Fischer Custom Communications, Inc.

Surge Coupling Decoupling Network (S-CDN) Considerations

Introduction

Surge Coupling-Decoupling Networks (SCDN) are used to couple the surge specified in IEC 61000-4-5 onto active telecom lines to determine if the telecom equipment sustains functional upset or damage due to the surge. Figure 1 shows the generic test setup to perform surge testing in accordance with IEC 61000-4-5. Four standard test levels, referenced to the surge generator open circuit voltage, are specified in IEC 61000-4-5: 0.5, 1, 2, and 4kV.

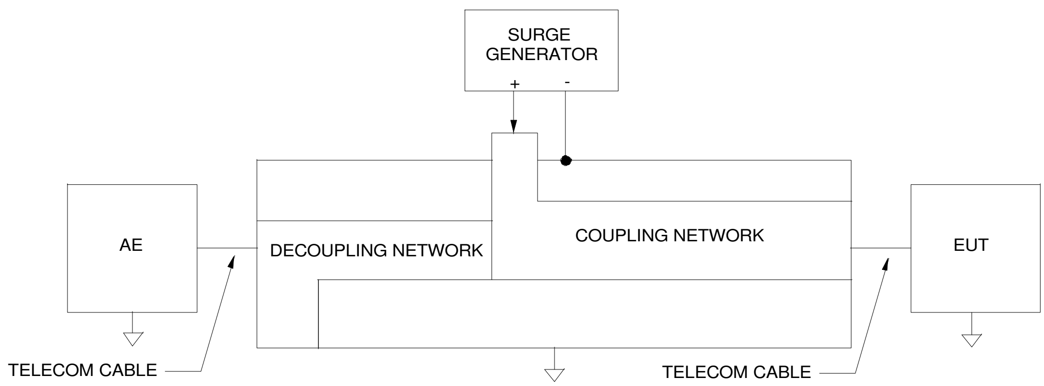

Figure 1. Generic Surge Coupling Decoupling Network (SCDN)

How a SCDN Works

General

The S-CDN itself consists of two major sections: the Coupling Network and the Decoupling Network. In addition to the basic coupling and decoupling requirements specified in IEC 61000-4-5, another key consideration not well addressed in the IEC specification is the impact of the S-CDN on the transmission quality of the telecom digital data flowing through the SCDN. Each of these 3 topics is discussed in the following sections.

Coupling Network

The Coupling Network connects the output of the Surge Generator to the Equipment Under Test (EUT). As per IEC 61000-4-5, the Coupling Network includes resistors whose values are dependent on the number of telecom wires being injected. These resistors act as current dividers to equally divide the surge current delivered to the individual telecom wires.

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The key intent of IEC 61000-4-5 is that the surge currents delivered to each telecom wire are applied common mode. That is, all currents have the same waveshape, peak value, and are applied simultaneously. In this context, simultaneously means the surge currents all start at exactly the same time. If the currents into the EUT telecom lines do not start simultaneously, a differential voltage can develop between those telecom lines. In general, the EUT's surge protection is designed for a common mode surge. If the EUT is not protected against differential signals, the EUT is at risk if the Coupling Network allows these surge currents to start at different times and create differential signals. EUT upset or failure could be attributed to the common mode surge when in reality the differential mode stress is the cause, resulting in unnecessary and expensive troubleshooting.

To ensure the S-CDN coupling circuit does not interfere with equal division of the current from the surge generator to the telecom lines, Fischer uses high quality high voltage resistors with 0.1% tolerance.

To ensure all of the surge currents start simultaneously, Fischer uses solid state non-linear devices instead of spark gaps (IEC 61000-4-5 allows either approach for unshielded symmetrical communications lines). The solid state devices behave in a highly repeatable manner unlike spark gaps. These devices have a repeatable breakdown voltage at any surge generator output level and all devices turn on simultaneously. The array breakdown voltage is also considerably lower than those of spark gaps (a factor of 8 to 10). The importance of this will be discussed in more detail below.

Fischer has looked at the 2 basic arrangements using spark gaps that would be applicable to surge testing: a 2-electrode spark gap wherein one spark gap is used for each telecom wire to be driven, and 3-electrode spark gaps wherein one spark gap drives 2 telecom wires.

The test configuration shown in Figure 2 was set up wherein the surge generator was driving 8 wires through eight 2-electrode spark gaps with the IEC specified 250 ohm series resistor in each of the 8 paths. At the 1kV surge generator setting, it was found for this configuration that, once in a while, 1 or 2 spark gaps out of the 8 being driven would not activate resulting in no surge current delivered to that/those wires.

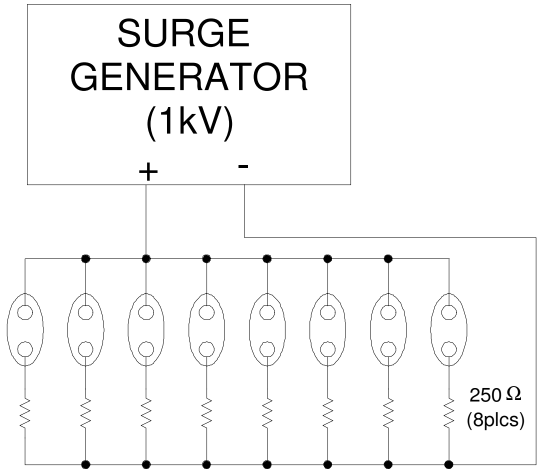

Figure 2. Test setup to investigate coupling surge using one spark gap per telecom wire.

To investigate the 3-electrode spark gap approach to coupling the surge, the test configuration shown in Figure 3 was used. The surge generator (EMC Partner TRA2006 F-S-T) drove two 3-electrode spark gaps which in turn drove 4 simulated telecom wires terminated in a short circuit through the appropriate resistor value (250 ohms) cited by IEC 61000-4-5 for the 8 telecom wire configuration. Several different brands of 3-electrode spark gaps were tested. Driving of four 3-electrode spark gaps to drive 8 wires was not attempted due to instrumentation limitations (only 4 simultaneous data channels available).

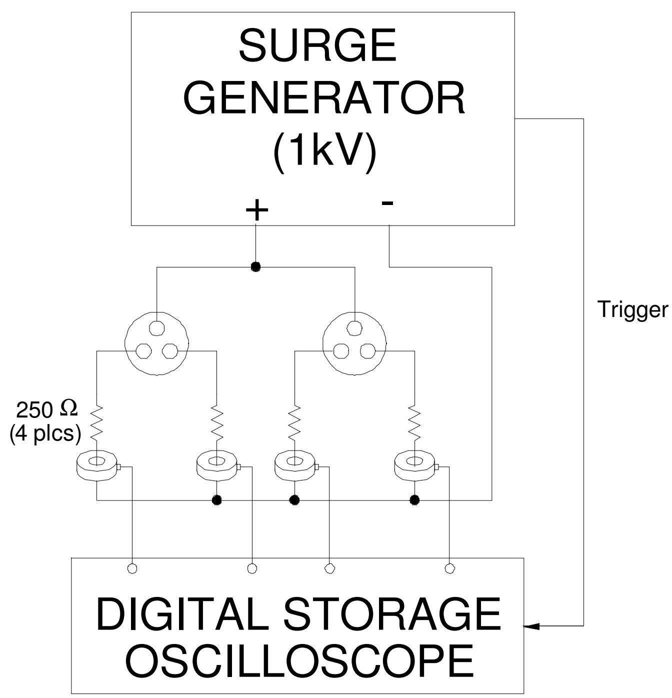

Figure 3. Test setup to investigate using one 3-electrode spark to drive a pair of telecom wires.

Figures 4 and 5 show an example of these test shots for two different spark gaps from different manufacturers tested at the 1kV IEC 61000-4-5 level. In each Figure, the 4 currents being monitored were acquired simultaneously on the same time base to observe any difference in turn-on time between the spark gaps.

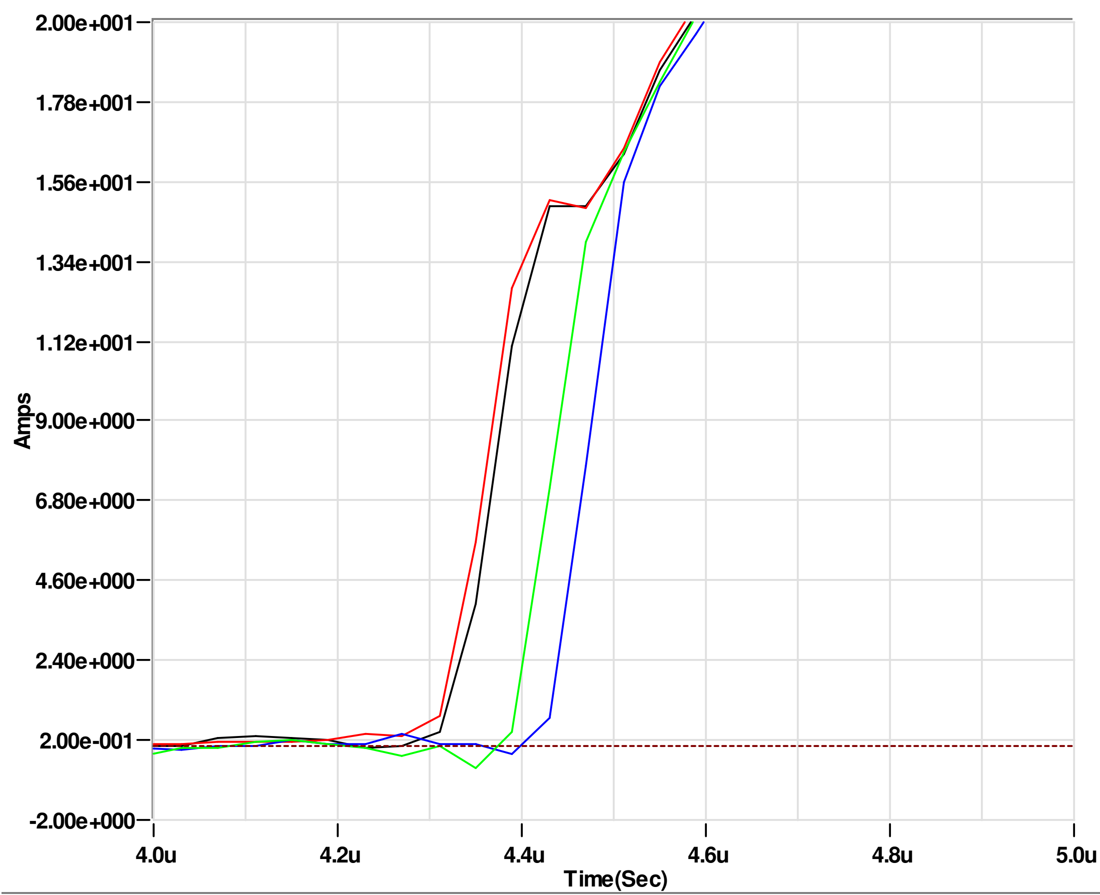

Figure 4. An example of variation in spark gap turn-on times for two 3-electrode spark gaps from manufacturer X. Vertical scale needs to be divided by 10.

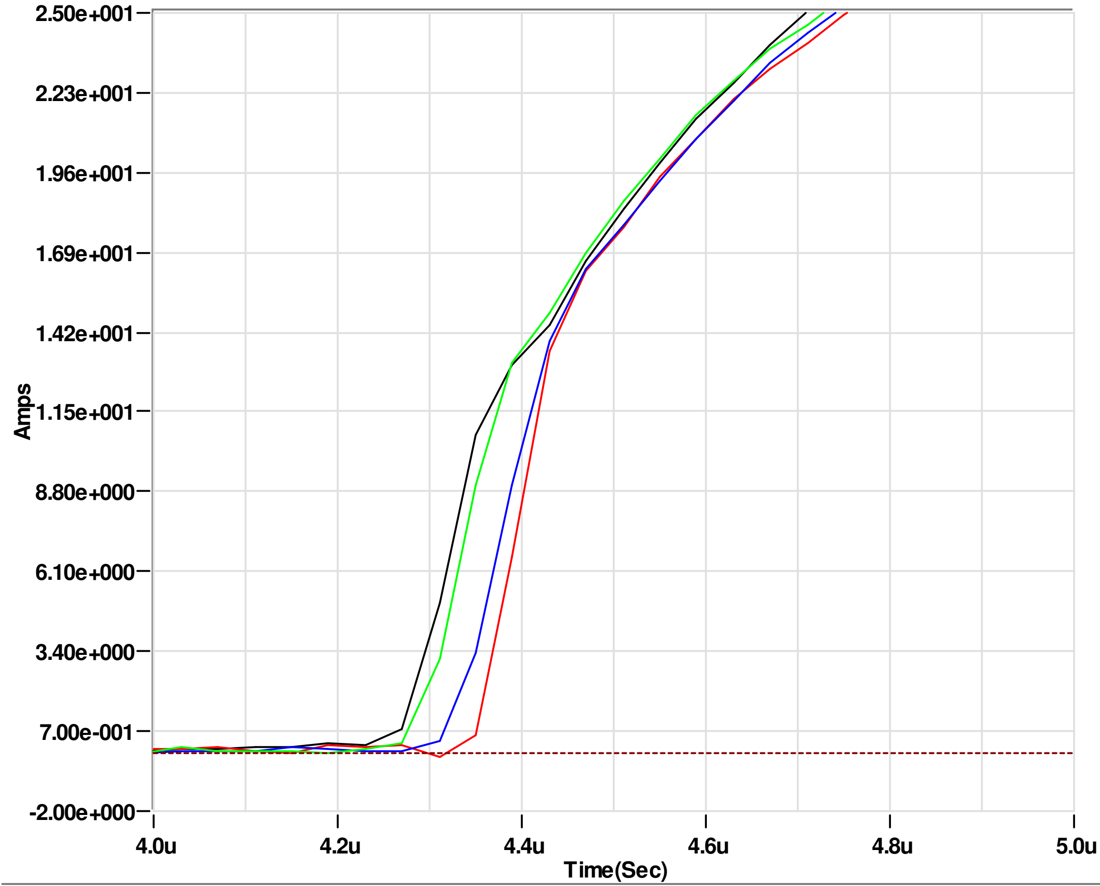

Figure 5. An example of variation in spark gap turn-on times for two 3-electrode spark gaps from manufacturer Y. Vertical scale needs to be divided by 10.

The test setup in Figure 6 was used as another way to look at this spark gap turn-on. This allowed comparing voltages delivered to a load that went through a spark gap turn on to what voltage waveform would look like if not spark gap was present. Figure 7 shows this comparison.

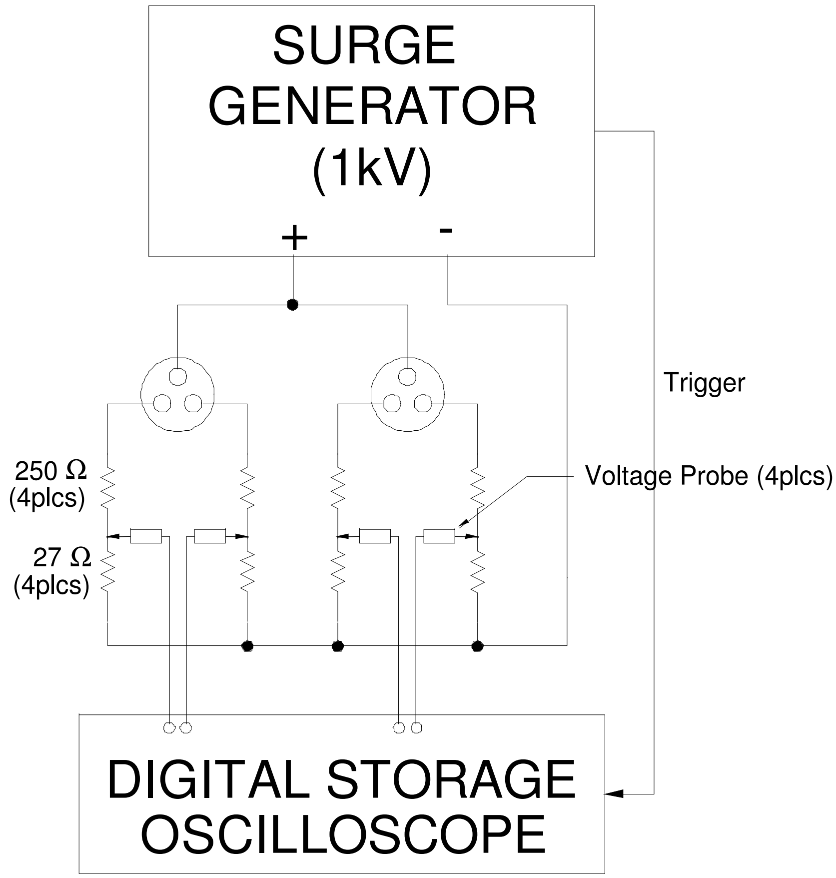

Figure 6. Test setup to compare surge voltage waveforms with and without spark gaps.

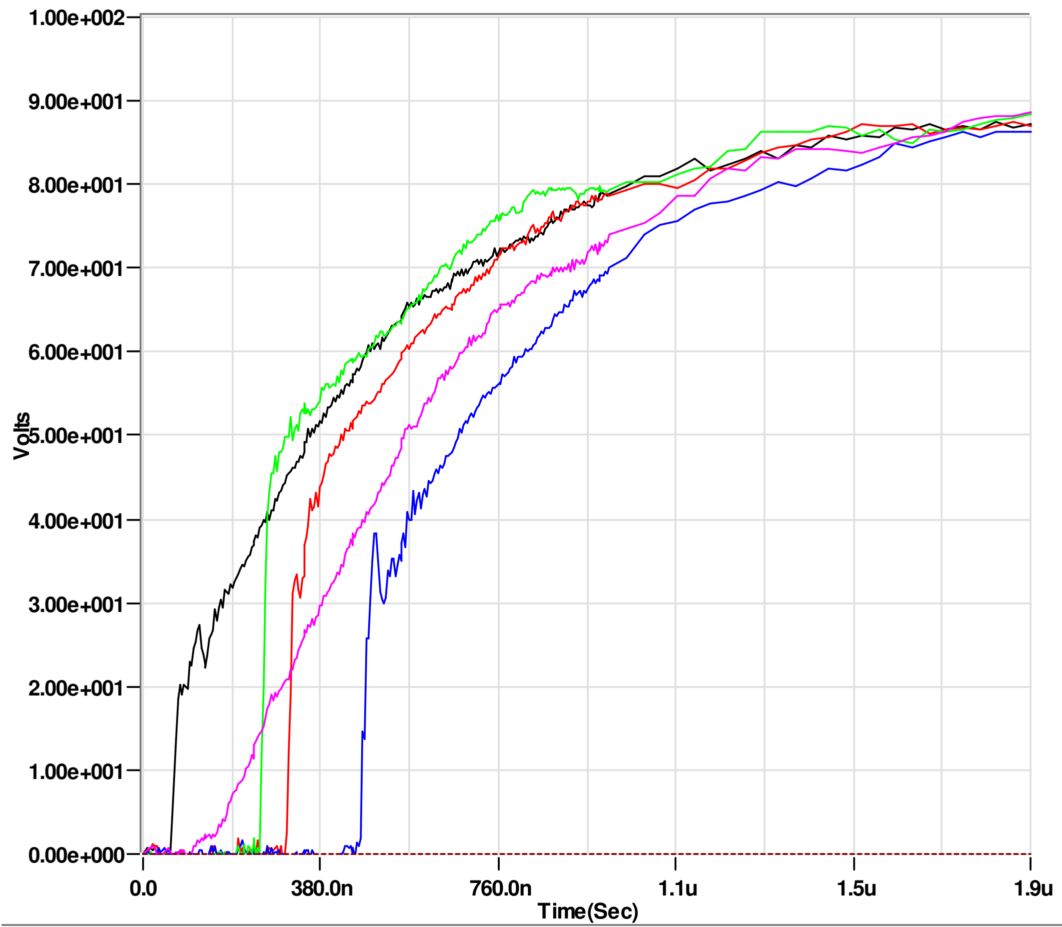

Figure 7. Comparing surge voltage delivered to a load through 4 different spark gaps from 3 different manufacturers to voltage delivered to load without spark gap present (purple trace). Note these are overlaid data taken from different oscilloscope sweeps and no inference should be made about relative turn-on times. Data are raw – vertical sensitivities have not been corrected for any differences in voltage probe gains.

We found the 3-electrode spark gaps all fired reliably for every surge applied, but that the individual spark gaps turned on at different points in time. Spark gaps from all manufacturers tested displayed similar characteristics regarding shot to shot variations. This is understandable from the perspective that these types of spark gaps self fire. Spark gaps have a rated DC breakdown voltage, but under transient conditions like the surge, the actual voltage at which the spark gap fires is typically much higher (4 to 6 times higher) than the DC breakdown voltage. So for a spark gap with a 75 volt DC breakdown, the surge breakdown voltage could be in the 300-400 volt range.

In addition, this firing voltage level can and likely will change shot to shot for a given charge voltage. When the spark gaps fire at different breakdown voltage levels, the points in time when these firings occur become spread out. This results in the situation described above wherein the surge currents to the telecom wires do not start simultaneously as desired/intended.

Note that there could be a difference within turn-on time for the 2 spark gaps contained within a single 3-electrode spark gap. These variations in turn on times can be expected whether regardless of the number of spark gaps involved.

Figure 8 shows the same spark gap used in Figure 4, but at a 250 volt charge level on the surge generator. Note that the firing times between the gaps increase from 100-200ns to a few usec (compare Figures 4 and 5 to Figure 8). If trying to troubleshoot an upset threshold, these additional variations in firing times between test levels may further complicate troubleshooting. The lower charge levels are getting closer to where the spark gaps fire, so when they do fire, there is a sharp rise to peak – much faster than the spec risetime. The variability in spark gap risetime between the 250 volt level and the 1 kV level may also complicate troubleshooting when starting at a lower surge level and gradually increasing to the intended spec level.

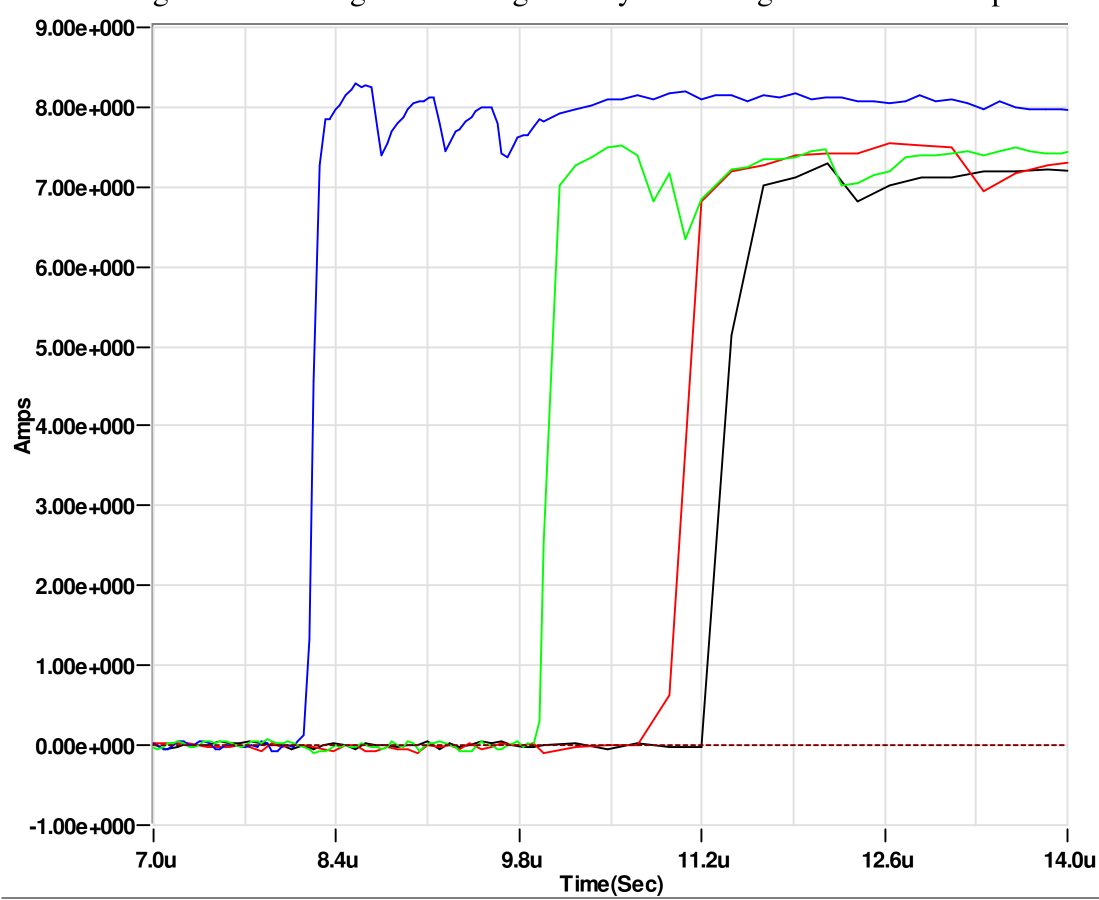

Figure 8. Example of spread in spark gap turn-on times for a 250 volt surge level for spark gaps shown in Figure 4.

The solid state devices approach used by Fischer mitigates the undesirable aspects of the spark gap. Figures 9 and 10 shows the measurements for a 500 volt and a 4kV surge generator charge voltage driving 8 solid state devices used by Fischer which in turn were driving 8 telecom wires.

Due to instrumentation limitations, all the drive to all 8 telecom wires could not be captured on a single digital oscilloscope sweep, but had to be split up into separate 2 sweeps.

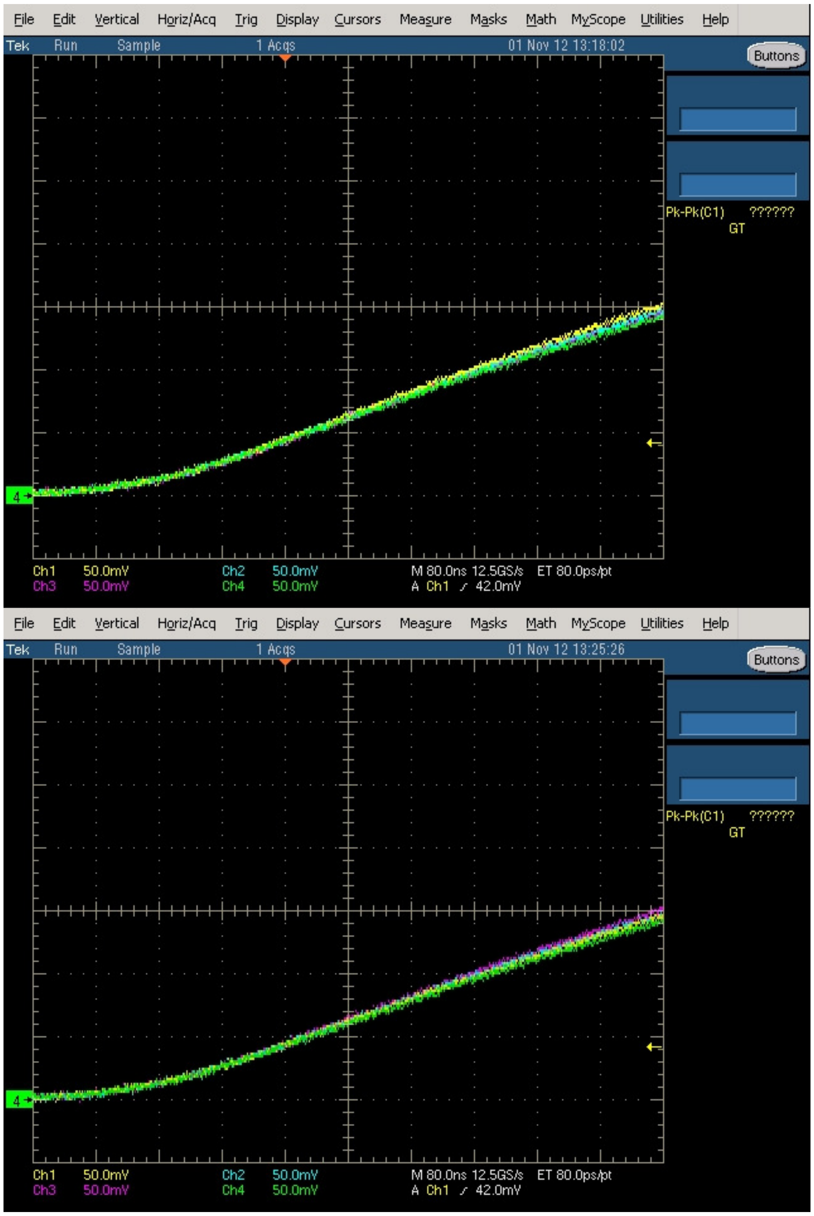

Figure 9. SCDN solid state array driven at 500 volt charge.Blue and Green pairs on top plot, Orange and Brown pairs on bottom plot. Data are raw – vertical sensitivities have not been corrected for any differences in voltage probe gains.

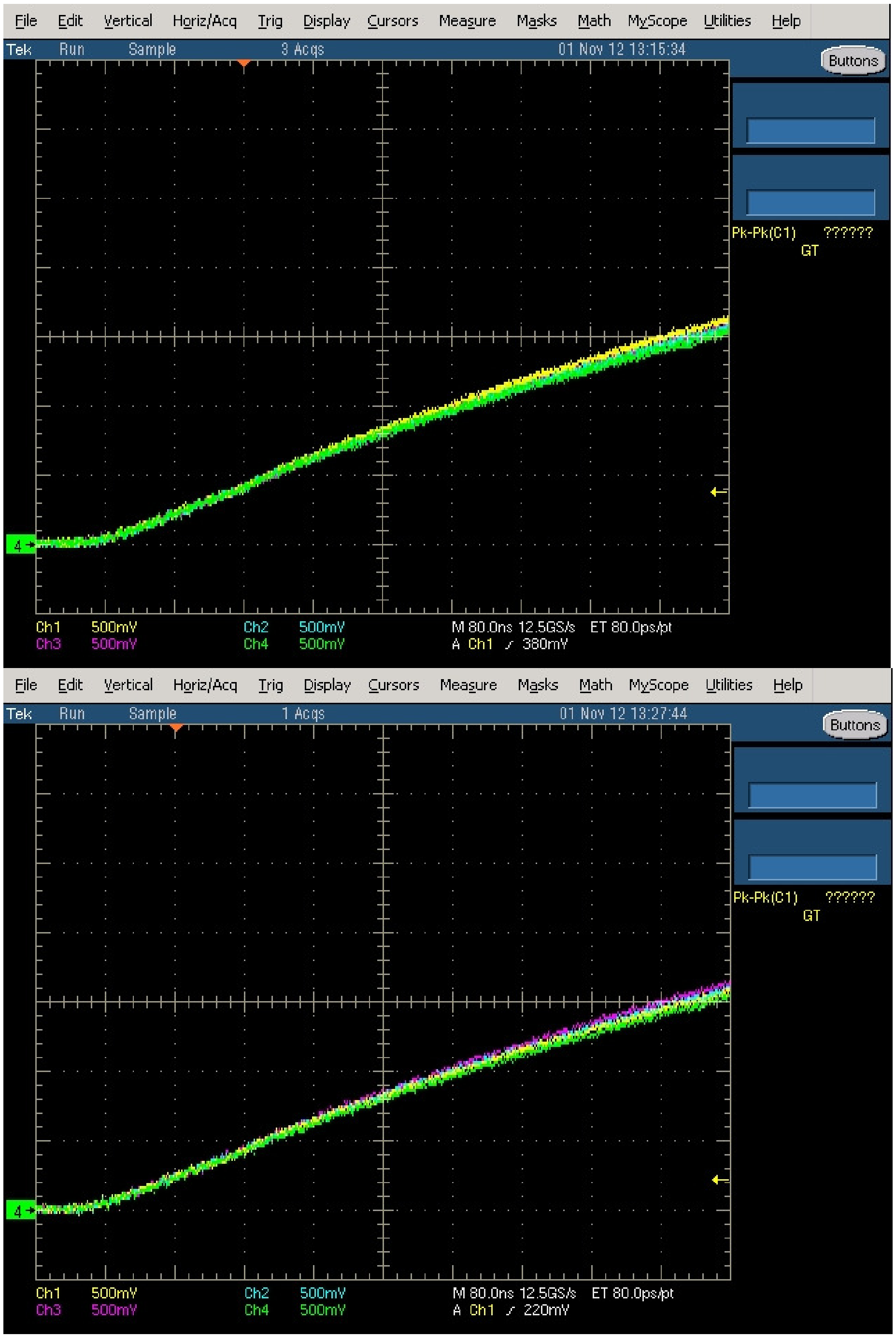

Figure 10. SCDN solid state array driven at 4000 volt charge.Blue and Green pairs on top plot, Orange and Brown pairs on bottom plot. Data are raw – vertical sensitivities have not been corrected for any differences in voltage probe gains.

Decoupling Network

The Decoupling Network isolates the surge applied at the EUT port of the SCDN from the AE port on the SCDN. This isolation maximizes the surge energy delivered to the EUT and simultaneously protects the AE from excessive voltage and/or current remnants of the surge which could damage the AE or create an upset condition that may be difficult to trace to the AE versus the EUT.

The amount of decoupling the SCDN is to provide is not specified in IEC 61000-4-5. Fischer has established a minimum of 50dB of decoupling for a wide range of EUT and AE voltage and current configurations. For example, for both the 2kV F-130814-1004-2 and the 4kV F-130814-1004-4 SCDNs, the peak common mode voltage appearing at the AE port is about 5 volts. For the maximum open circuit voltage at the EUT port of 2 and 4kV for these units, the isolation is about 52 and 58 dB respectively.

It is also important that any surge remnant that does make it to the AE port of the SCDN appears as a common mode signal, and not as a differential signal, for reasons similar to those stated above for the EUT. Fischer does not use non-linear devices to control the voltage level appearing at the AE port – if some devices fire and some do not, a differential signal will be created. Fischer relies on linear circuitry at the AE port as well as large inductive isolation to ensure a common mode signal at the AE port of the SCDN.

Data Transmission Quality Considerations

The SCDN requires physical attachment to the active telecom cable connecting the EUT and AE. By definition, any such attachment will degrade the quality of the transmitted data. The more the data quality is reduced, the lower the margin the EUT has to upset from external sources like the surge. Reduced data quality may also limit the data rate that can be applied through the SCDN, thus preventing the ability to demonstrate the ability of the EUT to recover from surge upset while operating at its highest rated data rate.

Fischer strives with all of its SCDNs to provide the highest data transmission quality. To quantify this, Fischer uses a Fluke DTX-1800 which normally is used to measure data transmission quality through a telecom cable. The Fluke measures 7 different parameters associated with data transmission quality (example: Near End Cross Talk – NEXT). The F-130814-1004-2 2kV SCDN satisfies the Category 6 Permanent Link criteria as measured with the Fluke, and the 4kV F-130814-1004-4 satisfies the Category 5e Permanent Link criteria.