

Designing for NEBS Compliance: The SMH4804

Introduction

A reference circuit design employing a Summit Microelectronics SMH4804 Quad Hot-Swap Controller and SMT4004 Quad Tracking Power Supply Manager is tested and hardened for NEBS EMI/EMC compliance. This reference design is intended to assist the design engineer with component selection and general PCB layout practices required to meet the NEBS Standards. Test results published herein were obtained in Summit Microelectronics' lab and are for reference only as NEBS compliance requires submission to an approved testing facility.

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Component Selection for NEBS

The NEBS compliance reference circuit is based on the SMH4804 evaluation board. Testing and hardening of the evaluation board resulted in the circuit displayed in

Figure 1. The added components are highlighted in red. NEBS compliance testing begins with an overview of the standards (see "NEBS: An Historical Overview") after which a suitable waveform generator is chosen. The UCS500-M from EM Test generates the necessary waveforms and includes Windows software with pre-programmed test routines to simplify testing and allow for easy documentation of each test step.

Before testing, identify all power and signal lines that interface directly with the host (-48V) supply. In this example, a dual-feed supply is employed. A short pin is used for each feed to hold off the in-rush current until the DUT is inserted. There are 6 external connections to the backplane; 4 must be fused to meet safety standards and otherwise prevent this system card from disrupting the host supply.

Though the NEBS EMI/EMC standards are quite exhaustive, much of the testing and hardening efforts are focused on immunizing the system from external noise sources such as ESD and lightning strikes. Additional noise sources, such as EMI originating from other cards operating on the -48V bus are rendered harmless using the same circuitry (EMI filters) that prevents the DUT itself from becoming a noise source.

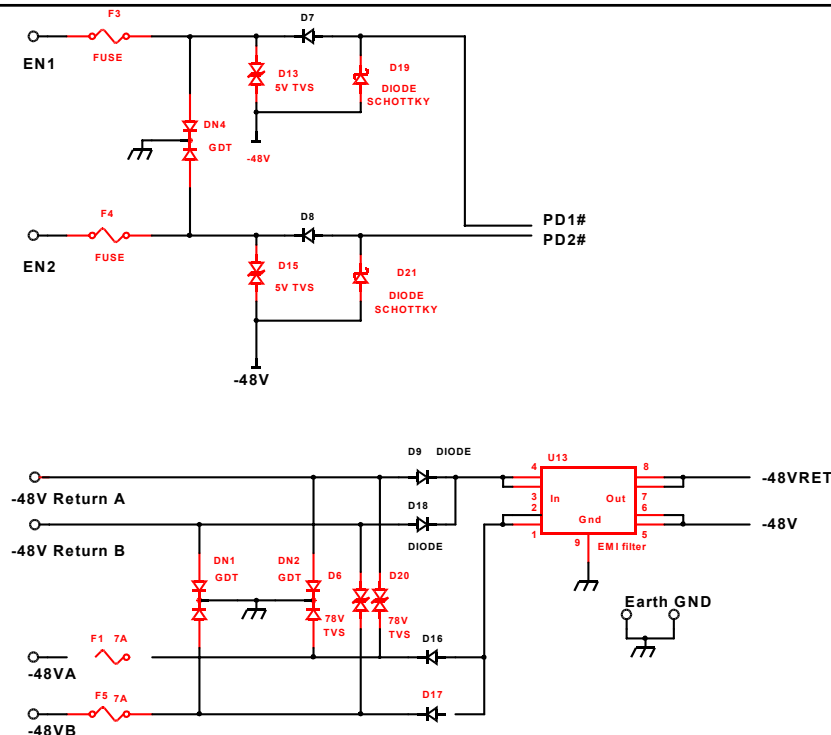


Figure 1: -48V Bus-Side Input Hardened for NEBS Compliance (added components in red)



Pre-Testing for NEBS Compliance

The UCS500 waveform generator applies waveforms to the DUT. Figure 2 displays the menu various test waveforms available from the UCS500

Selecting the 'Burst' waveform (F1, IEC 61000-4-4) generates a series of identical pulses with programmable amplitude, waveform shape, etc.

The UCS500 displays the selections as shown in Figure 3. Selecting the EN50082-1 (F5) test routine prepares the UCS500 to output the Burst Waveform. The Graphical Interface Window is used to set the test waveform characteristics, test duration and time interval between the pulse bursts (Figure 4).

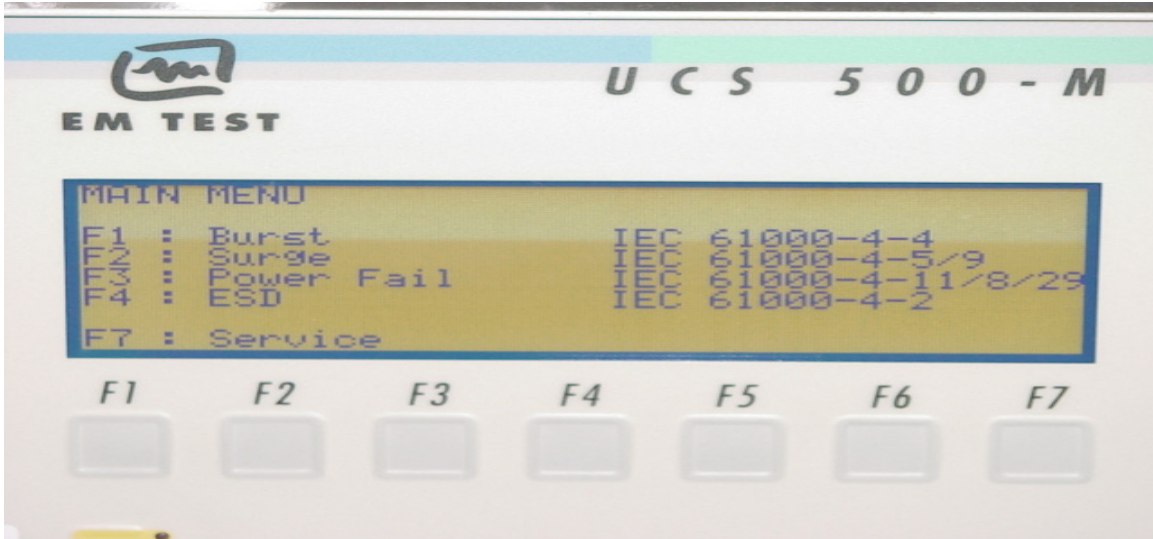


Figure 2: UCS500 Front Panel 'MAIN MENU' display

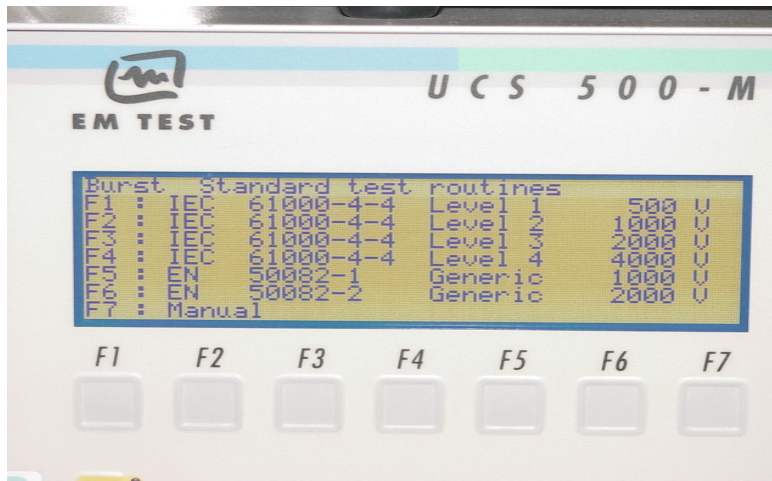


Figure 3: UCS500 Front Panel 'Burst Standard Test Routines' display.

*******CAUTION*******
High-voltages, as used in NEBS compliance testing, are extremely hazardous and can be lethal. Do not proceed with testing until all possible safety measures are taken. Be certain to wear eye protection and never perform testing alone.

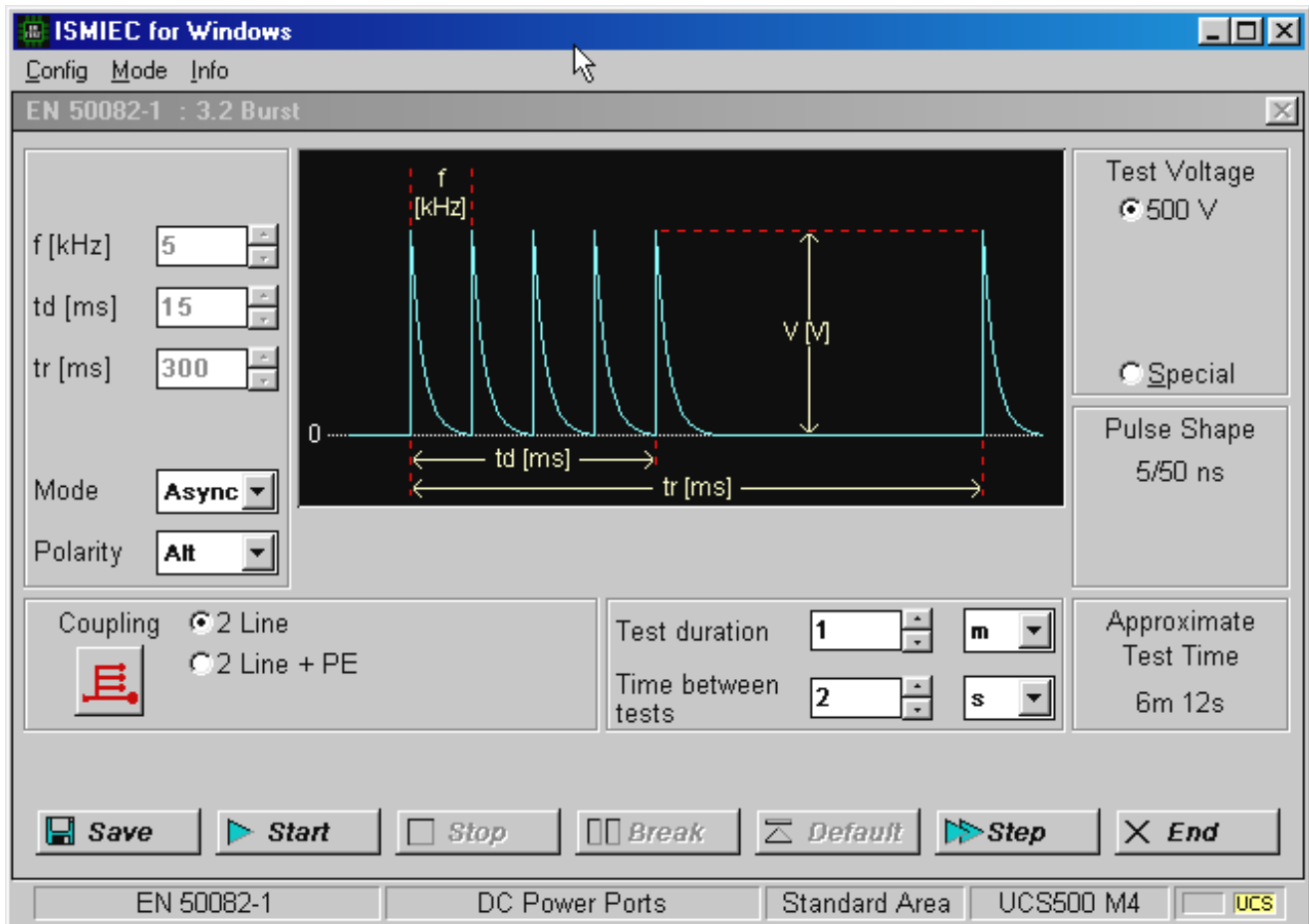


Figure 4: UCS500 Windows software GUI display.

Pre-Testing for NEBS Compliance, Cont'd

As a matter of safety and to avoid component failures, it is important to begin all tests using the lowest possible voltage amplitude required by each level of the standard. For the burst test, this is 500V. Also, during the burst test the number of pulses should be minimized and the time between pulses maximized.

The burst test begins at Level 1 (see Table 1). Once the system board is tested, hardened (if necessary), and found to comply, the DUT is moved to the next test level until component damage occurs or all test Levels have been applied to the DUT. Figure 5 is a photo of the actual DUT with the testing equipment connections made.

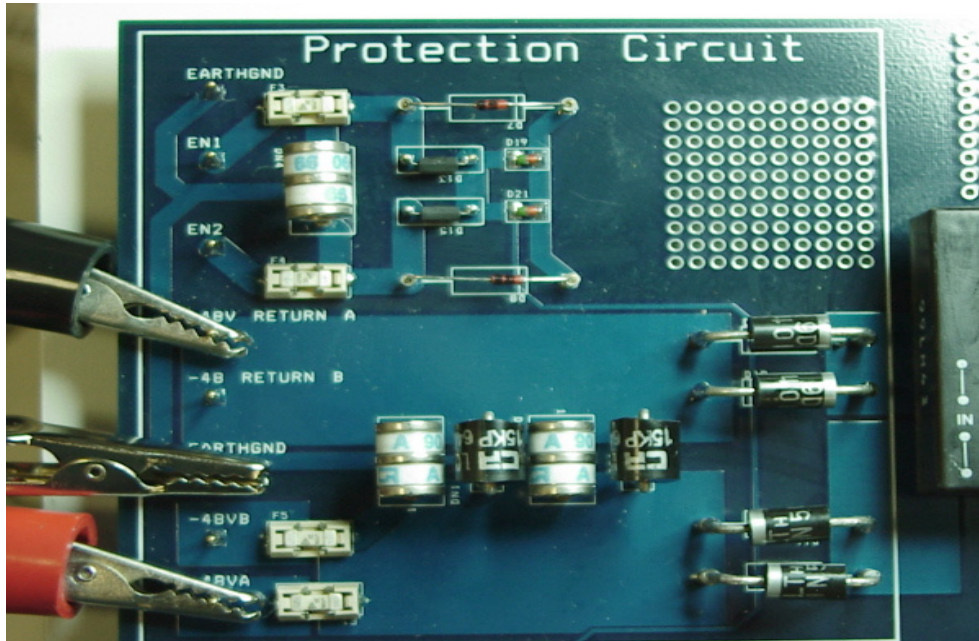


Figure 5: PCB protection circuit area and connections of the test equipment to the DUT

Pre-testing for NEBS Compliance, Cont'd

Note the transient-voltage suppressors (TVS), gas-discharge tubes (GDT), fuses and conducted EMI suppression filter.

The GDT is used for protection from lightning strikes. These devices act as a short when the breakdown voltage is exceeded. They are extremely rugged and are available in a number of different breakdown voltages.

The TVS are used for high voltage, short duration surges such as ESD. The TVS are available in many different breakdown voltages and power handling capabilities.

Fuses are used to protect the -48 Volt power supply from shutting down when the GDT or the TVS breakdown.

The EMI filters are used to suppress any noise coming from the -48 Volts supply and any noise coming from the DC-DC converter that may disturb the DUT itself or another card in the system. Often times these filters are

required to meet conducted (and radiated) emissions standards.

The advantages of split EMI filtering (U13 and U17) may be undermined by the introduction of excessive inrush currents into the filter (U13) residing on the -48V bus (see scope photo, Figure 7B and 7C). The cause of the inrush current is the C_x (line to line) capacitor, Figure 6. To minimize the inrush current choose a filter with the lowest possible C_x capacitor value. To ensure the inrush does not disturb the -48V bus, either add a capacitor with a value 5 times that of the filter's C_x capacitor nearby the system card on the motherboard or backplane or remove U13 and only use U17. Figure 7A shows the inrush current without the input EMI filter. Figure 7B shows the inrush current for a filter with a lower C_x capacitor value.

Note: Oscilloscope photos of the higher voltage tests were not taken because of the voltage limitation of the oscilloscope probes. If the protection circuit were to fail the applied test waveform might damage the oscilloscope probes or the oscilloscope.



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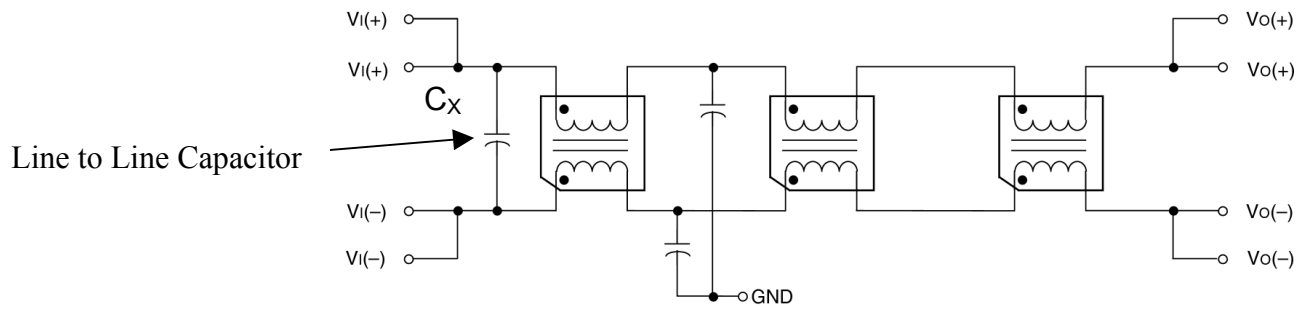


Figure 6 – Internal schematic of the EMI Filters

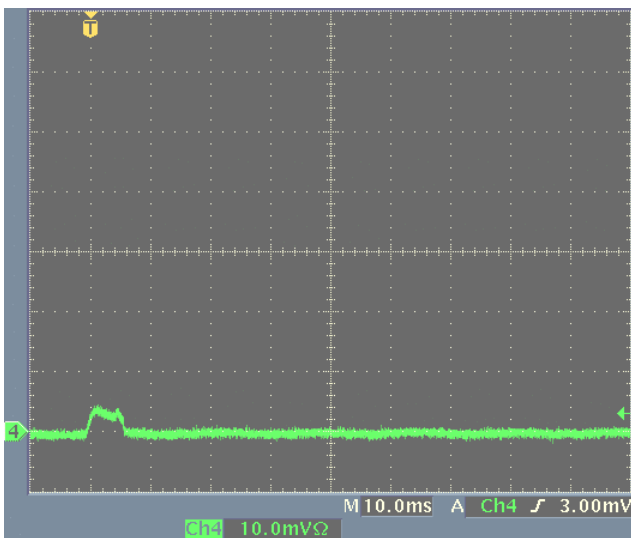


Figure 7A No EMI Filter before the SMH4804, 5A/div

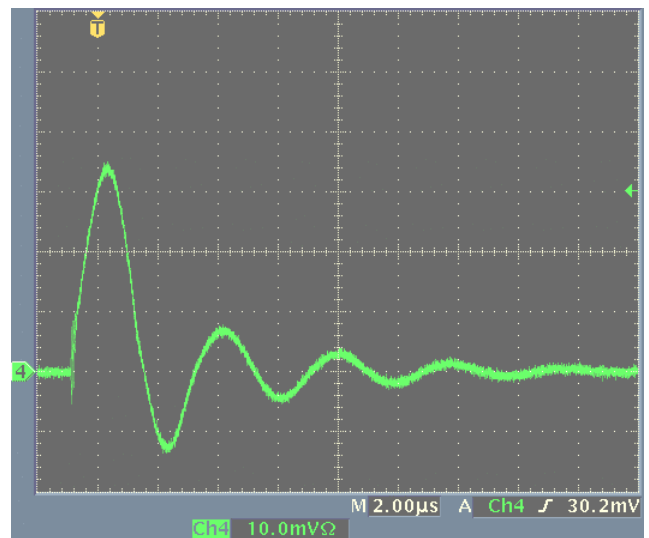


Figure 7B –Power One 10A EMI Filter, 5A/div

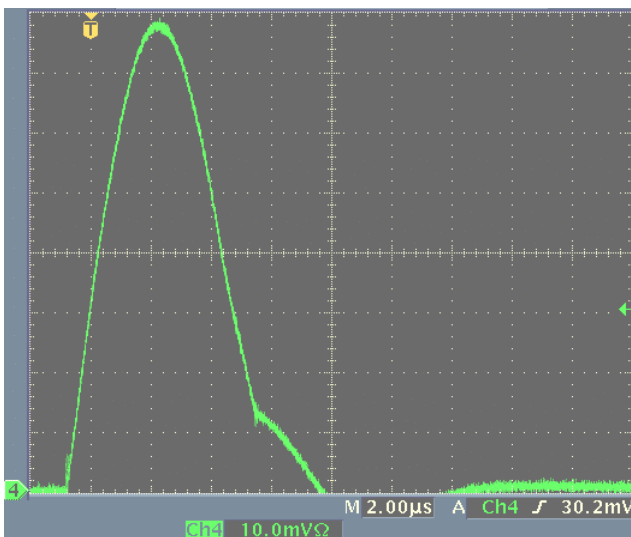


Figure 7C –Tyco 20A EMI Filter, 5A/div



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Pre-testing for NEBS Compliance, Cont'd

The scope photo in Figure 8 shows the effect of the 500V amplitude burst pattern on the -48Volts supply following the protection circuit. Channel 1 monitors the burst following the protection circuit and before the first EMI filter. Channel 2 monitors the burst pattern after the first EMI filter. Channel 3 monitors the burst pattern

after the Summit Microelectronics' SMH4804 device (see Figure 10) and channel 4 monitors the burst pattern after the second EMI filter. The varying amplitudes of the waveforms indicate the degree of attenuation each section contributes to 'squenching' the burst waveform disturbance.

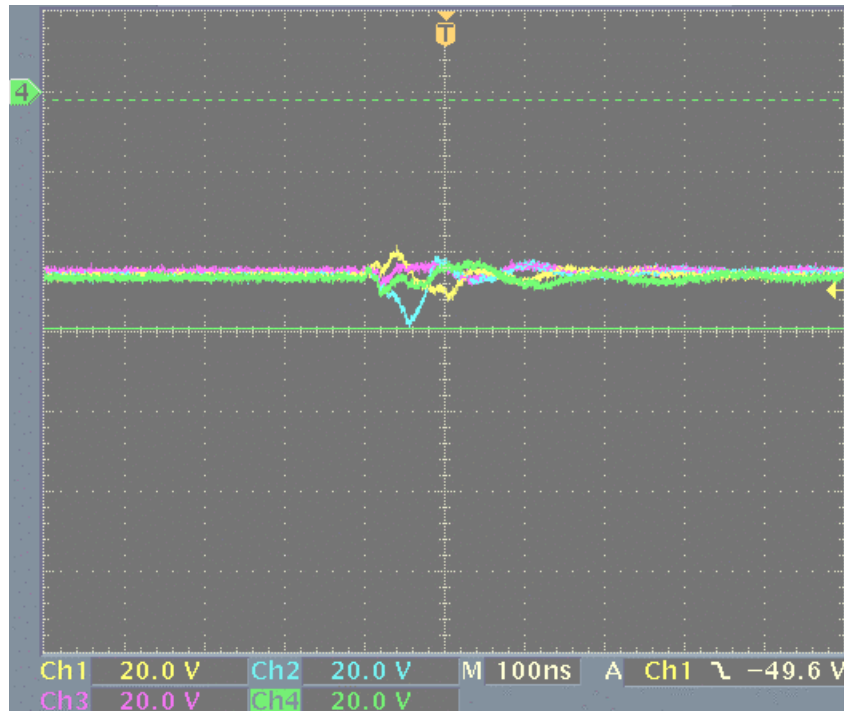


Figure 8: Results of the 500V Burst Test Pattern at Various Points on the DUT (see text)

Tektronix TDS3054

Time/Horizontal division = 100nS

Channel 1-4 = 20V/div, All scope probe returns connected to U13-3, & 4

Ch 1 = -48V (Yellow trace)

Ch 2 = U13-5, 6 (Blue trace)

Ch 3 = U17-1, 2 (Purple trace)

Ch 4 = U17-5, 6 (Green trace)

As shown, the protection circuitry clamped the burst voltages to approximately 60 Volts. No circuitry was damaged using the Level 1 (+/-500 Volts) waveform.

The burst voltage is then increased to Level 2, +/-1000 Volts. The burst pattern was then applied to the board with no damage occurring. This infers the DUT is NEBS compliant against the burst tests.

It is useful to extend the testing to at least 125% of the required compliance amplitude to be assured of obtaining NEBS compliance on all production boards.

The tests were increased to see how far the NEBS board could be taken before it was damaged. It is also useful to determine the amplitude at which a hard failure occurs.

The Level 3 (+/-2000 Volts) test pattern was applied to the NEBS board with no hard failures. In fact, this system passed the Level 4 requirements of +/-4000 Volts. This is the maximum level of protection this board can offer before a hard failure occurs.

The next test is the surge test. Figure 9 displays the Windows setup for the surge voltage waveform.

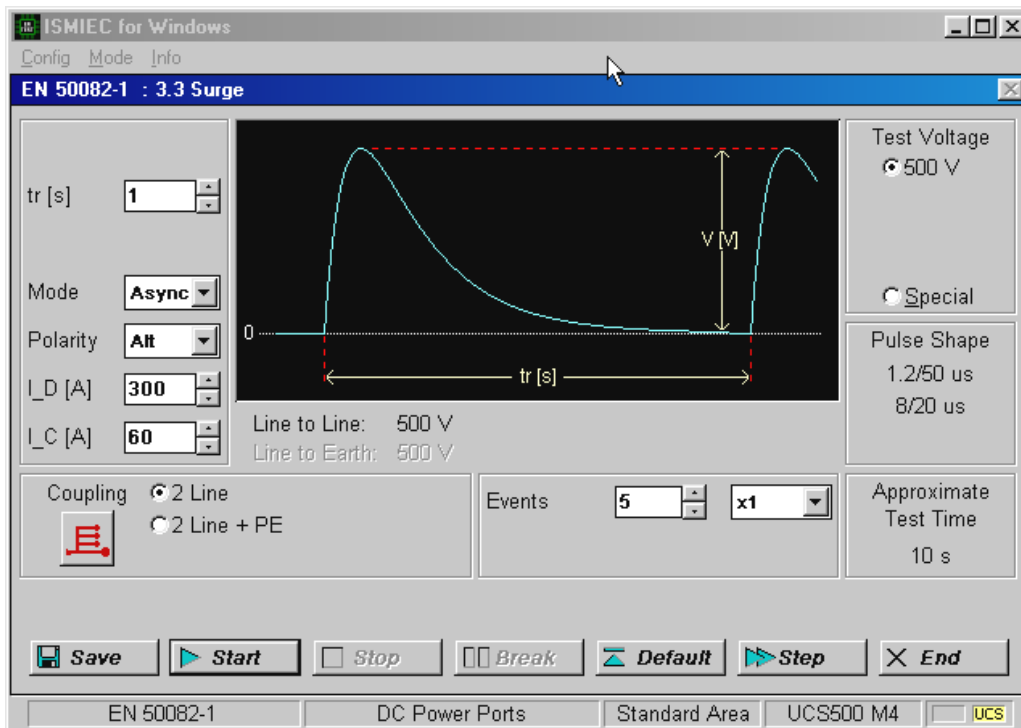


Figure 9: UCS500 Windows' display for setting the EN50082-1 Surge Test Waveform Parameters

Pre-testing for NEBS Compliance, Cont'd

The test begins with the lowest level of compliance, Level 1 (+/-500 Volts). The scope photo (Figure 10) displays the effect of surge after the protection circuitry.

This indicates the incoming surge is clamped to -80 Volts.

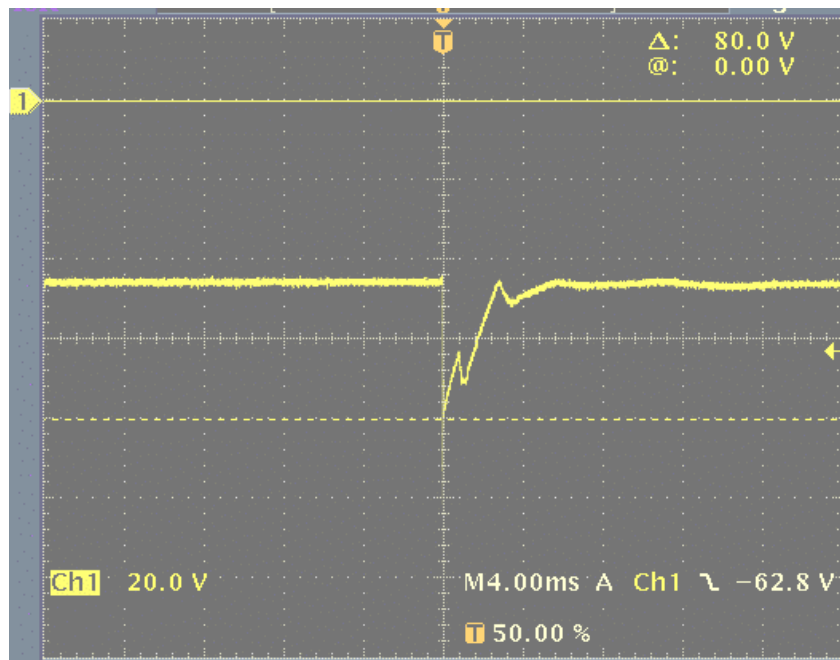


Figure 10: Results of the 500V Surge Test Waveform after the Protection Circuitry of the DUT (see text)



Pre-testing for NEBS Compliance, Cont'd

The Level 2 (+/-1000 Volts) surge waveform is then applied to the board. The scope photo (Figure 11) indicates the protection circuit is clamping the surge to a very safe -80 Volts.

The last test is the ESD test. Starting at the lowest level of protection according to NEBS, the Level 1 ESD test consists of 5 positive and 5 negative 2000 Volt hits to the board at 1-second intervals. Level 2 is similar to Level 1 except that it is at a higher voltage of 4000 Volts.

The same goes for Level 3 and Level 4 in which the voltage is raised to 6000 Volts and 8000 Volts, respectively. No scope photos were taken because of the potential damage it may cause the scope and the scope probes if the protection circuit were to fail.

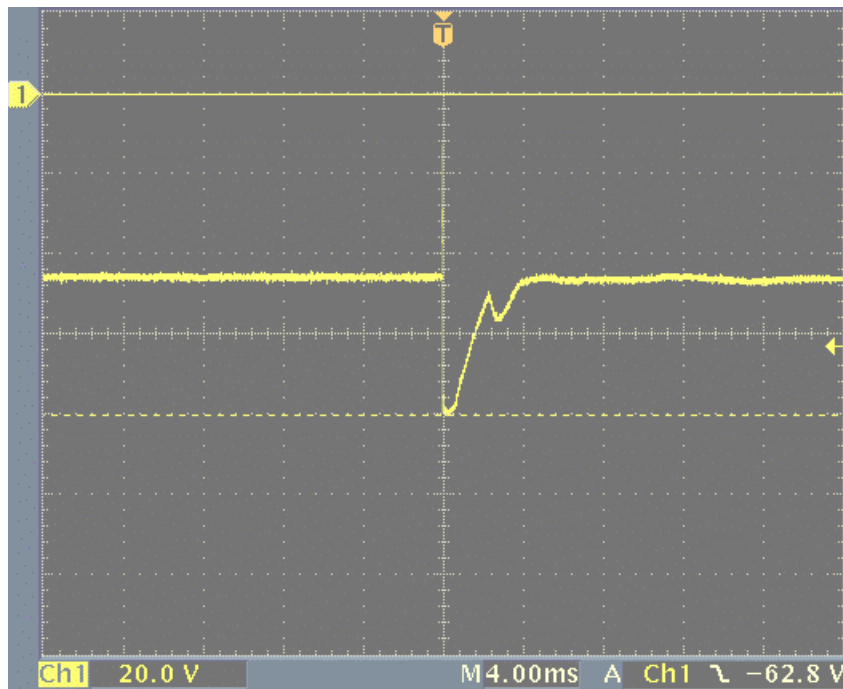


Figure 11: Results of the 1000V Surge Test Waveform after the Protection Circuitry of the DUT (see text)



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Table 1: NEBS Testing Level Limits and Compliance Requirements

NEBS	Standard Test Routine		Volts	Comments
ESD	IEC61000-4-2	Level 1	2000	Pass
		Level 2	4000	Pass
		Level 3	6000	Pass
		Level 4	8000	Pass
Burst	IEC61000-4-4	Level 1	500	Pass
		Level 2	1000	Pass
		Level 3	2000	Pass
		Level 4	4000	Pass
Surge	IEC61000-4-5	Level 1	500	Pass
		Level 2	1000	Pass
		Level 3	2000	Blown Fuse
		Level 4	4000	Not Tested

Table 2: NEBS Design Bill of Materials

Item	Description-	Vendor / Part Number	Qty	Ref. Des.
Fuses				
	Fuse, 7A, 125 Volts, Fast-acting, 7A	LittleFuse, SMTelecom Fuse	2	F1, F5
	Fuse, 1A, 125 Volts, Fast-acting, 1A	LittleFuse, SMTelecom Fuse	2	F3, F4
DC-DC Converters				
	-48V to 3.3V DC-DC Converter	Power One QHS40ZE-NT	1	U2
	-48V to 2.5V DC-DC Converter	Power One QHS40ZD-NT	1	U3
	-48V to 1.8V DC-DC Converter	Power One QHS40ZB-NT	1	U4
	-48V to 1.0V DC-DC Converter	Power One QHS50ZW-NT	1	U5
Semiconductors				
	Gas-Discharge Tube, Heavy Duty Arrestor, 90 Volts	Crydom, SL1122090RCIT Part# SL1021-B-090-R-X-1-N	2	DN1, DN2, DN4
	TVS, 70V	Crydom Part# 15KP70A		D6, D20
	TVS, 5V	Crydom Part# SMBJ5.0		D13, D15
	Diode, 1N5401DITR	Any		D9, D16-18
	Diode, 1N4148DITR	Any		D7, D8
	Diode, Schottky, 20V, 20mA	Diodes, Inc., LLS103C-7		D19, D21
	SMH4804-F	Summit Microelectronics, Inc.		U1
EMI Filter				
	Filter, Conducted-EMI – 10A	Power One, FC100V10A	1	U13, U17
	Filter, Conducted-EMI – 20A	Tyco, FLTR100V20	1	U17

VENDOR CONTACT INFO

Crydom: <http://www.crydom.com/>

Littlefuse: <http://www.littelfuse.com/>

Power One: <http://www.power-one.com/>

EM TEST: <http://www.emtest.com/>

Diodes, Inc.: <http://www.diodes.com/>

Tyco International: <http://power.tycoelectronics.com/>

NEBS: An Historical Overview

NEBS an acronym for "Network Equipment-Building System" and is a term commonly used for a family of documents that apply to testing telecommunications equipment located in a central office. Two of the more common documents outlining the testing are the GR-63-CORE, Network Equipment-Building System Requirements: Physical Protection and the GR-1089-CORE, Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment.

Reliability of the telephone system is considered a national security issue, is demanded by consumers and makes good business sense. Therefore, NEBS testing is taken very seriously by both the Regional Bell Operating Companies (RBOCs) and other service providers as well as manufacturers developing equipment used for the telecommunications network.

Equipment suppliers know that compliance with NEBS criteria is the key for getting products into a Central Office and other network facilities. Compliance demonstrates the equipment has been thoroughly tested for safety and functional criteria for use in telecommunications networks.

Pioneered by Telcordia, these rigorous standards - NEBS GR-63 and GR-1089 - have been industry benchmarks for more than two decades. They have been used to verify that products are truly carrier-class, installation-ready, and equipment compatible.

Testing and analysis of products ranging from digital switches to hubs and routers to wireless and xDSL products are performed to insure reliability. These include an FCC-listed semi-anechoic room and Open Area Test Site for EMI; thermal chambers; seismic and vibration shaker tables; a fully pollution-controlled fire test facility; lightning and surge test facilities; and contamination laboratories.

NEBS had its genesis in the 1970s when Bell Labs began producing guidelines for equipment designers to help them focus on physical protection, electromagnetic compatibility and safety, and overall reliability. While originally intended for central office equipment, NEBS criteria are of value when designing any kind of mission-critical electronic system no matter where it is deployed. NEBS is now administered by Telcordia, the direct corporate descendent of Bell Labs and Bellcore (Bell Communications Research). Today, in the vast majority of cases, telephone companies will not deploy network equipment until it has been tested and certified to the NEBS criteria. Key NEBS categories are included in the block on the next page.

Like all telecommunications equipment, embedded computer systems in a telecommunications network are susceptible to electromagnetic interference (EMI), electrostatic discharge (ESD), power faults, and damage from lightning strikes. NEBS covers all of these electromagnetic compatibility and safety issues into account.

i. Electrostatic discharge

Noting that electrostatic discharges can cause device damage, alter software and firmware, and affect data, NEBS outlines criteria for immunity to ESD during normal operation, installation, and repair. Testing for ESD immunity involves using either contact discharge or air discharge methods. For example, during normal operations a unit must show that its test points (including panels, doors, consoles, keypads, indicator LEDs, fuses, switches, sockets, etc.) can withstand 40 air discharges (15 kV) or 20 contact discharges (8 kV). During this test, according to GR-1089, "a service-affecting response, unless within system operating limits, and manual intervention shall not occur".

ii. Electromagnetic interference

Equipment is also tested to see how well it avoids interference with other nearby equipment. For example, radiated electronic emissions from a closed-door unit must not exceed certain specified field strengths. A similar test performed with doors open. Magnetic emissions are similarly proscribed as are conducted emissions (AC and DC power and signal leads) from the unit into public utility power lines.

iii. Jolts from the blue—lightning and AC power faults

While ESD and EMI represent the commonplace, everyday side of electromagnetic compatibility, power faults and lightning surges represent the arbitrary. These occurrences dictate two levels of criteria. First level compliance holds that the equipment be undamaged and able to continue operations after the fault or strike. Second level criteria state that the unit "may sustain damage, but shall not become a fire, fragmentation or electrical safety hazard". Tests include short circuit (tip to ring, tip to ground, etc.) and surge tests using a lightning surge generator on at least three units. Additional lightning surge tests exist for units that will operate on commercial AC power.

NEBS criteria are rigorous and formidable, but they are not monolithic. Designers have considerable latitude in how they meet certain criteria.

In addition, telephone companies in certain areas may place extra emphasis on certain aspects of NEBS, such as earthquake resistance in the western United States, humidity in the South, and airborne contaminants in the Midwest. Some telephone companies are even issuing their own extensions to the NEBS criteria. For example, to test for flame spread, one such company has established a more stringent requirement than NEBS requirement per RNSA-NEBS-95-0003, Revision 10. NEBS itself allows for three levels of conformance. Levels 1 and 2 exist essentially to facilitate the rapid deployment of new technologies and are defined thusly:

Level 1—"The minimum acceptable level of environmental compatibility needed to preclude hazards

and degradation of the network facility and hazards to personnel".

Level 2—"The minimum acceptable level of environmental compatibility need to provide limited assurance of equipment interoperability within the network facility environment".

Level 3—"The minimum level of environmental compatibility needed to provide maximum assurance of equipment interoperability within the network facility environment. The Level 3 criteria provide the highest assurance of product interoperability. Level 3 criteria are suited for equipment applications which demand minimal service interruptions over the equipment's life". Achieving compliance to NEBS Level 3 or above criteria is a costly and time-consuming process.

NEBS categories

Electromagnetic Compatibility - The Telcordia A2LA accredited EMC test facilities analyze product performance in the complex electromagnetic environments of telecommunications facilities. The facilities include an FCC-listed 10 meter OATS and 3 meter Semi-Anechoic Chamber, as well as a compact 3 meter Semi-Anechoic chamber which are used to test for EMI and ESD.

Fire Resistance - Experts perform both small-scale and large-scale fire tests on telecom equipment and cabling. Our fully pollution-controlled facility features the latest technology in oxygen calorimetry and infrared video photography.

Airborne Contaminants - Equipment is exposed to gaseous and particulate airborne contaminants found in such environments as densely populated areas.

Thermal Robustness - Equipment performance is evaluated under various temperature and humidity conditions. The facilities can also create environments that equipment may experience during transportation and/or storage.

High Voltage - Capable of delivering 375,000 VA of AC power faults and 45,000 V of lightning surges, the facility is used for lightning, power cross, power induction, and grounding analyses.

Earthquake and Vibration - To determine whether equipment will operate during and after earthquake and vibratory stresses, static and dynamic testing of network products, frameworks, cable racks, and battery stands is performed.

Bibliography

The FaultZone Recipe for Reliability:
 NEBS Testing and CompactPCI-based Equipment Design
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