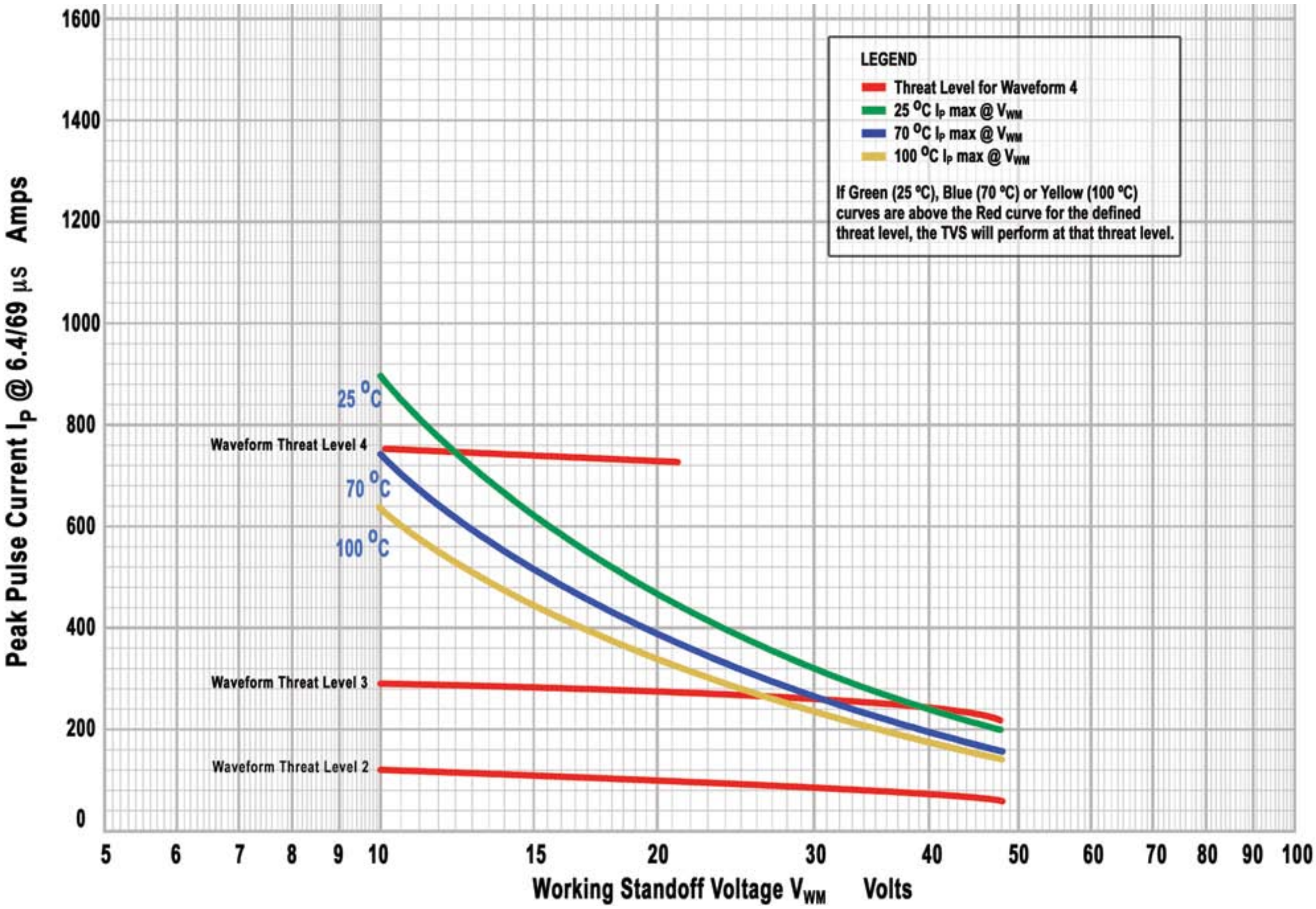
Standard Capacitance

- Axial Lead
  5KP5.0A - 110A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq.1). In the table above, the first three columns, V_{WM}, V_C, and I_{PP} 5000 W are taken from the data sheet while the subsequent three columns of 40/120 µs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 15: RTCA/DO-160, Waveform 5A, Levels 2 through 4, 6500 W TVS Series



Data Points for Curves in Graph 15

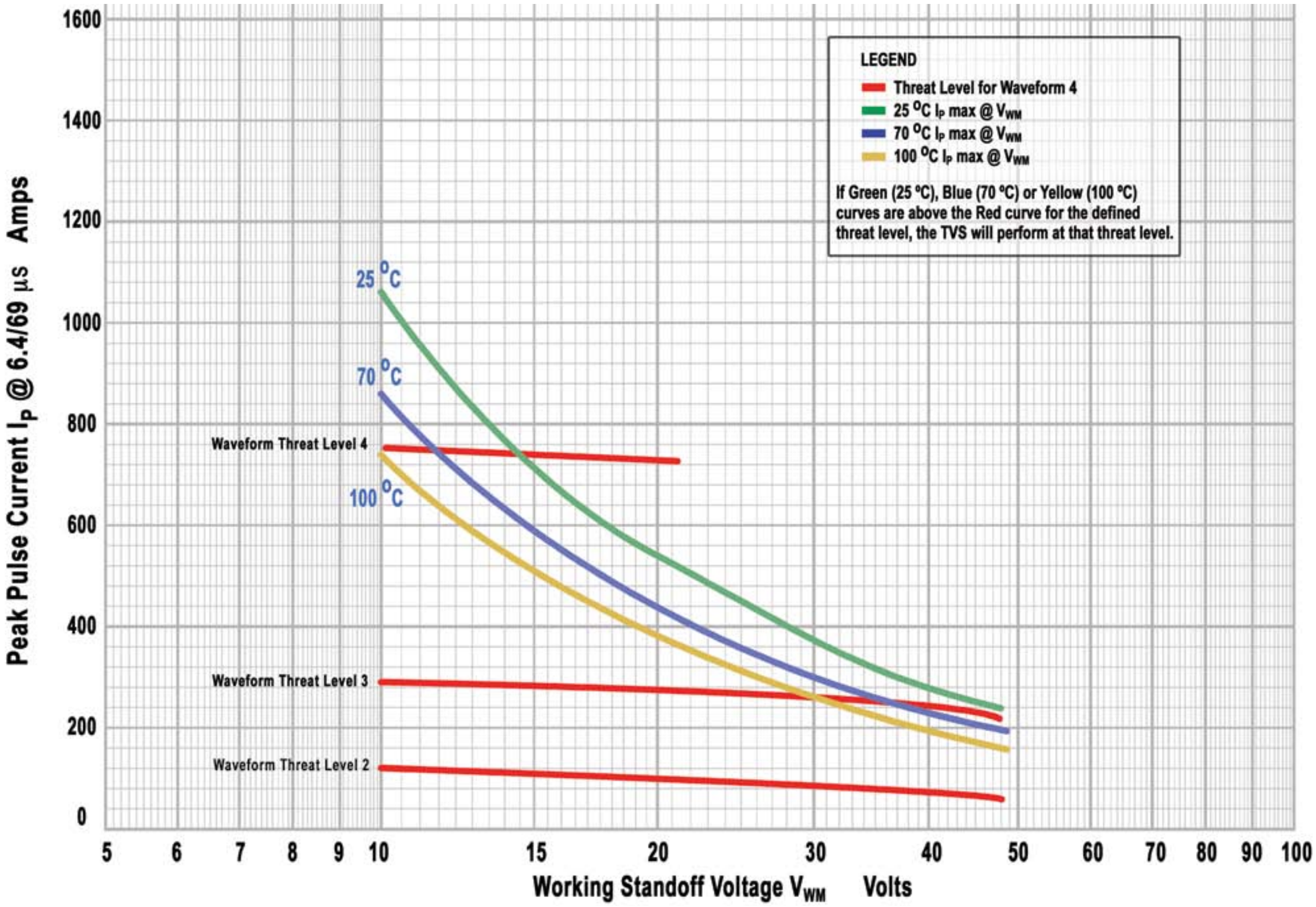
Waveform 5A RTCA/DO-160 using 6500 W TVS Diodes

6500 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 2-4			Microsemi TVS Part Numbers compliant to RTCA/DO-160
V_{WM} V	V_C V	I_{PP} 6500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	2 125V/125A A	3 300V/300A A	4 750V/750A A	Standard Capacitance • Surface Mount PLAD6.5KP10A – 48A, CA
10	17.0	383	892	731	624	108	283	733	
11	18.2	358	834	684	584	107	282	732	
12	19.9	327	762	625	533	105	280	730	
13	21.5	302	704	577	493	103	278	Over Limit 25°C	
14	23.2	280	652	535	456	102	277		
15	24.4	267	622	510	435	101	276		
16	26.0	250	582	477	407	99.0	274		
17	27.6	236	550	451	385	97.4	272		
18	29.2	223	520	426	364	95.8	271		
20	32.4	202	471	386	330	92.6	268		
22	35.5	183	426	349	298	89.5	264		
24	38.9	167	389	319	272	86.1	261		
26	42.1	154	359	294	251	82.9	258		
28	45.5	143	333	273	233	79.5	254		
30	48.4	135	315	258	220	76.6	252		
33	53.3	123	287	235	201	71.7	247		
36	58.1	111	259	212	181	66.9	242		
40	64.5	101	235	193	164	60.5	Over Limit 25°C		
43	69.4	93	217	178	152	55.6			
45	72.7	89	207	170	145	52.3			
48	77.4	85	198	162	139	47.6			

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 40/120 μs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 15

Graph 16: RTCA/DO-160, Waveform 5A, Levels 2 through 4, 7500 W TVS Series



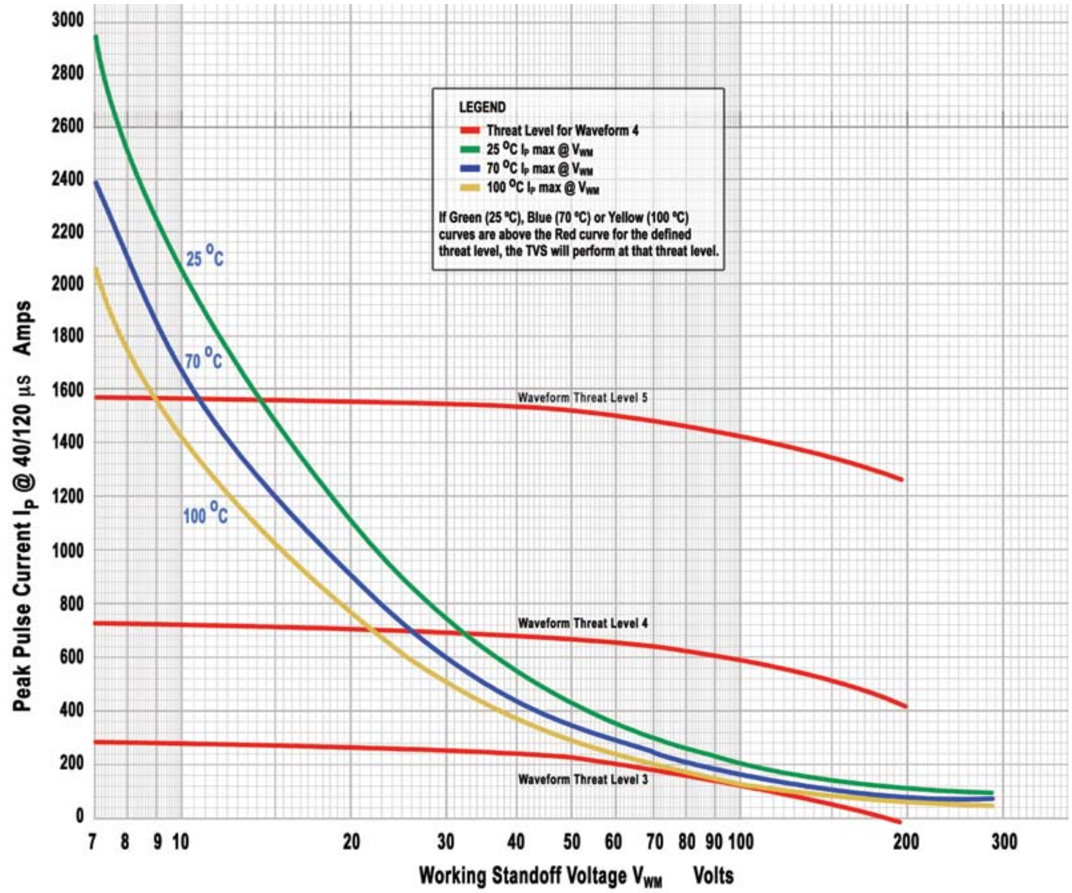
Data Points for Curves in Graph 16 — Waveform 5A RTCA/DO-160 using 7500 W TVS Diodes

7500 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 2-4			Microsemi TVS Part Numbers compliant to RTCA/DO-160
V_{WM} V	V_C V	I_{PP} 7500 W 10/1000 µs A	I_P 25 °C 6.4/69 µs A	I_P 70 °C 6.4/69 µs A	I_P 100 °C 6.4/69 µs A	2 125V/125A A	3 300V/300A A	4 750V/750A A	Standard Capacitance • Surface Mount PLAD7.5KP10A – 48A, CA
10	17.0	441	1028	843	720	108	283	733	
11	18.2	412	960	787	672	107	282	732	
12	19.9	377	878	720	615	105	280	730	
13	21.5	349	813	667	569	103	278	728	
14	23.2	323	753	617	527	102	277	727	
15	24.4	307	715	586	500	101	276	Over Limit 25°C ↓	
16	26.0	288	671	550	470	99.0	274		
17	27.6	272	634	520	444	97.4	272		
18	29.2	257	599	491	419	95.8	271		
20	32.4	231	538	441	377	92.6	268		
22	35.5	211	492	403	344	89.5	264		
24	38.9	193	450	369	315	86.1	261		
26	42.1	178	415	340	290	82.9	258		
28	45.5	165	384	315	269	79.5	254		
30	48.4	155	361	296	253	76.6	252		
33	53.3	141	329	270	230	71.7	247		
36	58.1	129	301	247	211	66.9	242		
40	64.5	116	270	221	189	60.5	236		
43	69.4	108	252	207	176	55.6	231		
45	72.7	103	240	197	168	52.3	227		
48	77.4	97	226	185	158	47.6	223		

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 40/120 μs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 16

Graph 17: RTCA/DO-160, Waveform 5A, Levels 2 through 4, 15,000 W TVS Series



Data Points for Curves in Graph 17

Waveform 5A RTCA/DO-160 using 15,000 W TVS Diodes

15,000 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 3-5		
V_{WM} V	V_C V	I_{PP} 15,500 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	3 300V/300A A	4 750V/750A A	5 1600V/1600A A
7.0	12.0	1251	2915	2390	2040	288	738	1588
9.0	15.4	975	2272	1863	1590	285	735	1585
10	17.0	882	2055	1685	1438	283	733	1583
12	19.9	753	1754	1438	1228	280	730	1580
14	23.2	645	1503	1232	1052	277	727	Over Limit 25°C
16	26.0	576	1342	1100	939	274	724	
18	29.2	516	1202	986	841	271	721	
22	35.5	423	986	809	690	264	714	
26	42.1	357	832	682	582	258	708	
30	48.4	309	720	590	504	252	702	
36	58.1	258	601	493	421	242	Over Limit 25°C	
43	69.4	216	503	412	352	231		
48	77.4	195	454	372	318	223		
54	87.1	171	398	326	279	213		
60	96.8	156	363	298	254	203		
70	113	132	308	253	216	187		
90	146	102	238	195	167	154		
130	209	71	165	135	115	91		
160	259	58	135	111	94.5	41		
200	322	47	110	90.2	77.0	0		
280	452	33	76.9	63.0	53.8	0		

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

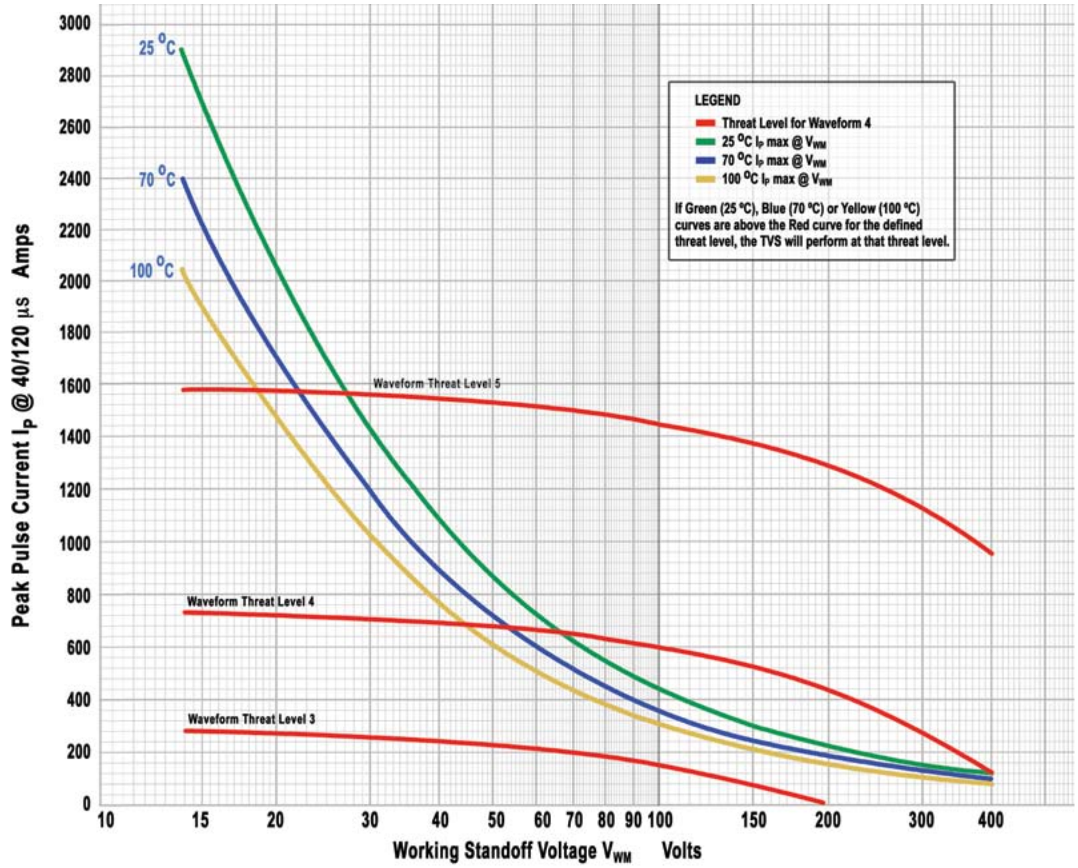
- Axial Lead
  15KP22A – 280A, CA
- Surface Mount
  PLAD15KP7.0A – 200A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 40/120 µs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

Graph 17

Graph 18: RTCA/DO-160, Waveform 5A, Levels 3 through 5, 30,000 W TVS Series



Data Points for Curves in Graph 18

Waveform 5A RTCA/DO-160 using 30,000 W TVS Diodes

30,000 W TVS @10/1000 µs			Conversion to 40/120 µs I_P Values			Peak Surge Currents for the Red Curves* I_S Threat for Levels shown on graph Threat Levels 3-5		
V_{WM} V	V_C V	I_{PP} 30,000 W 10/1000 µs A	I_P 25 °C 40/120 µs A	I_P 70 °C 40/120 µs A	I_P 100 °C 40/120 µs A	3 300V/300A A	4 750V/750A A	5 1600V/1600A A
14	24.0	1251	2915	2390	2040	276	726	1576
16	27.2	1101	2565	2103	1795	273	723	1573
18	30.8	975	2272	1863	1590	269	719	1569
22	36.4	822	1915	1570	1379	264	714	1564
26	43.0	696	1622	1330	1135	257	707	1557
30	48.8	618	1440	1181	1008	251	701	Over Limit 25°C
36	58.1	516	1202	986	841	242	692	
43	69.4	432	1007	826	705	231	681	
48	77.4	390	909	745	636	223	673	
54	87.1	342	797	654	558	213	663	
60	96.8	312	727	596	509	203	653	
70	113	264	615	504	430	187	Over Limit 25°C	
78	126	240	559	458	391	174		
90	146	204	475	390	332	154		
110	177	168	391	320	274	123		
130	209	142	331	271	232	91		
160	259	116	270	221	189	41		
180	291	104	242	198	169	9		
220	356	84	196	161	137	0		
300	483	62	144	118	101			
400	644	46	107	88	74.9			

Microsemi TVS Part Numbers compliant to RTCA/DO-160

Standard Capacitance

- **Surface Mount**
  PLAD30KP14A – 400A, CA

Add M prefix for the part numbers shown to add source control or MA, MX, or MXL for further upgrade screening options on plastic devices as described in Micronote 129.

Graph 18

* Surge currents are reduced by clamping voltage (see Eq 1). In the table above, the first three column (V_{WM}, V_C, and I_{PP}) are taken from the data sheet while the subsequent three columns of 40/120 μs data were derived as illustrated earlier in this document and also MicroNoteTM 127. The 70 °C and 100 °C curves were added for simplifying selection since many TVS devices require derating for higher temperatures.

For additional technical information,
please contact Design Support
at:
http://www.microsemi.com/designsupport
or
Kent Walters (kwalters@microsemi.com) at 602-458-3212

Microsemi®
Power Matters.™