An Unusual Source of Multiple ESD Events in Electronic Equipment

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Abstract. Small wall mounted power supplies that plug directly into AC power mains and furnish power, usually low voltage DC, to equipment over a low voltage cable are ubiquitous in the electronic field. It is shown that these low voltage supplies can be the source of multiple ESD events that are fed to the connected system on the low voltage cable when an ESD event is applied to the system or directly to the power supplies. The multiple ESD events produce nasty current waveforms Examples of these waveforms and the measurement method are given. The results have been duplicated in three laboratories, results are presented from two of the three.

1. Introduction

During troubleshooting of an ESD problem on a piece of equipment that was powered by a small plug type power supply connected to the equipment by a low voltage cord, strange current waveforms were noted on the low voltage cord that appeared to be multiple ESD events. This, even though only one ESD pulse was being applied to the system. The author had not observed such an effect previously.

The test setup was checked and sources of secondary ESD events were ruled out. Ultimately, the test was simplified to involve just the power supply, a current probe, and an ESD simulator. With this setup, a series of current waveforms could be quickly generated and so a number of power supplies could be checked in a short period of time.

2. Test and Measurement Setup

Figures 1 and 2 show details of the simplified test setup. In Figure 1, the AC mains connection of the supply was connected to the ground lead connection of the ESD simulator and the tip of the ESD simulator was connected to the low voltage connector from the supply. A Fischer Custom Communications F-65 current probe with a flat frequency response of 1 MHz to 1 GHz and a transfer impedance of one Ohm (one Volt/Amp) was used to measure the current.

In Figure 2, the two AC mains connections are shorted together to rule out the possibility that a protection device across the mains (such as an MOV device) could be contributing to the effects reported here. Shorting the mains connections of the supply did not change the results.

This test setup was used in three different laboratories involving different ESD simulators and different power supplies. The only common factor in the three test setups was the F-65 current probe. The performance of the current probe was verified and is reported later in this paper. The ESD simulators included a KeyTek MZ-15, a NoiseKen ESS-S3011, and one simulator at a client location.

The applied ESD level was between 500 Volts to as high as 3,000 Volts. The multiple discharges often started around 500 Volts, well below the breakdown voltage of the power supply, and did not happen above 3000 Volts. Note that the actual peak voltage across the dielectric barrier of the supply *should* be less than the setting of the ESD simulator as the charge would be split between the simulator and the capacitance across the dielectric of the supply.

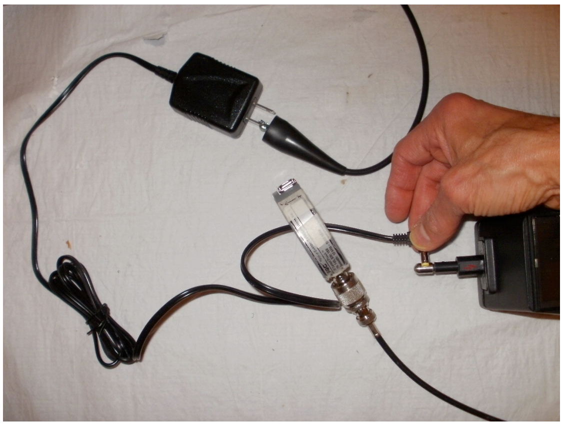

Figure 1. Test setup.

Figure 2. Shorting of the mains connections.

3. Characteristics of the Multiple Discharges

The pattern of apparent multiple discharges fell into a few types. One type is illustrated in Figures 3 and 4. The pattern of Figure 3 was a common one. The original ESD event is followed a few hundred nanoseconds later by a smaller ESD like event embedded in a low frequency discharge, itself lasting a few hundred nanoseconds. Sometimes the embedded ESD like event was not present, just the low frequency discharge was present.

Sometimes the pattern of Figure 3 was followed by a negative polarity event a few microseconds later as shown in Figure 4. A possible mechanism of the cause of the negative event will be discussed later. One thing is sure at this point, the time scales in Figures 3 and 4 are much larger than the propagation time of the current around the test setup loop composed of the power supply low voltage cord and the ground lead of the ESD simulator, which would be on the order of about 20 nanoseconds.

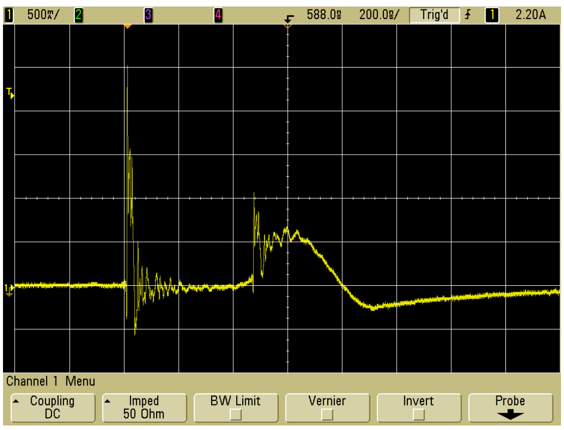

Figure 3. Secondary discharge embedded in larger low frequency event. Scale factors: 500 mA/div and 200 ns/div.

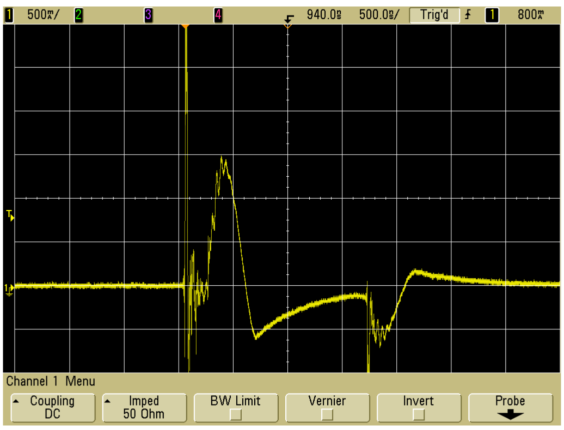

Figure 4. Additional negative polarity ESD event and low frequency event. Scale factors: 500 mA/div and 500 ns/div.

Figure 5 shows a long view at a horizontal scale of one µs/div. At this time scale, a secondary event of negative polarity can be seen about seven microseconds after the original event. This delay time is much, much greater than the approximately 20 nanosecond delay around the setup loop.

Figure 6 shows another frequent pattern. In this pattern, the secondary events come in a rapid sequence with each event 100 to 300 nanoseconds apart.

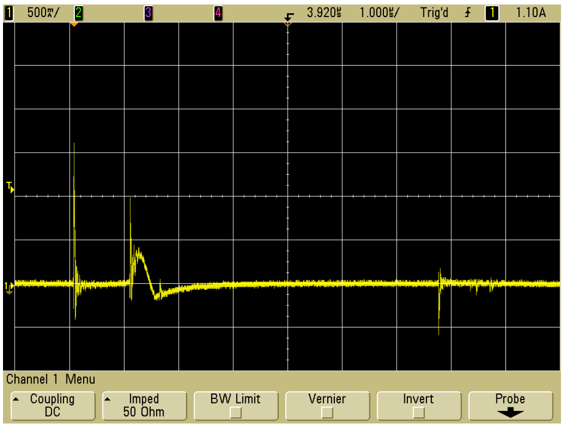

Figure 5. Long time view showing negative event. Scale factors: 500 mA/div and 1 µs/div.

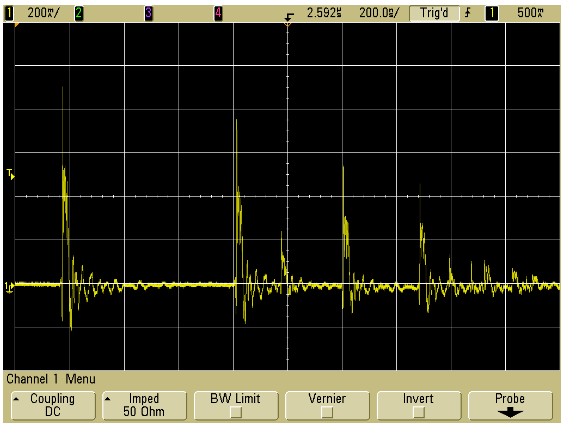

Figure 6. Multiple events in rapid secession. Scale factors: 200 mA/div and 200 ns/div.

Figure 7 shows an initial applied current waveform *and* a secondary one having the appearance of a human metal waveform, similar to that described in IEC 61000-4-2.[1] However, a secondary event shown in Figure 8 has the appearance of a cable discharge event, having a flat region of current corresponding to the discharge of a common mode transmission line.[2] Note the duration of about 20 nanoseconds. This is the expected time delay around the loop of the low voltage power cord of the power supply and the ground lead of the ESD simulator.

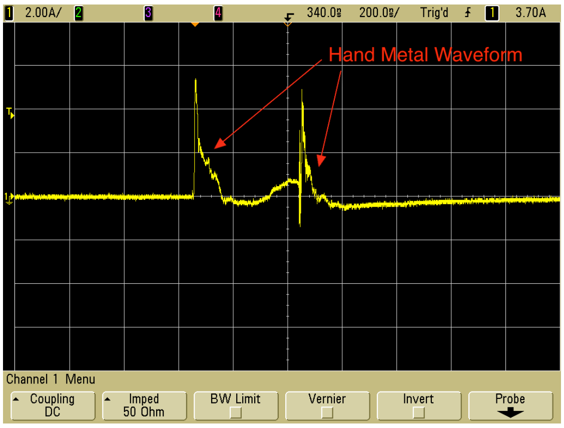

Figure 7. Secondary event showing human metal waveform characteristics. Scale factors: 2 A/div and 200 ns/div.

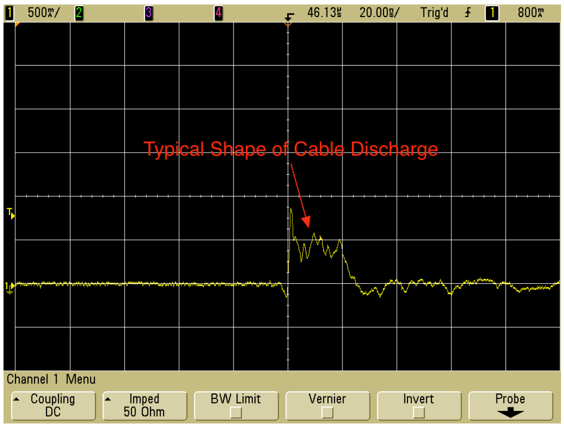

Figure 8. Secondary event showing cable discharge waveform characteristics with 20 ns width. Scale factors: 500 mA/div and 20 ns/div

Figure 9 shows a similar waveform to those above, but taken at a different laboratory using different equipment except for the current probe. To make sure the current probe or scope was not contributing significantly to the observations, Figure 10 shows the current waveform when the ESD simulator ground lead was connected to the simulator tip with the F-65 current probe measuring the current in the loop. As one can see, there is no evidence of any secondary events.

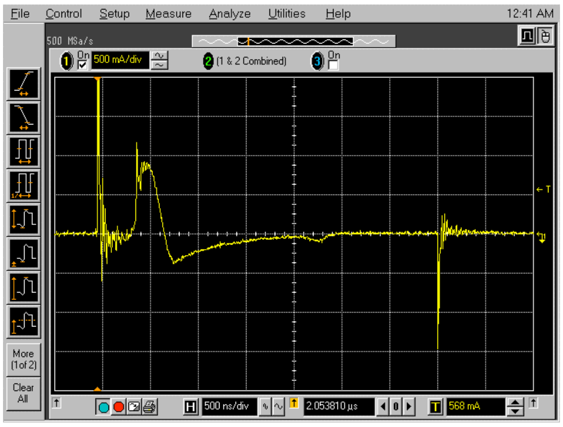

Figure 9. Secondary discharge recorded at different laboratory showing delayed negative pulse. Scale factors: 500 mA/div and 500 ns/div.

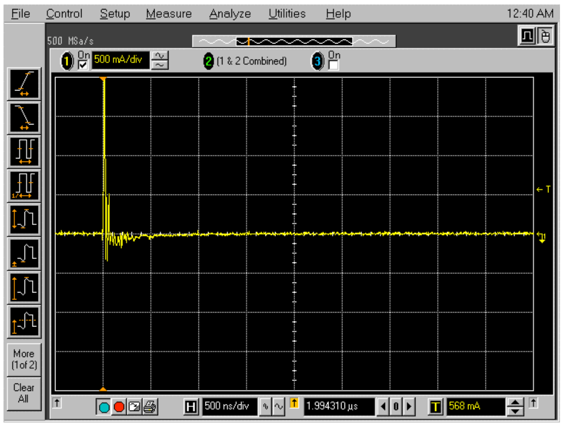

Figure 10. Current measured in ESD simulator ground lead shorted to the simulator tip showing no secondary discharges. Scale factors: 500 mA/div and 500 ns/div.

4. Analysis of Results and Possible Explanation

The long time delays in the above waveforms cannot be explained on the basis of the time delay around the current loop (about 4 meters). Likewise negative secondary events in response to a positive initial event must be explained as well a breakdown at significantly lower voltages than the barrier rating (500 V applied stress vs. >2000V barrier rating).

One possible theory is that a resonance between elements of the EMI filter and power transformer (leakage inductance, and inter-winding capacitance) causes a breakdown of the transformer insulation in both polarities.

5. Subsequent and Future Work

Similar current waveforms have been now produced using Electrical Fast Transients, IEC 61000-4-4, instead of ESD.[3] This is problematic as EFT happens frequently on AC power mains, much more so than ESD in the environment. There is the potential for power line spikes to cause system malfunctions by this mechanism!

Recently, similar results have been produced on a “brick” type power supply, such as used on laptop computers. Work to identify the mechanism within the power supply is planned.

6. Conclusion and Summary

Internally generated ESD/EFT events in system power supplies may be a cause for system upsets in normal use. Results presented in this paper may explain what may be happening. In any event, new power supply designs of all types should be checked for this problem. All that is needed is a current probe and an ESD simulator. A full ESD test area is not needed.

Reference

[1] IEC 61000-4-2, “Testing and measurement techniques – Electrostatic discharge”, https://webstore.iec.ch/publication/4189

[2] “Cable Effects Part 1: Cable Discharge Events,” January 2002, http://www.emcesd.com/tt2002/tt010102.htm, Douglas C. Smith

[3] IEC 61000-4-4, “Testing and measurement techniques – Electrical fast transient/burst immunity test”, https://webstore.iec.ch/publication/22271