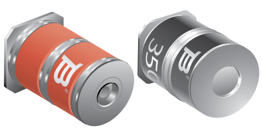
Understanding Elusive V_{fp} and its Effects on Surge Protection Performance

WHITE PAPER



Bourns® Gas Discharge Tubes (GDTs)

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Introduction

What is Front Protection Voltage (V_{fp})? Why is it elusive? And why should I care? New, cutting-edge electronic component products are – in some cases – so innovative that new terminology must be defined to adequately characterize their performance. Such is the case with the “elusive V_{fp}”. This paper describes what V_{fp} is, how it is defined and measured, why it may appear “elusive” at times, and when it becomes important to design engineers. It also describes the causes of V_{fp} and some considerations involved in protecting circuits against it. Since V_{fp} can determine the maximum let-through voltage a protected circuit is exposed to, designers should become familiar with V_{fp} to properly consider how it may impact the designer’s circuit. Therefore, this paper also seeks to answer the question “should I be concerned about this high let-through voltage?”.

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What is V_{fp}?

Front Protection Voltage (V_{fp}) is defined as the front spike (d_v/d_t) during a surge. The V_{fp} typically lasts no more than 300 ns, during which there is very little current until conduction occurs. The V_{fp} can be created when a Gas Discharge Tube (GDT) is placed in series with a Metal Oxide Varistor (MOV). GDTs typically have a high impulse voltage, so when combined with an MOV, its impulse voltage may add to the MOV voltage to create a total combined breakdown voltage. For example, if a GDT has 650 V impulse voltage and an MOV has 300 V, the V_{fp} may be as high as 950 V. The V_{fp} may or may not be present depending on the inherent capacitive divider between the GDT and MOV, and whether the GDT is already ionized. If the GDT is already ionized, it is likely that the V_{fp} will be low or, in some instances, not be present at all. The V_{fp} will never be higher than the combination of the MOV at 1 mA breakdown plus the maximum impulse voltage of a GDT. Figure 1 shows a comparison of the behavior of a standalone MOV component and a hybrid GDT and MOV surge protector.

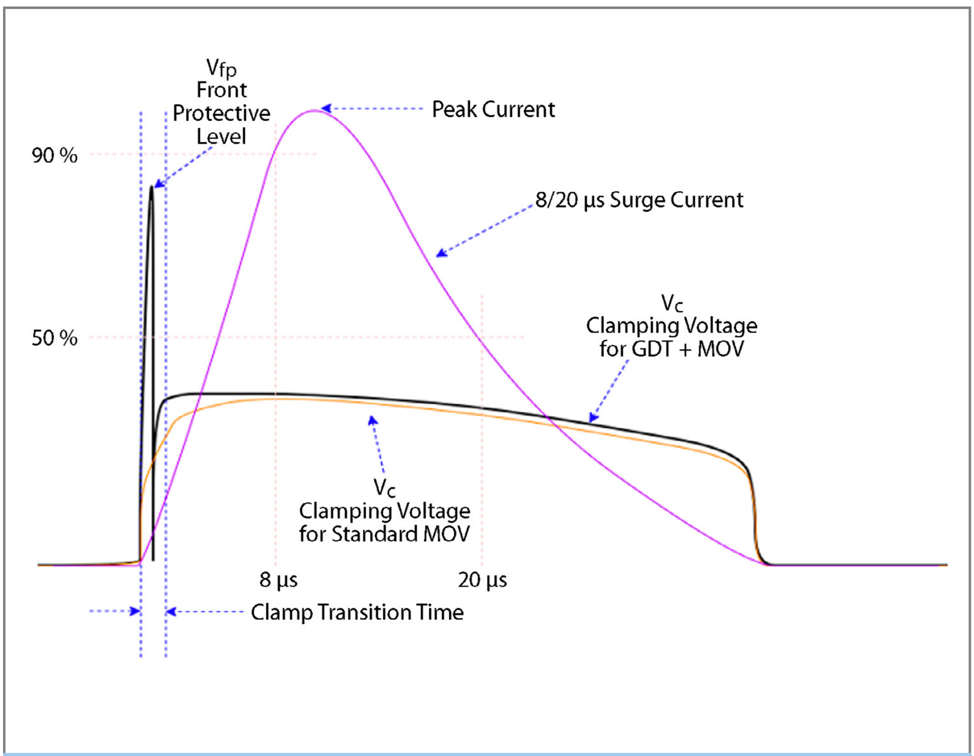

Figure 1 - Comparison between standalone MOV and GDT + MOV in series

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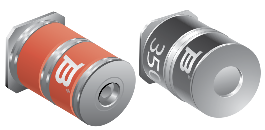

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V_{fp} Voltage Spike Considerations

A GDT has a crowbar characteristic, also known as a shunt. Once the GDT is in the crowbar state, it will maintain this state (often referred to as "arc mode") until the surge current dissipates. The arc voltage is typically between 10 to 20 V. See Figure 2.

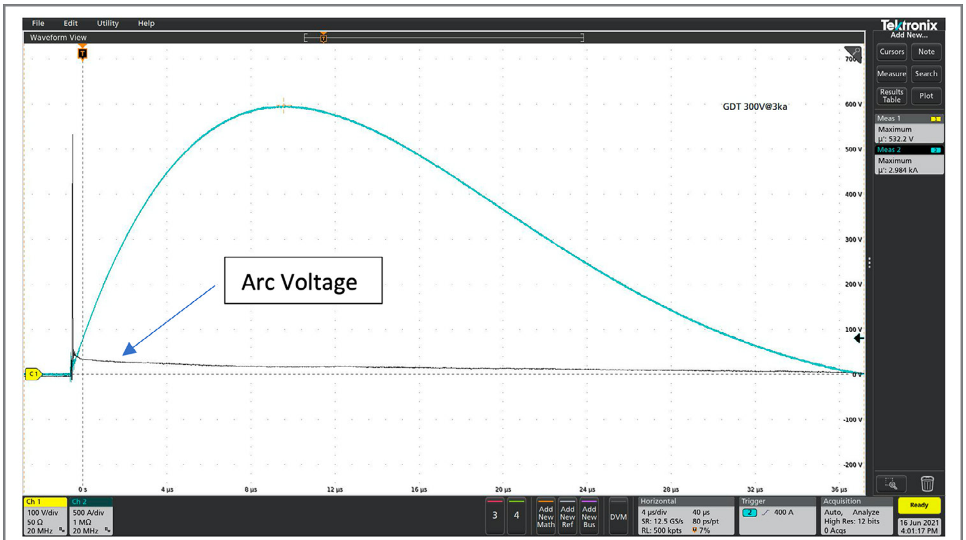

Figure 2 - GDT under surge condition

An MOV does not have a V_{fp} behavior (see Figure 3). An MOV component will start clamping the voltage at the beginning of the surge and continue to clamp until the current dissipates. However, the voltage will increase as the current increases. The specified clamping voltage is measured at the peak current (blue line).

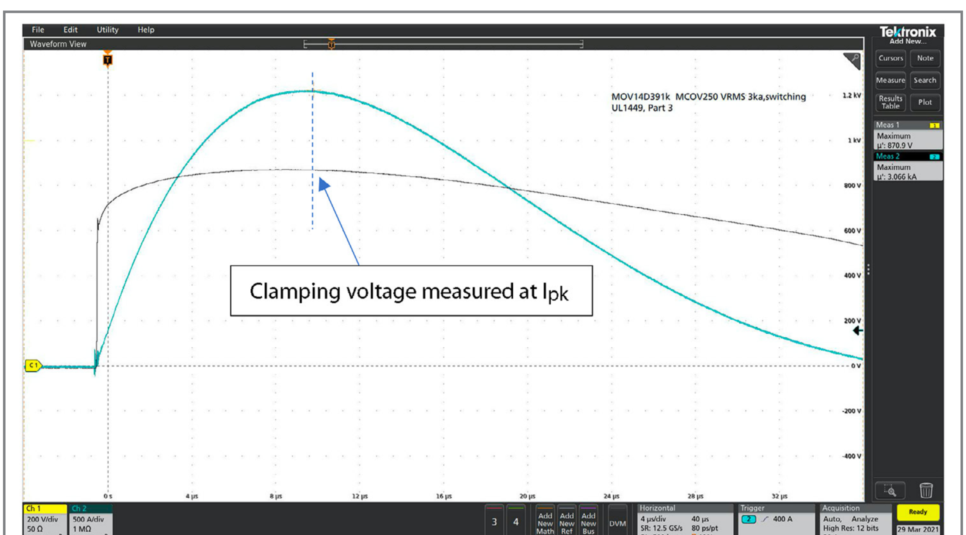

Figure 3 - MOV Clamping vs. Surge Current

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V_{fp} Voltage Spike Considerations (Continued)

Some TVS diodes have voltage foldback, which looks very similar to V_{fp} and may be confused with V_{fp}. However, a key difference between foldback voltage and V_{fp} is the associated current flow. There is substantial current flowing through a TVS diode during voltage foldback while there is negligible current flowing during V_{fp}. This is important because a great amount of power is being dissipated during voltage foldback. The power dissipation during V_{fp} is too small to be considered. A TVS component's clamping voltage is also typically measured at the peak current. Depending on the installation or setup, any wire inductance may cause the maximum clamping voltage to lag slightly after the peak current (see Figure 4).

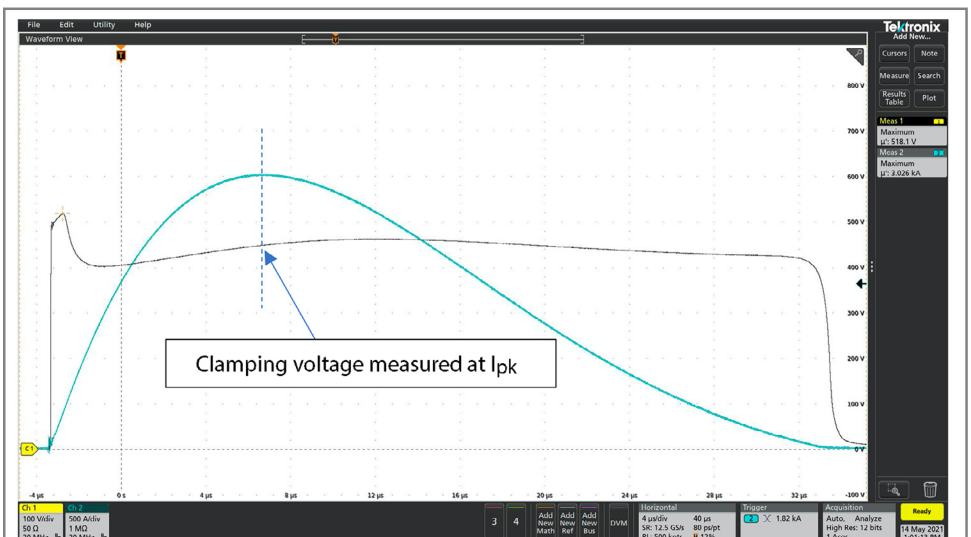

Figure 4 - PTVS Clamping vs Surge Current

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V_{fp} Voltage Spike Considerations (Continued)

When combining a GDT and an MOV in series, the V_{fp} typically lasts less than 300 ns with no current flow. Below is the surge waveform at 400 ns/div. In this scenario, V_{fp} is less than 200 ns.

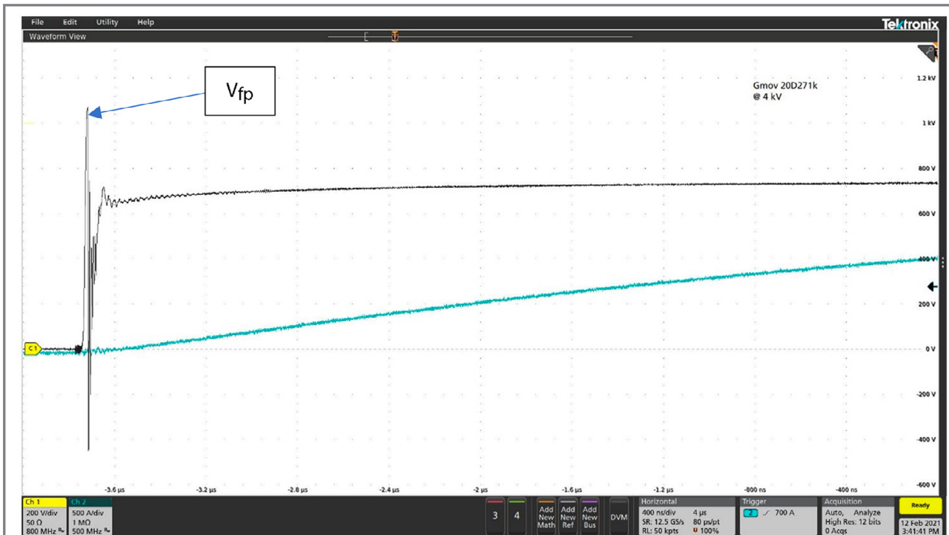

Figure 5 - Front Protection Voltage (Vfp)

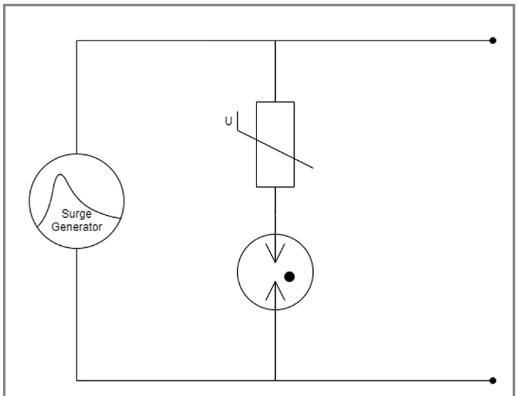

Figure 6 - Surge setup with no load

The above voltage capture was done with no load.

Figure 6 depicts the schematic diagram for this voltage capture.

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Surge Testing With and Without Load

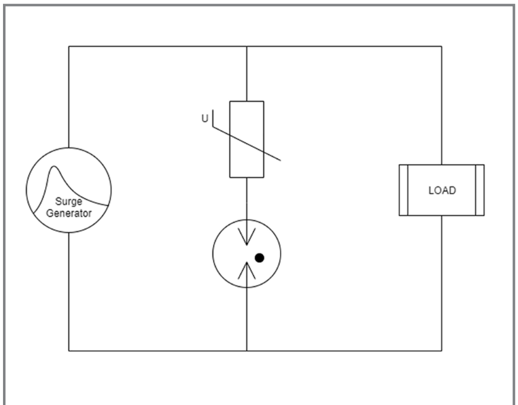

Figure 7 - Surge setup with load

When surge testing is performed without any load, V_{fp} is clearly visible as seen in Figure 5. However, when a load is added (see Figure 7, with the load representing a laptop switching power supply), the dv/dt slows down and V_{fp} is significantly lower as seen in Figure 8. The initial ringing and disturbance are most likely caused by the inductance or reactance of the test setup. When the GDT conducts, the voltage is pulled down to near zero as seen in Figure 8, which appears similar to a reverse spike. At this point, the MOV will start conducting and the voltage will rise to its final clamping level.

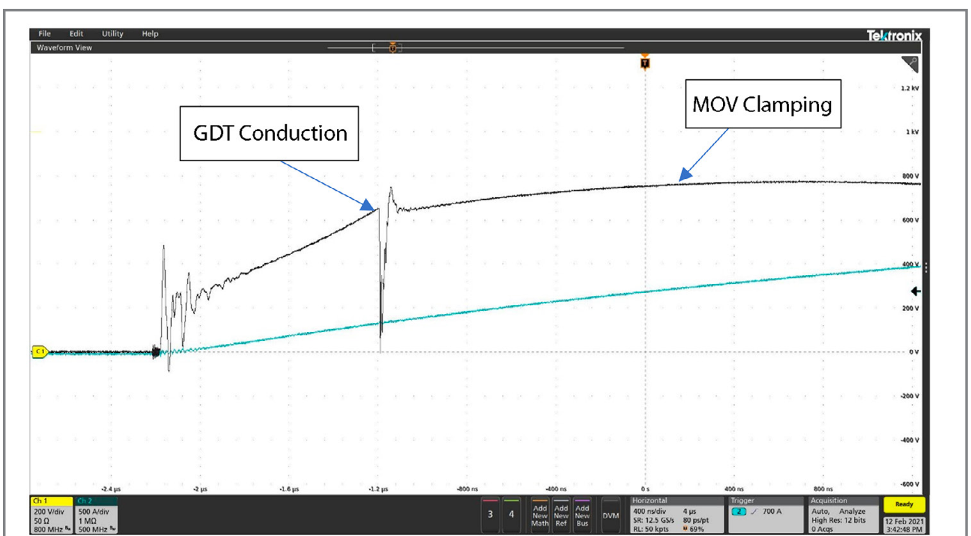

Figure 8 - Surge GDT+MOV with load

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Surge Testing With and Without Load (Continued)

When overlaying the load and the no-load capture images (see Figure 9), it is clear that the V_{fp} is not as much of a threat when a load is present.

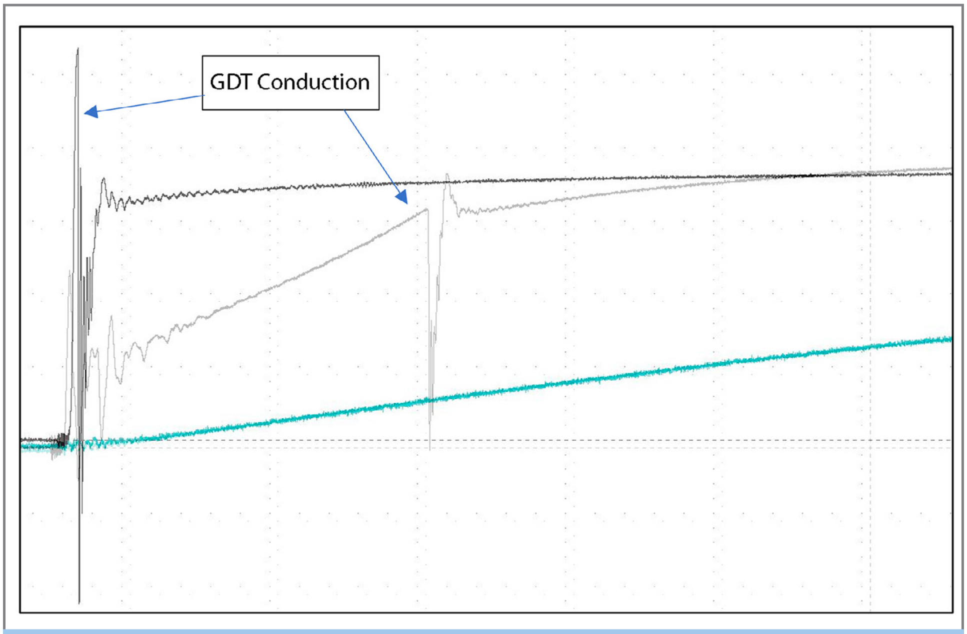

Figure 9 - Image showing overlaying capture images between load and no load

Is Vfp Elusive in Your Circuit Design?

In conclusion, V_{fp} does exist and may be visible when measured with no-load or a high impedance load. During the V_{fp}, virtually no current is present on the line until the components start to clamp. With a load connected to the protection scheme, V_{fp} may be non-existent – or elusive. Because not all loads are the same, design engineers are encouraged to conduct their own tests to see if their circuit will be exposed to V_{fp}.