EMC Testing of the

Data Panel Corp.
40044-1

In accordance with:
ISO 13766-1:2018
ISO 13766-2:2018

America

Add value.
Inspire trust.

Prepared for: Data Panel Corp.
181 Cheshire Lane, Suite 300
Plymouth, MN 55441

COMMERCIAL-IN-CONFIDENCE

Document Number: NC721000515.1 | Issue: 1

SIGNATURE			
NAME	**JOB TITLE**	**RESPONSIBLE FOR**	**ISSUE DATE**
Brad A Reasoner	EMC Technical Lead	**Authorized Signatory**	5 June 2024

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD America, Inc. document control rules.

EXECUTIVE SUMMARY
A sample of this product was tested and found to be compliant with the standards listed above.

A2LA Cert. No. 2955.11

ACCREDITATION
Our A2LA Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our A2LA Accreditation.

TÜV SÜD America Inc
141 14th Street NW
New Brighton, MN 55112

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Contents

1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Table 1.1-1 – Modification Record

Issue	Description of Change	Date of Issue
1	First Issue	4 June 2024

1.2 Introduction

Applicant	Tony Otis
Manufacturer	Data Panel
Applicant's Email Address	totis@datapanel.com
Model Number(s)	40044-1
Serial Number(s)	DP-40044-01-000
Number of Samples Tested	1
Test Specification/Issue/Date	ISO 13766-1:2018 ISO 13766-2:2018
Order Number	721000515
Date of Receipt of EUT	15 May 2024
Start of Test	15 May 2024
Finish of Test	30 May 2024
Related Document(s)	N/A

1.3 Summary of Tests & Results

A summary of the tests carried out in accordance with the specifications shown below.

Table 1.3-1 – Summary of Tests

Report Section	Specification Clause		Test Description	Accreditation	Comments/Base Standard
	ISO 13766-1	ISO 13766-2			
2.1	4.5 & 4.6	N/A	Radiated Emissions	A2LA	CISPR 25
2.2	4.7	5.3.1	Radiated Immunity	A2LA	ISO 11451-2
2.2	4.7	5.3.1	Bulk Current Injection (BCI)	A2LA	ISO 11452-4
2.3	4.8	5.3.4	Electrostatic Discharge	A2LA	ISO 10605
2.4	4.9	5.3.3	Conducted Transients – Power Lines	A2LA	ISO 7637-2
2.5	n/a	5.3.3	Conducted Transients – Non-Power Lines – Fast	A2LA	ISO 7637-3
2.6	n/a	5.3.3	Conducted Transients – Non-Power Lines – Slow	A2LA	ISO 7637-3
2.7	4.9.3	5.3.3	Conducted Transient Emissions	A2LA	ISO 7637-2

Table 1.3-2 – Summary of Results

Test Name	Name of Tester(s)	Result
Radiated Emissions	Diego Reyes	Pass
ESA RF Immunity	Diego Reyes	Pass
Electrostatic Discharge	Diego Reyes	Pass
Conducted Transients – Power Lines	Diego Reyes	Pass
Conducted Transients – Non-Power Lines – Fast	Diego Reyes	Pass
Conducted Transients – Non-Power Lines – Slow	Diego Reyes	Pass
Conducted Transient Emissions	Diego Reyes	Pass

1.4 Product Information

1.4.1 Technical Description

The Equipment Under Test (EUT) was a CAN BUS Module.

A full description and detailed product specification details are available from the manufacturer.

Photo 1.4-1 – Front View of the EUT

Table 1.4-1 – Cable Descriptions

Cable/Port	Description
Harness	Main power Lines

Table 1.4-2 – Support Equipment Descriptions

Make/Model	Description
--	CAN Communication
--	Resistance Bank
--	Resistance connection
Rigol / DL3031A	Resistance Bank with switch
BK Precision / 1900B	Power Supply

1.4.2 Modes of Operation

The tested mode of operation was Regular operation.

1.5 Deviations from the Standard

No deviations from the applicable test standard were made during testing.

1.6 EUT Modification Record

The table below details modifications made to the EUT during the test program. The modifications incorporated during each test are recorded on the appropriate test pages.

Table 1.6-1 – Modification Record

Modification State	Description of Modification still fitted to EUT	Modification Fitted By	Date Modification Fitted
0	Initial State		

1.7 Test Location

TÜV SÜD conducted the following tests at our New Brighton, MN Test Laboratory.

Office address:

TÜV SÜD America
141 14th Street NW
New Brighton, MN 55112 USA

2 Test Details

Functional status	Description
A	All functions of a device/system perform as designed during and after exposure to a disturbance.
B	All functions of a device/system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain criterion A.
C	One or more functions of a device/system do not perform as designed during exposure but returns automatically to normal operation after exposure is removed.
D	One or more functions of a device/system do not perform as designed during exposure and does not return to normal operation until exposure is removed and the device/system is reset by simple "operator/use" action.
E	One or more functions of a device/system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device/system.

2.1 Radiated Emissions

2.1.1 Specification Reference

CISPR 25 per ISO 13766-1

2.1.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.1.3 Test Voltage

15 VDC

2.1.4 Date of Test

15 May 2024

2.1.5 Test Method

The EUT was setup in a semi-anechoic chamber and laid on a non-conductive support 5cm above a copper ground plane table with a height of 90cm (± 10cm). The EUT was placed 20cm from the front edge of the ground plane while the stretched-out cable bundle was 10cm from the front edge. Each measurement antenna had a height of 10cm above the ground plane table and a measurement distance of 1m from the front edge of the routed cabling. For the frequency range of 30-1000 MHz, the antenna was centered on the test setup and focused on the cable bundle.

The EUT emission profile was made using a measurement receiver that utilized a peak and average detector for the required frequency ranges. The peak and average data collected was compared to the applicable peak and average test limits via software to determine pass or fail conditions. In the event a Quasi-Peak measurement was required, the test software would identify those frequencies and a subsequent Quasi-Peak measurement would be made. The test measurements were made in both horizontal and vertical antenna orientation for all frequencies above 30 MHz.

2.1.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.1.7 Additional Observations

Measurements up to 1 GHz were done using BAT-EMC (v2022.0.27) automated software. Reported level is the actual level with all the correction factors factored in. Correction Factor column is for informational purposes only. See Section 2.1.8 for sample computation.

2.1.8 Sample Computation (Radiated Emissions)

Measuring equipment raw measurement (dBµV) @ 30 MHz			20.0
Correction Factor (dB/m)	Cable 1	0.24	18.94
	Antenna	18.70	
	Preamp	-26.00	
Reported Quasi-Peak Final Measurement (dBµV/m) @ 30 MHz			12.94

2.1.9 Test Results

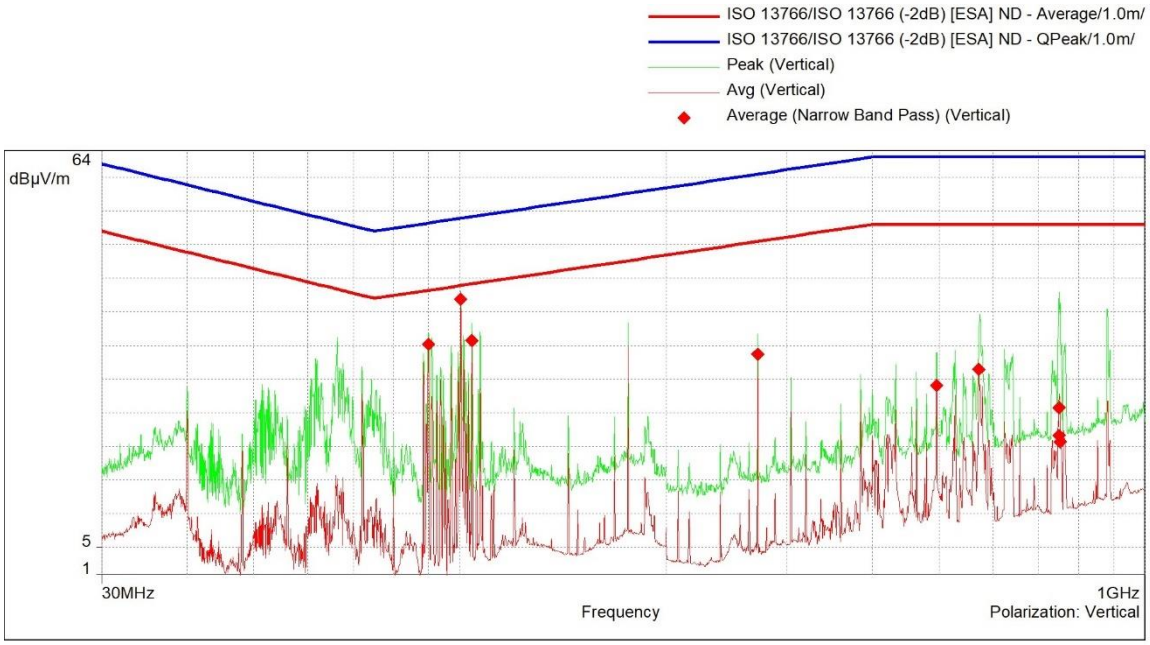
Test Summary: EUT operated as intended before, during, and after testing.

Test Result: Pass

Detailed results are shown below.

Ambient - Vertical

Frequency Range	Antenna Distance	Antenna Height	Antenna Polarization	RBW	Step Size	Sweep Time
30MHz- 200MHz	1m	1m	Vertical	120kHz	50kHz	5 ms/Step
200MHz- 1GHz	1m	1m	Vertical	120kHz	50kHz	5 ms/Step



Limit:	Class	EUT Orientation:	Test Results:
ISO 13766 (-2dB) [ESA]	ND	Front	n/a

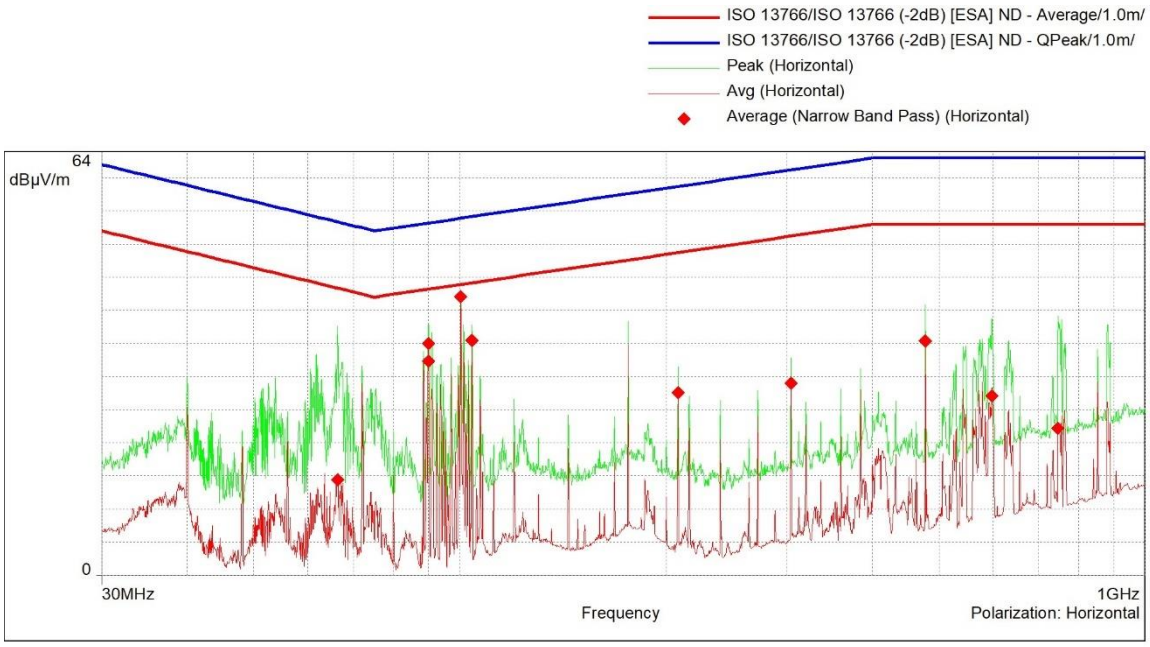
Figure 2.1-1 – Graphical Results for 30 MHz-1 GHz – Vertical Ambient Measurement

Table 2.1-1 – Data Table for 30 MHz-1 GHz – Vertical Ambient Measurement

Frequency	Peak (dBuV/m)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dB)	QPeak Limit (dBuV/m)	Peak-Avg Delta	Results
89.9MHz	36.80	35.18	43.19	-8.01	53.19	1.62	Pass
100.3MHz	43.09	41.86	43.91	-2.05	53.91	1.22	Pass
104.1MHz	38.35	35.74	44.15	-8.41	54.15	2.61	Pass
272MHz	36.79	33.70	50.47	-16.77	60.47	3.09	Pass
496MHz	34.02	29.13	53.00	-23.87	63.00	4.89	Pass
572.3MHz	37.75	31.48	53.00	-21.52	63.00	6.27	Pass
748.1MHz	40.68	21.67	53.00	-31.33	63.00	19.01	Pass
749.05MHz	42.91	25.73	53.00	-27.27	63.00	17.18	Pass
751.05MHz	41.37	20.67	53.00	-32.33	63.00	20.71	Pass

Ambient - Horizontal

Frequency Range	Antenna Distance	Antenna Height	Antenna Polarization	RBW	Step Size	Sweep Time
30MHz- 200MHz	1m	1m	Horizontal	120kHz	50kHz	5 ms/Step
200MHz- 1GHz	1m	1m	Horizontal	120kHz	50kHz	5 ms/Step



Limit:	Class	EUT Orientation:	Test Results:
ISO 13766 (-2dB) [ESA]	ND	Front	n/a

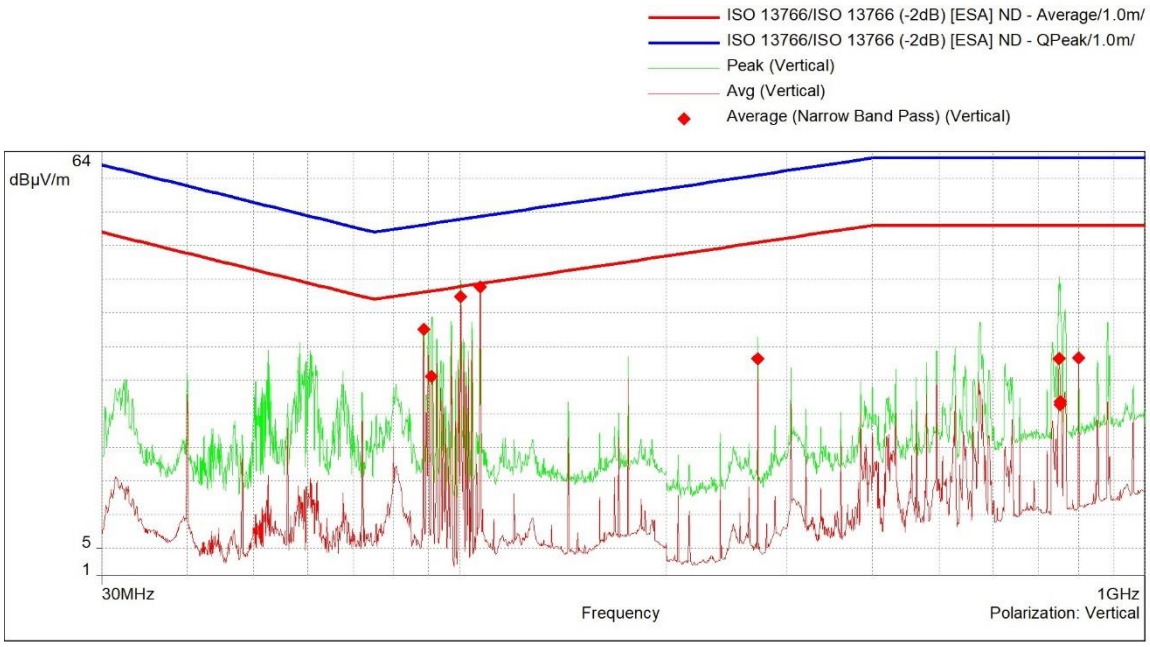
Figure 2.1-2 – Graphical Results for 30 MHz-1 GHz – Horizontal Ambient Measurement

Table 2.1-2 – Data Table for 30 MHz-1 GHz – Horizontal Ambient Measurement

Frequency	Peak (dBuV/m)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dB)	QPeak Limit (dBuV/m)	Peak-Avg Delta	Results
66.3MHz	37.61	14.40	43.35	-28.95	53.35	23.21	Pass
89.9MHz	36.48	35.04	43.19	-8.15	53.19	1.44	Pass
89.95MHz	37.84	32.35	43.19	-10.84	53.19	5.49	Pass
100.3MHz	42.72	42.07	43.91	-1.84	53.91	0.65	Pass
104.1MHz	37.90	35.49	44.15	-8.66	54.15	2.41	Pass
208MHz	31.44	27.58	48.70	-21.12	58.70	3.86	Pass
304MHz	32.78	28.97	51.20	-22.23	61.20	3.81	Pass
478.05MHz	40.82	35.37	53.00	-17.63	63.00	5.45	Pass
597.8MHz	38.74	27.10	53.00	-25.90	63.00	11.64	Pass
746.35MHz	39.21	22.26	53.00	-30.74	63.00	16.96	Pass

Unit 40044-1 - Vertical

Frequency Range	Antenna Distance	Antenna Height	Antenna Polarization	RBW	Step Size	Sweep Time
30MHz- 200MHz	1m	1m	Vertical	120kHz	50kHz	5 ms/Step
200MHz- 1GHz	1m	1m	Vertical	120kHz	50kHz	5 ms/Step



Limit:	Class	EUT Orientation:	Test Results:
ISO 13766 (-2dB) [ESA]	ND	Front	Pass

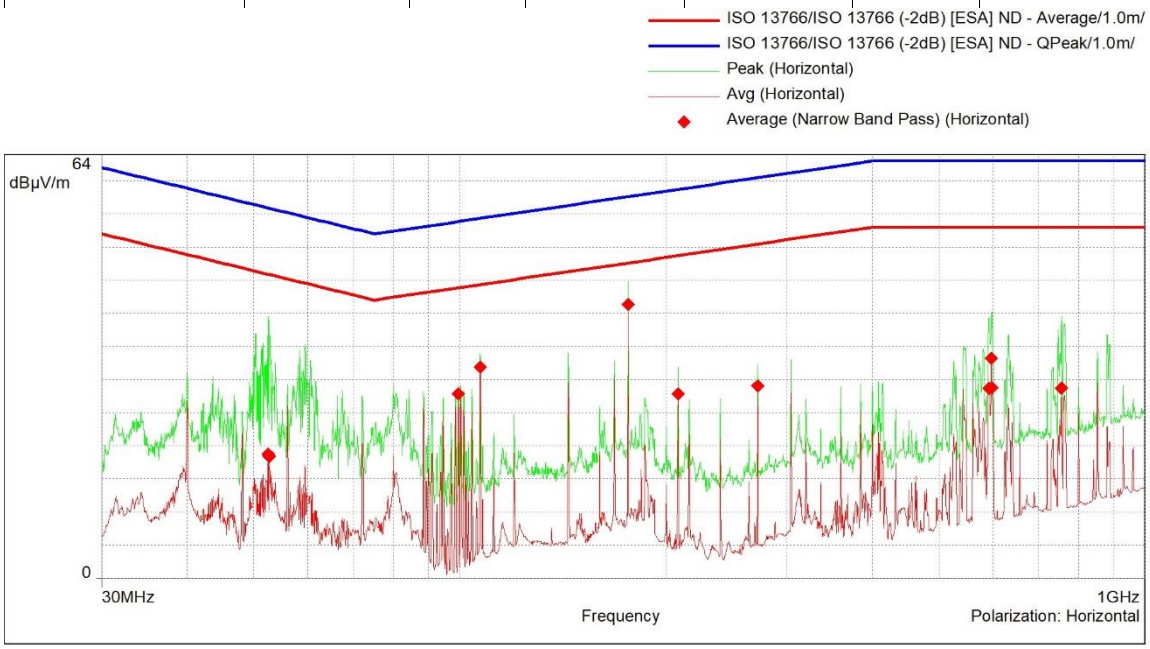
Figure 2.1-3 – Graphical Results for 30 MHz-1 GHz – Vertical Operational Measurement

Table 2.1-3 – Data Table for 30 MHz-1 GHz – Vertical Operational Measurement

Frequency	Peak (dBuV/m)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dB)	QPeak Limit (dBuV/m)	Peak-Avg Delta	Results
88.5MHz	38.40	37.60	43.09	-5.48	53.09	0.79	Pass
90.95MHz	39.44	30.54	43.27	-12.73	53.27	8.91	Pass
100.3MHz	44.81	42.38	43.91	-1.53	53.91	2.43	Pass
107.1MHz	44.42	43.92	44.34	-0.43	54.34	0.51	Pass
272MHz	36.47	33.23	50.47	-17.24	60.47	3.24	Pass
748.6MHz	45.39	33.20	53.00	-19.80	63.00	12.19	Pass
751.1MHz	44.38	26.36	53.00	-26.64	63.00	18.02	Pass
751.55MHz	43.91	26.78	53.00	-26.22	63.00	17.14	Pass
800MHz	34.90	33.25	53.00	-19.75	63.00	1.65	Pass

Unit 40044-1 - Horizontal

Frequency Range	Antenna Distance	Antenna Height	Antenna Polarization	RBW	Step Size	Sweep Time
30MHz- 200MHz	1m	1m	Horizontal	120kHz	50kHz	5 ms/Step
200MHz- 1GHz	1m	1m	Horizontal	120kHz	50kHz	5 ms/Step



Limit:	Class	EUT Orientation:	Test Results:
ISO 13766 (-2dB) [ESA]	ND	Front	Pass

Figure 2.1-4 – Graphical Results for 30 MHz-1 GHz – Horizontal Operational Measurement

Table 2.1-4 – Data Table for 30 MHz-1 GHz – Horizontal Operational Measurement

Frequency	Peak (dBuV/m)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dB)	QPeak Limit (dBuV/m)	Peak-Avg Delta	Results
52.45MHz	39.56	18.78	45.90	-27.12	55.90	20.78	Pass
52.65MHz	38.96	18.44	45.86	-27.43	55.86	20.52	Pass
99.5MHz	29.10	27.81	43.86	-16.05	53.86	1.30	Pass
107.1MHz	33.32	31.93	44.34	-12.42	54.34	1.39	Pass
176MHz	44.78	41.32	47.61	-6.28	57.61	3.46	Pass
208MHz	31.79	27.85	48.70	-20.86	58.70	3.95	Pass
272MHz	32.31	29.08	50.47	-21.38	60.47	3.22	Pass
592.05MHz	39.36	28.68	53.00	-24.32	63.00	10.68	Pass
596.3MHz	39.76	33.30	53.00	-19.70	63.00	6.46	Pass
597.65MHz	40.24	28.83	53.00	-24.17	63.00	11.41	Pass
755.15MHz	39.68	28.73	53.00	-24.27	63.00	10.95	Pass

2.1.10 Radiated Emissions Test Setup Photos

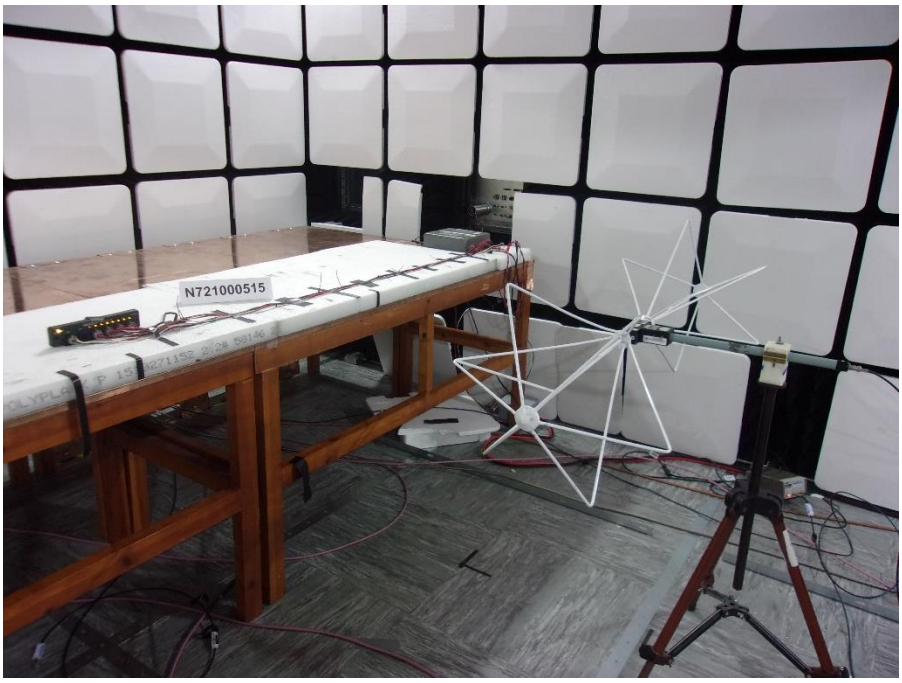


Photo 2.1-1 – 30-200 MHz Test Setup

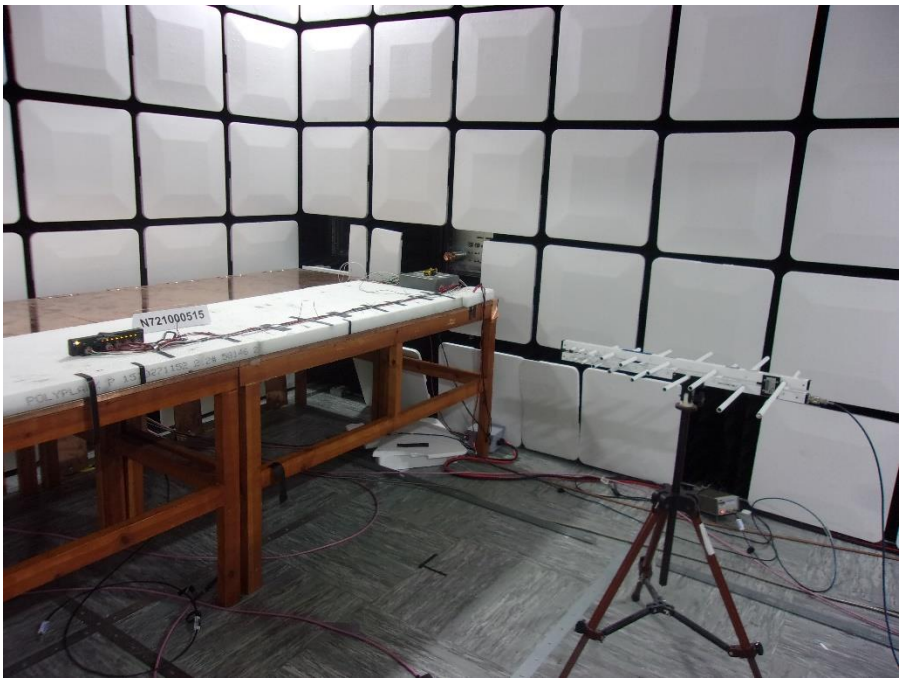


Photo 2.1-2 – 200-1000 MHz Test Setup

2.1.11 Test Location and Test Equipment Used

The tests were carried out in New Brighton, MN.
Test Area: SAC2

Table 2.1-5 – Radiated Emissions Equipment List

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE02324	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379517	G	02/08/2024	02/08/2025
NBLE02327	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379522	G	02/08/2024	02/08/2025
NBLE02667	Hewlett-Packard	Preamplifier, 0.1-1300 MHz	8447D	1616A00688	B	01/12/2024	01/12/2025
NBLE03346	Electro-metrics	Antenna, Bicon 20-300 MHz	6912	635	G	06/12/2023	06/12/2025
NBLE03348	Electro-metrics	Antenna, Log Per. 200 MHz-1 GHz	EM-6950	724	G	02/13/2023	02/13/2025
NBLE11501	Ametek CTS Europe GmbH	Power Supply	XHR33-33	1725A02286	Y	N/A	N/A
NBLE11810	Rohde & Schwarz	Signal Analyzer, 2 Hz-43 GHz	FSW43	102394	G	08/18/2023	08/18/2024

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.2 ESA RF Immunity

2.2.1 Specification Reference

ISO 11452-2 per ISO 13766-1 and ISO 13766-2

2.2.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.2.3 Test Voltage

15 VDC

2.2.4 Date of Test

15 & 16 May 2024

2.2.5 Test Method

Radiated Immunity Method – The EUT was setup in a semi-anechoic chamber and laid on a non-conductive support 5cm above a copper ground plane table with a height of 90cm (±10cm). The EUT was placed 20cm from the front edge of the ground plane while the stretched-out cable bundle was 10cm from the front edge. Each transmit antenna had a height of 10cm above the ground plane table and a measurement distance of 1m from the front edge of the routed cabling. For the frequency range of 200-1000 MHz the antenna was centered on the test setup and focused on the cable bundle, while for frequencies above 1 GHz a horn antenna was centered on the EUT enclosure.

Prior to testing each applicable frequency range, a field strength calibration was performed for both vertical and horizontal antenna orientations. During the calibration an isotropic field probe was placed within the antenna beamwidth and the RF field was increased until the required field strength was measured. Once the required field strength was measured the forward power was recorded for test playback. This procedure was performed each frequency step within the required frequency range.

Bulk Current Injection Method – The EUT was setup in a semi-anechoic chamber and laid on a non-conductive support 5cm above a copper ground plane table with a height of 90cm (±10cm). The EUT was placed ≥10cm from the front edge of the ground plane while the stretched-out cable bundle was ≥20cm from the front edge. The injection probe was placed 150mm, 450mm, and 750mm from the connector of the EUT. The frequency range tested is 1-200 MHz using the substitution method.

Prior to testing a calibration is performed using the test setup as described in ISO 11452-4. At each frequency to be tested, the induced current is increased to 60 mA, at which point the forward power is recorded.

All Testing – During testing each frequency step was increased in amplitude until the calibrated forward power is reached. Once the forward power is reached the frequency is set to dwell at that RF amplitude for a minimum of 2sec. See Table 2.3-3 for exact step sizes, dwell times, and modulations used during testing.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.2.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.2.7 Test Results

Table 2.2-1 – Requirements – ISO 13766-2

Frequency Range (MHz)	Level	Modulation	Step Size (%)	Dwell (sec)	Performance Criteria
1 to 200	100 mA	AM (80%,1 kHz, Sine Wave)	5	2	A
200 to 400	100 V/m	AM (80%,1 kHz, Sine Wave)	5	2	A
400 to 800	100 V/m	AM (80%,1 kHz, Sine Wave)	2	2	A
800 to 1000	100 V/m	PM (577/4600µs)	2	2	A
2000 to 2400	10 V/m	PM (577/4600µs)	2	2	A
2400 to 2700	5 V/m	PM (577/4600µs)	2	2	A
Supplementary information: Must degrade from criteria A in a safe manner.					

Table 2.2-2 – Observations During Testing

Testing to highest levels of all required standards							Performance Criteria Met
Frequency Range (MHz)	Level	Modulation	Antenna/Probe Distance	Step Size (%)	Dwell (sec)	EUT Side	
1 to 200	100 mA	AM (80%,1 kHz, Sine Wave)	150, 450, & 750mm	5	2	Front	A
200 to 400	100 V/m	AM (80%,1 kHz, Sine Wave)	1m	5	2	Front	A
400 to 1000	100 V/m	AM (80%,1 kHz, Sine Wave)	1m	2	2	Front	A
800 to 1000	100 V/m	PM (577/4600µs)	1m	2	2	Front	A
1000 to 2000	30 V/m	PM (577/4600µs)	1m	2	2	Front	A
2000-2400	10 V/m	PM (577/4600µs)	1m	2	2	Front	A
2400-2700	5 V/m	PM (577/4600µs)	1m	2	2	Front	A
Note: The test was performed for both vertical and horizontal antenna polarizations for all frequency ranges.							

Test Summary: The EUT was tested in both horizontal and vertical antenna polarizations per the tables referenced above. The EUT continued to operate as intended during and after the test.

Test Result: Pass

2.2.8 ESA RF Immunity Test Setup Photos

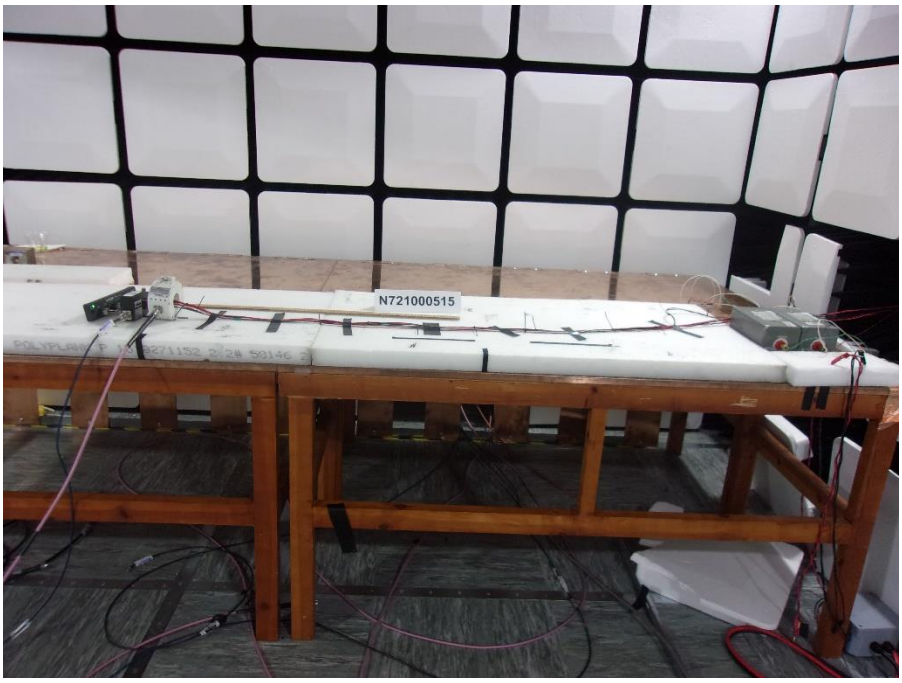


Photo 2.2-1 – ESA RF Immunity Test Setup – BCI 15 CM

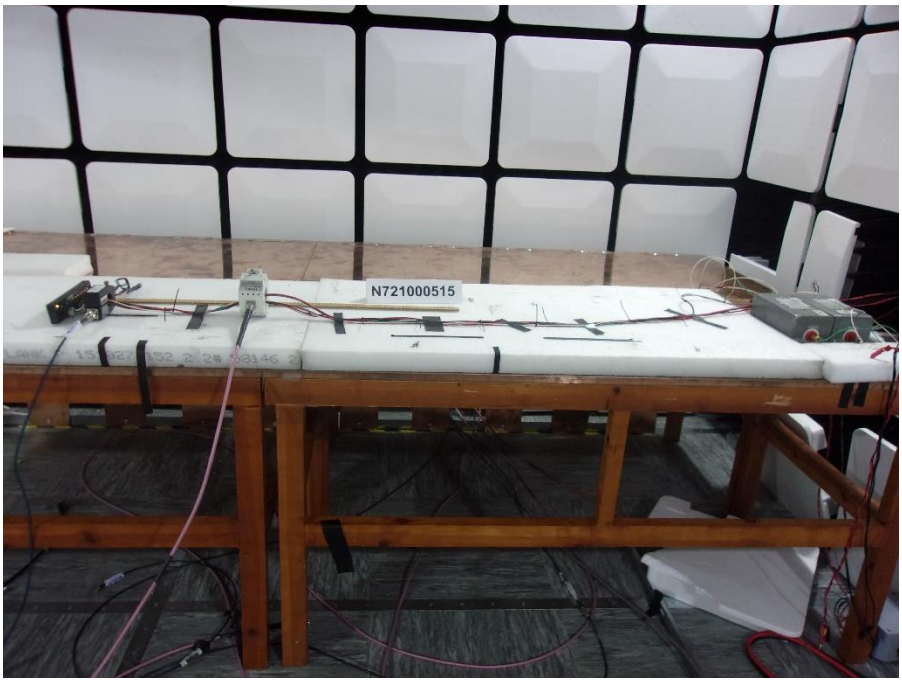


Photo 2.2-2 – ESA RF Immunity Test Setup – BCI 45 CM

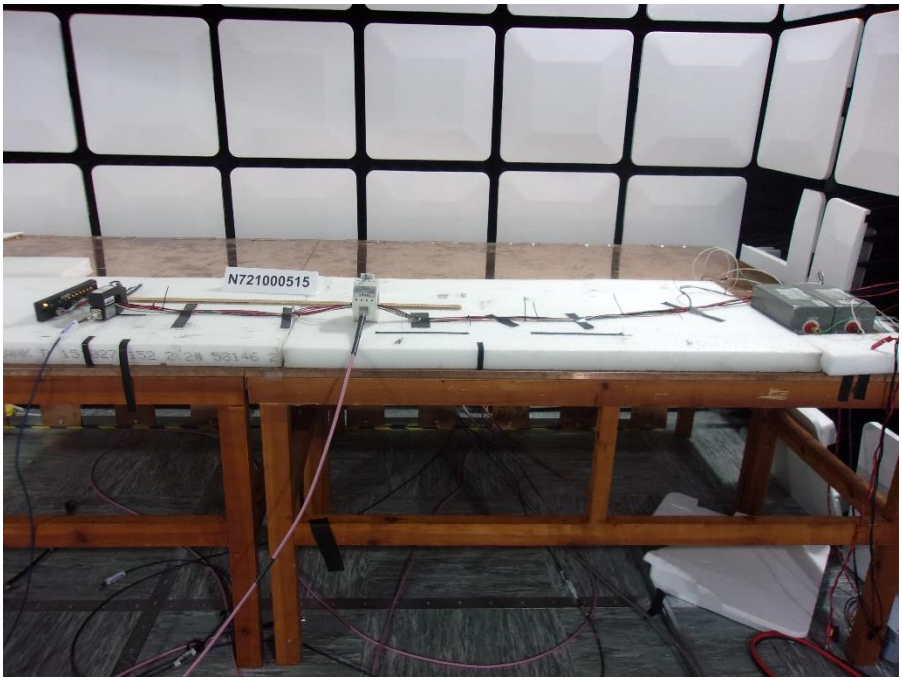


Photo 2.2-3 – ESA RF Immunity Test Setup – BCI 75 CM

Photo 2.2-4 – ESA RF Immunity Test Setup – Radiated – 200-1000 MHz

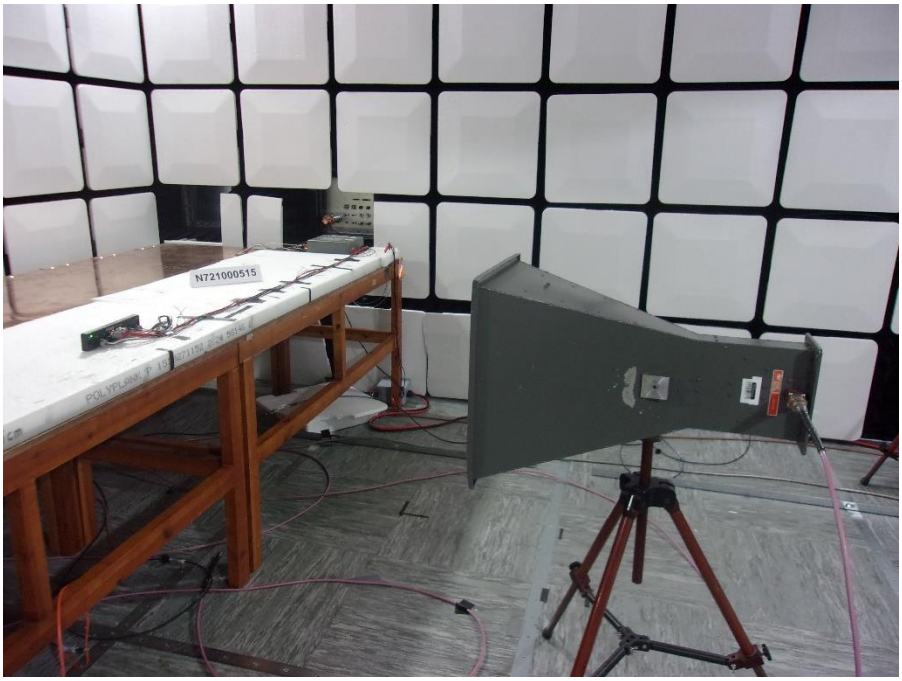


Photo 2.2-5 – ESA RF Immunity Test Setup – Radiated – 1000-2700 MHz

2.2.9 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: SAC2

Table 2.2-3 – ESA RF Immunity Equipment List – BCI

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE02055	Bird	50 Ohm Load, Coax	8201	4451	Y	N/A	N/A
NBLE02085	Electro Impulse	Attenuator, 20 dB	AX-500-20	928700	B	10/26/2023	10/26/2024
NBLE03490	Hewlett-Packard	Spectrum Analyzer, Portable	8563E	3846A09834	G	08/01/2023	08/01/2024
NBLE10618	Amplifier Research	Amplifier, 10 kHz-250 MHz	250A250A	311619	Y	N/A	N/A
NBLE11038	Agilent Technologies	Power Meter	E4419B	GB43316903	G	01/17/2024	01/17/2025
NBLE11039	Agilent Technologies	Power Sensor	E9304A	MY49000103	G	01/16/2024	01/16/2025
NBLE11244	Werlatone, Inc.	Coupler, 30dB 100 kHz-1 GHz	C6934-10	105794	B	02/29/2024	02/28/2025
NBLE11288	Teseq	Injection Probe	CIP 9136A	39276	Y	N/A	N/A
NBLE11289	Teseq	Calibration Jig	PCJ 9201E	39748	Y	N/A	N/A
NBLE11350	Solar	Current Probe, 30 Hz-500 MHz	9215-1N	9215150501	B	02/26/2024	02/26/2025
NBLE11753	Rohde & Schwarz	Signal Generator, 8 kHz-40 GHz	SMA100B	105638	G	08/29/2023	08/29/2024
NBLE02324	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379517	G	02/08/2024	02/08/2025
NBLE02327	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379522	G	02/08/2024	02/08/2025
NBLE02667	Hewlett-Packard	Preamplifier, 0.1-1300 MHz	8447D	1616A00688	B	01/12/2024	01/12/2025

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

Table 2.2-4 – ESA RF Immunity Equipment List – Radiated

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE02355	Tensor	Antenna, 200 MHz-2 GHz	4106	2014	G	08/31/2022	08/31/2024
NBLE02324	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379517	G	02/08/2024	02/08/2025
NBLE02327	Solar	LISN, 5 uH	6338-5-PJ-50-N	8379522	G	02/08/2024	02/08/2025
NBLE02667	Hewlett-Packard	Preamplifier, 0.1-1300 MHz	8447D	1616A00688	B	01/12/2024	01/12/2025
NBLE03490	Hewlett-Packard	Spectrum Analyzer, Portable	8563E	3846A09834	G	08/01/2023	08/01/2024
NBLE10510	Werlatone, Inc.	Coupler, 50dB 80-1000 MHz	C6338-20	32619	B	09/06/2023	09/06/2024
NBLE10552	Pendel	Amplifier, .4-1 GHz	PS-6502	L456-1007	Y	N/A	N/A
WRLE03979	Amplifier Research	Antenna, Horn 1-4.2 GHz	AT4510	310429	Y	N/A	N/A
NBLE11753	Rohde & Schwarz	Signal Generator, 8 kHz-40 GHz	SMA100B	105638	G	08/29/2023	08/29/2024
NBLE11857	Amplifier Research	Amplifier, 250W, 1-6 GHz	250S1G6C	0361254	Y	N/A	N/A
NBLE11858	Werlatone, Inc.	Coupler, 40dB 700-6000 MHz	C10117-10	131753	B	05/31/2023	05/31/2024

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.3 Electrostatic Discharge

2.3.1 Specification Reference

ISO 10605 per ISO 13766-1 and ISO 13766-2

2.3.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.3.3 Test Voltage

24 VDC

2.3.4 Date of Test

16 May 2024

2.3.5 Test Method

The method described in ISO 10605 will be used as the method of measurement of the construction machinery in such areas where an ESD in standard us is possible (i.e. by touching by the operator). A R/C network of 330pF/2kΩ will be used for locations that can easily be accessed from inside the construction machinery and a R/C network of 150pF/2 kΩ will be used for areas that can easily be touched only from the outside of the construction machinery.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.3.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

Temperature:	25.3°C
Relative Humidity:	44.7%

2.3.7 Test Results

Table 2.3-1 – Requirements – ISO 13766-2

Discharge Type	Discharge Level (kV)		Number of Discharges per Location (Each Polarity))	Performance Criteria
	Positive	Negative		
Contact – Direct	8	8	3	A or FS[1]
Air – Direct	15	15	3	A or FS[1]
Notes: 1. Criteria FS = EUT performance was degraded but reverted to a failsafe mode.				

Table 2.3-2 – Functional Status

(from ISO 13766-1:2018, Table3)

Functional status	Description
A (I)	All functions of a device/system perform as designed during and after exposure to a disturbance.
B (II)	All functions of a device/system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain criterion A.
C (III)	One or more functions of a device/system do not perform as designed during exposure but returns automatically to normal operation after exposure is removed.
D (IV)	One or more functions of a device/system do not perform as designed during exposure and does not return to normal operation until exposure is removed and the device/system is reset by simple "operator/use" action.
E (V)	One or more functions of a device/system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device/system.
NOTE Roman numerals refer to the system used in ISO 16750-1:2006.	

Table 2.3-3 – Observations for ISO 13766-2:2018

Test Point Location	Discharge Type		8 kV Reps		15 kV Reps		Complies		Criteria Met	Remarks
	Direct/ Indirect	Contact/ Air	+	-	+	-	Yes	No		
										RC Network = 150 pF/2 kΩ
HCP	Indirect	Contact	3	3			✓		A	4 Sides Tested
1 - 8	Direct	Air			3	3	✓		A	
										RC Network = 330 pF/2 kΩ
HCP	Indirect	Contact	3	3			✓		A	4 Sides Tested
1 - 8	Direct	Air			3	3	✓		A	

Test Summary: The EUT showed no signs of susceptibility during testing at any of the injection probe locations.

Test Result: Pass

2.3.8 ESD Test Setup/Discharge Point Photos

Photo 2.3-1 – ESD Test Setup Photo

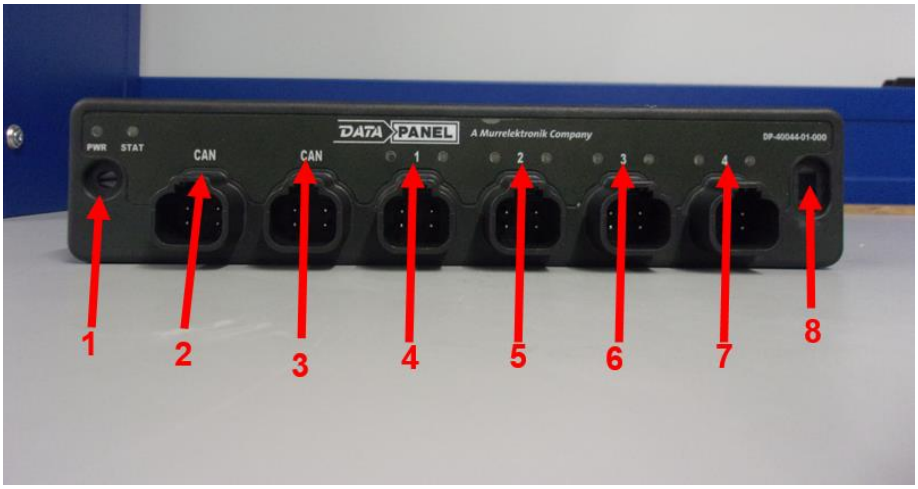


Photo 2.3-2 – ESD Test Location Photo (1)

2.3.9 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: ESD1

Table 2.3-4 – ESD Equipment List

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE11157	Fluke	Temperature and Humidity Meter	08/28/1902	07/18/1930	G	07/12/2023	07/12/2024
NBLE11674	Ametek CTS GmbH	ESD Simulator, Base Station	NSG 438	07/22/1904	G	11/20/2023	11/20/2024
NBLE11676	Ametek CTS GmbH	ESD Simulator, 150pF-2kOhm	INA 4381	12/04/1902	G	11/20/2023	11/20/2024
NBLE11677	Ametek CTS GmbH	ESD Simulator, 330pF-2kOhm	INA 4382	01/27/1903	G	11/20/2023	11/20/2024
NBLE11679	Ametek CTS GmbH	ESD Simulator, Pistol & Stand	438	12/22/1931	G	11/20/2023	11/20/2024
NBLE11680	Ametek CTS GmbH	ESD Simulator, AD TIP	AD TIP	12/23/1931	Y	N/A	N/A
NBLE11682	Ametek CTS GmbH	ESD Simulator, CD-Tip	CD-Tip	12/25/1931	Y	N/A	N/A

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.4 Immunity to Conducted Transients on Power Leads

2.4.1 Specification Reference

ISO 7637-2 and ISO 16750-2 per ISO 13766-1 and ISO 13766-2

2.4.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.4.3 Test Voltage

15, 27 VDC

2.4.4 Date of Test

16 May 2024

2.4.5 Test Method

The EUT was setup on a conductive test bench 50 mm (±10 mm) above the ground plane on top of an insulating support.

Prior to testing each applicable transient was verified open circuit. Once verified, the EUT was connected to the transient generator, and the test was performed. EUT functioning was monitored throughout the test and a post-test functional test was performed.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.4.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.4.7 Test Results

Table 2.4-1 – Requirements

Pulse (12 V System)	Level	Severity (Volts)	Number of Pulses/ Duration	Status
1	IV	-150	500	D

Pulse (24 V System)	Level	Severity (Volts)	Number of Pulses/ Duration	Status
1	III	-450	500	D
1	IV	-600	500	D
2a	IV	+112	500	D
2b	III	+20	10	D
3a	IV	-300	1 Hour	D
3b	IV	+300	1 Hour	D
Starting Profile	I	6	10	C
Starting Profile	II	8	10	C
Starting Profile	III	10	10	C
5 (Load Dump)	III	151	10	C

Table 2.4-2 – Summary of Observations During Testing

Pulse 24 V System	Level	Severity	Required Status	Severity Achieved	# of Pulses / Duration	Status Met
1	III	-450 V	D	-450 V	500 pulses	B
1	IV	-600 V	D	-600 V	500 pulses	B
2a	III	+112 V	D	+112 V	500 pulses	A
2b	III	+20 V	D	+20 V	10 pulses	B
3a	III	-300 V	D	-300 V	1 hour	A
3b	III	+300 V	D	+300 V	1 hour	A
Starting Profile	I	6	C	6	10 pulses	A
Starting Profile	II	8	C	8	10 pulses	A
Starting Profile	III	10	C	10	10 pulses	A
5 (Load Dump)	III	151	D	151	10 pulses	A

Notes:
Higher levels and test durations used to cover all standards.
Severity level of load dump test depends on internal resistance used.

2.4.7.1 Test Pulse 1

Table 2.4-3 – Test Pulse 1 Parameters

Test Voltage (Volts)	test Level (Volts)	Pulse Width (mSec)	Pulse Period (Sec)	Source Impedance (Ohms)	repetitions
13.5	-150	2	0.50	10	500

Test Voltage (Volts)	test Level (Volts)	Pulse Width (mSec)	Pulse Period (Sec)	Source Impedance (Ohms)	repetitions
27	-450	1	0.50	50	500

Test Voltage (Volts)	test Level (Volts)	Pulse Width (mSec)	Pulse Period (Sec)	Source Impedance (Ohms)	repetitions
27	-600	1	0.50	50	500

Table 2.4-4 – Observations During Test

EUT Power / Configuration	Result	Observation
13.5 VDC	Pass	The unit restarts during the test but comes back after the test, Met Criteria B
27 VDC	Pass	The unit restarts during the test but comes back after the test, Met Criteria B

Test Summary: The unit restarts during the test but comes back after the test.

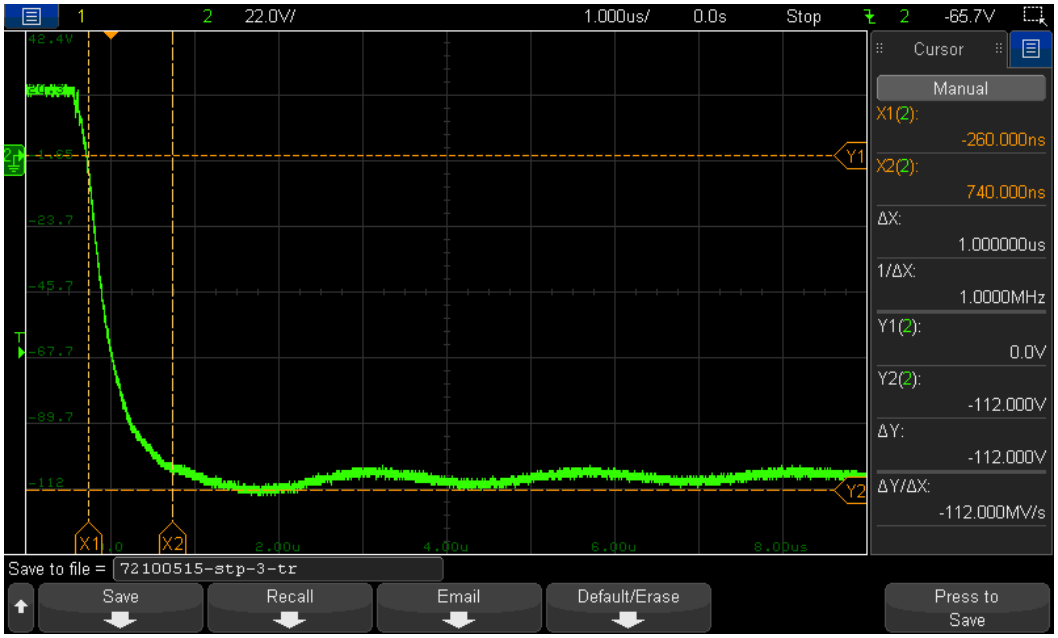


Figure 2.4-1 – Pulse 1 – Tr, T3, & Us – Open Circuit 12 Volts

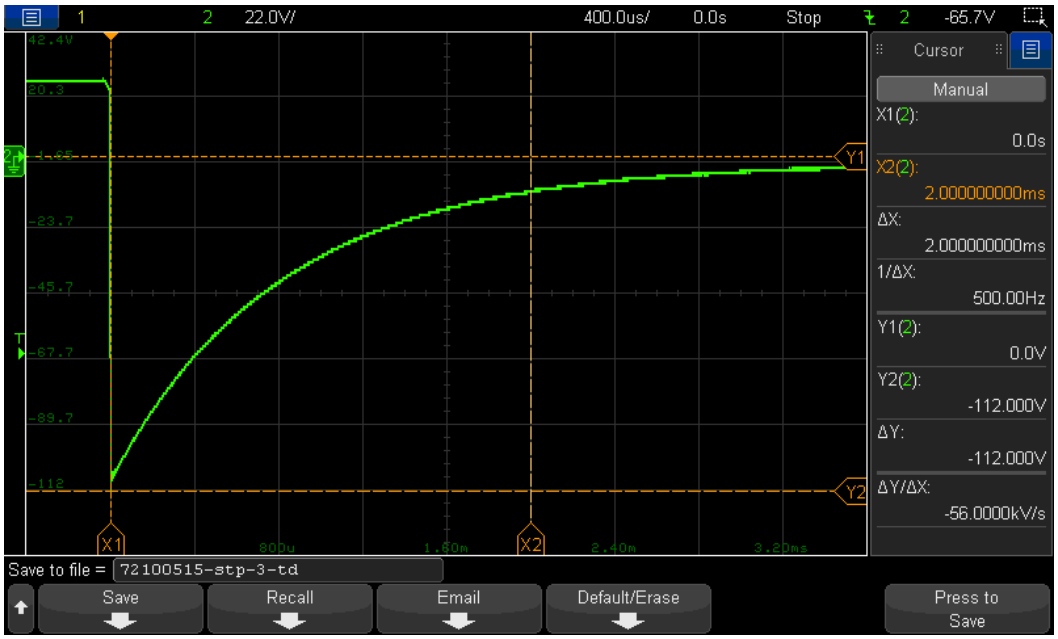


Figure 2.4-2 – Pulse 1 – Td – Open Circuit 12 Volts

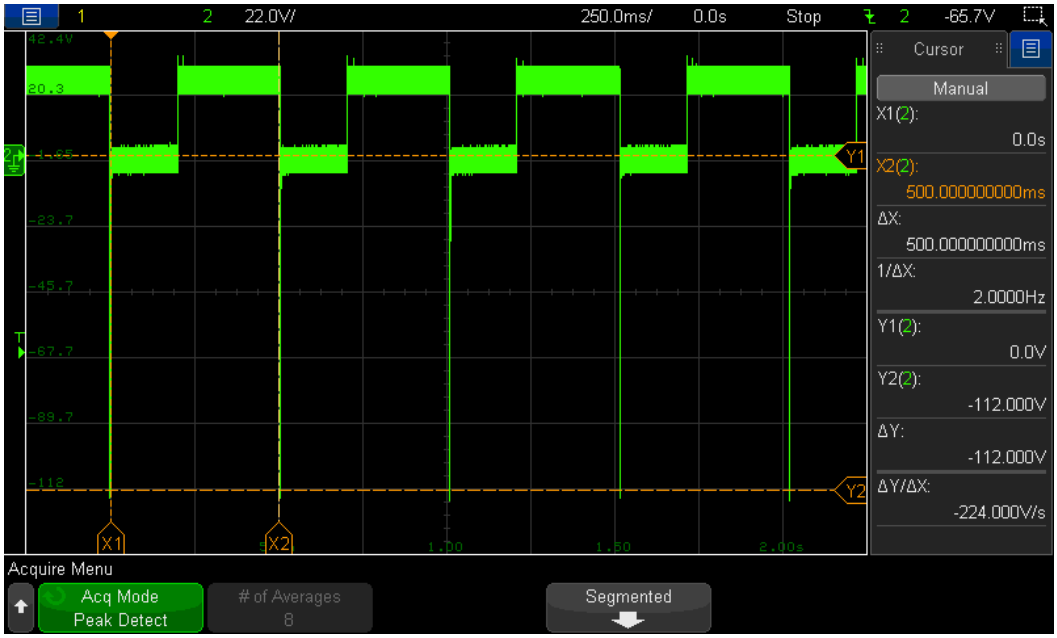


Figure 2.4-3 – Pulse 1 – T1 & T2 – Open Circuit 12 Volts

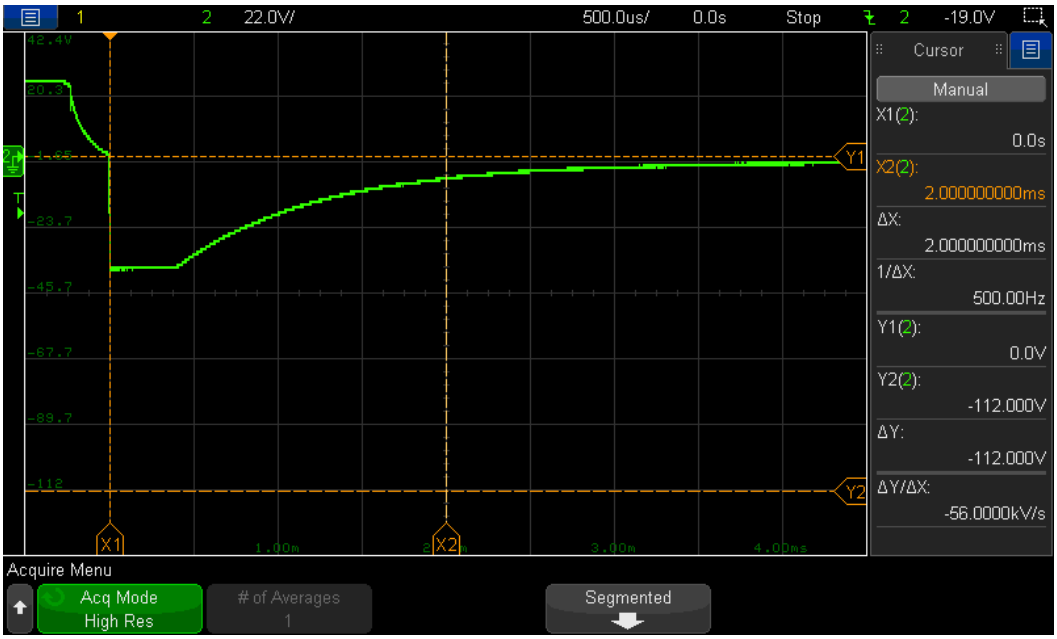


Figure 2.4-4 – Pulse 1 – Us & Td – EUT 12 Volts

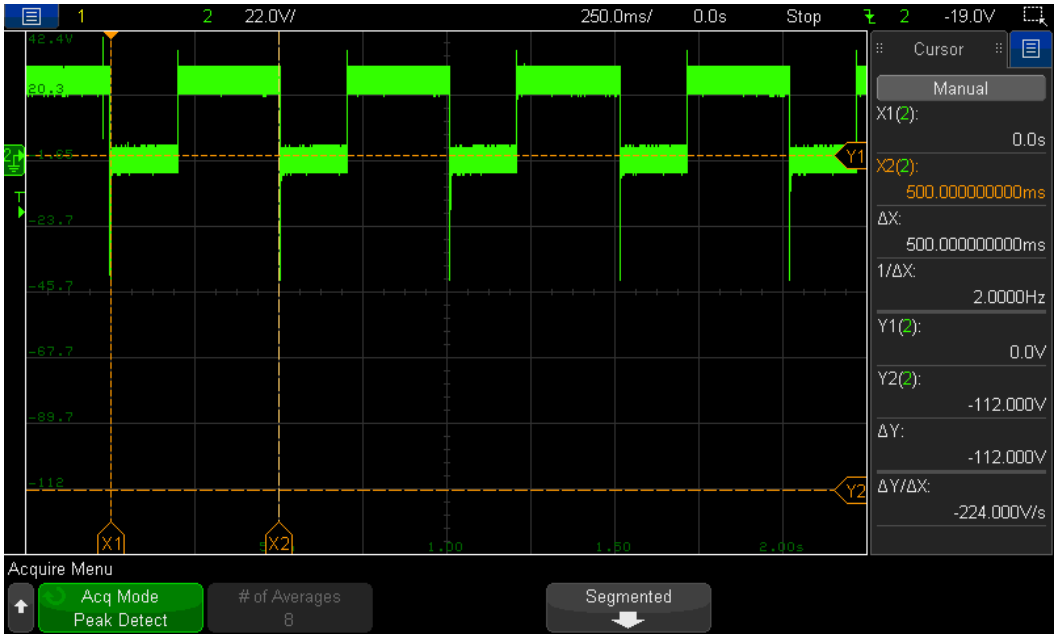


Figure 2.4-5 – Pulse 1 – T1 & T2 – EUT 12 Volts

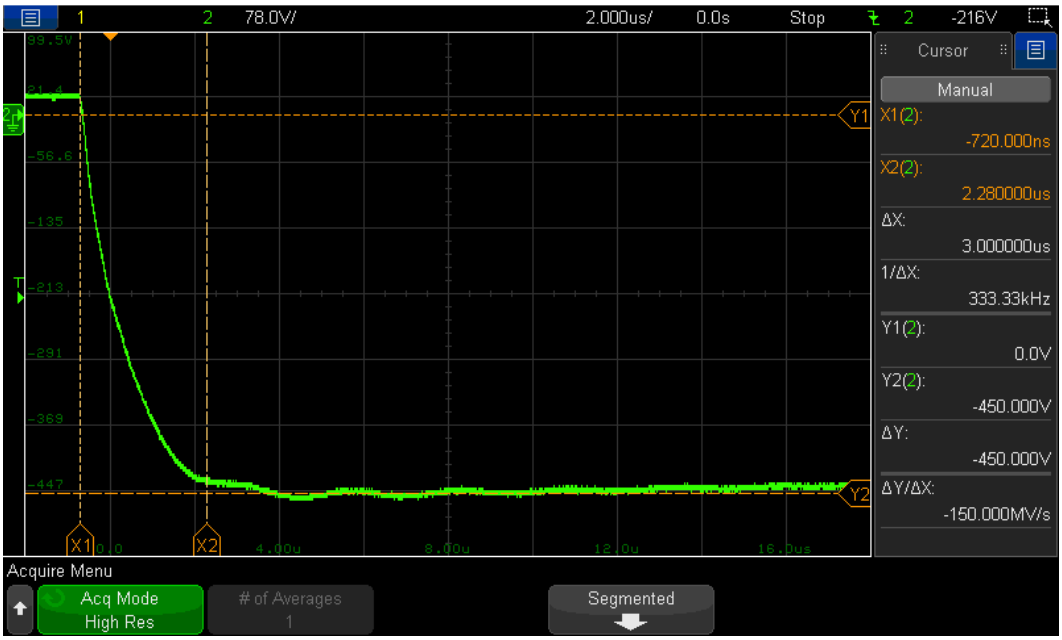


Figure 2.4-6 – Pulse 1 – Tr, T3, & Us – Open Circuit 24 Volts, Level III

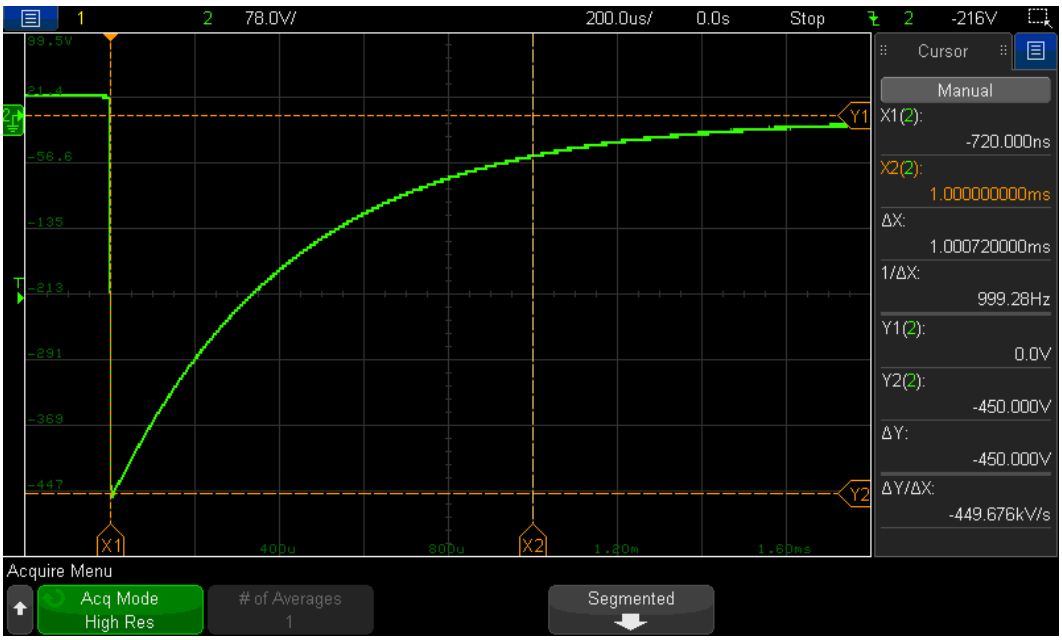


Figure 2.4-7 – Pulse 1 – Td – Open Circuit 24 Volts, Level III

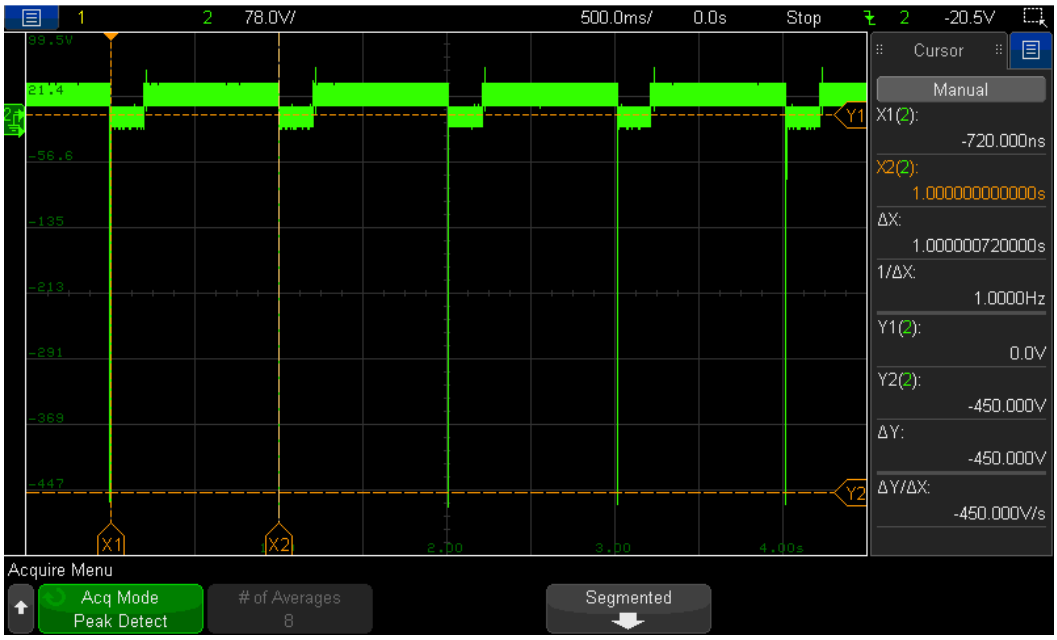


Figure 2.4-8 – Pulse 1 – T1 & T2 – Open Circuit 24 Volts, Level III

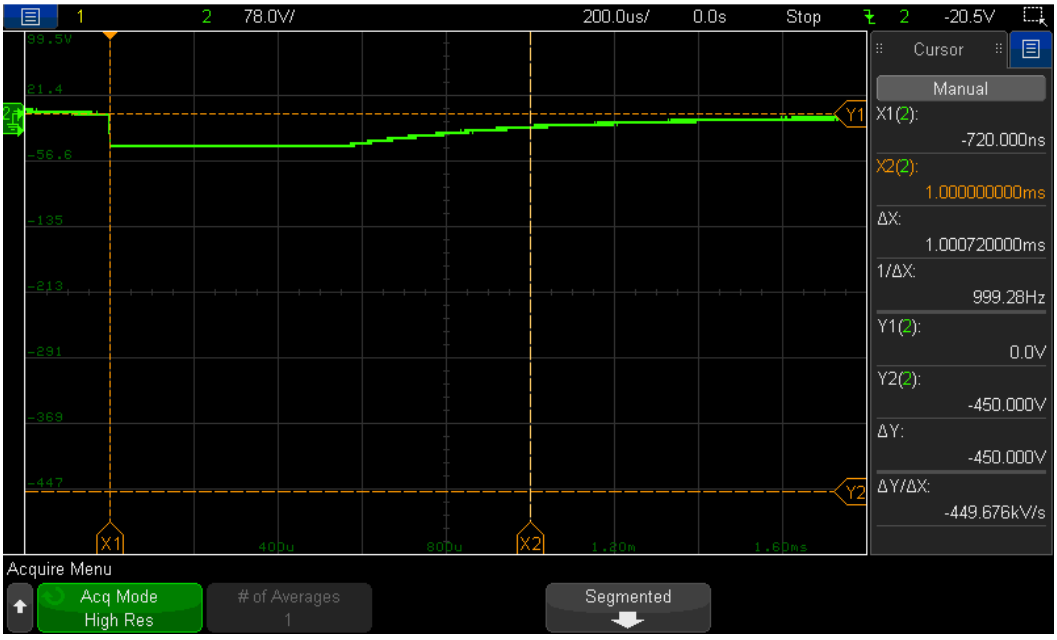


Figure 2.4-9 – Pulse 1 – Us & Td – EUT 24 Volts, Level III

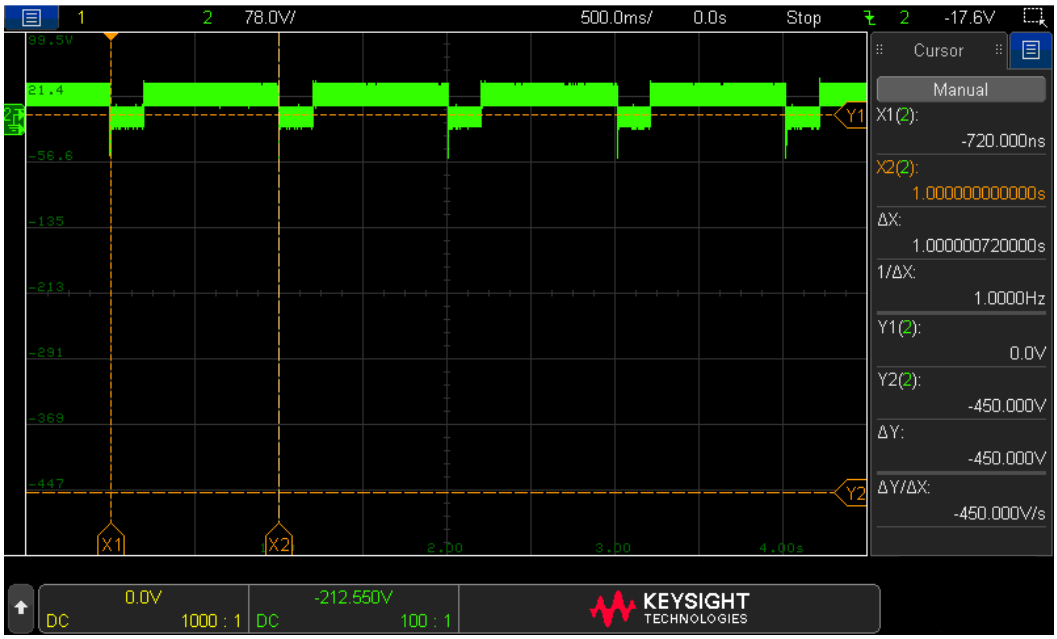


Figure 2.4-10 – Pulse 1 – T1 & T2 – EUT 24 Volts, Level III

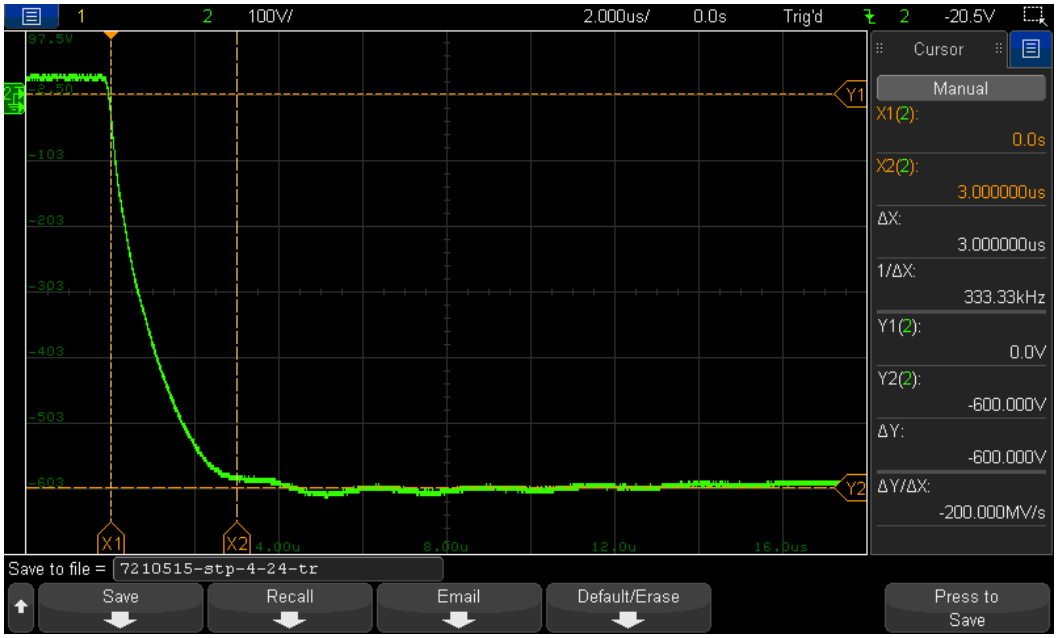


Figure 2.4-11 – Pulse 1 – Tr, T3, & Us – Open Circuit 24 Volts, Level IV

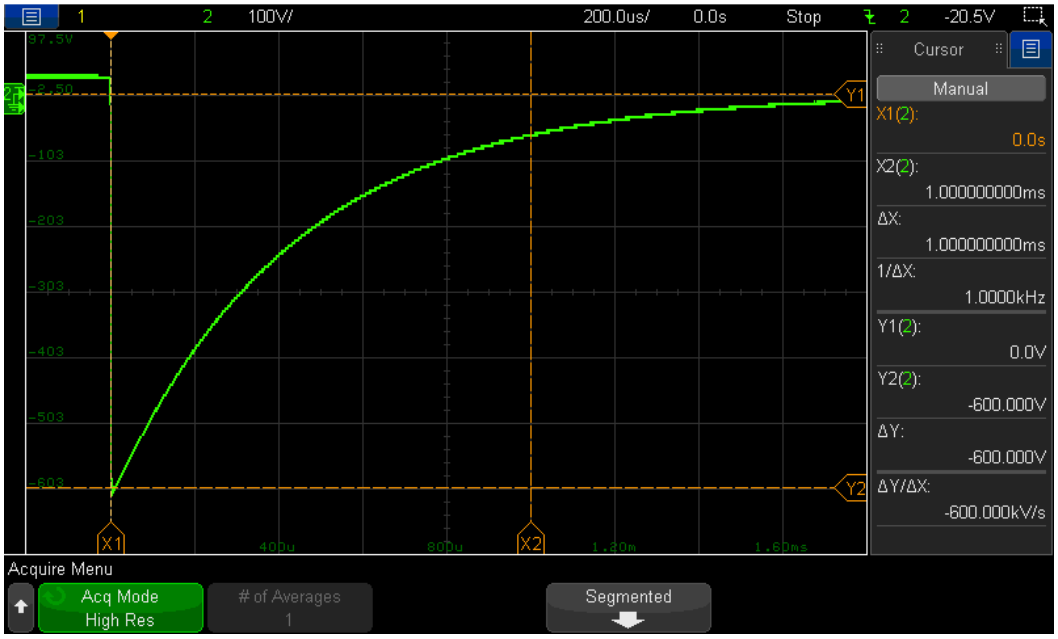


Figure 2.4-12 – Pulse 1 – Td – Open Circuit 24 Volts, Level IV

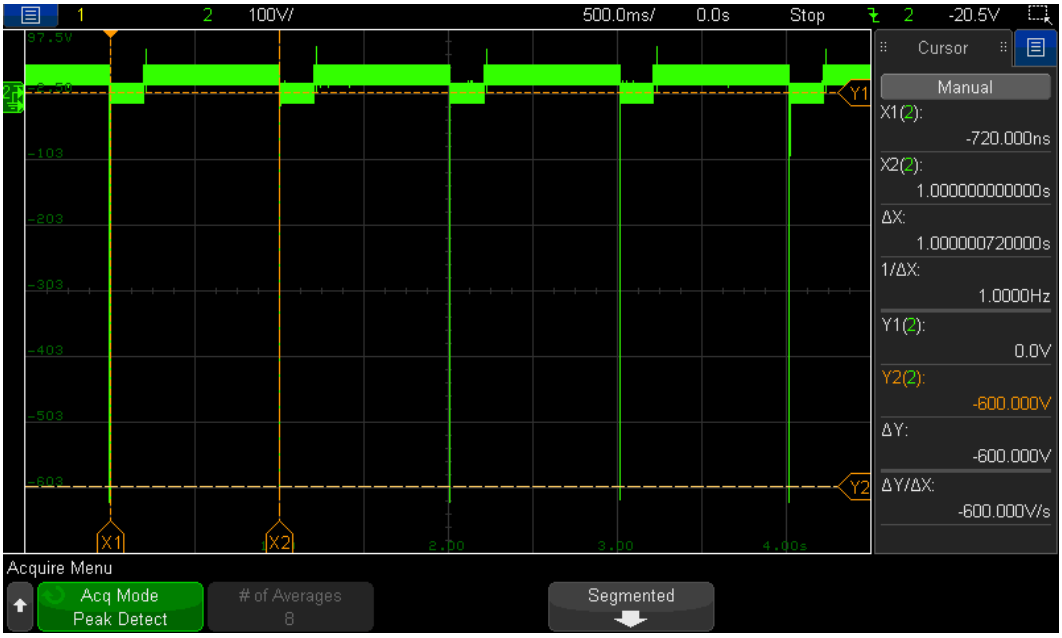


Figure 2.4-13 – Pulse 1 – T1 & T2 – Open Circuit 24 Volts, Level IV

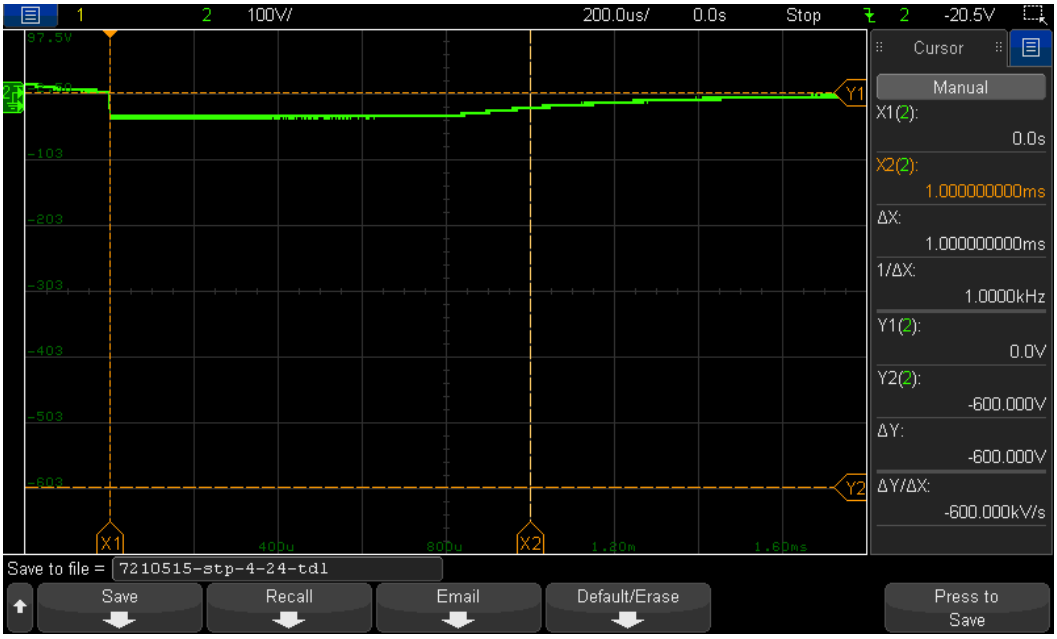


Figure 2.4-14 – Pulse 1 – Us & Td – EUT 24 Volts, Level IV

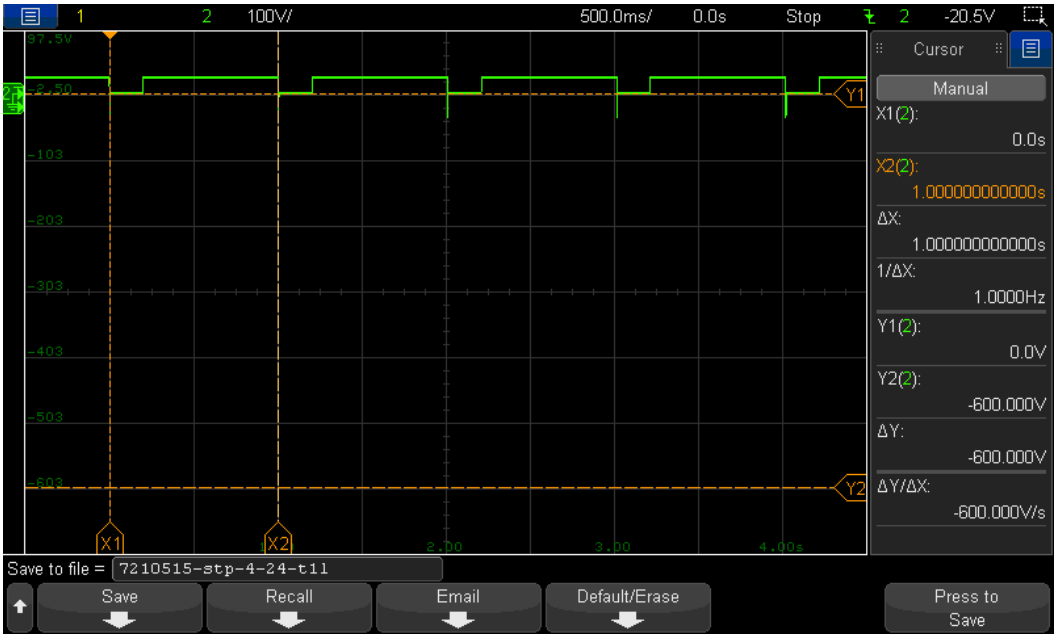


Figure 2.4-15 – Pulse 1 – T1 & T2 – EUT 24 Volts, Level IV

2.4.7.2 Test Pulse 2a

Table 2.4-5 – Test Pulse 2a Parameters

Test Voltage (Volts)	test Level (Volts)	Pulse Width (mSec)	Pulse Period (Sec)	Source Impedance (Ohms)	repetitions
27	+112	0.05	0.50	2	500

Table 2.4-6 – Observations During Testing

EUT Power / Configuration	Result	Observation
27 VDC	Pass	Met Criteria A

Test Summary: The EUT showed no signs of susceptibility during testing.

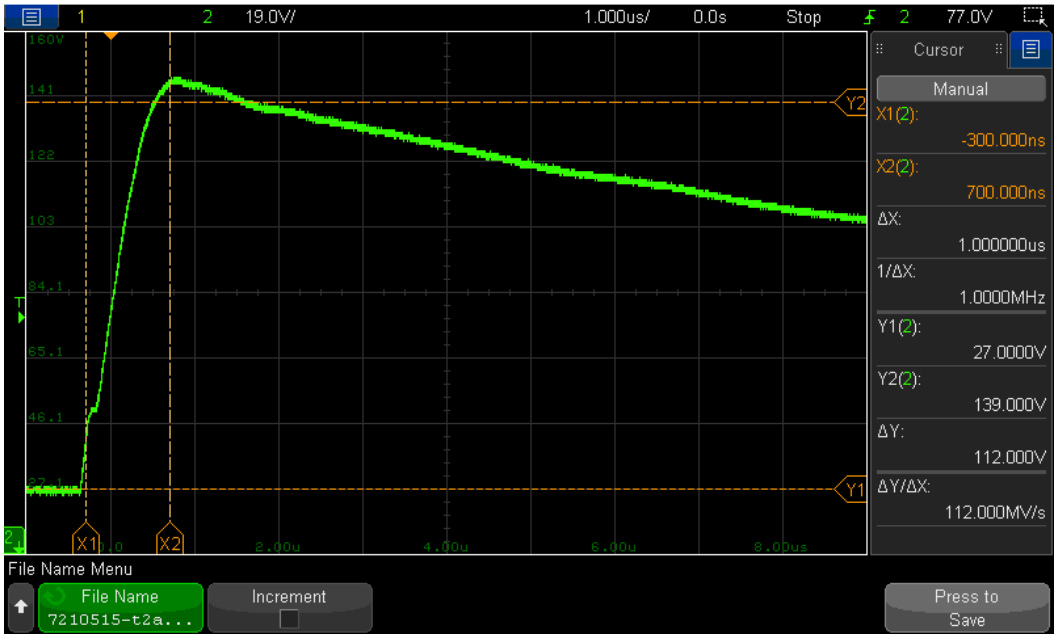


Figure 2.4-16 – Pulse 2a – Us & Tr – Open Circuit

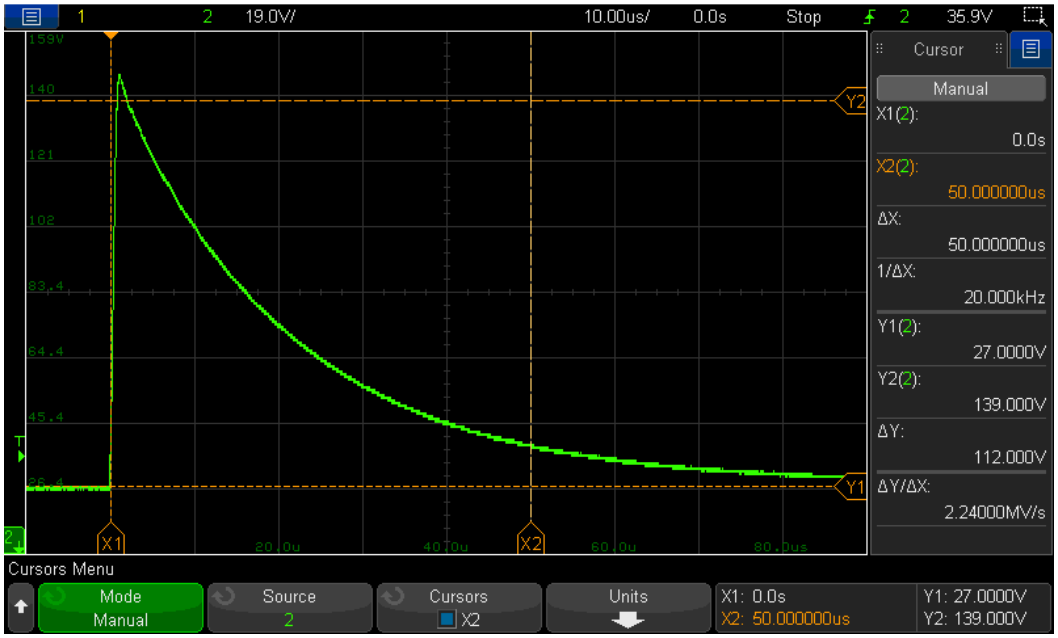


Figure 2.4-17 – Pulse 2a – Td – Open Circuit

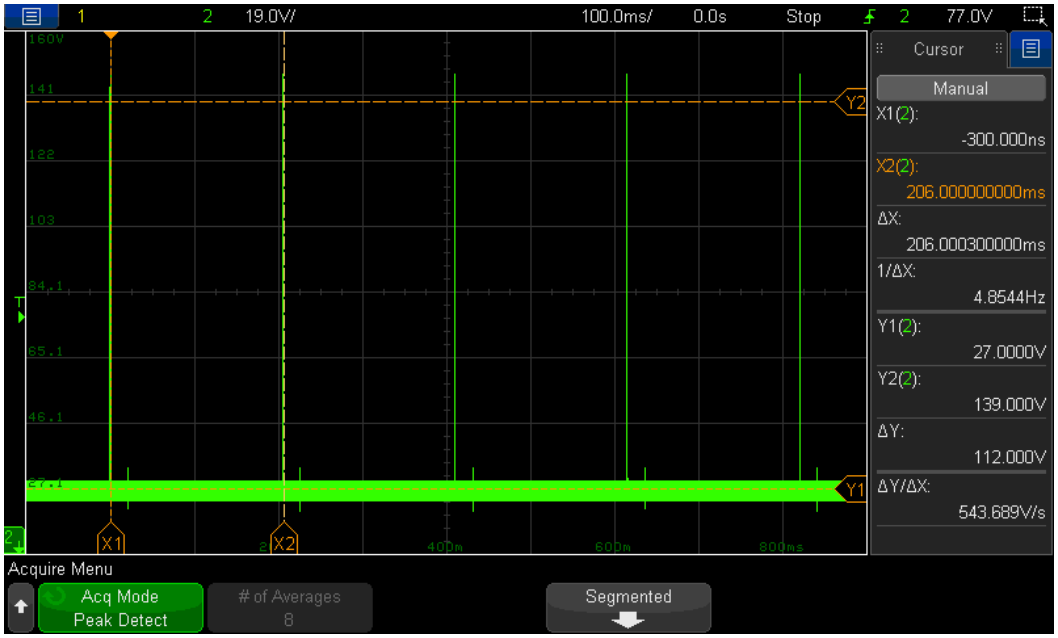


Figure 2.4-18 – Pulse 2a – T1 – Open Circuit

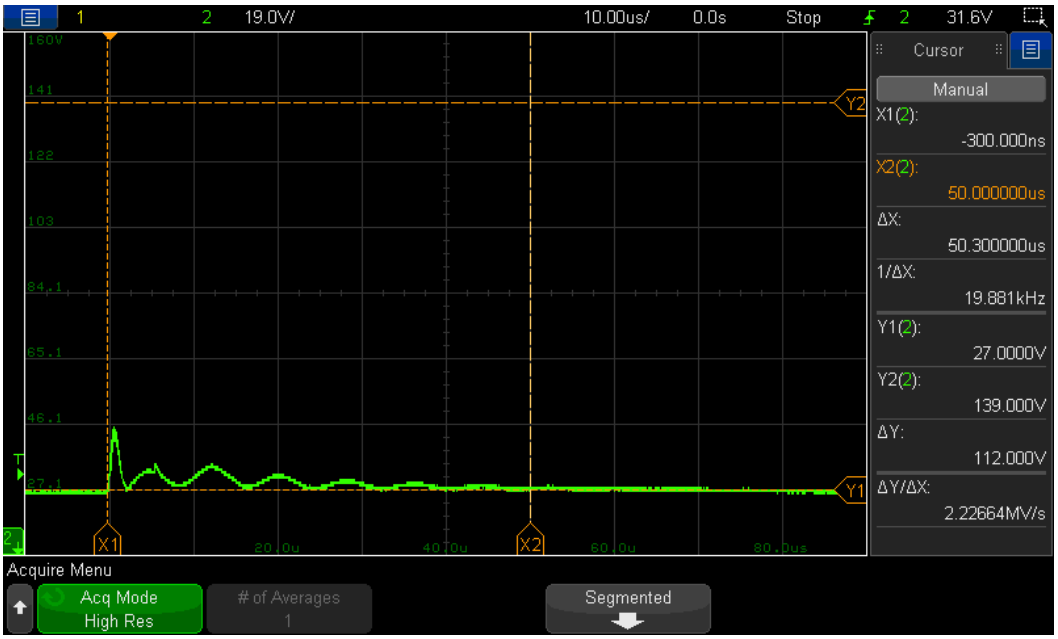


Figure 2.4-19 – Pulse 2a – Us, Tr, & Td – EUT

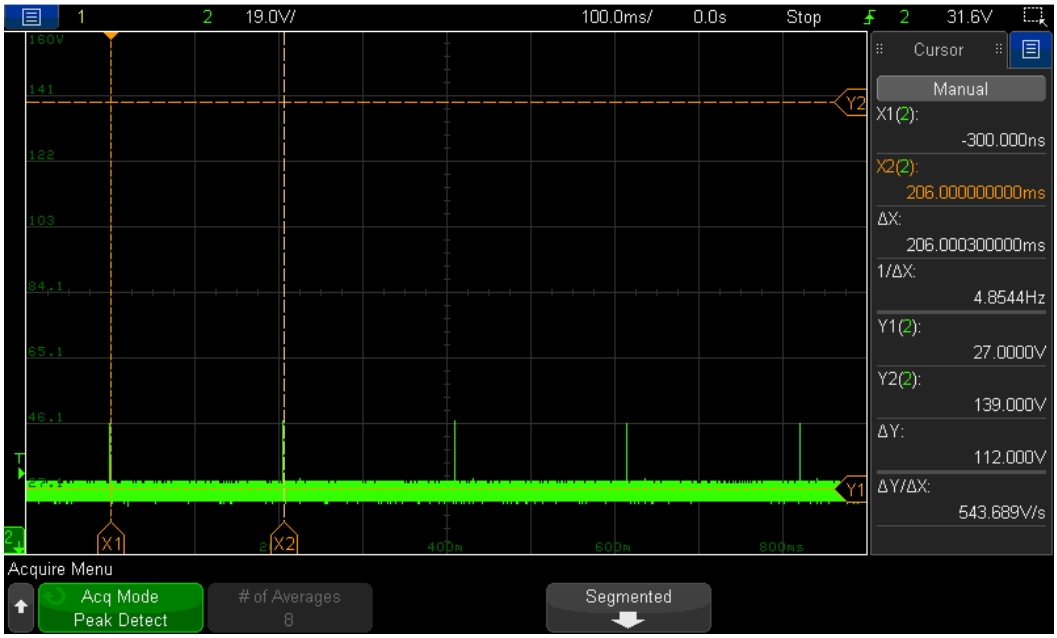


Figure 2.4-20 – Pulse 2a – T1 – EUT

2.4.7.3 Test Pulse 2b

Table 2.4-7 – Test Pulse 2b Parameters

TEST VOLTAGE (VOLTS)	TEST LEVEL (VOLTS)	PULSE WIDTH (Sec)	REP RATE (Sec)	SOURCE IMPEDANCE (OHMS)	REPETITIONS
27	20	0.2	1	0	10

Table 2.4-8 – Observations During Testing

EUT Power / Configuration	Result	Observation
27 VDC	Pass	The unit restarts during the test but comes back after the test, Met Criteria B

Test Summary: The EUT showed no signs of susceptibility during testing.

Figure 2.4-21 – Pulse 2b – T6 & Us – Open Circuit

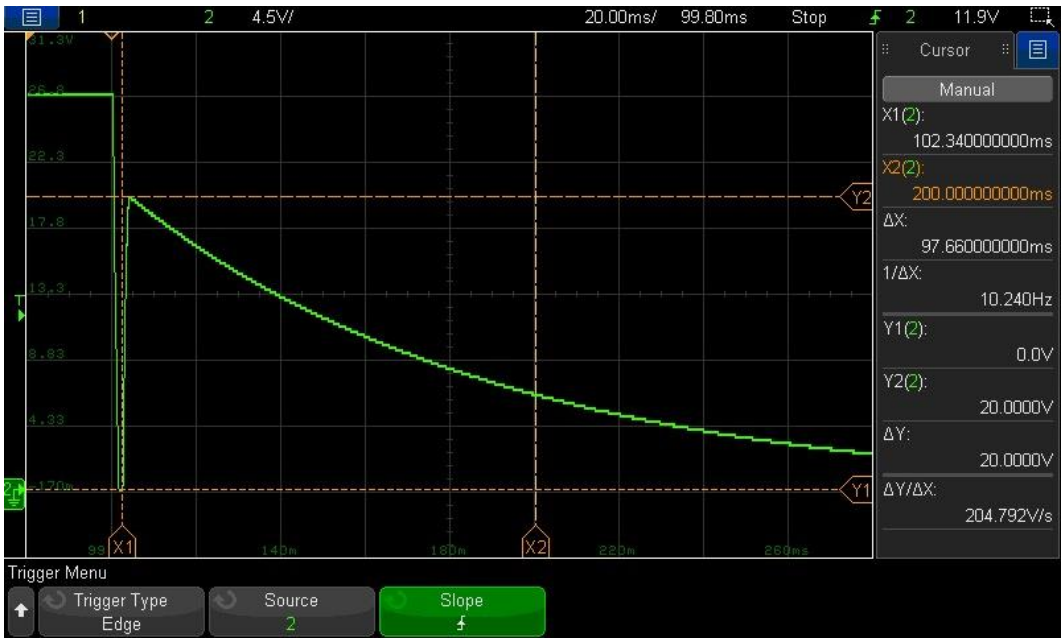


Figure 2.4-22 – Pulse 2b – Td – Open Circuit

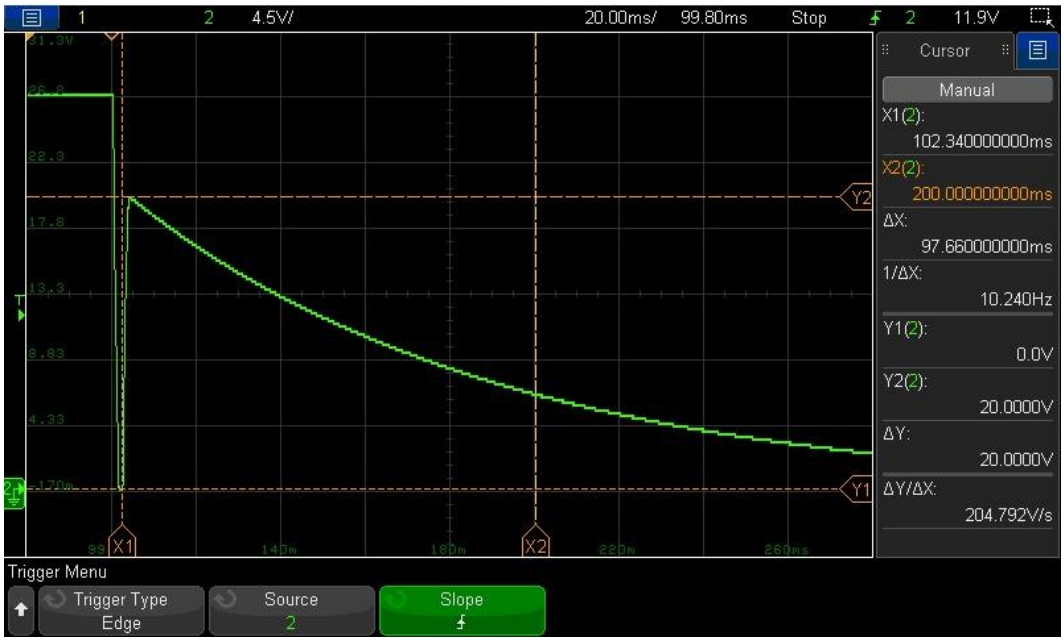


Figure 2.4-23 – Pulse 2b – Td – EUT

2.4.7.4 Test Pulse 3a

Table 2.4-9 – Test Pulse 3a Parameters

Test Voltage (Volts)	test Level (Volts)	Rep Rate (µSec)	Burst Width (mSec)	Burst Period (mSec)	Source Impedance (Ohms)	Test Time (Min)
27	-300	100	10	100	50	60

Table 2.4-10 – Observations During Testing

EUT Power / Configuration	Result	Observation
27 VDC	Pass	Met Criteria A

Test Summary: The EUT showed no signs of susceptibility during testing.

Figure 2.4-24 – Pulse 3a – Us &Tr – Open Circuit

Figure 2.4-25 – Pulse 3a – Us & Td – Open Circuit

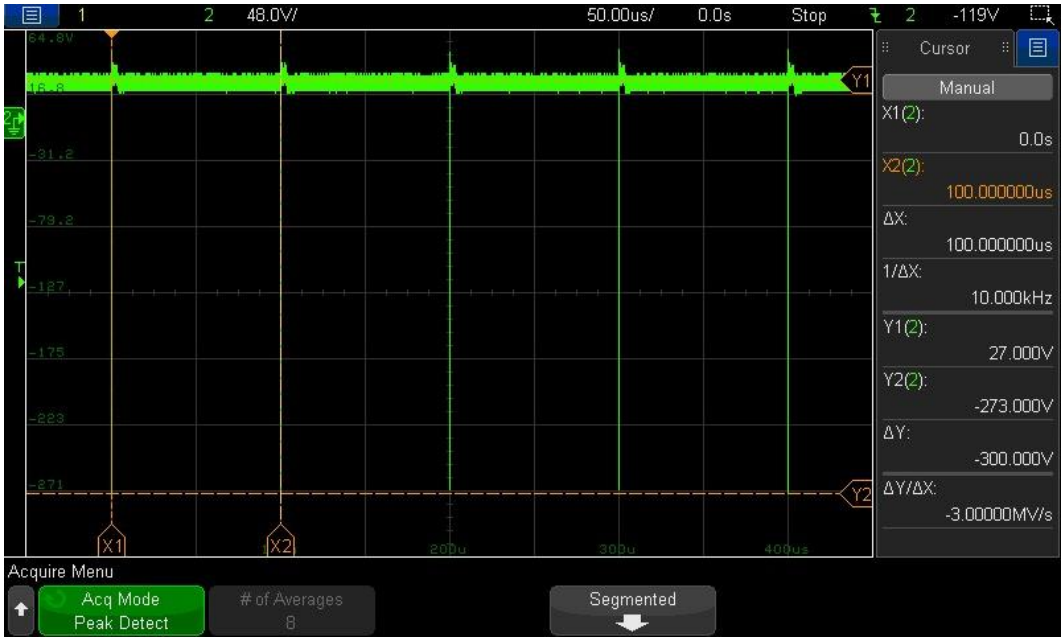


Figure 2.4-26 – Pulse 3a – T1 – Open Circuit

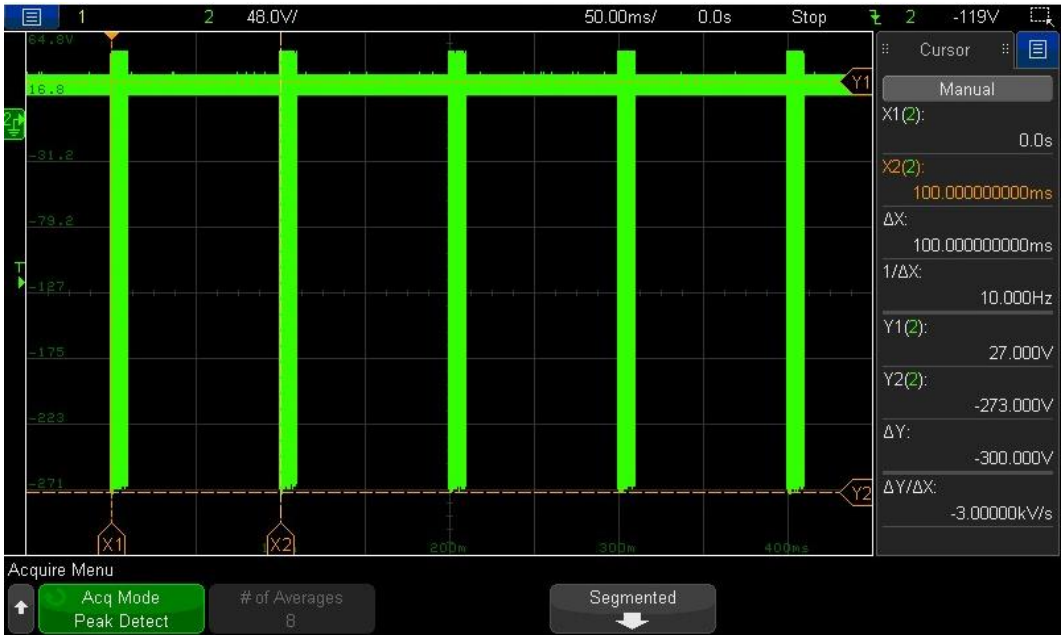


Figure 2.4-27 – Pulse 3a – T4 & T5 – Open Circuit

Figure 2.4-28 – Pulse 3a – Us & Tr – EUT

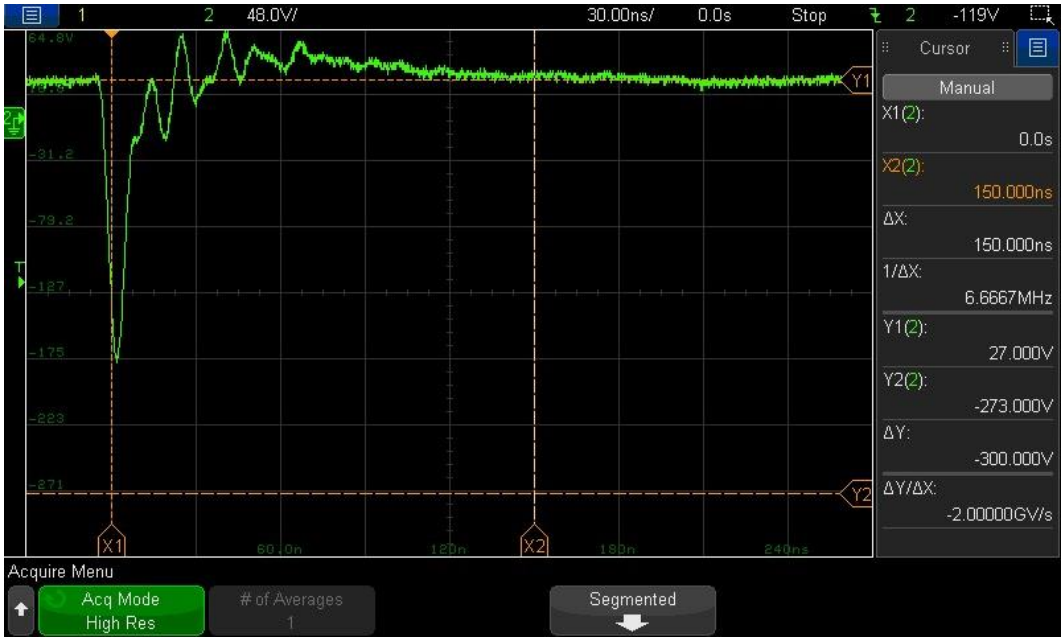


Figure 2.4-29 – Pulse 3a – Us & Td – EUT

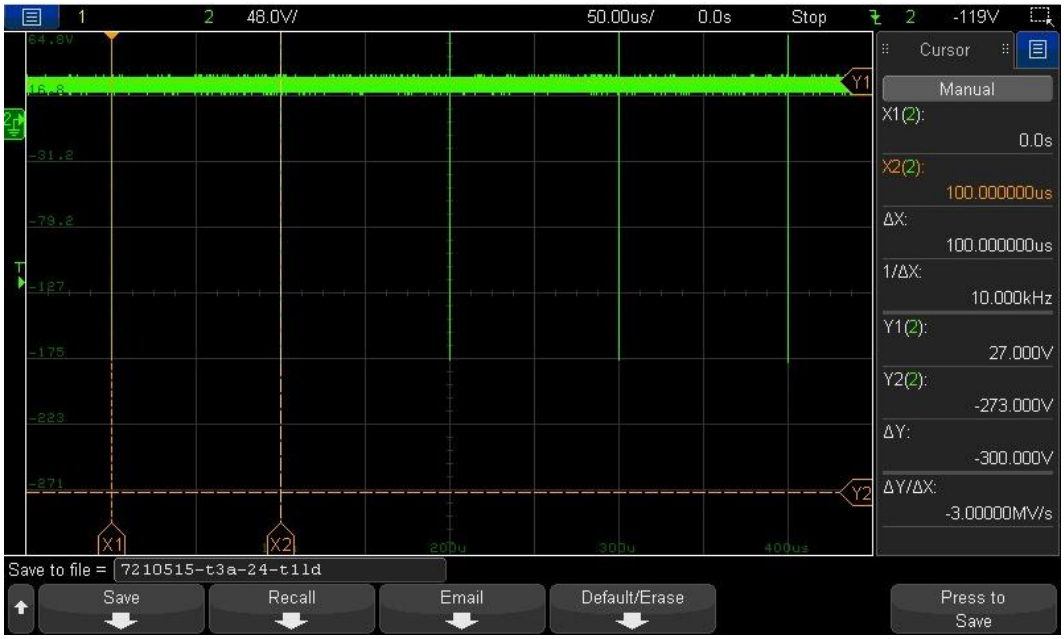


Figure 2.4-30 – Pulse 3a – T1 – EUT

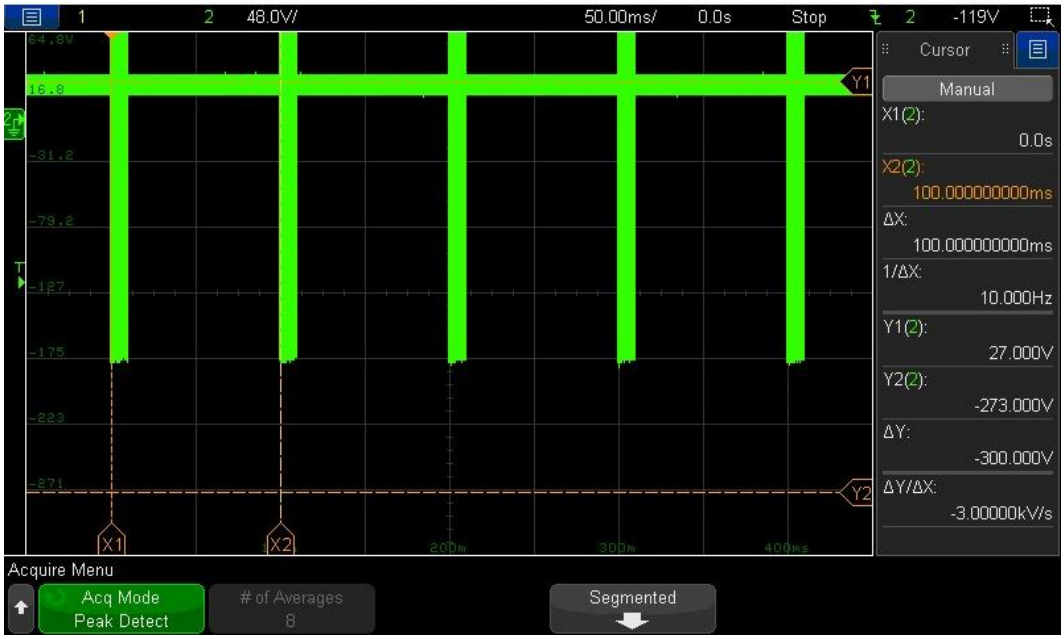


Figure 2.4-31 – Pulse 3a – T4 & T5 – EUT

2.4.7.5 Test Pulse 3b

Table 2.4-11 – Test Pulse 3b Parameters

TEST VOLTAGE (VOLTS)	TEST LEVEL (VOLTS)	REP RATE (µSec)	BURST WIDTH (mSec)	BURST PERIOD (mSec)	SOURCE IMPEDANCE (OHMS)	TEST TIME (MIN)
27	+300	100	10	100	50	60

Table 2.4-12 – Observations During Testing

EUT Power / Configuration	Result	Observation
27 VDC	Pass	Met Criteria A

Test Summary: The EUT showed no signs of susceptibility during testing.

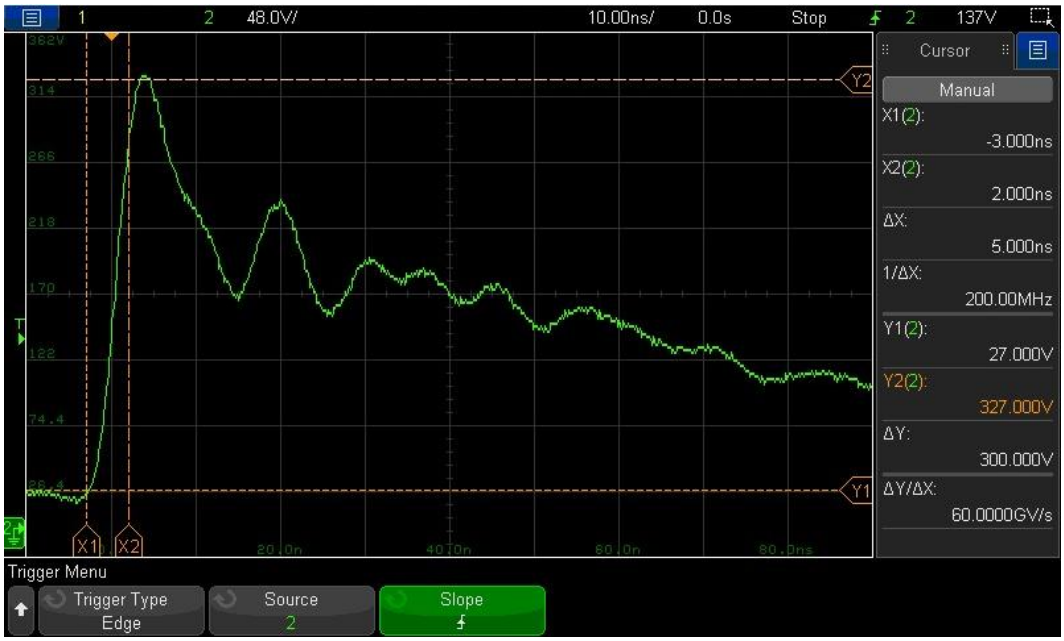


Figure 2.4-32 – Pulse 3b – Us & Tr – Open Circuit

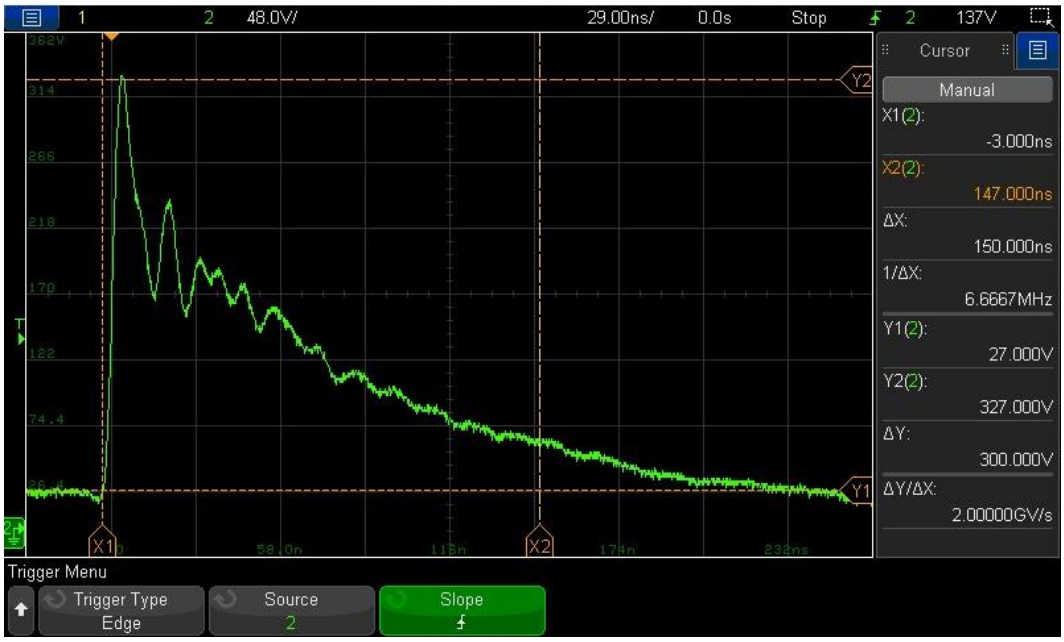


Figure 2.4-33 – Pulse 3b – Us & Td – Open Circuit

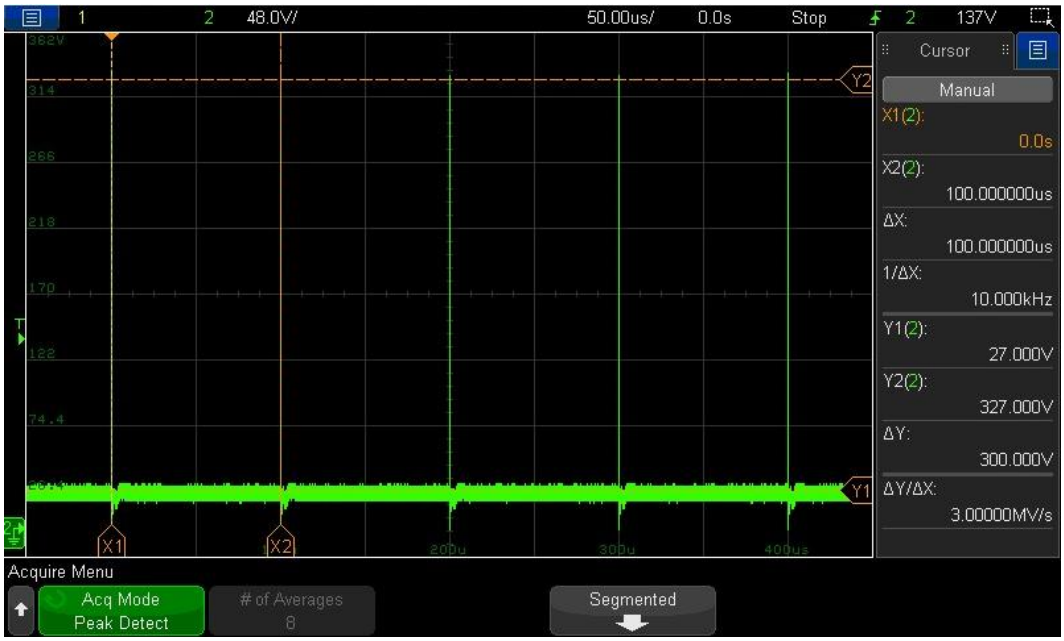


Figure 2.4-34 – Pulse 3b – T1 – Open Circuit

Figure 2.4-35 – Pulse 3b – T4 & T5 – Open Circuit

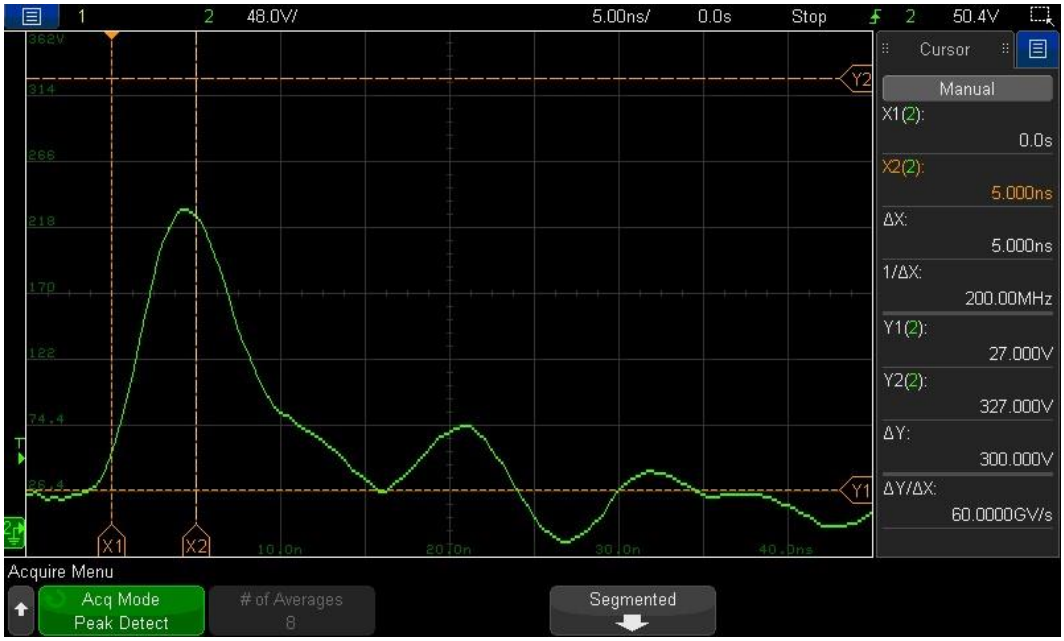


Figure 2.4-36 – Pulse 3b – Us & Tr – EUT

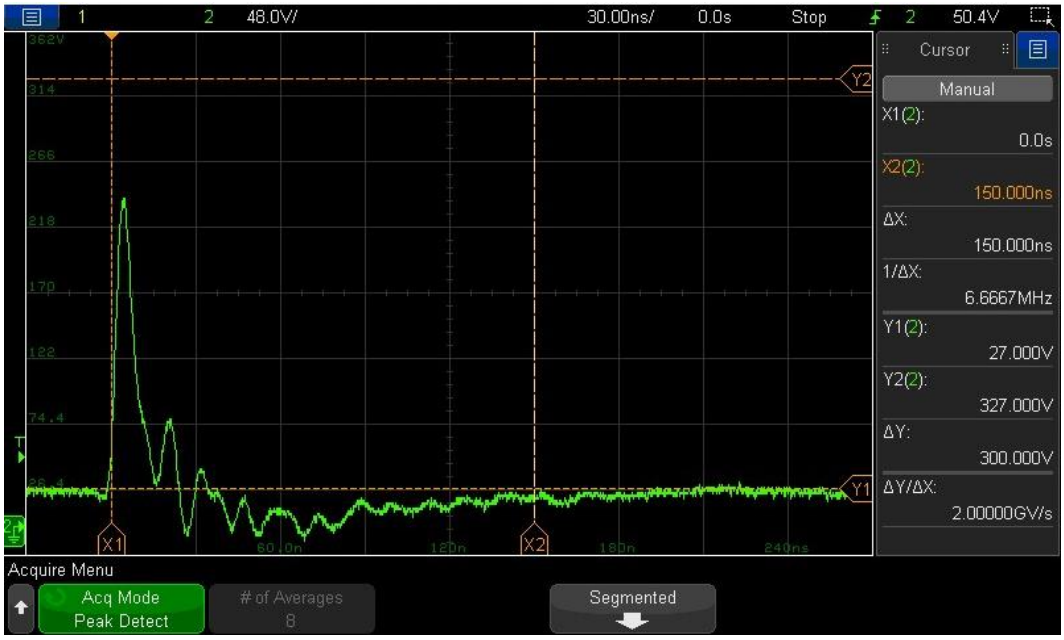


Figure 2.4-37 – Pulse 3b – Us & Td – EUT

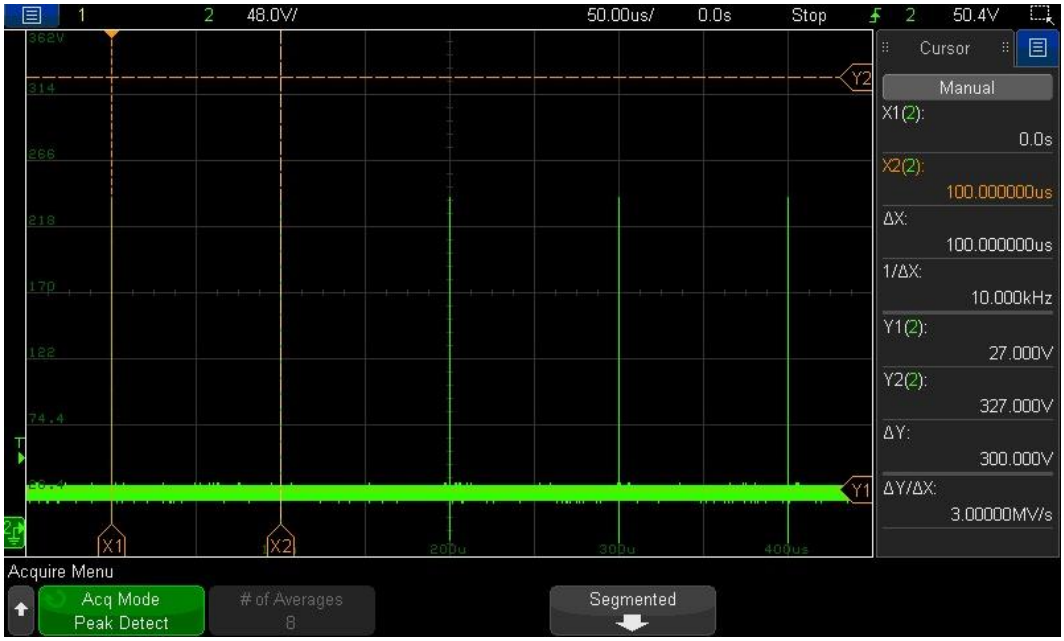


Figure 2.4-38 – Pulse 3b – T1 – EUT

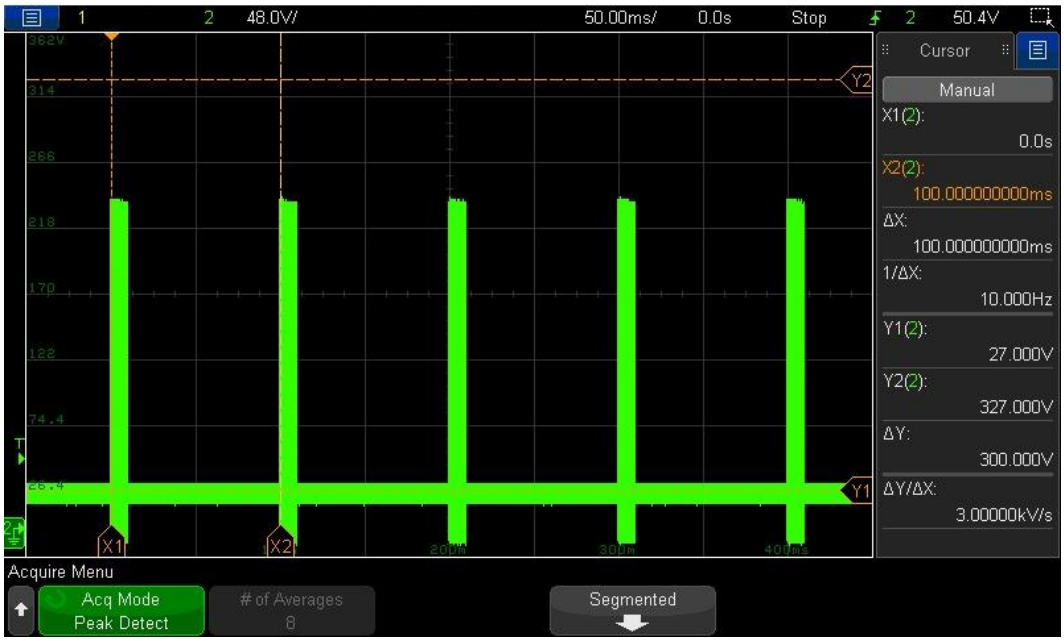


Figure 2.4-39 – Pulse 3b – T4 & T5 – EUT

2.4.7.6 Starting Profile

Table 2.4-13 – Starting Profile Parameters

Test Voltage (Volts)	test Level (U_{S6})	Transient Time (mSec)	Test Level (U_S)	Transient Time (Sec)	Source Impedance (Ohms)	Repetitions
24	6	50	20	10	0	1

Test Voltage (Volts)	test Level (U_{S6})	Transient Time (mSec)	Test Level (U_S)	Transient Time (Sec)	Source Impedance (Ohms)	Repetitions
24	8	50	15	10	0	1

Test Voltage (Volts)	test Level (U_{S6})	Transient Time (mSec)	Test Level (U_S)	Transient Time (Sec)	Source Impedance (Ohms)	Repetitions
24	10	50	10	10	0	1

Table 2.4-14 – Observations During Testing

EUT Power / Configuration	Result	Observation
24 VDC	Pass	Met Criteria A

Test Summary: The EUT showed no signs of susceptibility during testing.

Figure 2.4-40 – Starting Profile – Us, Us6, & T6 – Open Circuit Level I

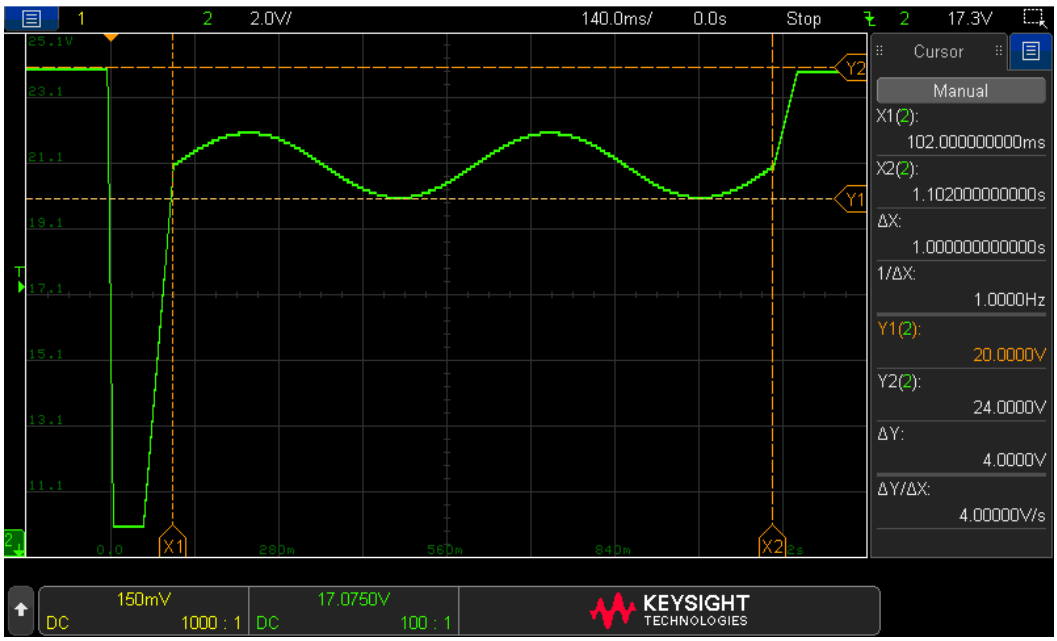


Figure 2.4-41 – Starting Profile – T8 – Open Circuit Level I

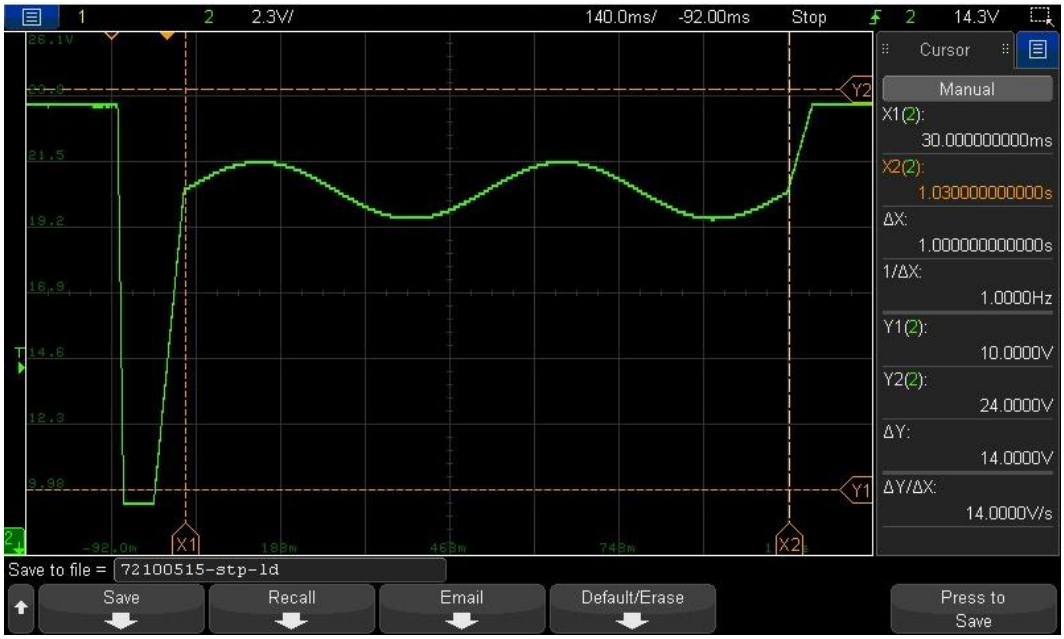


Figure 2.4-42 – Starting Profile – T8 – EUT Level I

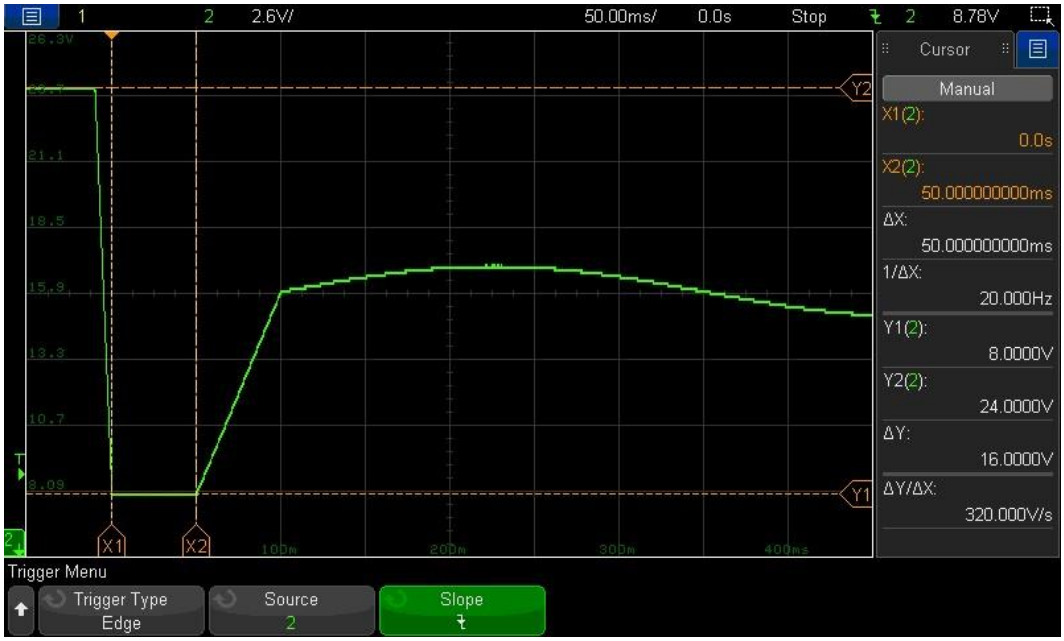


Figure 2.4-43 – Starting Profile – Us, Us6, & T6 – Open Circuit Level II

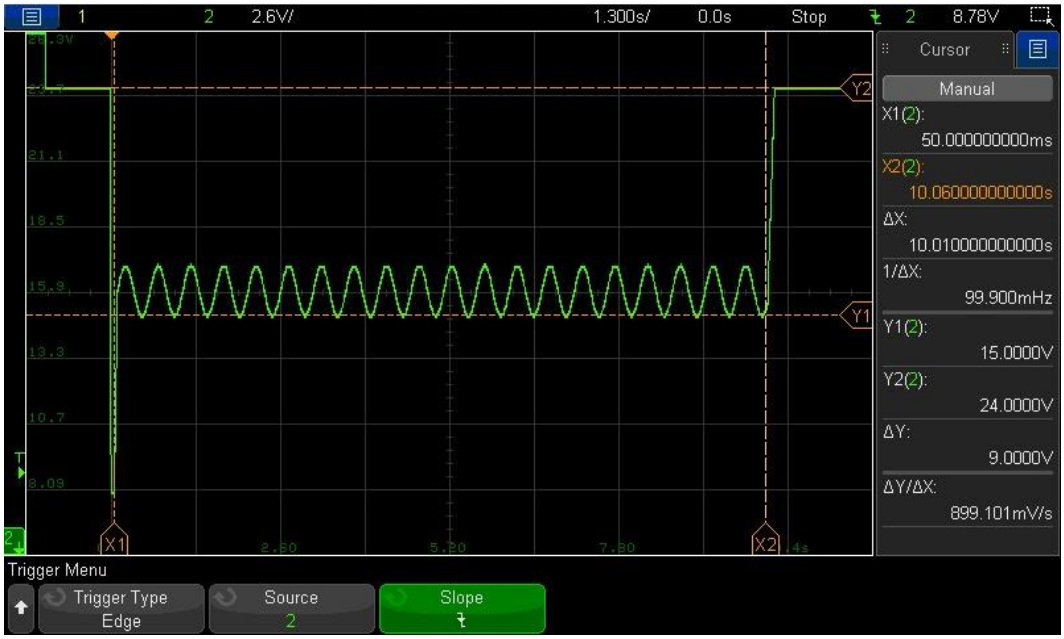


Figure 2.4-44 – Starting Profile – T8 – Open Circuit Level II

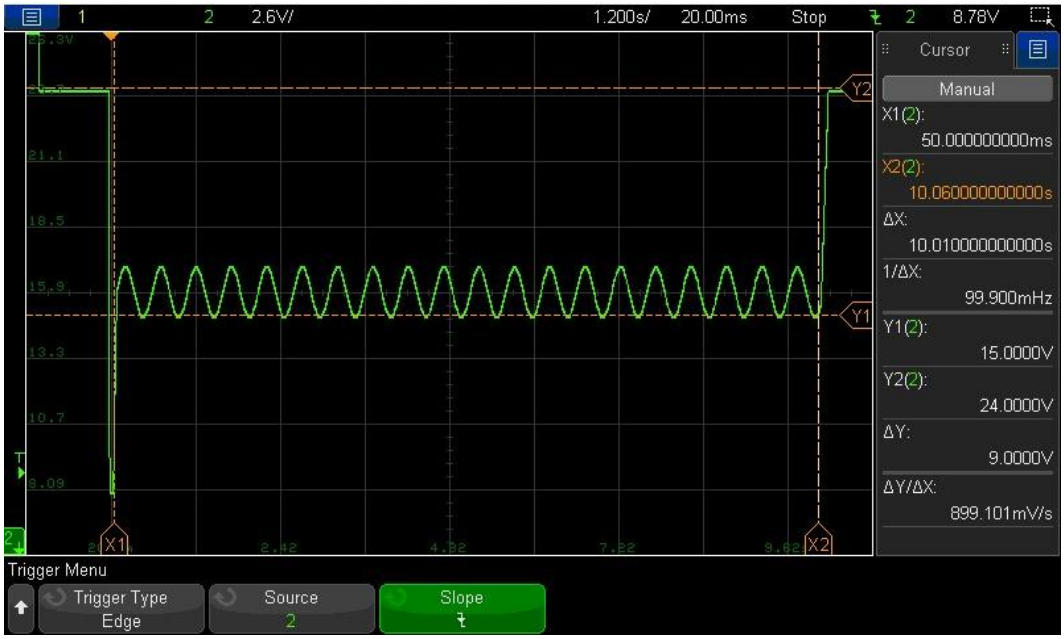


Figure 2.4-45 – Starting Profile – T8 – EUT Level II

Figure 2.4-46 – Starting Profile – Us, Us6, & T6 – Open Circuit Level III

Figure 2.4-47 – Starting Profile – T8 – Open Circuit Level III

Figure 2.4-48 – Starting Profile – T8 – EUT Level III

2.4.7.7 Test Pulse 5a

Table 2.4-15 – Test Pulse 5a Parameters (without Centralized Load Dump Suppression)

Test Voltage (Volts)	test Level (Volts)	Pulse Width (mSec)	Source Impedance (Ohms)	Rep Rate (Sec)	Number of Pulses
27	+151	200	1 to 8	60	10

Table 2.4-16 – Observations During Testing

EUT Power / Configuration	Result	Observation
27 VDC	Pass	Met Criteria A

Test Summary: The EUT showed no signs of susceptibility during testing.

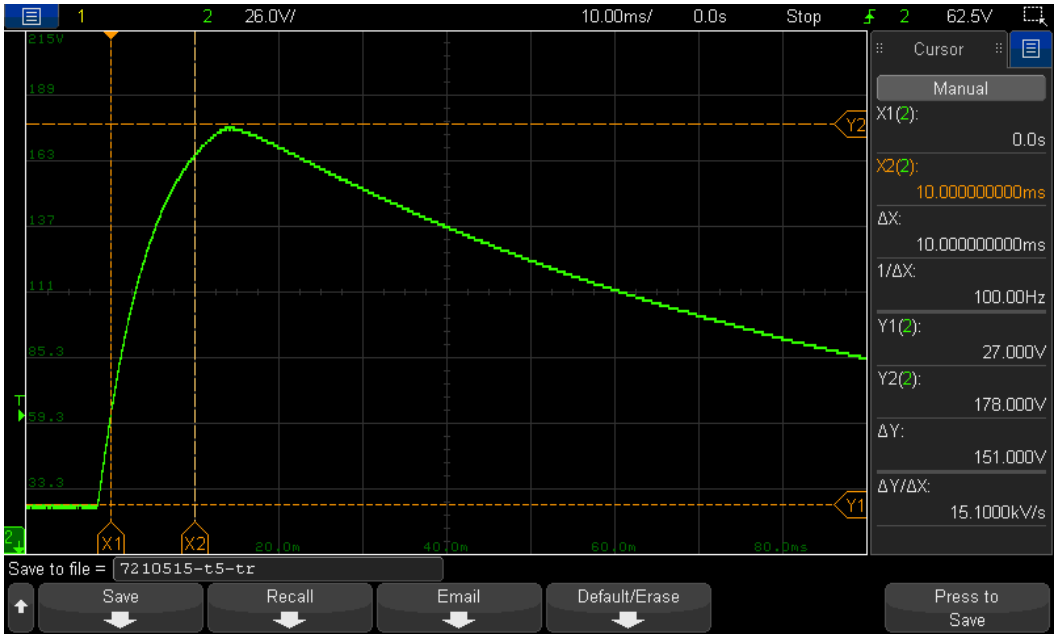


Figure 2.4-49 – Pulse 5a – Tr & Us – Open Circuit

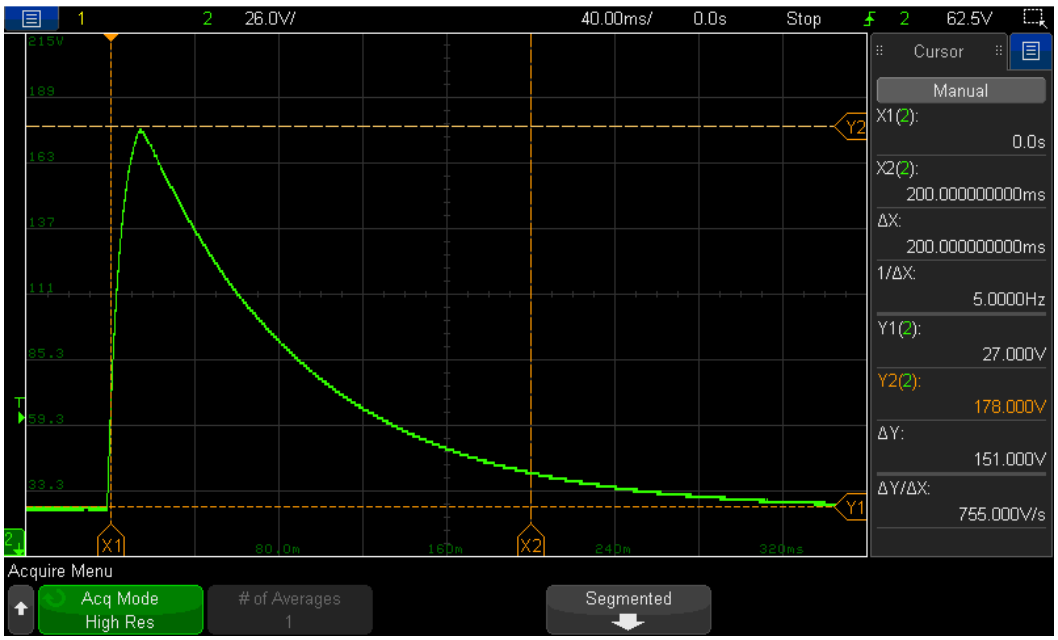


Figure 2.4-50 – Pulse 5a – Td – Open Circuit

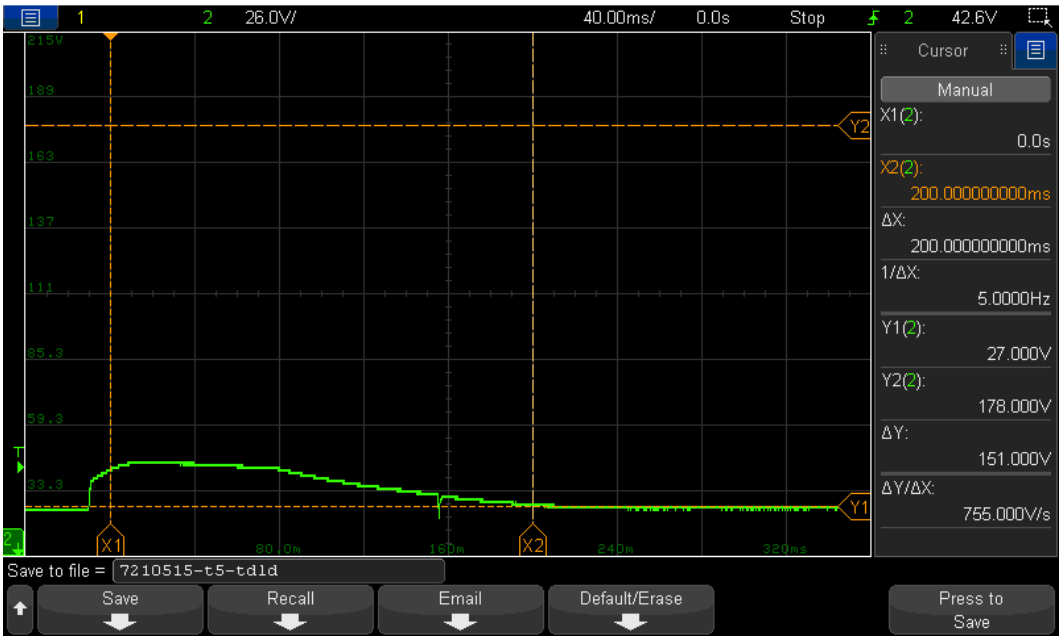


Figure 2.4-51 – Pulse 5a – Td – EUT

2.4.8 Immunity to Conducted Transients Test Setup Photo

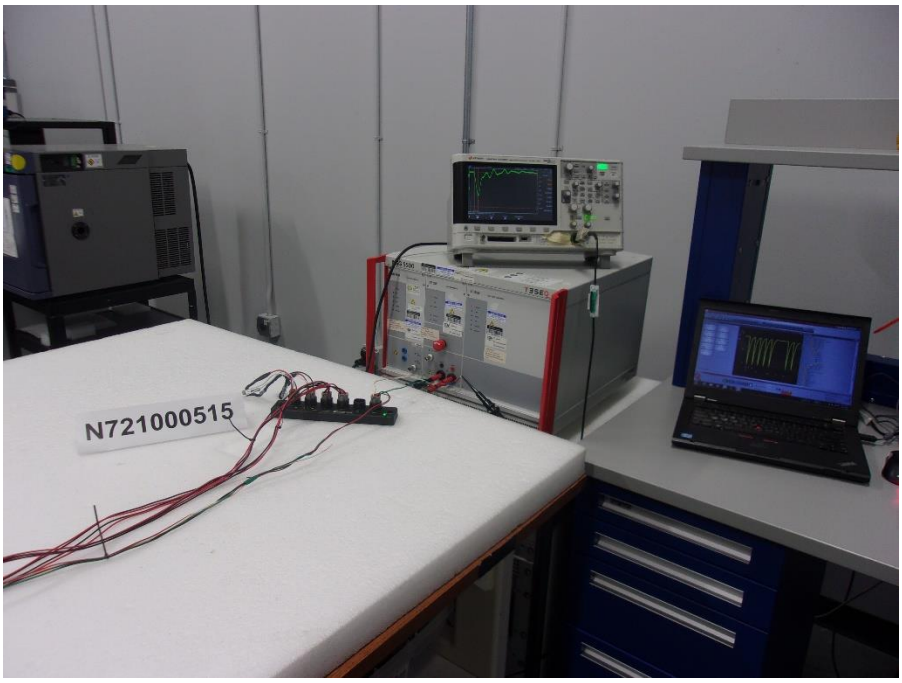


Photo 2.4-1 – Immunity to Conducted Transients on Power Leads

2.4.9 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: TRN2

Table 2.4-17 – Equipment List – Conducted Transient Immunity

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE03471	Tektronix	Scope Probe, 100:1	P5100	1-181496	G	08/02/2023	08/02/2024
NBLE11483	Teseq	Battery Simulator	PA 5840 (SAP 21007421)	12/30/1913	B	11/10/2023	11/10/2024
NBLE11486	Teseq	Micro Transient Module	MT5511	11/03/1903	B	11/10/2023	11/10/2024
NBLE11534	Keysight Technologies	Oscilloscope, 500 MHz, 2 Ch	DSOX3052T (SAP 21005363)	MY57250276	G	08/02/2023	08/02/2024
NBLE11692	Teseq	Fast Transient Module	FT 5531	04/25/1906	B	11/10/2023	11/10/2024
NBLE11693	Teseq	Load Dump Generator	LD 5550	06/07/1906	B	11/10/2023	11/10/2024

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.5 Conducted Transient Immunity on Non-Power Lines – Fast Transients

2.5.1 Specification Reference

ISO 7637-3 per ISO 13766-2

2.5.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.5.3 Test Voltage

12 VDC

2.5.4 Test Method

The EUT was setup on a non-conductive support 5cm above a copper ground plane table. The EUT signal lines were placed within a capacitive coupling clamp for the applicable transient pulses. The cable length inside the coupling clamp was 1 meter per ISO 7637-3.

Prior to the application of the transient test pulse an open circuit verification was performed to ensure all required parameters of the pulse are within tolerance levels. The open circuit verification screen captures are shown in the following sections.

During testing the EUT signal lines were subjected to a positive and negative inductance transient pulse as described in ISO 7637-3. Specific parameters of the test are described in tables in the following sections.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.5.5 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.5.6 Test Results

Table 2.5-1 – Requirements

Required Test Levels						
Test Level (Volts)	**Rep Rate (µSec)**	**Burst Width (mSec)**	**Burst Period (mSec)**	**Source Impedance (Ohms)**	**Test Time (min)**	**Performance Criteria**
+110	100	10	100	50	10	A
-110	100	10	100	50	10	A
Supplementary information: Note 1: Test level corresponds to level III of ISO 7637-3 per ISO 13766-1:2018						

Table 2.5-2 – Observations

Cable Tested	Pulse Type	Result	Observation
Main Harness	Positive	Pass	EUT continued to operate as normal throughout testing – Meets Performance Criteria A
Main Harness	Negative	Pass	EUT continued to operate as normal throughout testing – Meets Performance Criteria A

Test Summary: The EUT continued to operate as normal throughout and after testing.

2.5.7 Open Circuit Verifications

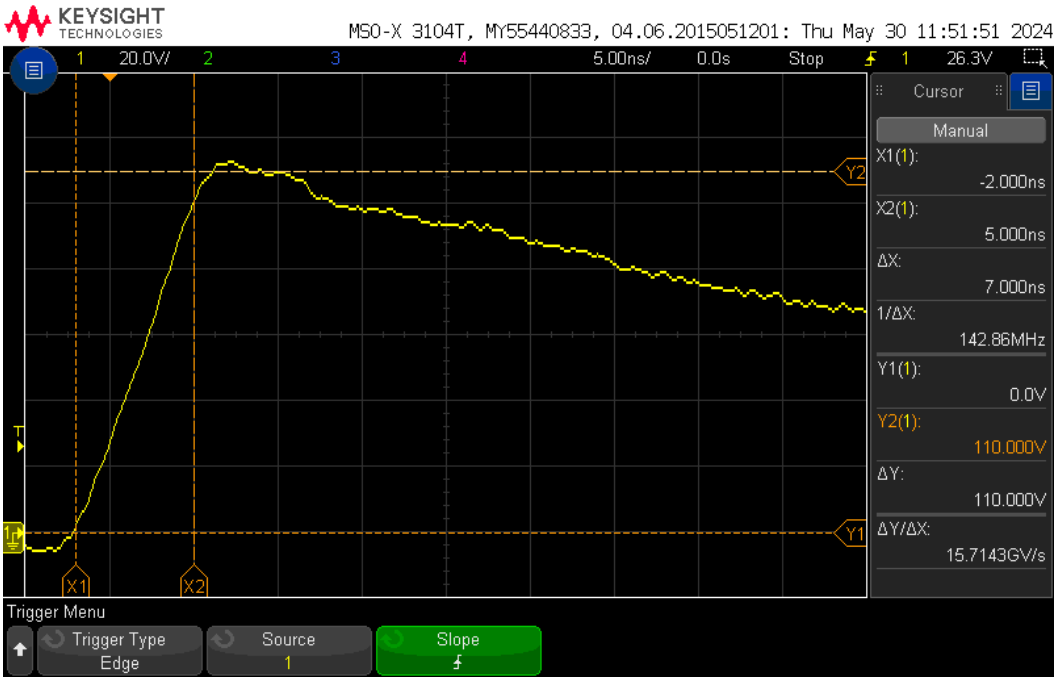


Figure 2.5-1 – Us & Tr – Open Circuit – Positive Pulse

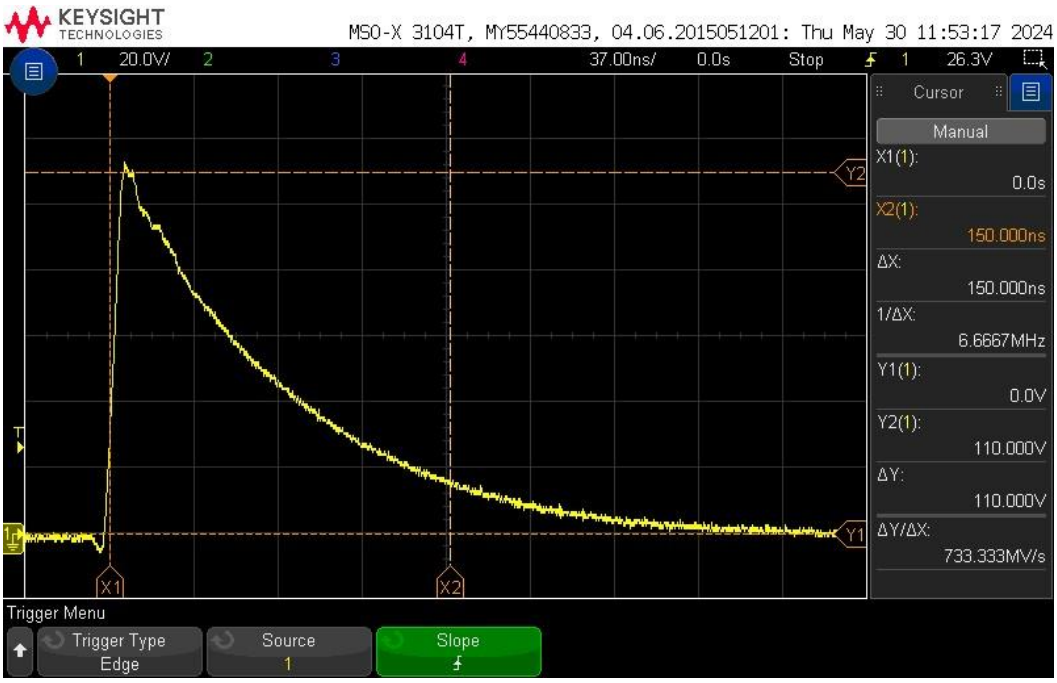


Figure 2.5-2 – Us & Td – Open Circuit – Positive Pulse

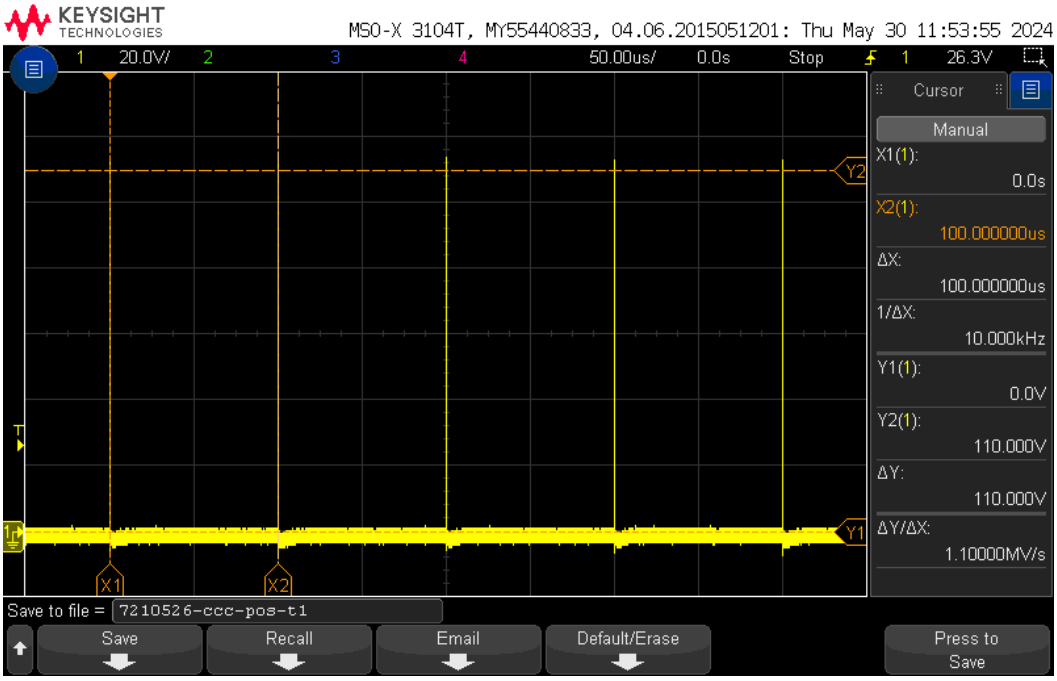


Figure 2.5-3 – T1 – Open Circuit – Positive Pulse

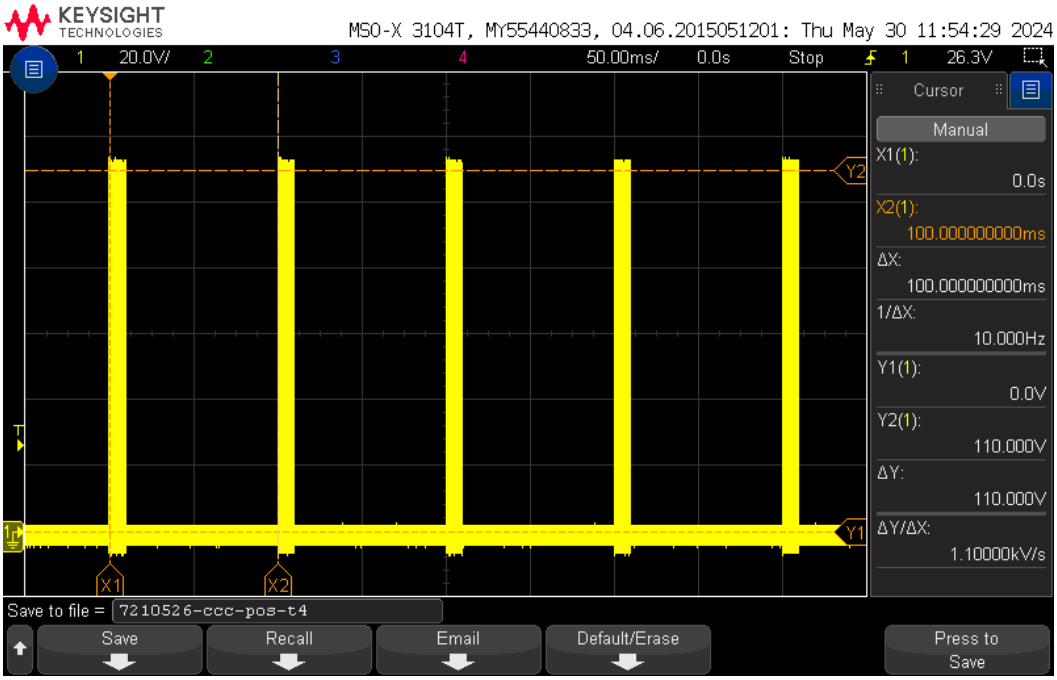


Figure 2.5-4 – T4 + T5 – Open Circuit – Positive Pulse

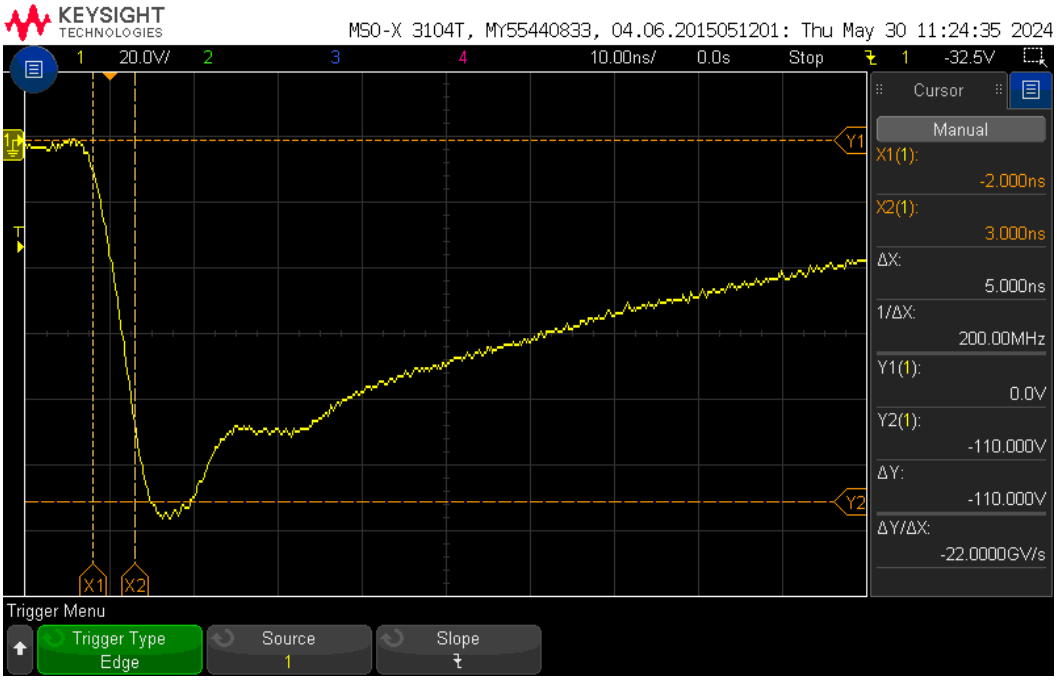


Figure 2.5-5 – Us & Tr – Open Circuit – Negative Pulse

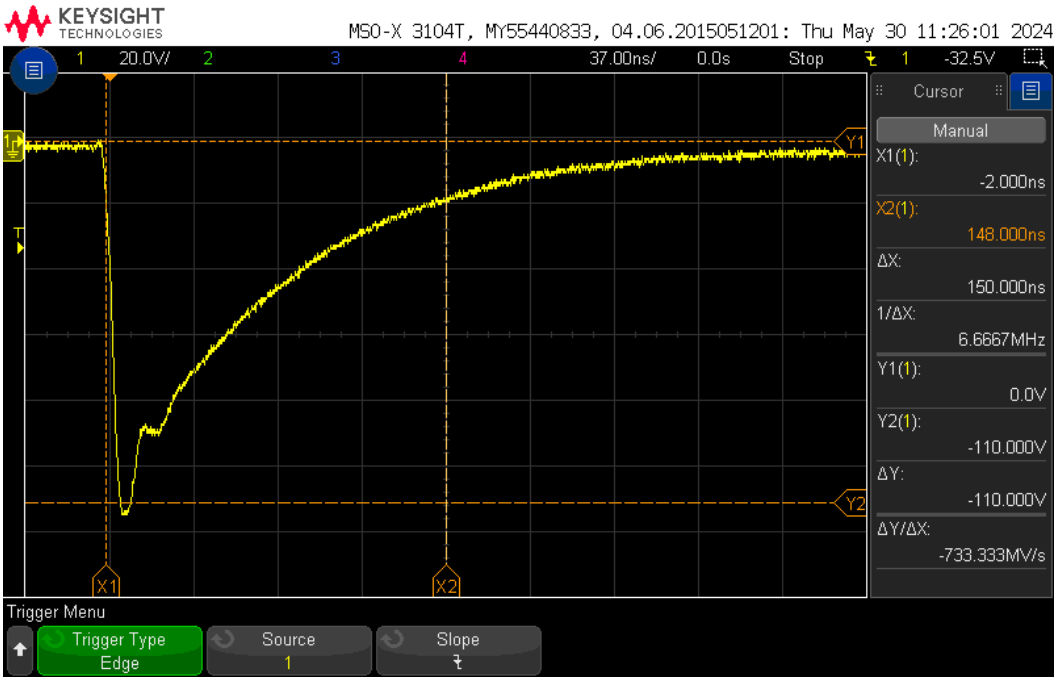


Figure 2.5-6 – Us & Td – Open Circuit – Negative Pulse

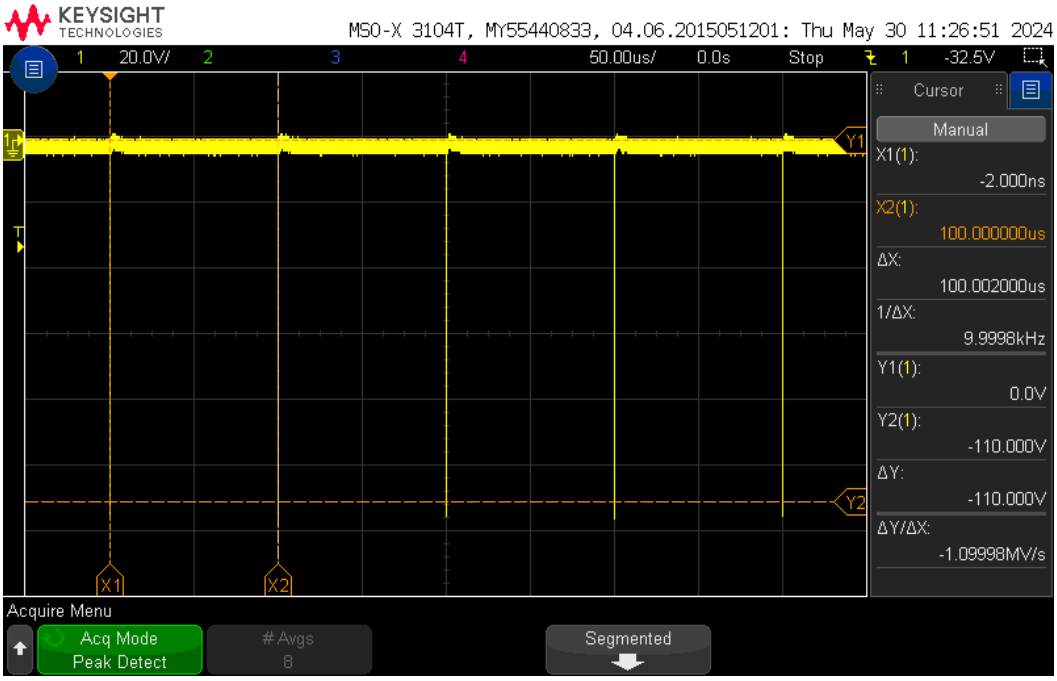


Figure 2.5-7 – T1 – Open Circuit – Negative Pulse

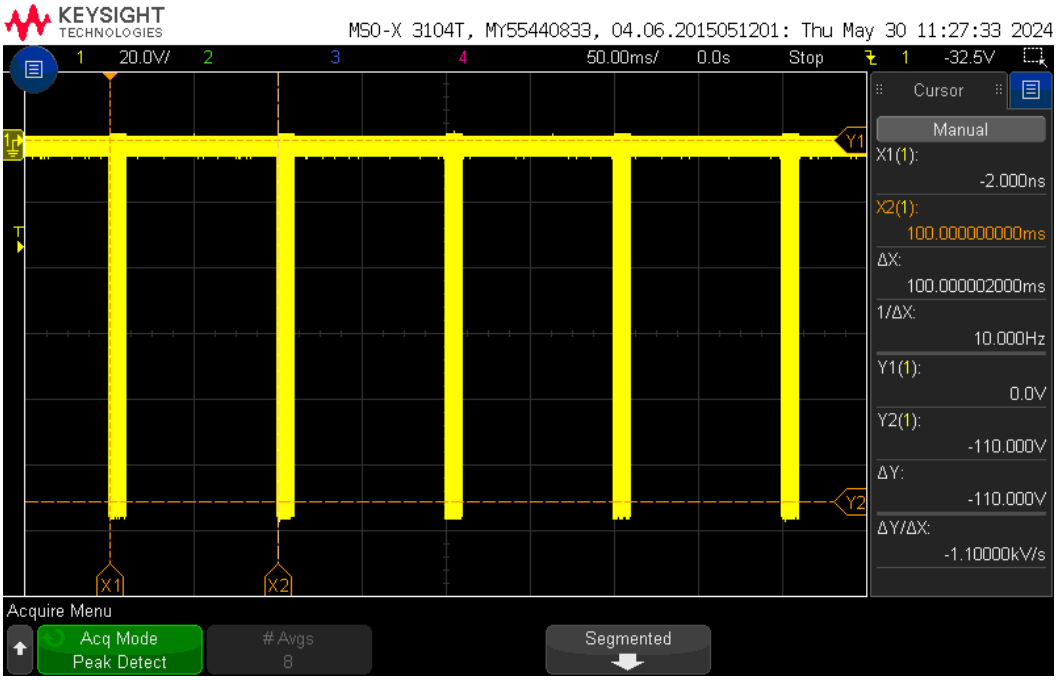


Figure 2.5-8 – T4 + T5 – Open Circuit – Negative Pulse

2.5.8 Test Screen Captures

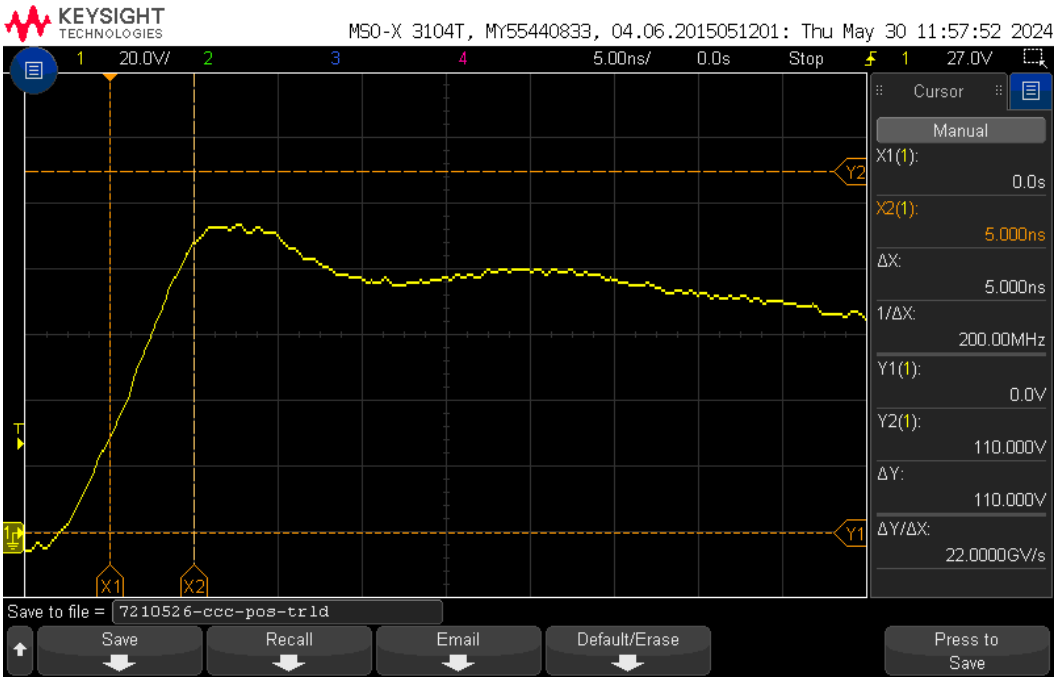


Figure 2.5-9 – Us & Tr – Data Cable – Positive Pulse

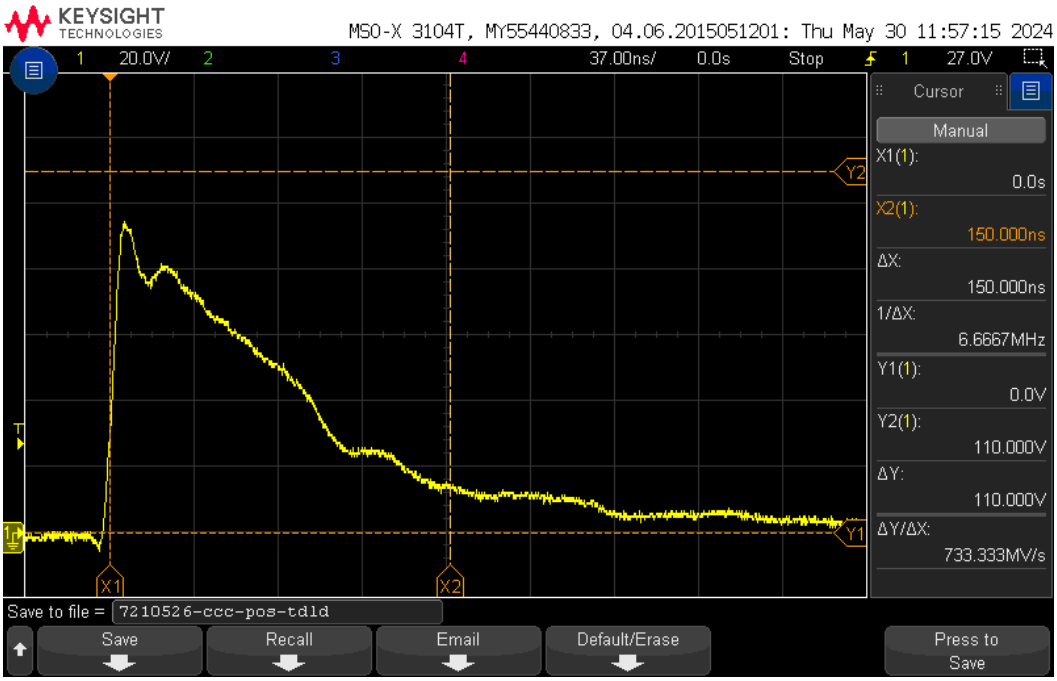


Figure 2.5-10 – Us & Td – Data Cable – Positive Pulse

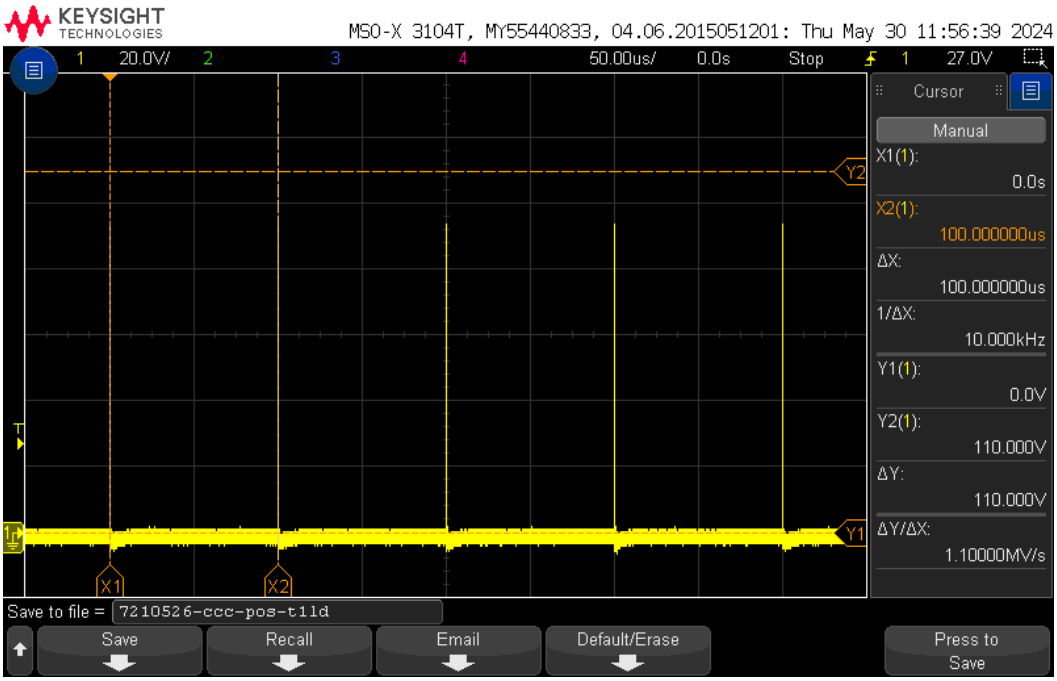


Figure 2.5-11 – T1 – Data Cable – Positive Pulse

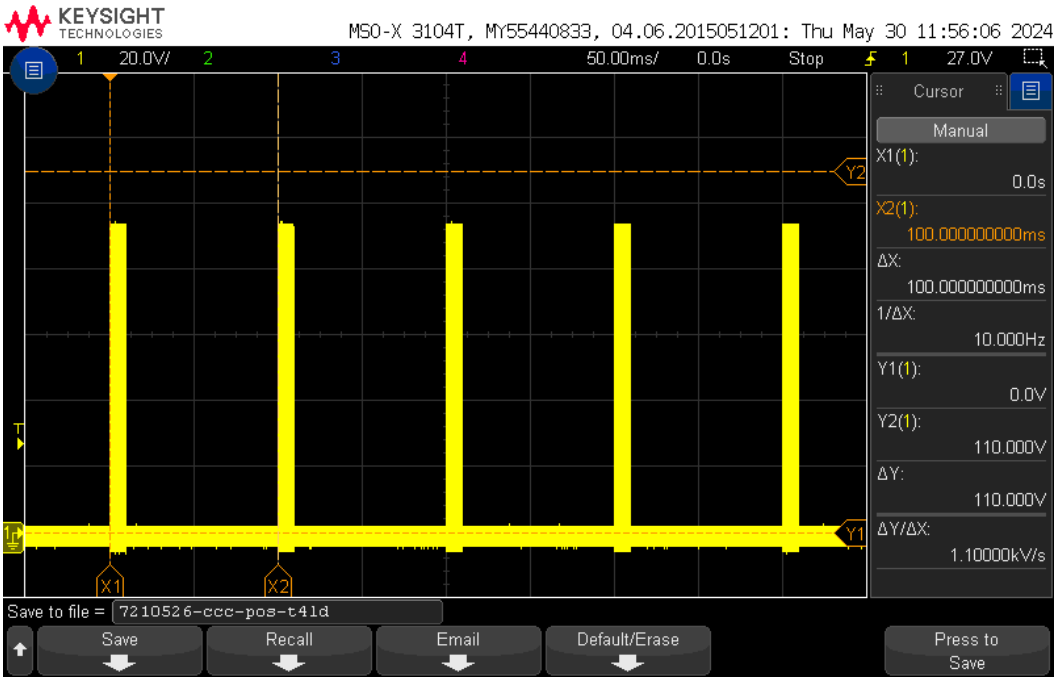


Figure 2.5-12 – T4 + T5 – Data Cable – Positive Pulse

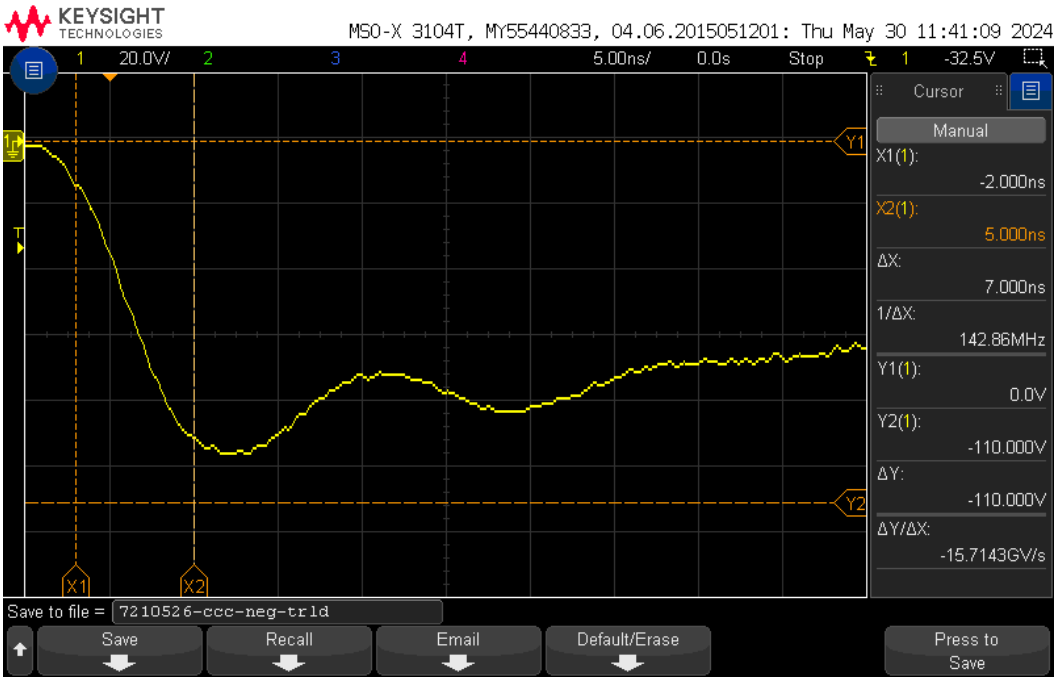


Figure 2.5-13 – Us & Tr – Data Cable – Negative Pulse

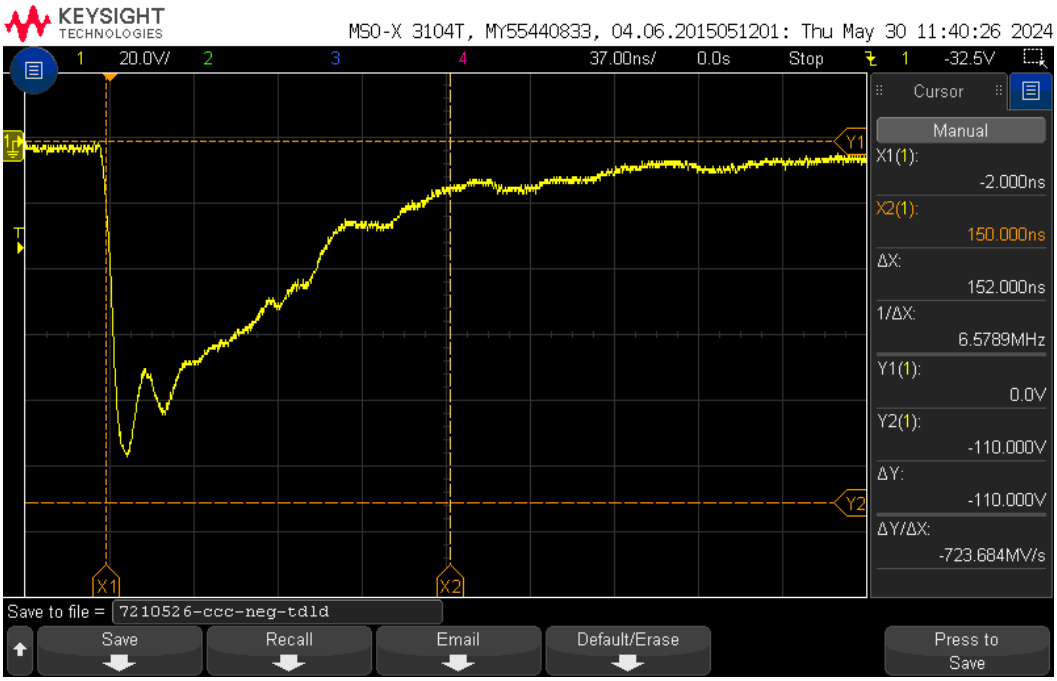


Figure 2.5-14 – Us & Td – Data Cable – Negative Pulse

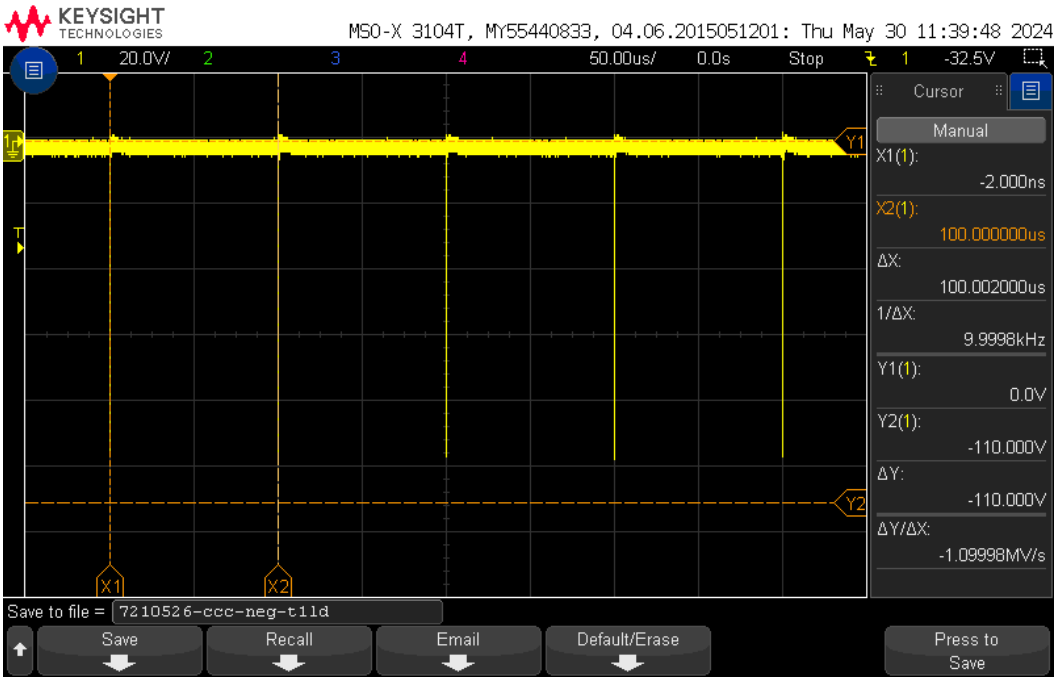


Figure 2.5-15 – T1 – Data Cable – Negative Pulse

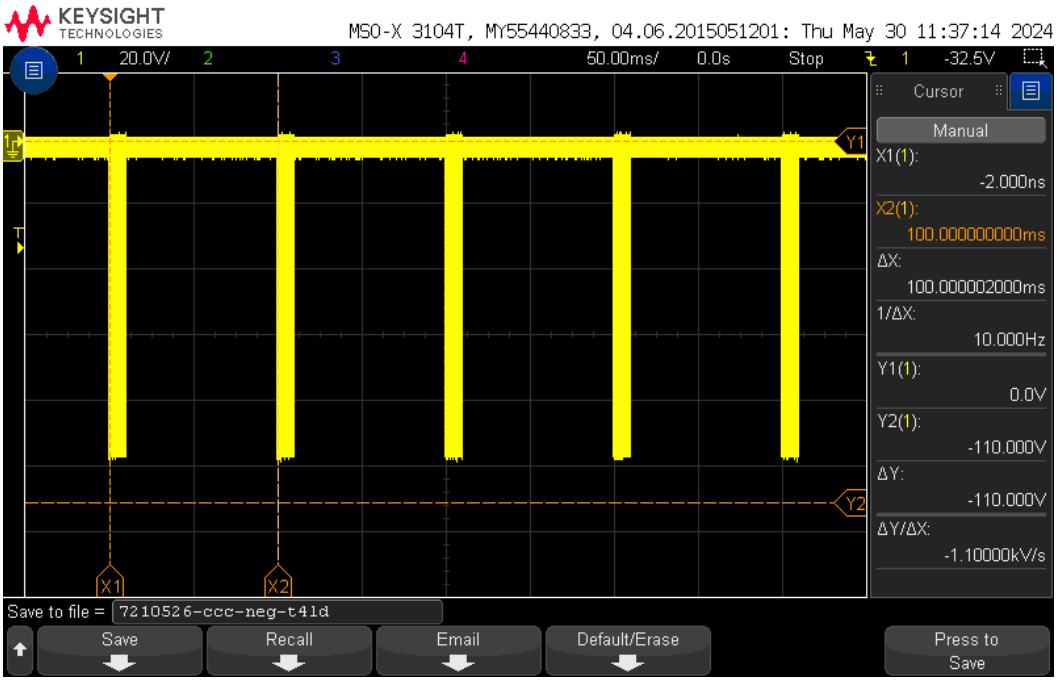


Figure 2.5-16 – T4 + T5 – Data Cable – Negative Pulse

2.5.9 Fast Transient Test Setup Photo

Photo 2.5-1 – Transient Test Pulse Setup Photo

2.5.10 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: TRN1

Table 2.5-3 – Fast Transient on Non-Power Lines Equipment List

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE10554	Amplifier Research	Capacitive Coupling Clamp	---	05/27/1964	Y	N/A	N/A
NBLE03471	Tektronix	Scope Probe, 100:1	P5100	1-181496	G	08/02/2023	08/02/2024
NBLE11411	EM Test	Ultra-Compact Simulator	UCS 200N100	P1548168213	B	04/04/2023	04/04/2024
NBLE11412	EM Test	Load Dump Generator, TP5/7	LD 200N	P1551169016	B	04/04/2023	04/04/2024
NBLE11500	Ametek CTS Europe GmbH	Power Supply	XHR33-33	1725A02285	Y	N/A	N/A
NBLE11534	Keysight Technologies	Oscilloscope, 500 MHz, 2 Ch	DSOX3052T	MY57250276	G	08/02/2023	08/02/2024

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.6 Conducted Transient Immunity on Non-Power Lines – Slow Transients

2.6.1 Specification Reference

ISO 7637-3 per ISO 13766-2

2.6.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.6.3 Test Voltage

12 VDC

2.6.4 Date of Test

30 May 2024

2.6.5 Test Method

The EUT was setup on a non-conductive support 5cm above a copper ground plane table. The EUT signal lines were placed within an inductive injection clamp for the applicable transient pulses. The injection clamp was placed 15cm from the tested cable port per ISO 7637-3.

Prior to the application of the transient test pulse an open circuit verification was performed to ensure all required parameters of the pulse are within tolerance levels. The open circuit verification screen captures are shown in the following sections.

During testing the EUT signal lines were subjected to a positive and negative transient spike as described in ISO 7637-3. Specific parameters of the test pulse are described in the tables in the following sections.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.6.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.6.7 Test Results

Table 2.6-1 – Requirements

Required Test Levels					
Test Level (Volts)	**Pulse Width (mSec)**	**Pulse Period (Sec)**	**Source Impedance (Ohms)**	**Test Length (min)**	**Performance Criteria**
+8	0.05	1	2	5	A
-8	0.05	1	2	5	A
Supplementary information: Note 1: Test level correspond to level III of the ISO 7637-3 per ISO 13766-1:2018					

Table 2.6-2 – Observations

Cable Tested	Pulse Type	Result	Observation
Main Harness	Positive	Pass	EUT continued to operate as normal throughout testing – Meets Performance Criteria A
Main Harness	Negative	Pass	EUT continued to operate as normal throughout testing – Meets Performance Criteria A

Test Summary: The EUT continued to operate as normal throughout and after testing.

2.6.8 Open Circuit Verifications

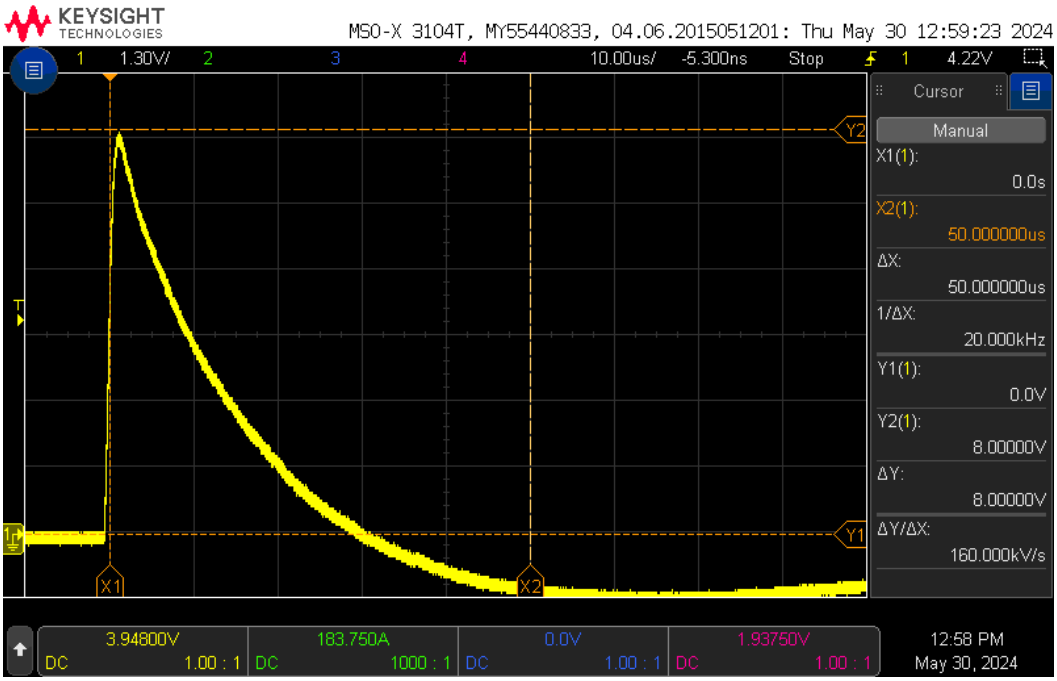


Figure 2.6-1 – Us, Tr, & Td – Open Circuit – Positive Pulse

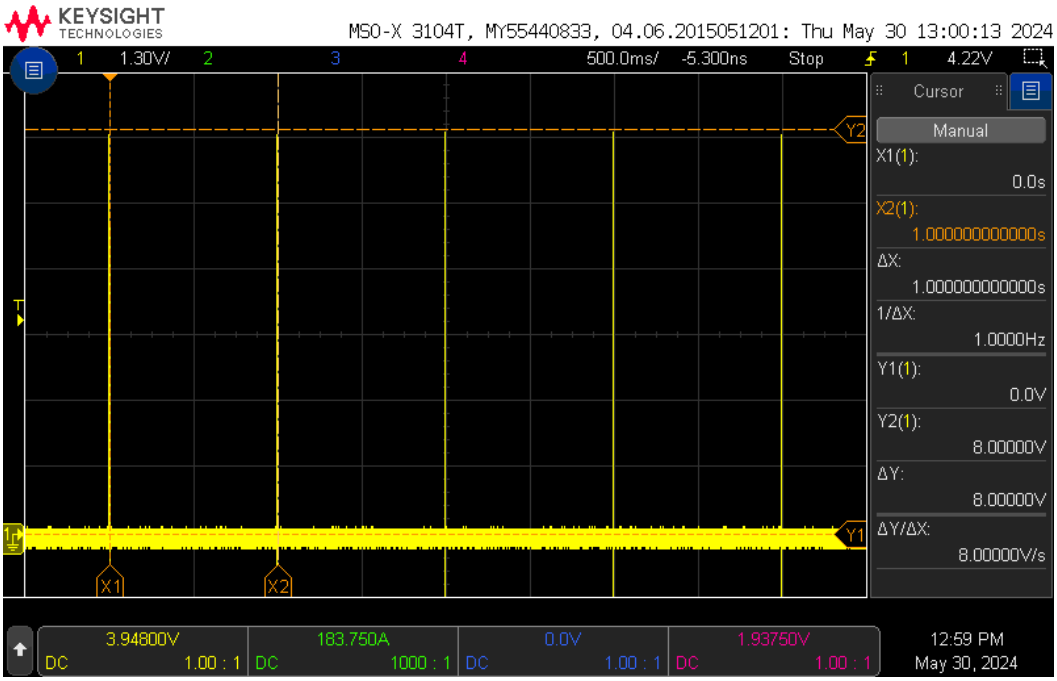


Figure 2.6-2 – T1 – Open Circuit – Positive Pulse

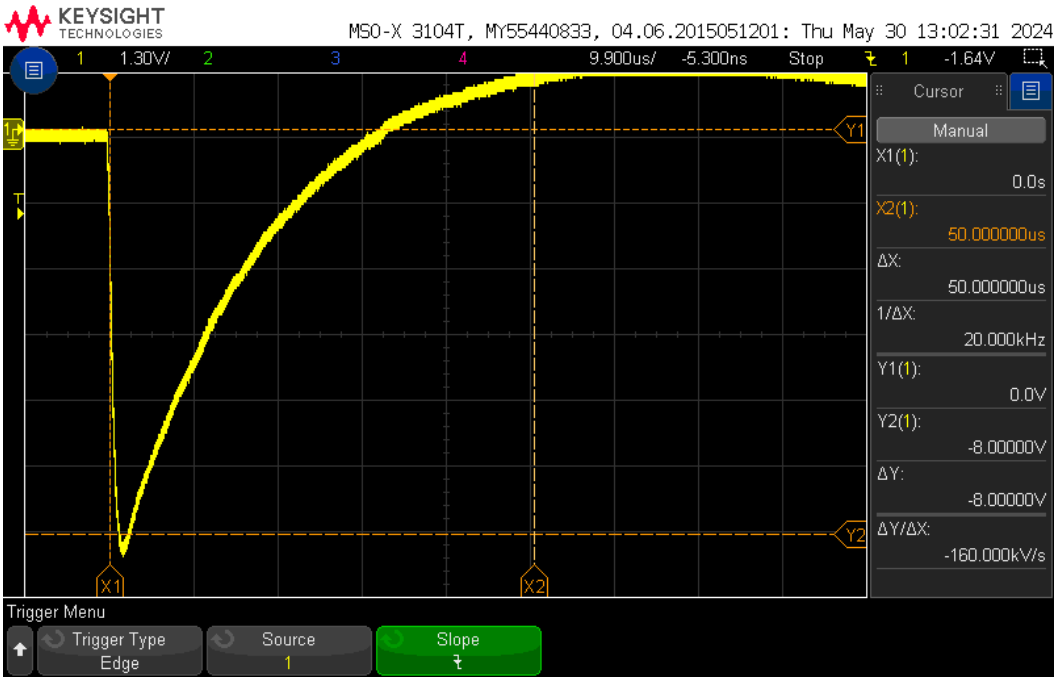


Figure 2.6-3 – Us, Tr, & Td – Open Circuit – Negative Pulse

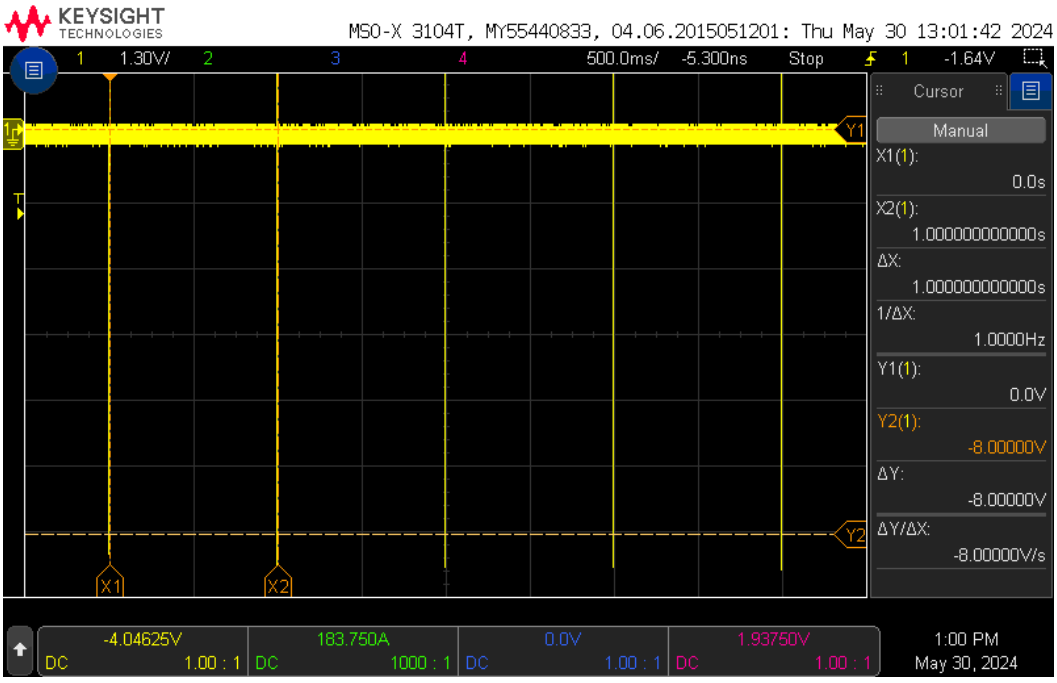


Figure 2.6-4 – T1 – Open Circuit – Negative Pulse

2.6.9 Slow Transient Test Setup Photo

Photo 2.6-1 – Slow Transient Test Pulse Setup Photo

2.6.10 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: TRN1

Table 2.6-3 – Slow Transient Equipment List

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE02858	Solar	Current Probe, 0.01-108 MHz	6741-1	735-22	Y	N/A	N/A
NBLE03471	Tektronix	Scope Probe, 100:1	P5100	1-181496	G	08/02/2023	08/02/2024
NBLE08056	EM Test	Ind Load Disconnect Trans	MPG 200	0497-06	Y	N/A	N/A
NBLE10502	Solar	Calibration Fixture	9330-1	None	Y	N/A	N/A
NBLE11534	Keysight Technologies	Oscilloscope, 500 MHz, 2 Ch	DSOX3052T	MY57250276	G	08/02/2023	08/02/2024

Cal Code G = Calibration performed by an accredited outside source.
Cal Code B = Calibration verification performed internally.
Cal Code Y = Passive Device, or Calibration not required when used with other calibrated equipment.

2.7 Transient Emissions

2.7.1 Specification Reference

ISO 7637-2 per ISO 13766-1

2.7.2 Equipment Under Test and Modification State

As shown in §1.4 with modification state “0”, as noted in §1.6.

2.7.3 Test Voltage

24 VDC

2.7.4 Date of Test

17 May 2024

2.7.5 Test Method

The EUT and cable harness were setup on a non-conductive support 5cm above a copper ground plane table. The EUT power lines was connected directly to the artificial network for the slow transient emissions measurement. For the fast-transient emission measurements the EUT power lines were connected directly to the manual switch which was then connected to the artificial network. For both measurement configuration the EUT power lines has a length of 20cm (±5cm).

For each test setup configuration, the EUT was subjected to 10 repetitions of on / off power cycles which were controlled by the manual switch shown in the setup diagrams. Each of the 10 transient conditions were measured via oscilloscope and voltage probe, and only the worst-case measured emission recorded for the report.

Specific parameters of the test pulse were defined in ISO 7637-2 Section 4.3 as well as described in the tables in the following sections.

During this testing any anomalies in the equipment under test’s performance were recorded.

2.7.6 Environmental Conditions

The EUT was evaluated within the climatic range of the EUT as specified by the manufacturer. When the manufacturer does not specify climatic parameters for the EUT, all tests are performed within the ambient climatic conditions of the laboratory.

2.7.7 Test Results

Table 2.7-1 – Requirements

Required Test Levels – 24 VDC				
EUT Test Voltage (Volts)	**Transient Type**	**Transient Limits (Volt)**	**Repetitions**	**Source Impedance (Ohms)**
27	Positive Slow	+37	10	40
27	Negative Slow	-150	10	40
27	Positive Fast	+150	10	40
27	Negative Fast	-150	10	40
Supplementary information: Note: Test limits are based off an immunity test level III per ISO 13766-1:2018.				

Table 2.7-2 – Observations During Testing

Test Condition	Max Measured Transient Positive (Volts)	Max Measured Transient Negative (Volts)	Transient Limits (Volts)	Complies
Slow – ON	+9.83	-13.00	+37 / -150	Yes
Slow – OFF	0	0	+37 / -150	Yes
Fast – ON	+10.53	-2.60	+150 / -150	Yes
Fast – ON	0	0	+75 / -150	Yes

Test Summary: All measured EUT transients were below the applicable limit requirements.

2.7.8 Test Screen Captures

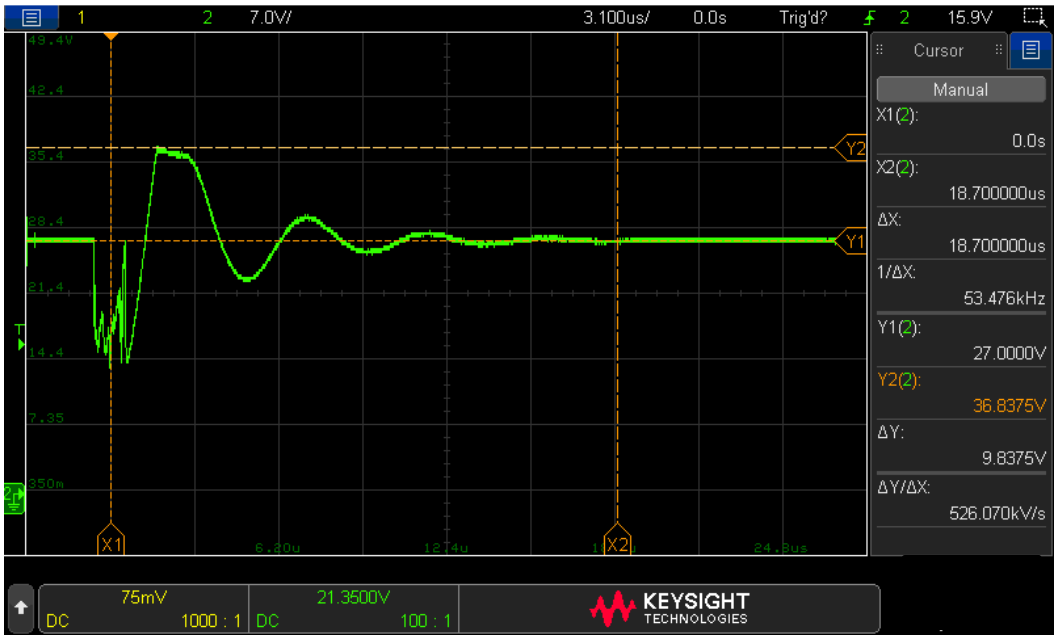


Figure 2.7-1 – Input Power Switched On – Slow Pulse – Positive

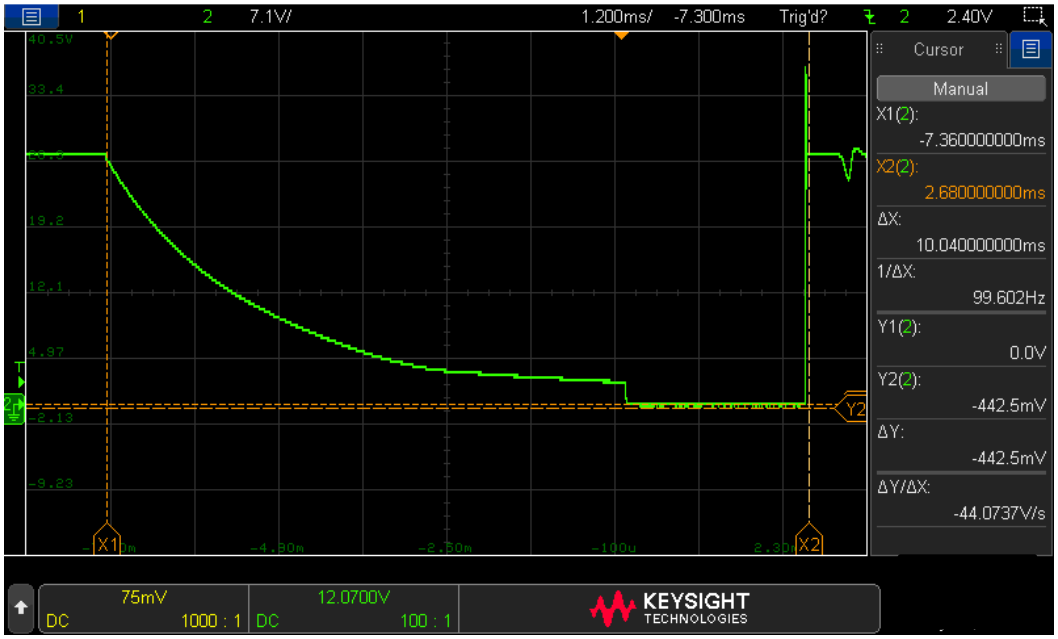


Figure 2.7-2 – Input Power Switched Off – Slow Pulse – Negative

Figure 2.7-3 – Input Power Switched On – Slow Pulse

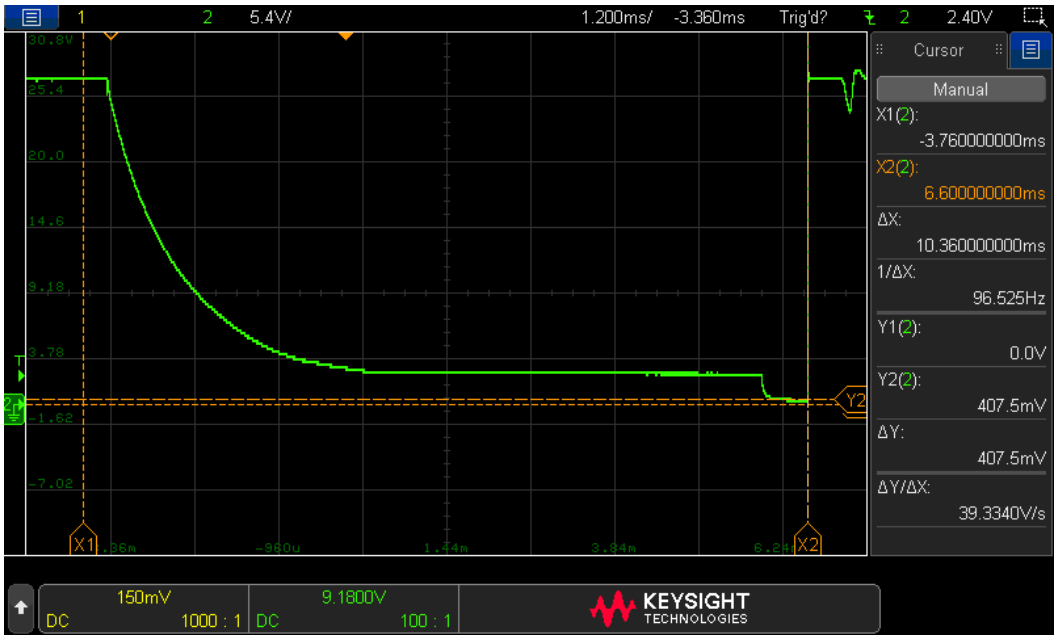


Figure 2.7-4 – Input Power Switched Off – Fast Pulse – Positive

2.7.9 Transient Emissions Test Setup Photos

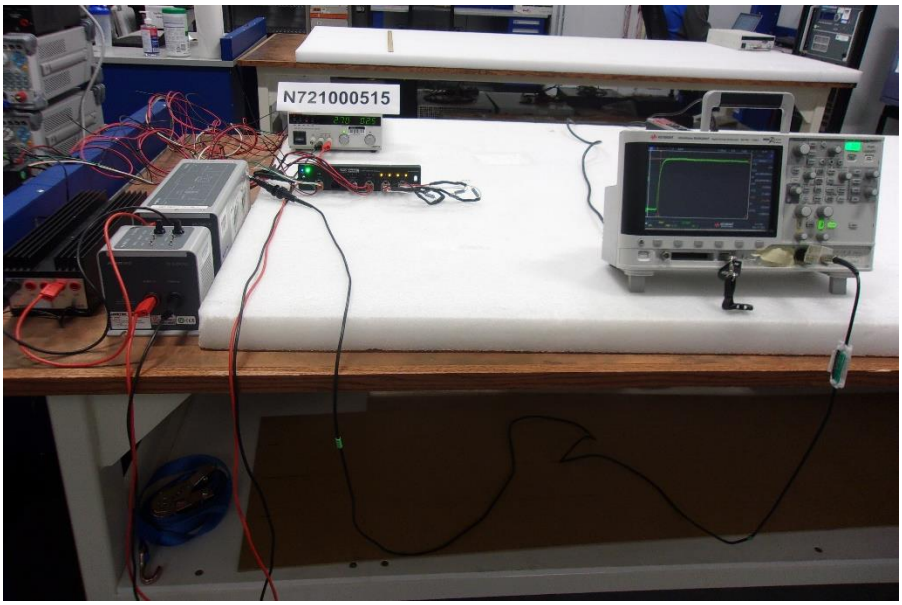


Photo 2.7-1 – Transient Emission Test Setup – Slow Transients

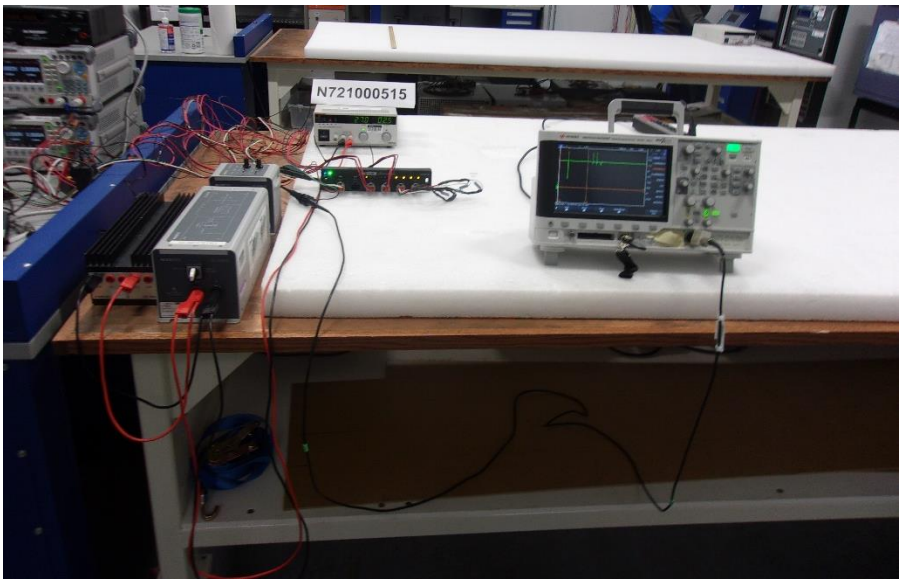


Photo 2.7-2 – Transient Emission Test Setup – Fast Transients

2.7.10 Test Location and Test Equipment Used

This test was carried out in New Brighton, MN.
Test Area: TRN2

Table 2.7-3 – Conducted Transient Emissions Equipment List

Device #	Manufacturer	Description	Model	Serial #	Cal Code	Cal Date	Cal Due
NBLE03471	Tektronix	Scope Probe, 100:1	P5100	1-181496	G	08/02/2023	08/02/2024
NBLE11105	Sorensen	Power Supply, DC 33V-33A	XHR33-33-MGA	1215A01757	Y	N/A	N/A
NBLE11417	EM Test	Single line Artificial Network	AN 200N100	P1606171531	B	06/17/2023	06/17/2024
NBLE11425	EM Test	Load Impedance for BS200N Semiconductor Switch	RS-BOX	P1605171472	B	06/17/2023	06/17/2024
NBLE11534	Keysight Technologies	Oscilloscope, 500 MHz, 2 Ch	DSOX3052T	MY57250276	G	08/02/2023	08/02/2024
NBLE11899	Ametek CTS GmbH	Electronic Switch for Transient Emissions	BS 200N100.1	P2335278810	B	04/10/2024	04/10/2025

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STATEMENT OF MEASUREMENT UNCERTAINTY – Immunity

The data and results referenced in this document are accurate. The reader is cautioned that there is some measurement variability due to the tolerances of the test equipment that can contribute to a nominal product measurement uncertainty. Furthermore, component differences and manufacturing process variability of production units similar to that tested may result in additional product uncertainty. If necessary, refer to the test lab for the actual measurement uncertainty for specific tests.

STATEMENT OF MEASUREMENT UNCERTAINTY – Emissions

The test system for conducted emissions is defined as the LISN, tuned receiver or spectrum analyzer, and coaxial cable. This test system has a measurement uncertainty of ±3.30 dB. The test system for radiated emissions is defined as the antenna, the pre-amplifier, the spectrum analyzer, and the coaxial cable. This test system for 30 to1000 MHz has a measurement uncertainty of ±5.88 dB and above 1 GHz a measurement uncertainty of ±4.47 dB. The measurement uncertainty values for conducted and radiated emissions meet the requirements as expressed in CISPR 16-4-2. The equipment comprising the test systems is calibrated on an annual basis.

TEST EQUIPMENT

All measurement instrumentation is traceable to the National Institute of Standards and Technology and is calibrated to meet test method standard requirements and/or manufacturer's specifications.

4 Appendix A – Customer Test Plan