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PSL-AC-CP-1102-004-04: Electrostatic Discharge Simulator Kit Model 930D and Associated Current-Viewing Resistor

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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CHANGE HISTORY

VERSION	CHANGES MADE	DATE
00	PSL.T.004.004	2/8/2018
01	First Revision	22 July 2016
02	Second Revision	11 June 2018
03	Third Revision	4 Feb. 2019
04	Added funding statement and logos for external release	6/13/2019

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1. PURPOSE, SCOPE, AND OWNERSHIP

This document provides instructions for calibrating the Electro-Tech (ETS) electrostatic discharge (ESD) simulator, Model 930D. The calibration shall meet the ± 5% specification for resistance and capacitance as specified in MIL-STD-331C 2009 newer. A series of direct measurements of the Device Under Test (DUT) output at 25 kV using a calibrated LeCroy HDO 6104 oscilloscope (or equivalent 1 MΩ input impedance storage oscilloscope) are recorded through the 500-pF capacitor, 500-Ω resistor, and a 1-Ω Current Viewing Resistor (CVR). The certified value of the DUT's 25 kV output is calculated using Ohms Law and the certified system resistance and capacitance described in this procedure. Read this document in its entirety before proceeding with the calibration.

2. REQUIRED DOCUMENTS

Before beginning the calibration procedure, ensure the most current revision of these documents are available.

- MIL-STD-331C 2009 or newer
- ETS ESD Simulator Model 930D Operating Manual
- T&M Research Products, Inc. Model SDN-100 1.0 Ω CVR Datasheet
- Pearson Model 4100 1V/A Current Viewing Transformer (CVT) Datasheet
- LeCroy HDO 6104 Oscilloscope Operating Manual
- PSL-AC-CP-1302-001: Impedance Procedure
- Excel datasheet "PSL-AC-SW-1102-004-06.xls"

3. GENERAL REQUIREMENTS

The general requirements for the calibration are given below.

3.1. Required Standards

Minimum requirements for calibration standards are included to enable the selection of substitute items. The equipment shown in the table below should be calibrated to meet a minimum of the manufacturer's specifications.

Description	Parameters	Range	Minimum Required Uncertainty (k=2)
LeCroy HDO 6104, 1 GHz Oscilloscope	Voltage Time	0 – 100 V 0 s – 1 µs	N/A* 1 ns
Agilent E4980A (1 kHz) LCR Meter	Resistance, Capacitance	1 Ω – 500 Ω 500 pF	1.0% 1.0%

*The absolute uncertainty of the voltage does not have an impact on the calibration, the timing is critical.

3.2. Other Equipment

- DUT: ESD Simulator Kit ETS Model 930D
- ETS 500-Ω resistor (provided with ESD simulator)
- ETS 500-pF capacitor (provided with ESD simulator)
- T&M Research Products, Inc. Model SDN-100 1.0 Ω CVR (Provided with ESD simulator)
- Pearson Model 4100 1V/A CVT (Provided with ESD simulator)
- 50 Ω thru termination (provided with ESD simulator)
- BNC cable for connection of CVR to oscilloscope channel 2
- BNC cable for connection of CVT to oscilloscope channel 1
- High-voltage cables provided with ESD simulator
- Lexan high voltage sheet

3.3. Safety Considerations

The instrumentation used in this procedure can produce both single and repetitive pulses up to 52 A for 1 microsecond. The system uses voltages up to 26 kV volts with energy of 0.16 Joules, which puts it in the low hazard category. As such, this process does not require an Operating Procedure or Limited Approach Boundary.

It is important to have clean, properly functioning, and properly rated connectors and cables with no surface damage, bends, breaks, or debris in and around the connector interfaces. Any of the aforementioned issues can cause arcing and other deleterious effects. Additionally, it is important to make proper connections to the 500-pF capacitor, 500 Ω resistor, and the CVR. Verify orientation and placement is correct. No calibrations or experiments should be performed without the operator present. It is highly recommended to have two people present for the setup and teardown of the calibration system.

The setup, run, and teardown processes described below are recommended.

- **Setup.** The AC power cord for the source should remain disconnected (physically) while setting up the load end of the test. After making all connections of the load (capacitor, resistor, CVR, and termination), ensure all exposed connections are covered with a high-voltage Lexan sheet. The Lexan high voltage sheet is used to prevent accidental exposure to exposed energized connections during discharge. See Figure 1 and Figure 2.
- **Run.** Plug in the ESD simulator to the AC power. Do *not* adjust the DUT or make modifications/manipulations of the test set up while the ESD simulator is powered ON. The simulator should not be left unattended while powered ON. Additionally, the unit should not be left unattended until zero volts is verified at the calibrated oscilloscope input.

- **Tear Down.** After the ESD simulator is powered down and the AC power cord removed, *then* verify zero volts at the calibrated oscilloscope input. After zero volts (< 0.1 volts) is verified, remove the high-voltage Lexan sheet and disconnect (physically) the 500-Ω resistor and the 500-pF capacitor from the ESD source prior to removing the load end of the test setup.

3.4. Prerequisites

All standards used in this procedure shall be certified for calibration use (e.g. Systeme International [SI] traceable, traceable to an intrinsic standard, or traceable to a time of test), and the calibration expiration date for each standard shall not be exceeded.

All users of this system shall be trained and authorized per Primary Standards Laboratory operations and procedures.

3.5. Measurement Precautions and Limitations

The instrumentation used in this procedure can produce pulses up to 52 A for 1 microsecond, both single and repetitive pulses.

3.6. Records

All records are stored in the AC Laboratory's Common Drive.

4. PROCEDURE

4.1. Calibration of the ETS 930D

1. Using calibration procedure PSL-AC-CP-1302-001: Impedance and a calibrated Agilent E4980 LCR meter, calibrate the following DUT components:

    a. ETS 500-pF capacitor

    b. ETS 500-Ω resistor

    c. T&M 1-Ω CVR

    d. 50-Ω termination

    NOTE: Inductance and resistance measurements should be performed at 1 V and 1 kHz using a 1-meter cable. The T&M Research CVR model SDN-100 is calibrated across the 1-Ω output.

2. Connect the provided white HV cable from the ETS 500-Ω resistor output to the T&M SDN-100 CVR center conductor.

3. Connect the provided black cable from the CVR outer conductor to the 500-pF capacitor.

4. Using a BNC cable, connect the T&M SDN-100 CVR BNC output to the calibrated 50-Ω termination at the LeCroy HDO 6104 Channel 2 input, as shown in Figure 1.

5. Using a BNC cable, connect the Pearson CVT BNC output to the LeCroy HDO 6104 Channel 1 input, as shown in Figure 1.

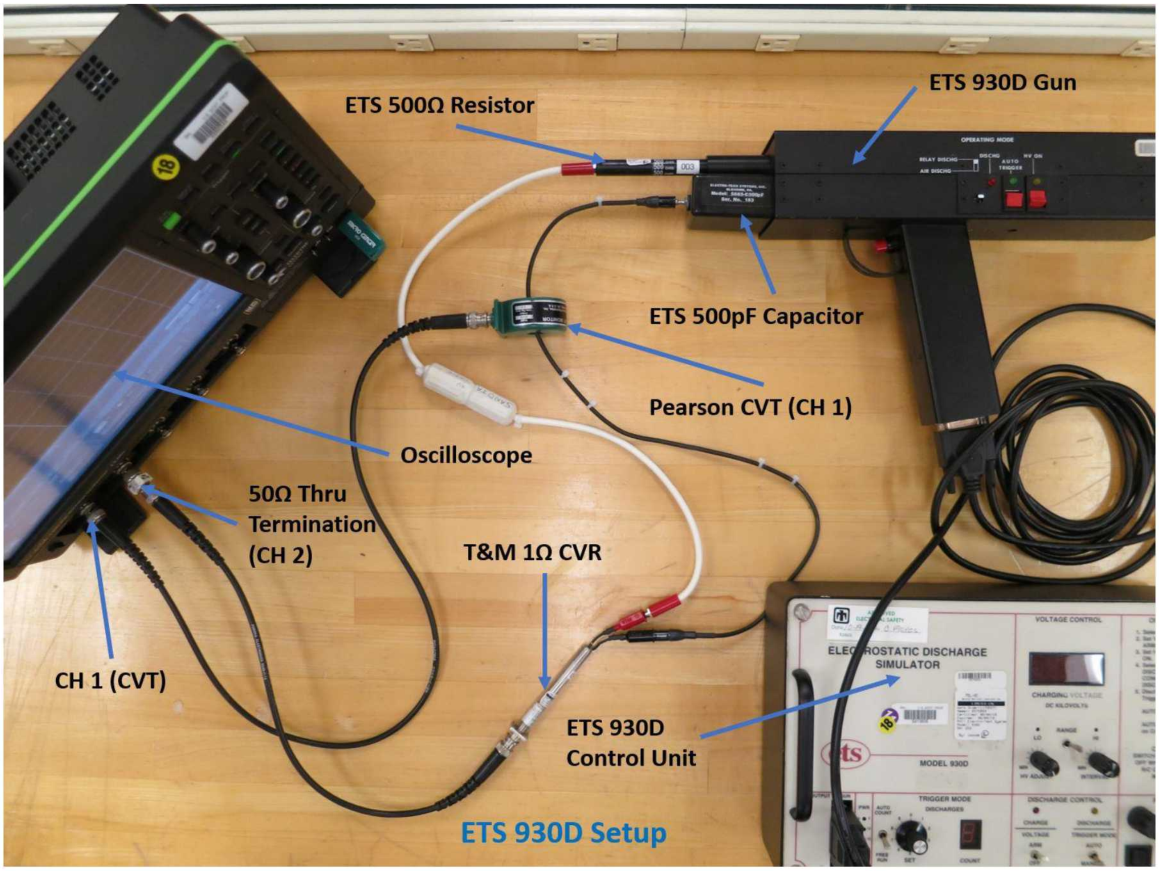


Figure 1. ETS 930D Connection Setup

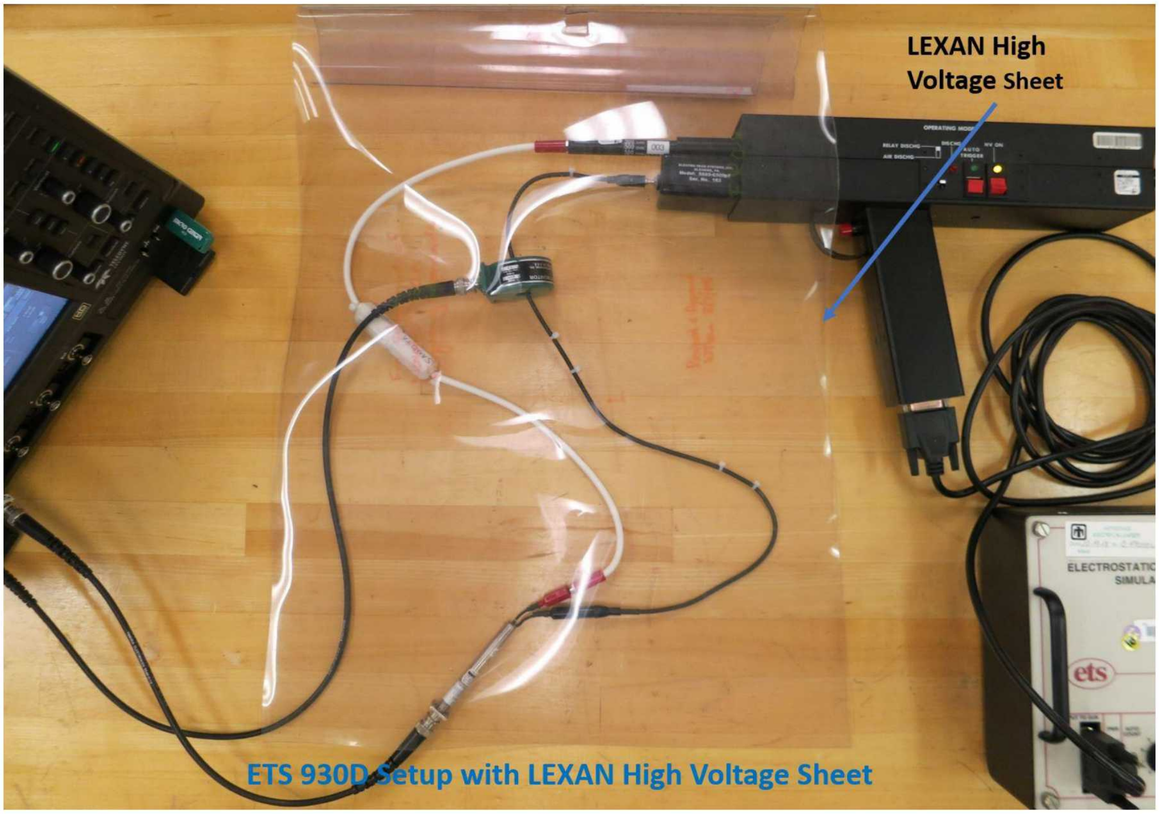


Figure 2. ETS 930D Setup with LEXAN High Voltage Sheet"

6. The AC power cord for the source should remain disconnected (physically) while setting up the load end of the test. After making all connections of the load (capacitor, resistor, CVT, CVR, and termination), ensure all exposed connections are covered with a high-voltage Lexan sheet. The Lexan high voltage sheet is used to prevent accidental exposure to exposed energized connections during discharge. See Figure 1 and Figure 2.

7. Plug the ESD simulator into the AC power outlet.

8. Turn on the ESD power supply.

9. Turn on the LeCroy HDO 6104 and set the input impedance to 1 MΩ.

10. Set the LeCroy HDO 6104 CH1 and CH2 Frequency Bandwidths to 20 MHz.

11. Set the LeCroy HDO 6104 CH1 and CH2 to 10V/Division.

12. Set the LeCroy HDO 6104 CH1 and CH2 to -30.00V Offset Reference.

13. Set the LeCroy HDO 6104 Timebase to 2.5 GS/s.

14. Set the LeCroy HDO 6104 trigger mode to Single to capture a single pulse.

15. Set trigger value ~ 2V

16. Set the HV RANGE switch on the control unit to the HI position.

17. Set the Trigger Mode switch on the control unit to the center position. This enables manual single-pulse discharge.

18. Set the Gun switch to RELAY DISCHG position.

19. Set the Gun AUTO TRIGGER switch to the OFF position.

20. Set the ESD simulator power supply voltage to 25.0 kV.

21. Set the HV ON switch on the gun to the ON position.

22. Set the Charge Voltage switch to ARM. This turns on the high voltage.

23. When ready to pulse, depress the Discharge Control Trigger Mode switch to MANUAL. This outputs a single pulse.

24. Verify that the Channel 2 CVR output is approximately equal to the Channel 1 CVT output. This is a visual verification that the system is operating correctly and should line up within 5%. See Figure 3. Store the CH1 and CH 2 combined waveform as a Microsoft® Excel file on a USB stick and name the file with the Pearson Model 4100 Serial Number, date, and pulse number. The CH1 data will be archived but not reported or used for the calibration certificate.

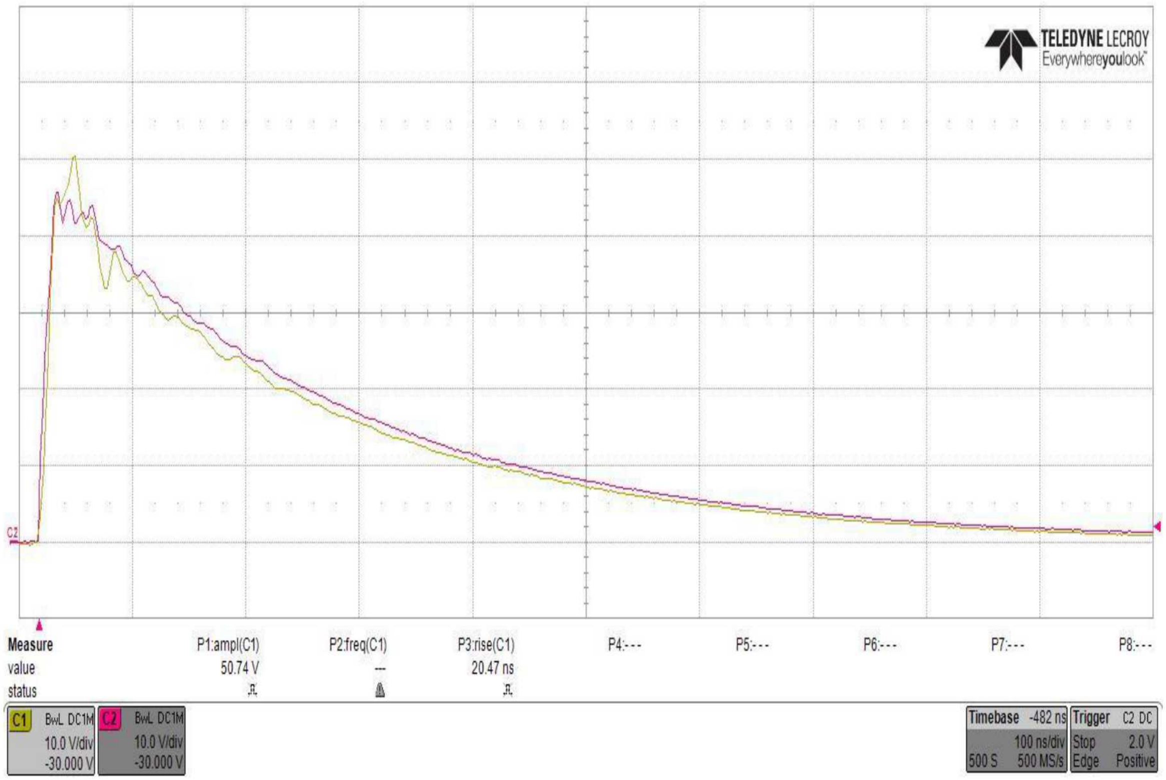


Figure 3. CVR and CVT Comparison Example

25. Collect waveforms from 10 separate CH 2 ONLY pulses, saving to a USB stick for each waveform and name the files with the Asset Number, date, and pulse number. See Figure 4.

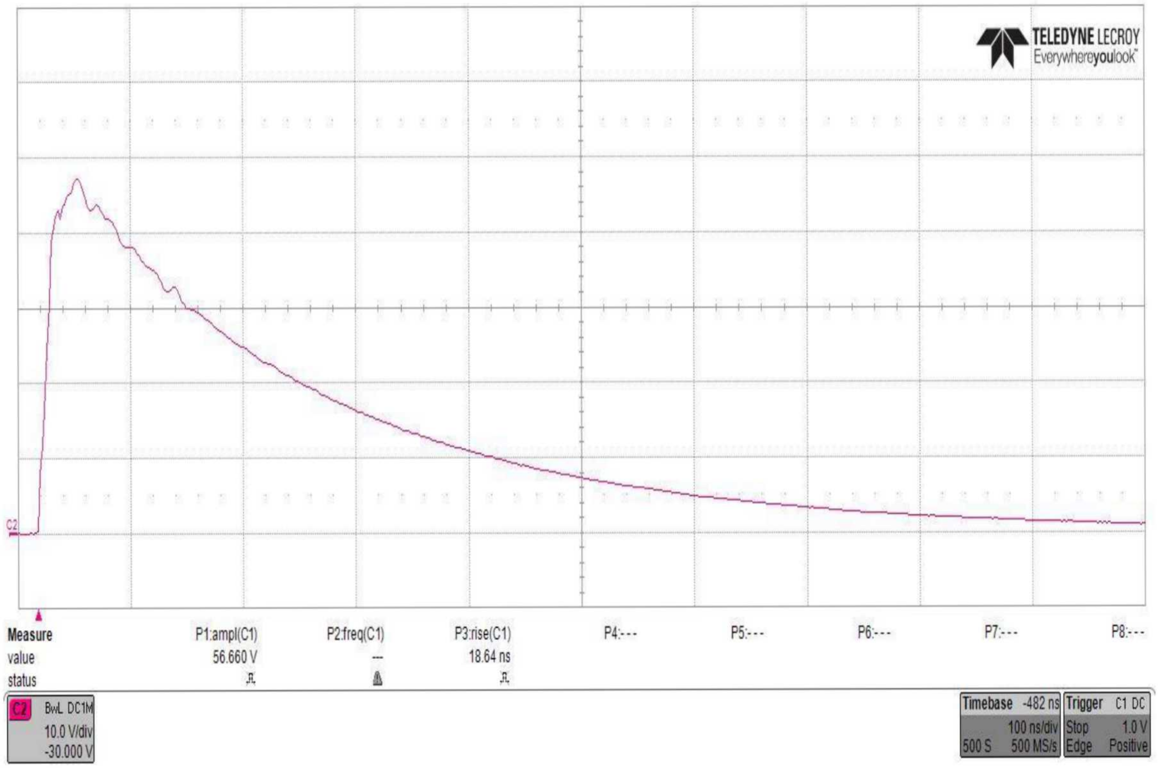


Figure 4. CVR Channel 2 Measurement Example

26. Copy and paste the LeCroy HDO 6104 data into the PSL-AC-SW-1102-004-06.xls Excel spreadsheet. Amend the name of the file to include the asset number at the start of the filename and the date at the end of the filename. This data file reports the voltage measured by the oscilloscope and must be converted to the actual voltage from the ESD Simulator output using Ohms Law. The Excel file uses the As-Found and As-Left certified values for the 500-pF capacitor, 500-Ω resistor, CVR output resistance, and the 50-Ω termination.

27. The 25-kV voltage source and 500-Ω resistor are in series. The current from this source then views the 1-Ω CVR, 50-Ω termination, and the 1-MΩ oscilloscope as parallel connections. This is then read as a voltage on the oscilloscope (V_{Scope}). Use the certified values from Step 1 in this equation. For the 1-Ω CVR, the ESD output voltage (V_{ESD}) is as follows: See Figure 5.

$$V_{ESD} = V_{Scope} * 500\Omega * \left(\frac{1}{1\Omega_{CVR}} + \frac{1}{50\Omega_{Term}} + \frac{1}{1M\Omega_{Scope}}\right)$$

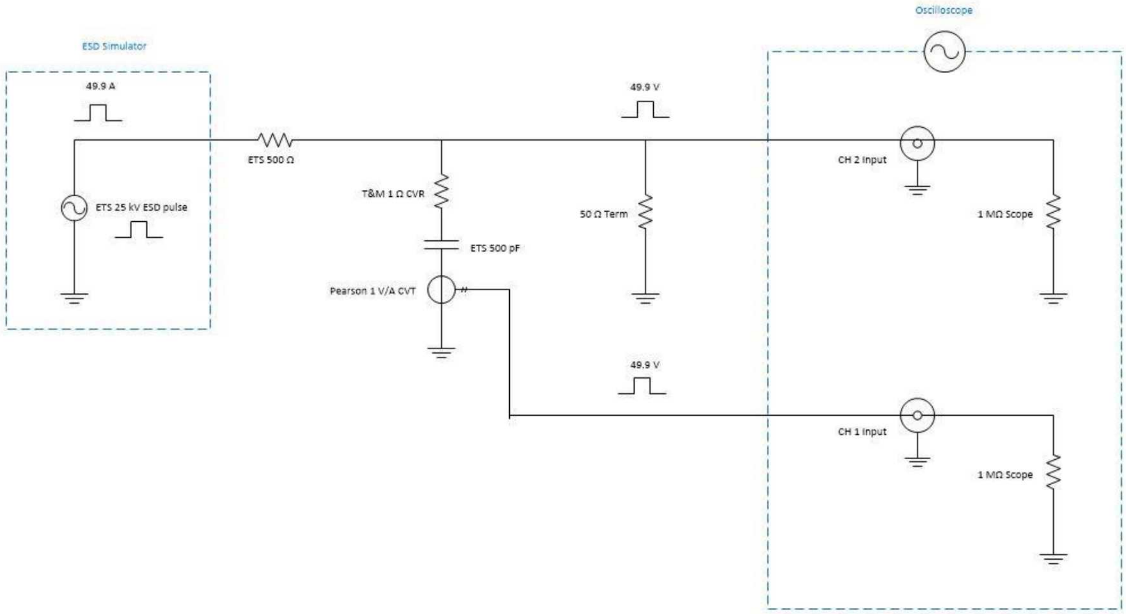


Figure 5. ETS 930D Calibration Schematic

28. Graph V_{ESD} vs. time in the PSL-AC-SW-1102-004-06.xls spreadsheet. This is now the actual voltage output from the ESD Simulator. The theoretical RC discharge curve is also calculated and displayed in the ESD Excel spreadsheet.

    NOTE: Theoretical RC discharge is based on certified values obtained from Step 1a and 1b.

29. The certified results for the ETS ESD simulator Model 930D are compared to the tolerances specified below in Section 4.2.

30. From the graph in Step 23, determine that the 10% to 90% rise time of the calibrated 25 kV pulse is < 20 ns.

31. From the graph in Step 23 determine that the difference at 9.2 kV between measured voltage and the calculated theoretical voltage is ≤ 40nS.

    NOTE: The 9.2kV is 37% of the max voltage 25kV. The 37% is the percentage of full charge of the capacitor after one full time constant in the RC circuit.

32. Complete the required steps for processing the DUT in the calibration management system, Maximo.

4.2. Tolerance Requirements

The tolerances from MIL-STD-331C APPENDIX F1.1 must be compared to the Excel spreadsheet results as follows:

- CVR resistance('s) ± 5%

- 50Ω Thru Termination ± 3%
- 500 -Ω resistor ± 5%
- 500-pF capacitor ± 5% (As-Found), 485 to 510 pF (As-Left)

  NOTE: Replace the capacitor whenever the As-Found value exceeds 485 to 510 pF. The replacement capacitor must meet the 485 to 510 pF As-Left criteria to allow for interval drift.

- The 10% to 90% rise time of the calibrated 25 kV pulse shall be < 20 ns.
- The difference at 9.2 kV between the measured voltage and the calculated theoretical voltage shall be ≤ 40 ns.
- If the certified timing measurements approach the one-sided timing tolerances within 0.5 ns, it is recommended to replace or repair the equipment. This is typically caused by a bad capacitor.

Measurement	Tolerance
T&M CVR resistance	± 5%
50-Ω Termination	± 3%
ETS 500-Ω resistor	± 5%
ETS 500-pF capacitor	± 5% (As-Found), 485 to 510 pF (As-Left)
Rise time	< 20 ns (As-Found), < 19.5 ns (As-Left)
9.2 kV difference	≤ 40 ns (As-Found), ≤ 39.5 ns (As-Left)

4.3. Calibration Summary

The tolerances stated in Section 4.2 must be met to PASS the calibration; otherwise the calibration is FAIL and an Out of Tolerance will be generated.

Initial calibrations will be issued at a six-month calibration interval. After one interval has passed, the calibration interval may be increased to up to one year. Due to wear and tear the calibration interval should not be greater than one year.

5. MEASUREMENT UNCERTAINTY

Tolerance testing shall meet the ± 5% specification as specified in MIL-STD-331C for resistance and capacitance. All calibration standards used during the calibration shall meet ≥ 4:1 accuracy; otherwise, guardbanding shall be used. The following is the Test Uncertainty Ratio (TUR) for the standards used in this calibration:

If other standards are used for this calibration, it is important to reevaluate the TURs and guardbanding calculations.

Measurement	Uncertainty (k=2)	Certified Tolerance	TUR (approx.)
ETS 500Ω Resistance	0.1%	± 5%	50

Measurement	Uncertainty (k=2)	Certified Tolerance	TUR (approx.)
50 -Ω Termination	0.1%	± 3%	50
T&M 1-Ω CVR Resistance	0.3%	± 5%	10
500-pF Capacitance	0.2% 0.2%	± 5% As-Found ≈ ± 3% As-Left	25 15
Time	~3.5 µs/s	< 20 ns ≤ 40 ns	N/A, Guardband by 0.14 ps

6. REFERENCES

6.1. Draft Calibration Certificate

6.1.1. Impedance Measurements

500-Ω resistor S/N 003

This T&M Research 500- Ω resistor S/N 003. The + and – Limits stated below are requirements specified in MIL-STD-331C APPENDIX F1.1.

Frequency	Resistance (ohms)	- Limit	+ Limit
1 kHz	496.8	475 ohms	525 ohms

500pF capacitor S/N 183

500-pF capacitor S/N 150 was replaced with 500 pF capacitor S/N 176. The + and – Limits stated below are requirements specified in MIL-STD-331C APPENDIX F1.1.

Frequency	Capacitance (pF)	- Limit	+ Limit
1 kHz	501.4	475 pF	525 pF

SDN-100 CVR S/N 001

T&M Research SDN-100 current viewing resistor S/N 001. The + and – Limits stated below are requirements specified in MIL-STD-331C APPENDIX F.

Frequency	Resistance (ohms)	- Limit	+ Limit
1 kHz	1.015	0.95 ohms	1.05 ohms

50-Ω Termination S/N 001

Pomona 4119 50-Ω Termination S/N 001. The + and – Limits stated below are requirements specified in MIL-STD-331C APPENDIX F1.1.

Frequency	Resistance (ohms)	- Limit	+ Limit
1 kHz	49.7	47.5 ohms	52.5 ohms

The certification tolerance has been certified with a TUR greater than 4:1. Traceability to the SI is through the calibration of the LCR Meter.

6.1.2. Pulsed Measurement Results

The rise time and decay time of this device were verified using a calibrated 50-Ω terminator, 500-pF capacitor S/N 176, 500- Ω resistor S/N 003, Lecroy HD6104 oscilloscope, and a 1- Ω CVR S/N 001 provided by the customer. The ESD simulator output display was set to 25 kV.

The calculated rise time from 10% to 90% was measured to be < 20 ns.

Measured value = 12 ns.

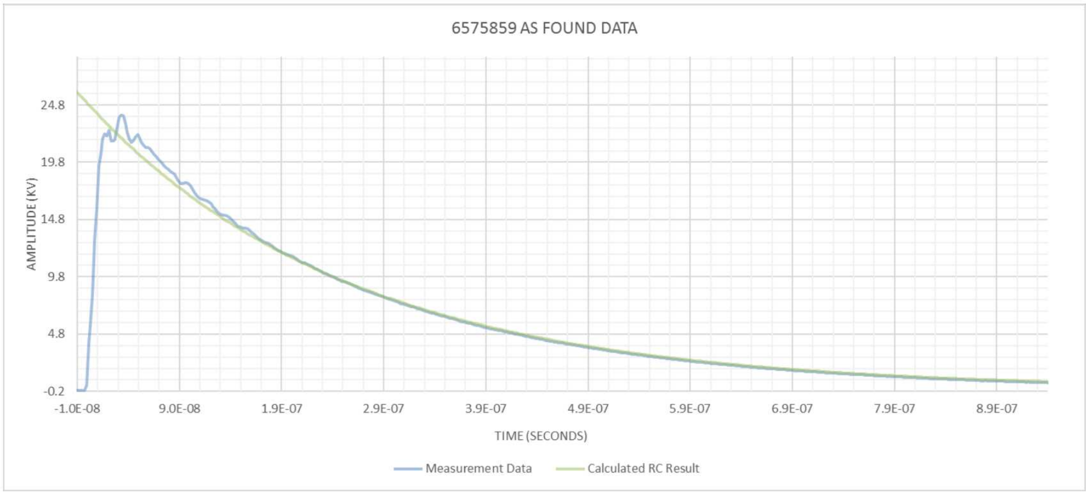
9.2 kV difference between measured values and predicted RC time constant was measured to be < 40 ns.

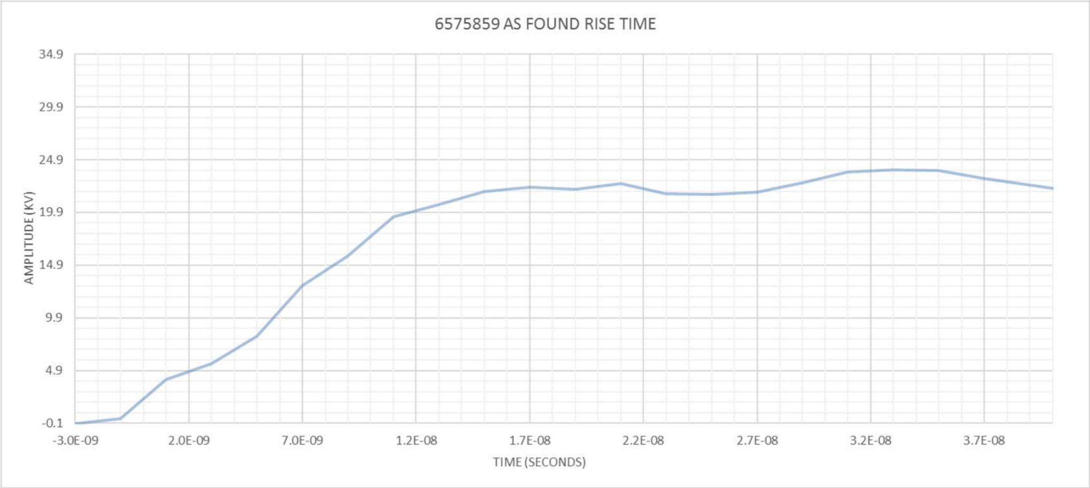
Measured value = 1 ns.

Average waveform from 10 measurements:

Blue = Measured data

Green = Predicted RC time constant from measured 1 kHz values




6575859 AS FOUND RISE TIME
AMPLITUDE (KV)
34.9
29.9
24.9
19.9
14.9
9.9
4.9
-0.1
-3.0E-09
2.0E-09
7.0E-09
1.2E-08
1.7E-08
2.2E-08
2.7E-08
3.2E-08
3.7E-08
TIME (SECONDS)


6575859 AS FOUND 9.2 kV DIFFERENCE
AMPLITUDE (KV)
9.5
9.45
9.4
9.35
9.3
9.25
9.2
9.15
9.1
9.05
9
2.50E-07
2.52E-07
2.54E-07
2.56E-07
2.58E-07
2.60E-07
2.62E-07
2.64E-07
TIME (SECONDS)
Series1
Series3