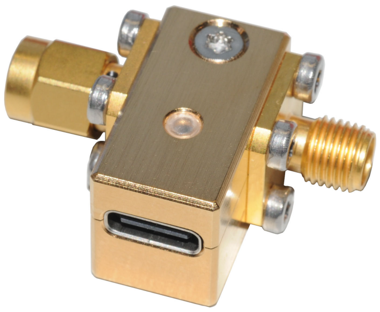
Very Fast Transient Voltage Suppressor TVS-5VRR

Advanced TLP/HMM/HBM Solutions



1 Features

- Input overload protection for 50 Ω high speed oscilloscopes and other RF measurement equipment
- Suitable for VF-TLP, CC-TLP, standard TLP, HMM, HBM
- ±5 V rail-to-rail protection, powered by USB-C port
- DC to 7 GHz (−1 dB) bandwidth
- −5 V to +5 V working voltage range
- ±15 kV overload according IEC 61000-4-2 (air/contact)
- 12 V clamping voltage at 5 A or 250 V overload into 50 Ω
- 0.2 dB insertion loss at 3 GHz
- 30 dB return loss at 3 GHz

2 Description

The TVS-5VRR transient voltage suppressor can be used to protect sensitive high speed oscilloscope inputs against possibly too high input overload from high voltage pulse generators.

Please note, that the protection device TVS-5VRR shall only be used in strict compliance with the hardware manual of TLP-3010C/4010C/8010AC/12010AC and that the TVS-5VRR is intended and approved for the use with HPPI systems only.

3 Characteristics

3.1 DC Characteristic

Fig. 1 shows the DC characteristic of the TVS-5VRR. The working voltage range of the TVS-5VRR is in the range −5 V to 5 V.

Applying a DC voltage beyond ±0.3 V (USB un-powered) and beyond ±5 V (USB powered) must be absolutely avoided. Otherwise damage of the TVS-5VRR may occur.

3.2 Frequency Response

Fig. 2 shows the typical insertion loss of the TVS-5VRR. In Fig. 3 the typical return loss is presented.

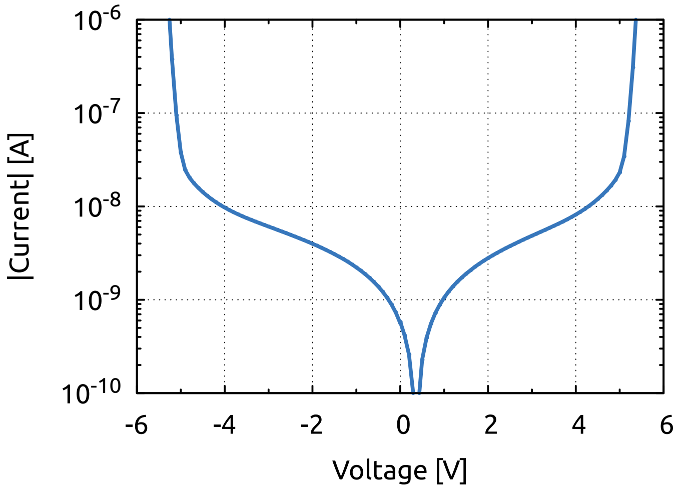


Figure 1: DC characteristic. The current is plotted as absolute value for negative input voltage. Measured with Keithley 2400 SMU in 4-wire mode and sweep start from zero for both polarities.

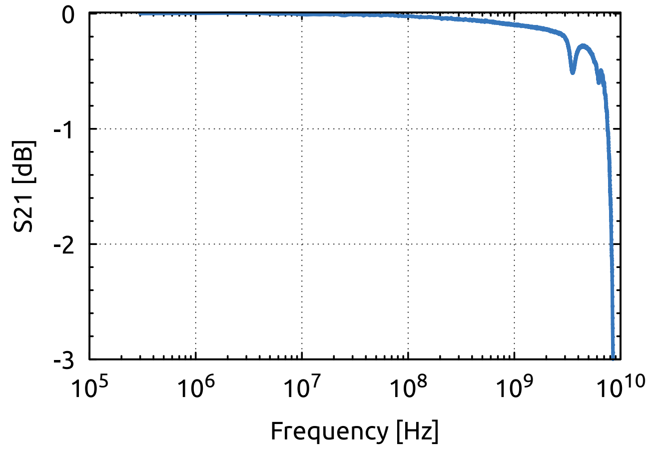


Figure 2: Frequency response (insertion loss) S21 (S12) versus frequency

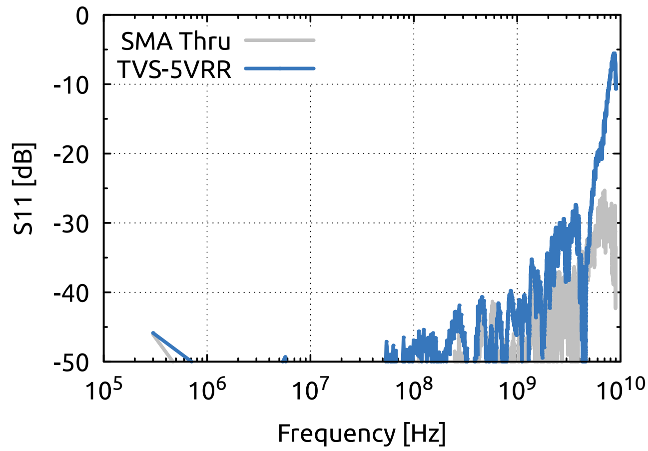


Figure 3: S11 (S22) versus frequency. For reference a SMA (female/female) thru is also shown.

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3.3 Pulse Transfer Characteristics

Fig. 4 and Fig. 5 show that the TVS-5VRR does not distort fast pulse signals. The TVS-5VRR is suitable for VF-TLP.

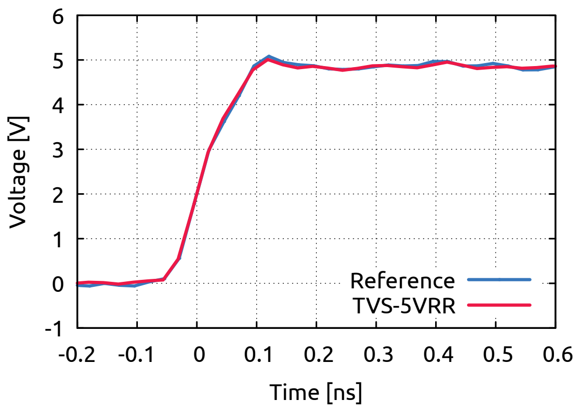

Figure 4: Step response at 100 ps rise time measured with 12 GHz bandwidth at 40 GS/s sampling rate

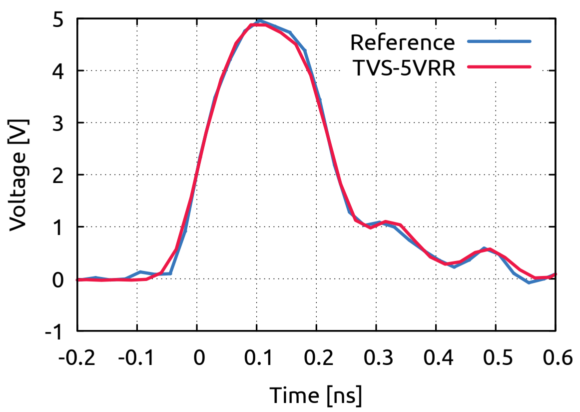

Figure 5: VF-TLP pulse transfer characteristic at 100 ps rise time and 230 ps pulse width measured with 12 GHz bandwidth at 40 GS/s sampling rate

3.4 Clamping Characteristic

Fig. 6 and Fig. 7 show the clamping and overshoot characteristics of the TVS-5VRR.

3.5 Ports and Dimensions

RF Input: 50 Ω input connected usually to the pulse sense signal.

RF Output: 50 Ω output connected usually directly to the oscilloscope input Fig. 11. For increased level of protection an additional attenuator A2 can be used Fig. 12.

USB-C: USB power supply. Not used for communications. Just connect to any available USB port at the oscilloscope.

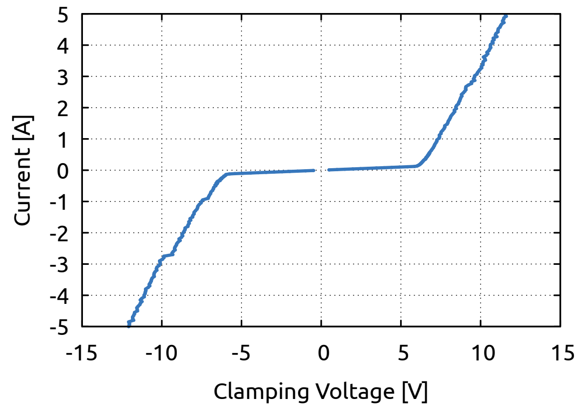

Figure 6: Clamping characteristic at 50 Ω, 100 ns pulse width, 100 ps rise time, 70 ns to 90 ns averaging window

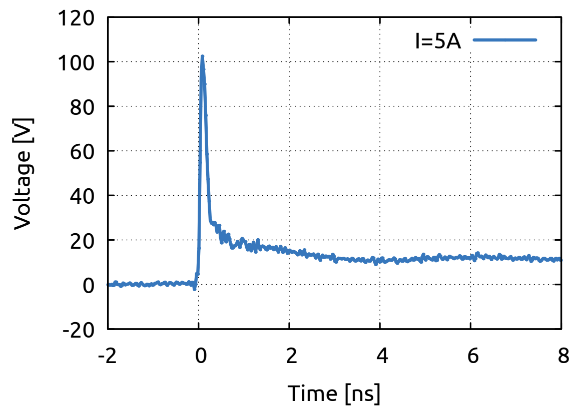

Figure 7: Overshoot and clamping characteristic at 5 A or 250 V overload into 50 Ω at 100 ps rise time and 100 ns pulse width

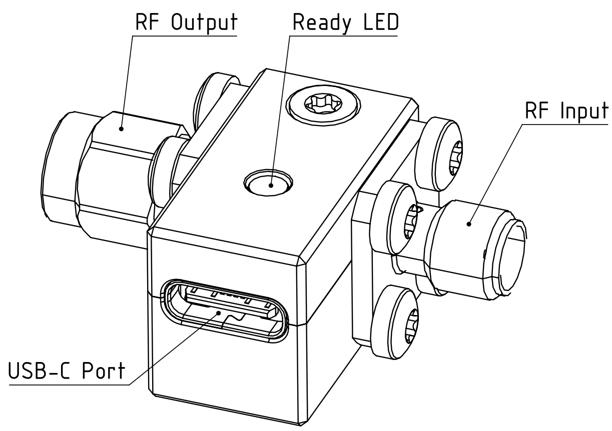

Figure 8: TVS-5VRR overload protection with 50 Ω SMA (female) input and SMA (male) output. The USB-C port is used for power supply. The green LED indicates active power supply required for proper operation of the protection device.

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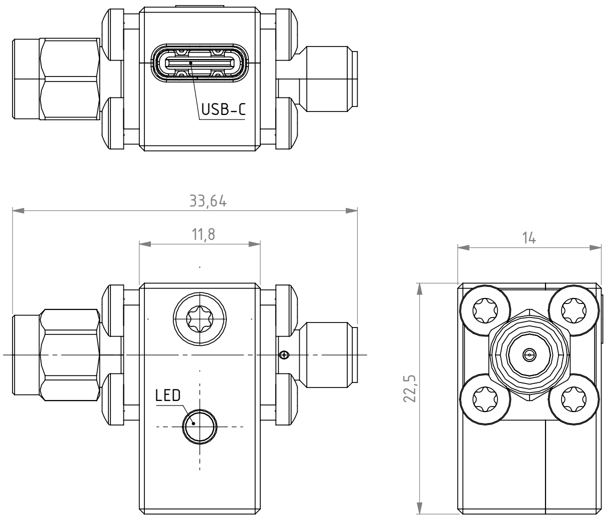

Figure 9: TVS-5VRR enclosure dimensions in [mm]

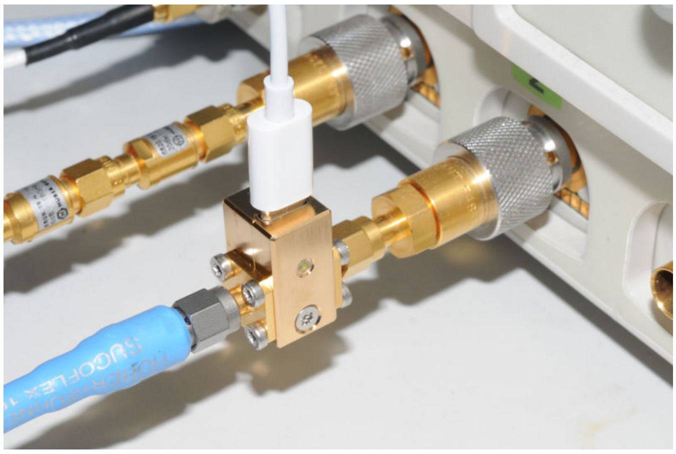

Figure 10: Application of the TVS-5VRR overload protection device, connected directly to the oscilloscope RF input. The USB-C port of the TVS-5VRR must be connected to any free USB port of the oscilloscope.

4 Application of the TVS-5VRR

The TVS-5VRR overload protection device shall be connected in the measurement setup as shown in Fig. 11. The USB-C port of the TVS-5VRR must be connected to any free USB port of the oscilloscope. The USB is used only for power supply of the TVS-5VRR and not for data communications. Fig. 10 shows a photograph how the TVS-5VRR is connected directly to the oscilloscope input. The pulse sense path in Fig. 11 represents a voltage divider of 4950 Ω and 50 Ω. Therefore the voltage scale factor at CH3 results to:

$$k_{\mathrm{CH3}} = \frac{4950\,\Omega + 50\,\Omega}{50\,\Omega} = 100 \qquad (1)$$

If some additional level of protection for the oscilloscope is required or intended to be implemented, then an additional attenuator A2 can be connected after the TVS-5VRR, as shown in Fig. 12. This attenuator scales down further the clamping voltage of the TVS-5VRR to a lower level, which is not harmful for the oscilloscope anymore. A2 could be 20 dB, 10 dB or 6 dB. The voltage scale factor at CH3 results to:

$$k_{\mathrm{CH3}} = \frac{4950\,\Omega + 50\,\Omega}{50\,\Omega} \cdot 10^{\frac{\mathrm{A2[dB]}}{20}} \qquad (2)$$

However, drawback is that the voltage measurement at CH3 is getting more noisy in case of high value of A2.

The TVS-5VRR is based on rail-to-rail low capacitance transient voltage suppressor (TVS) diodes. It protects the sensitive oscilloscope input against overload and destruction. In general, oscilloscopes from different vendors have different input maximum ratings at pulsed overstress at ESD/EOS condition. Therefore, HPPI cannot specify or guarantee any resulting level of protection. The resulting level of protection may be evaluated together with the oscilloscope vendor using the clamping characteristic of the TVS-5VRR shown in Fig. 6. The TVS-5VRR can be used from DC up to 7 GHz. Applying a DC voltage exceeding ±5 V may cause damage of the TVS-5VRR and must be avoided.

5 How to Check the TVS-5VRR Is Still Functional?

It is highly recommended to check the functionality of the device from time to time since it might be destroyed by misuse or overstress in the measurement setup.

5.1 TVS-5VRR Verification Test Procedure

The following subsections explain the parameter verification test procedure for DC, frequency response and clamping characteristics of the TVS-5VRR.

5.1.1 DC Test

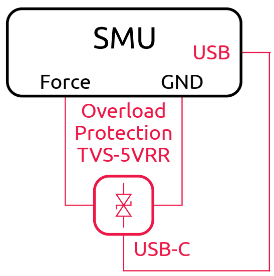

Figure 13: DC test setup

1. Connect the TVS-5VRR to a SMU as shown in Fig. 13.

   Connect the USB-C port of the TVS-5VRR to any free USB port of the SMU or use a general purpose 5 V USB power supply, e.g. a mobile phone charger.

2. Run a DC sweep from −6 V to +6 V with current compliance at 1 µA.

3. Compare the measurement results with Fig. 1.

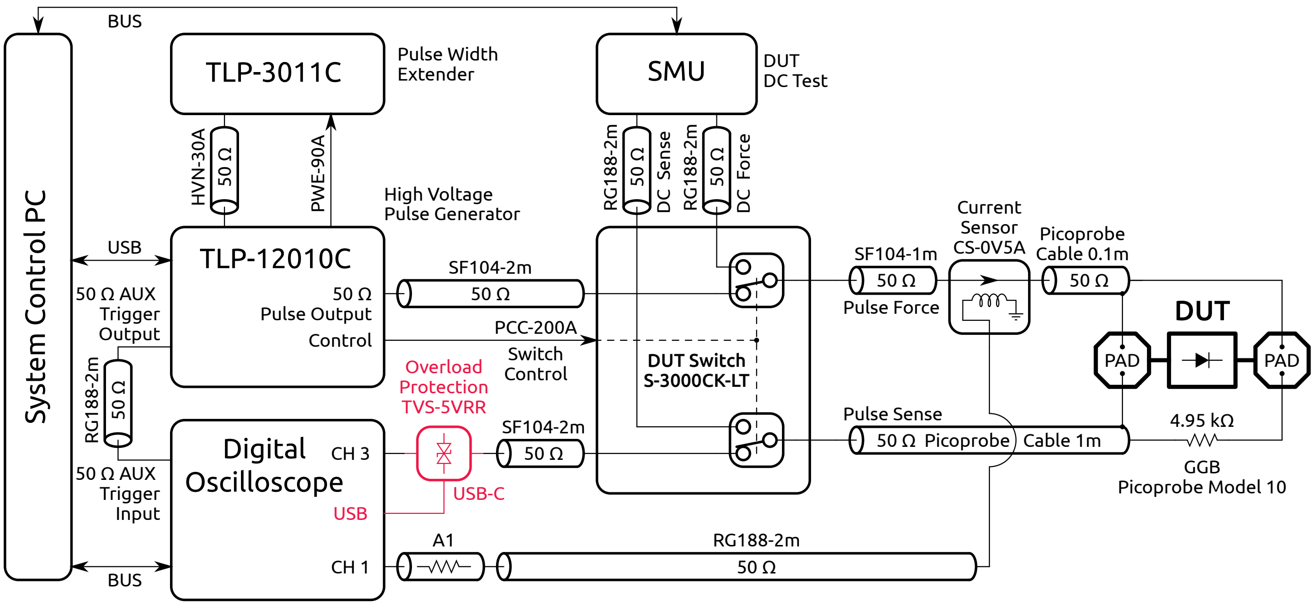

Figure 11: TVS-5VRR typical application

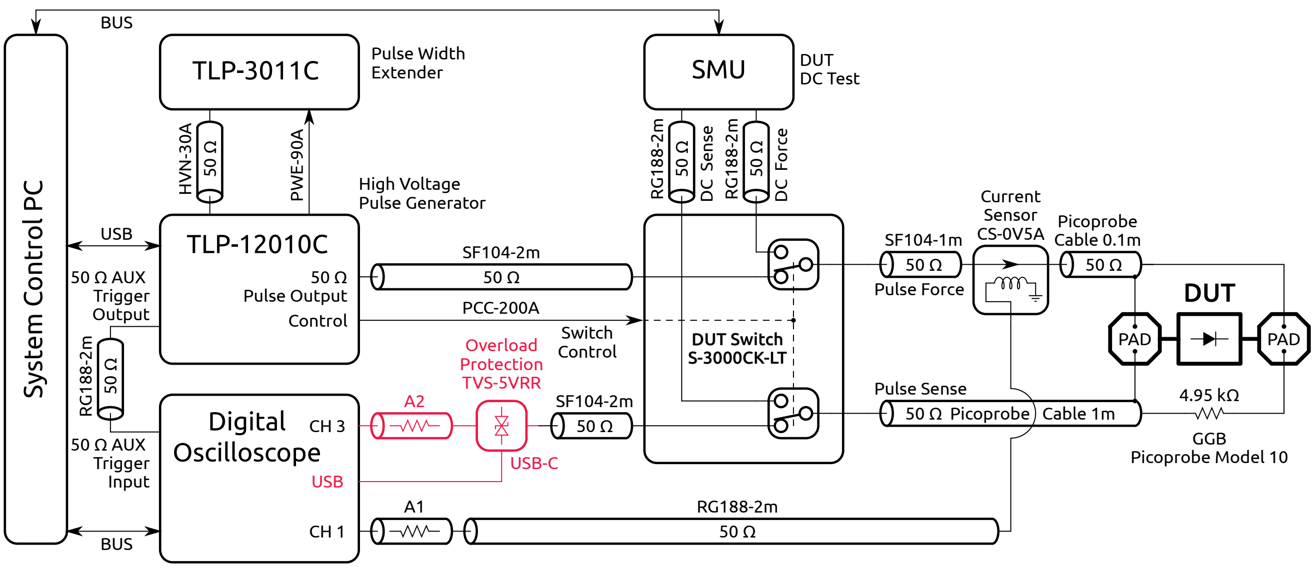

Figure 12: TVS-5VRR typical application with improved oscilloscope input protection by attenuator A2

5.1.2 S-Parameter Test

1. Connect the TVS-5VRR to a VNA (vector network analyzer) as shown in Fig. 14.

   Connect the USB-C port of the TVS-5VRR to any free USB port of the VNA or use a general purpose 5 V USB power supply, e.g. a mobile phone charger.

2. Measure the S-parameters from 300 kHz to 10 GHz.

3. Compare the measurement results with Fig. 2 and Fig. 3.

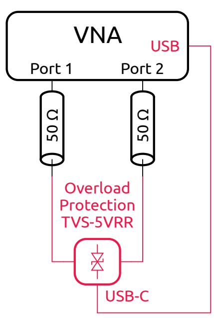

Figure 14: S-parameter test setup

5.1.3 Clamping Test

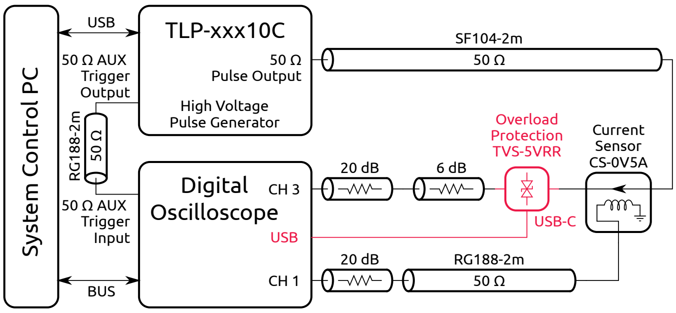

Figure 15: Clamping voltage test setup

1. Connect the TVS-5VRR according test setup shown in Fig. 15.

   Connect the USB-C port of the TVS-5VRR to any free USB port of the oscilloscope or use a general purpose 5 V USB power supply, e.g. a mobile phone charger.

2. Measure TLP characteristic from 1 V to 500 V pulse voltage at 100 ns pulse width, 100 ps rise time, 70 ns to 90 ns averaging window.

   The voltage scale factors in the settings results to:

$$k_{CH3} = 10^{\frac{20\,dB}{20}} \cdot 10^{\frac{6\,dB}{20}} = 10 \cdot 2 = 20 \quad (3)$$

$$k_{CH1} = 10^{\frac{20\,dB}{20}} \cdot k_{CS\text{-}0V5\text{-}A} = 10 \cdot 2 = 20 \quad (4)$$

3. Compare the measurement result with Fig. 6.

In addition to the clamping test above, the TVS-5VRR maybe tested with a VF-TLP signal at 100 ps rise time and 1 ns to 5 ns pulse width at 10 V pulse voltage, directly connected to the oscilloscope input: with and without TVS-5VRR.

There should be no visible transient waveform distortions, as shown in Fig. 4 and Fig. 5.

6 Ordering Information

Pos.	Description	Part No.
01	Very Fast Transient Voltage Suppressor, USB 5 V Rail-to-Rail, SMA(m/fm), 7 GHz	TVS-5VRR

General

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