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AMP2030B-LC	1.0-6.0GHz	400	250	56
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AMP2030-LC-3KW	1.0-6.0GHz	3000	2500	65

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Meet the 2023 Editorial Board

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He is a third-party auditor for local governments and has provided expert opinions on the use of cellular transmitters, including health and safety concerns. Patrick has published numerous articles for a variety of magazines. He is the co-author of EMI Troubleshooting Cookbook for Product Designers.

Patrick has been a senior member of the IEEE EMC Society which he joined in 1984, serving as chairman, vice chairman, secretary, and arrangements chairman of the Puget Sound Section, and has received The Legends of the IEEE Seattle Section Award in 2010. He also been on the Board of Trustees of the Seattle Gilbert and Sullivan Society where he also works as the sound engineer and. He enjoys audio and video recording musical groups, mostly in the Seattle area, and has engineered and mastered several CD's. And when he is not busy with all this, he can be found hiking somewhere with his camera.

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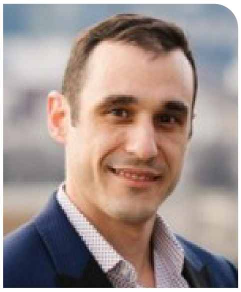

ZACHARIAH PETERSON | PCB DESIGN EXPERT & ELECTRONICS DESIGN CONSULTANT

Zachariah Peterson received multiple degrees in physics from Southern Oregon University and Portland State University, and he received his MBA from Adams State University. In 2011, he began teaching at Portland State University while working towards his Ph.D. in Applied Physics. His research work originally focused on topics in random lasers, electromagnetics in random materials, metal oxide semiconductors, sensors, and select topics in laser physics; he has also published over a dozen peer reviewed papers and proceedings. Following his time in academia, he began working in the PCB industry as a designer and technical content creator. As a designer, his experience focuses on high-speed digital systems and RF systems for commercial and mil-aero applications. His company also produces technical content for major CAD vendors and consults on technology strategies for these clients. In total, he has produced over 2,000 technical articles on PCB design, manufacturing, simulation, modeling, and analysis. Most recently, he began working as CTO of Thintronics, an innovative PCB materials startup focusing on high-speed, high-density systems.

He is a member of IEEE Photonics Society, IEEE Electronics Packaging Society, American Physical Society, and the Printed Circuit Engineering Association (PCEA). He previously served as a voting member on the INCITS Quantum Computing Technical Advisory Committee working on technical standards for quantum computing and quantum electronics. He now sits on the IEEE P3186 Working Group focused on Port Interface Representing Photonic Signals Using SPICE-class Circuit Simulators.

MIKE VIOLETTE | iNARTE CERTIFIED EMC ENGINEER

Mike is President of Washington Laboratories and Director of American Certification Body. He has over 35 years of experience in the field of EMC evaluation and product approvals and has overseen the development of engineering services companies in the US, Europe and Asia. Mike is currently on the Board of Directors of the IEEE EMC Society.

He is a Professional Engineer, registered in the State of Virginia. He has given numerous presentations on compliance topics and is a regular contributor to technical and trade magazines.

DAVID A. WESTON | iNARTE EMC ENGINEER

David A. Weston is an electromagnetic compatibility (EMC) consultant and certified National Association of Radio and Telecommunications Engineers (iNARTE) EMC engineer at EMC Consulting Inc. Merrickville, Ontario, Canada. A life member of the Institute of Electrical and Electronics Engineers, Weston has worked in electronic design for 55 years, specializing in the control, prediction, measurements, problem solving, analysis, and design aspects of EMC for the last 44 years.

He is the author of the third edition of the 1,157-page book Electromagnetic Compatibility, Methods, Analysis, Circuits, and Measurement published by CRC press in 2017, as well as numerous papers of a practical nature.

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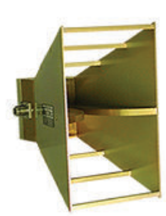

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EMC EQUIPMENT MANUFACTURERS

Introduction

The following chart is a quick reference guide of test equipment and includes everything you'll need from the bare minimum required for key evaluation testing, probing, and troubleshooting, to setting up a full in-house precompliance or full compliance test lab for military and aerospace testing. The list includes amplifiers, antennas, current probes, ESD simulators, LISNs, near field probes, RF signal generators, spectrum analyzers, EMI receivers, and TEM cells. Equipment rental companies are also listed. The products listed can help you evaluate radiated and conducted emissions, radiated and conducted immunity and a host of other immunity tests, such as the new ESD test for MIL-STD-461G.

EMC Equipment Manufacturers		Type of Product/Service																
Manufacturer	Contact Information - URL	Amplifiers	Antennas	Chokes	Conducted Immunity	Current Probes	EMC Filters	EMC Testing	ESD Simulators	LISNs	Near Field Probes	Pre-Compliance Test	Radiated Immunity	Rental Companies	RF Signal Generators	Software	Spectrum Analyzers/EMI Receivers	TEM Cells
A.H. Systems	www.ahsystems.com	X	X			X						X						
Aaronia AG	www.aaronia.com	X	X									X					X	
Advanced Test Equipment Corp. (ATEC)	www.atecorp.com	X	X		X	X			X	X	X	X	X	X	X		X	X
ALTAIR	www.altair.com															X		
Anritsu	www.anritsu.com											X			X		X	
AR RF/Microwave Instrumentation	www.arworld.us	X	X		X			X		X	X	X	X		X	X	X	
Coilcraft	www.coilcraft.com			X														
DLS Electronic Systems, Inc.	www.dlsemc.com							X										
Electro Rent	www.electrorent.com	X			X				X	X		X	X	X	X		X	
EM Test	www.emtest.com/home.php				X							X						X
EMC Partner	www.emc-partner.com				X				X									
Empower RF Systems	www.empowerrf.com	X											X					
Exodus Advanced Communications	www.exoduscomm.com	X	X					X										
Gauss Instruments	www.gauss-instruments.com/en/																X	
Haefley-Hippotronics	www.haefely-hipotronics.com				X				X									
Instrument Rental Labs	https://bhdtm.com/	X			X				X	X		X	X	X	X		X	

EMC Equipment Manufacturers		Type of Product/Service																
Manufacturer	Contact Information - URL	Amplifiers	Antennas	Chokes	Conducted Immunity	Current Probes	EMC Filters	EMC Testing	ESD Simulators	LISNs	Near Field Probes	Pre-Compliance Test	Radiated Immunity	Rental Companies	RF Signal Generators	Software	Spectrum Analyzers/EMI Receivers	TEM Cells
Instruments For Industry (IFI)	www.ifi.com	X			X								X					
ITG Electronics	www.itg-electronics.com						X											
Keysight Technologies	www.keysight.com									X	X	X			X	X	X	
Kikusui America, Inc.	www.kikusuiamerica.com/solution/	X																
Microlease	www.microlease.com/us/home	X			X				X	X		X	X	X	X		X	
Milmega	www.milmega.co.uk	X			X								X					
Narda/PMM	www.narda-sts.it/narda/default_en.asp	X	X		X					X		X	X		X		X	
Noiseken	www.noiseken.com				X				X			X						
Ophir RF	www.ophirrf.com	X			X													
Pearson Electronics	www.pearsonelectronics.com					X												
PPM Test	www.ppmtest.com		X									X	X			X	X	
R&B Laboratory	www.rblaboratory.com							X										
RECOM Power GmbH	www.recom-power.com							X										
Rigol Technologies	www.rigolna.com	X				X					X	X			X	X	X	
Rohde & Schwarz	www.rohde-schwarz.com/us/	X	X		X	X				X	X	X	X		X	X	X	
Siglent Technologies	www.siglentamerica.com										X	X			X	X	X	
Signal Hound	www.signalhound.com										X	X			X	X	X	
TekBox Technologies	www.tekbox.net	X								X	X	X				X		X
Tektronix	www.tek.com										X	X				X	X	
Teseq	www.teseq.com/en/index.php	X			X	X			X			X	X					X
Test Equity	www.testequity.com/leasing/	X			X				X	X		X	X	X	X		X	
Thermo Keytek	www.thermofisher.com				X				X									
Thurlby Thandar (AIM-TTi)	www.aimtti.us											X			X		X	
Toyotech (Toyo)	www.toyotechus.com/emc-electromagnetic-compatibility/	X	X							X		X	X				X	
TPI	www.rf-consultant.com											X			X			
Transient Specialists	www.transientspecialists.com				X								X					X
TRSRenTelCo	https://www.trsrentelco.com/	X	X		X					X		X	X	X	X		X	
Vectawave Technology	www.vectawave.com	X																
Windfreak Technologies	www.windfreaktech.com											X			X			


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MILITARY RELATED E3 DOCUMENTS AND POCS

Tony Keys
EMC Analytical Services

The following references are not intended to be all inclusive, but rather a representation of available sources of additional information.

About the Author

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MIL-HDBK-235-1C Military Operational Electromagnetic Environment Profiles Part 1C General Guidance, 1 Oct 2010.

MIL-HDBK-237D Electromagnetic Environmental Effects and Spectrum Certification Guidance for the Acquisition Process, 20 May 2005.

MIL-HDBK-240A Hazards of Electromagnetic Radiation to Ordnance (HERO) Test Guide, 10Mar2011.

MIL-HDBK-263B Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), 31 Jul 1994.

MIL-HDBK-274A Electrical Grounding for Aircraft Safety, 14 Nov 2011.

MIL-HDBK-335 Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance Systems, Notice 4, 08 Jul 2008.

MIL-HDBK-419A Grounding, Bonding, and Shielding for Electronic Equipment and Facilities, 29 Dec 1987.

MIL-HDBK-454B General Guidelines for Electronic Equipment, 15 Apr 2007.

MIL-HDBK-1004-6 Lightning Protection, 30 May 1988.

MIL-HDBK-1195, Radio Frequency Shielded Enclosures, 30 Sep 1988.

MIL-HDBK-1512 Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods, 30 Sep 1997.

MIL-HDBK-1857 Grounding, Bonding and Shielding Design Practices, 27 Mar 1998.

MIL-STD-188-124B Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communications-Electronics Facilities and Equipment, 18 Dec 2000.

MIL-STD-188-125-1 High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions Part 1 Fixed Facilities, 17 Jul 1998.

MIL-STD-220C Test Method Standard Method of Insertion Loss Measurement, 14 May 2009.

MIL-STD-331CFuze and Fuze Components, Environmental and Performance Tests for, 22 Jun 2009.

MIL-STD-449D Radio Frequency Spectrum Characteristics, Measurement of, 22 Feb 1973.

MIL-STD-461F Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 10 Dec 2007.

MIL-STD-461G Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 11 Dec 2015.

MIL-STD-464C Electromagnetic Environmental Effects Requirements for Systems, 01 Dec 2010.

MIL-STD-704E Aircraft Electric Power Characteristics, 12 Mar 2004.

MIL-STD-1310H Standard Practice for Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility Electromagnetic Pulse (EMP) Mitigation and Safety, 17 Sep 2009.

MIL-STD-1377 Effectiveness of Cable, Connector, and Weapon Enclosure Shielding and Filters in Precluding Hazards of EM Radiation to Ordnance; Measurement of, 20 Aug 1971.

MIL-STD-1399 Section 300B Interface Standard for Shipboard Systems, Electric Power, Alternating Current, 24 Apr 2008.

MIL-STD-1541A Electromagnetic Compatibility Requirements for Space Systems, 30 Dec 1987.

MIL-STD-1542B Electromagnetic Compatibility and Grounding Requirements for Space System Facilities, 15 Nov 1991.

MIL-STD-1605 Procedures for Conducting a Shipboard Electromagnetic Interference (EMI) Survey (Surface Ships), 08 Oct 2009.

MIL-STD-1686C Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices). 25 Oct 1995.

ADS-37A-PRF Electromagnetic Environmental Effects (E3) Performance andVerification Requirements, 28 May 1996.

DOD-STD-1399 Section 070 Part 1 D.C. Magnetic Field Environment, Notice 1, 30 Nov 1989.

DoDI 3222.03 DoD Electromagnetic Environmental Effects (E3) Program, 24Aug 2014.

DoDD 4650.01 Policy and Procedures for Management and Use of the Electromagnetic Spectrum, 09 Jan 2009.

DoDI 6055.11 Protecting Personnel from Electromagnetic Fields, 19 Aug 2009.

AIAA - S-121-2009e - Electromagnetic Compatibility Requirements for Space Equipment and Systems

ITU Recommendation SM.1541-6 (08/2015) - Unwanted emissions in the out-of-band domain

ITU Recommendation M.1314-1 (06/05) - Reduction of unwanted emissions of radar systems operating above 400 MHz

ITU Recommendation M.1177 (04/2011) - Techniques for measurement of unwanted emissions of radar systems

ITU ITU-R SG01 Contribution 75 (06/2013) - Draft new Recommendation ITU-R SM.[SPEC_MON_EVOLUTION] - Spectrum monitoring evolution

NASA GSFC-STD-7000A, GODDARD TECHNICAL STANDARD: GENERAL ENVIRONMENTAL VERIFICATION STANDARD (GEVS) FOR GSFC FLIGHT PROGRAMS AND PROJECTS (22-APR-2013)

RTCA DO-160G 12/2010 for Airborne equipment

DOD E3 Point of Contacts

ARMY
Commander, U.S. Army, AMRDEC
RDMR-AES-E3
Building 4488
Redstone Arsenal, AL 35898
Mr. Duane Driver
DSN 897-8447; Commercial (256) 313-8447
E-mail: duane.e.driver.civ@mail.mil

NAVAIR
Naval Air Systems Command
Code: 4.1.13
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Building 4010
Patuxent River, MD 20670
Mr. Craig Simmons
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INTRODUCTION TO DoD POLICY, GUIDANCE, AND THE ACQUISITION PROCESS

Tony Keys
EMC Analytical Services

Brian Farmer
EMC Management Concepts

This article provides an introduction to DoD policy, guidance and the acquisition process. E3 is defined as the impact of the Electromagnetic Environment (EME) upon the operational capability of military forces, equipment, systems, and platforms. E3 encompasses all electromagnetic disciplines, including Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC); Electromagnetic Vulnerability (EMV); Electromagnetic Pulse (EMP); natural phenomena such as lightning, electrostatic discharge (ESD) and precipitation static; and Hazards of Electromagnetic Radiation to Personnel (HERP), Ordnance (HERO), and Fuel (HERF). In addition, Spectrum Supportability must be addressed in conjunction with E3 for Spectrum Dependent (S-D) systems.

Early consideration of E3 and Spectrum Supportability (SS) in electronic and S-D systems is a fundamental criterion that must be satisfied before communications-electronics (CE) equipment and related weapons systems are developed and fielded. Development or acquisition of systems that meet operational requirements, but are not electromagnetically compatible or fail to obtain spectrum supportability, creates a potential for severe mutual interference between themselves and other spectrum users, squanders resources, and delays fielding warfighting capabilities to field units.

Equipment, subsystems and systems employed for military purposes are exposed to extreme EMEs. Providing the warfighter with systems that will operate within these extreme EMEs requires specific requirements, design and test considerations. This new mini guide from Interference Technology will review E3 related policies and requirements specific to military equipment, subsystems and systems, from a top down perspective, including overviews of MIL-STD-464C and MIL-STD-461G, a listing of relevant military E3 related documents and points of contact.

Real World Operational Impacts/Examples

There are many examples of EMC and spectrum supportability problems in military systems which have caused serious, and even catastrophic, operational and programmatic problems. Some examples include:

> Between 1981 and 1987, several UH-60 Blackhawk helicopters nose-dived and crashed, killing 22 servicemen. The crashes were attributed to insufficient flight control immunity to high intensity radiated fields when flying past radio broadcast towers. This interference produced uncommanded control surface movements causing fatal dives.
>
> The US Air Force has had to address a potential frequency-interference issue with their B-2 bombers. Analysis indicates a high probability of the Raytheon AN/APQ-181 radar system on the B-2As interfering with commercial satellite communications after 2007. The B-2's radar would most likely disrupt their transmissions and could damage commercial communications satellites, for which the USAF likely would be liable, according to industry sources. The total estimated cost is expected to exceed $1.3B.
>
> An AV-8B Harrierwas lost and the pilot killed as a result of the indirect effects of a lightning strike. The lightning strike caused large internal electrical currents inside the wing. A coupler inside the wing fuel tank system was not designed to withstand such a current flowing across it and sparked, causing a fuel explosion.

While there have been these and other catastrophic examples, the vast majority are simply performance degradation problems that put our fighting forces at risk, delay fielding of important capabilities or stretch budgets beyond their limits.

DOD Policy and Perspective

The need for control of the electromagnetic spectrum and the EME is understood at the highest levels of DoD management and military operational directors, who must ensure that U.S. Forces have the ability to operate effectively in all domains: space, sea, land, air, information; and can conduct operations with a combination of forces tailored to different situations. Military success relies on Information Superiority: Obtaining, processing, distributing, and protecting accurate information while exploiting or denying the adversary's ability from doing the same. Much of the information superiority depends on access to the RF spectrum. The priority placed on force mobility, range, and speed dictates that much of the information technology be wireless. Again, the critical medium is the EM spectrum with EMI free operations.

Spectrum dominance is a cornerstone of the DoD's warfighting strategy. To maintain this spectrum dominance, the spectrum and system EMC within the spectrum must be carefully controlled. While EMI (including interference caused by spectrum management problems) can cause catastrophic problems, the majority of interference problems render systems less than fully effective, which reduces operational readiness and increases costs. These may be hard to see, and more difficult to quantify in terms of return on investment; however, taking care of E3 and Spectrum Certification requirements early on in a program provides significant future cost savings. Figure 1 illustrates the concept of spectrum dominance.

Acquisition Process

The military procurement system is driven by high level policies that flow down to processes and procedures covering anything that is considered a technical requirement. E3 and SS are no different. There are high level policies that require programs to consider E3 and SS in system design, procurement and fielding as well as policies requiring that military systems follow the rules of frequency use. The two most significant top level directives that require spectrum management and E3 control in the acquisition cycle are:

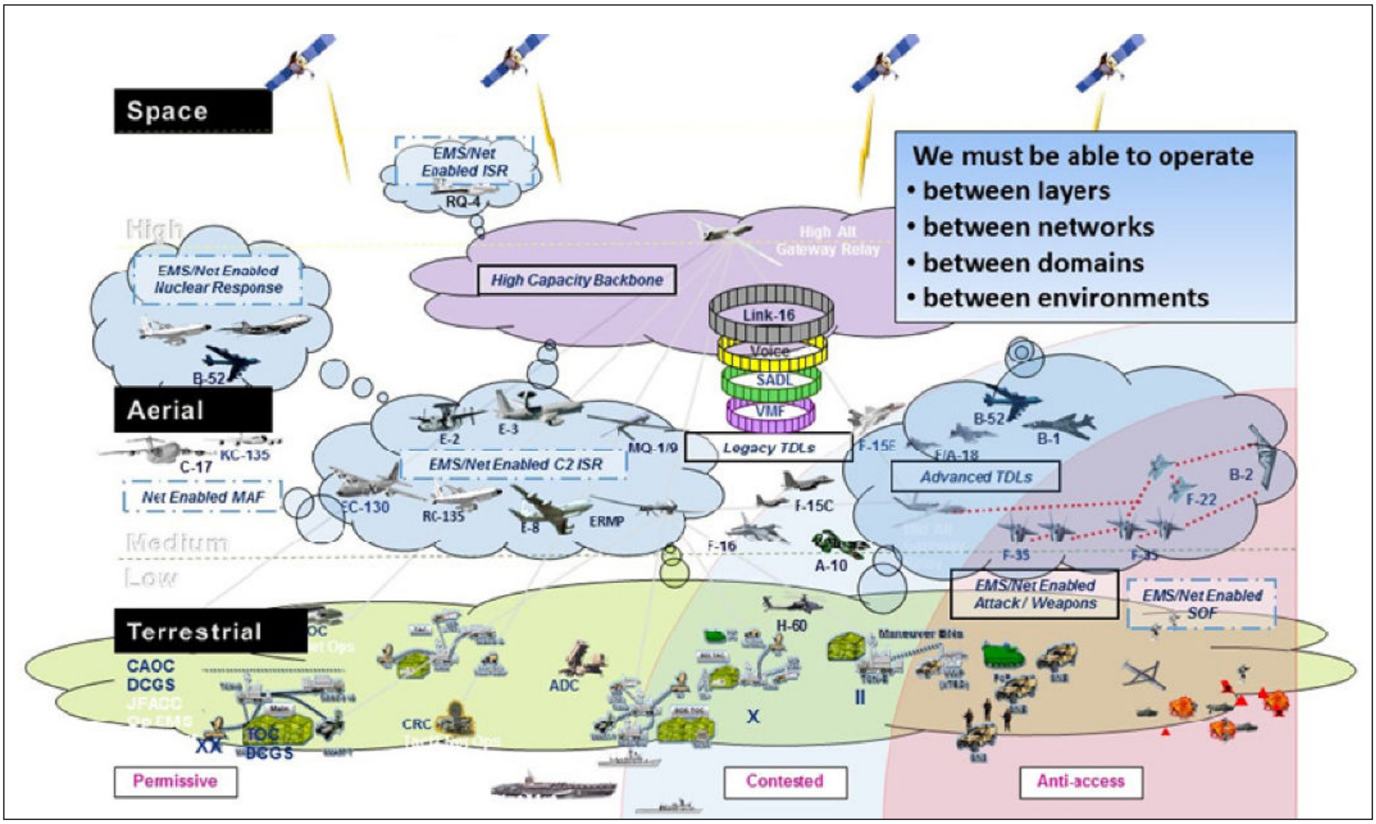

Figure 1: Spectrum Dominance Illustration

DODI 3222.03 DoD Electromagnetic Environmental Effects (E3) Program, 24 Aug 2014

This Instruction drives the requirement that "All electrical and electronic systems, subsystems, and equipment, including ordnance containing electrically initiated devices, shall be mutually compatible in their intended EME without causing or suffering unacceptable mission degradation due to E3." It identifies many high level DoD organizations and outlines their responsibilities for E3 control within systems acquisition and operational communities.

DoD Instruction 4650.01, Policy and Procedures for Management and Use of the Electromagnetic Spectrum, 09 Jan 2009

This instruction outlines the requirements for DoD spectrum use to ensure that systems can operate without interference. Some requirements include:

- Obtaining a written determination that there is reasonable assurance of Spectrum Supportability for DoD organizations developing or acquiring spectrum-dependent equipment.
- Applicability of Spectrum Supportability determination requirements for "off-the-shelf" or other non-developmental systems (including commercial items).
- The requirement to produce a Spectrum Supportability Risk Assessment (SSRA) to identify and assess an acquisition's potential to affect the required performance of the newly acquired system or other existing systems within the operational EME. SSRAs identify SS and E3 risks and the steps that need to be taken to mitigate the risks.

The fundamental E3 and SS related processes and tasks over the military system procurement cycle are shown in Figure 2.

About the Authors

Tony Keys is the President and Principal Consultant for EMC Analytical Services. Mr. Keys has over 20 years of experience in Electromagnetic Environmental Effects (E3) engineering. His experience covers a wide range of E3 specialty areas from a multitude of organizational aspects including E3 support contracting, DoD E3 service, and DoD system development. He can be reached at tony.keys@emcanalyticalservices.com.

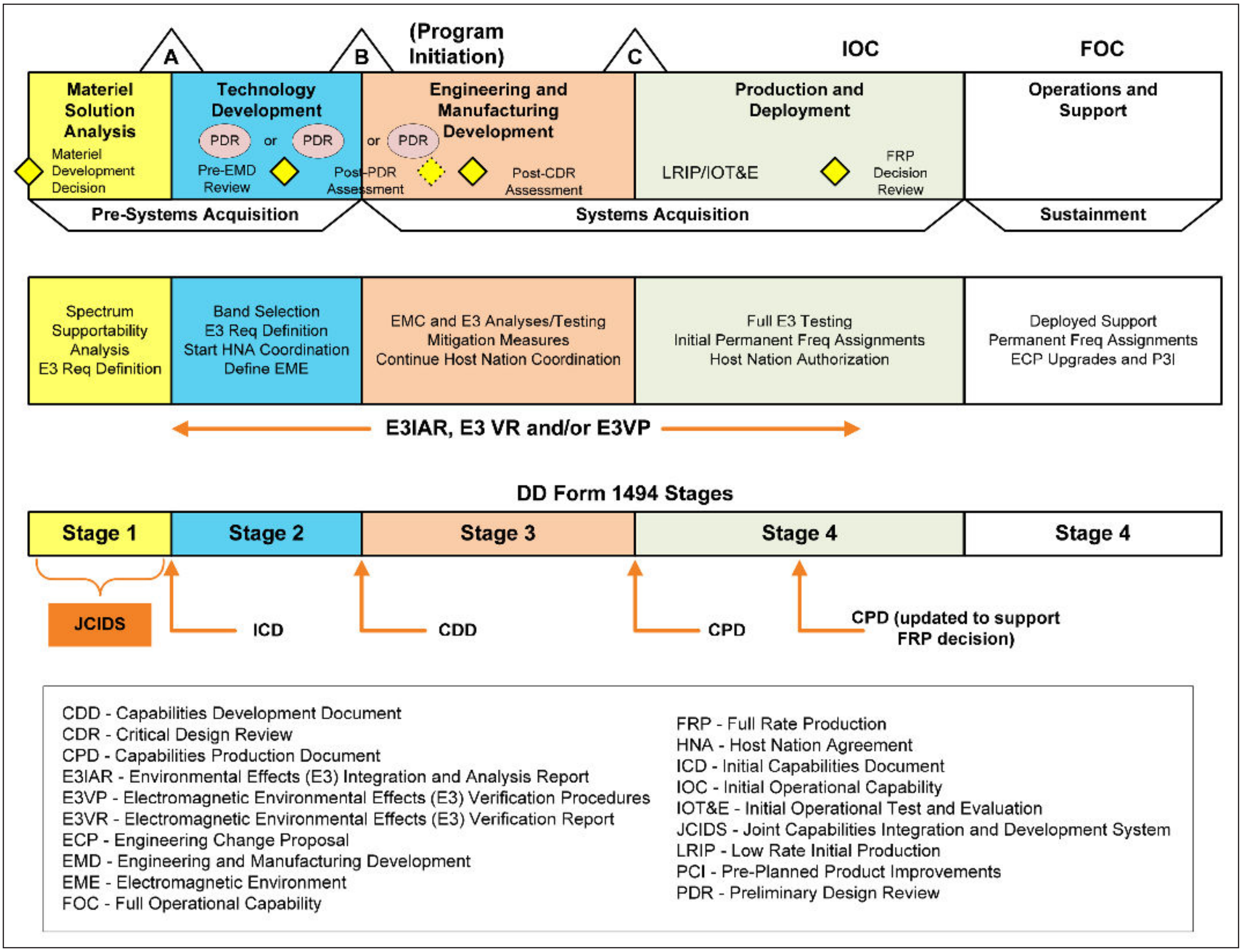

Figure 2: E3 and SS Processes

The author would like to thank Brian Farmer for his significant contribution to the article.

Brian Farmer has a long career providing E3 and Spectrum Supportability systems engineering and program management services to the DoD, including the Naval Air Systems Command (NAVAIR), the Joint Spectrum Center (JSC) and the Naval Surface Warfare Center Dahlgren Division. After working for several companies in the E3 engineering business, Brian formed EMC Management Concepts in 2002. In addition to being CEO of EMC Management Concepts, Brian still provides direct E3 program management support to several Navy offices and the JSC. He leads contract efforts to develop and deliver E3 and Spectrum Supportability training to the acquisition community.He can be reached at bdfarmer@emcmanagement.com.

PROTECTING RF, RECEIVER, ANALOG AND CONTROL LINE INPUT CIRCUITS AGAINST THE RTCA DO-160 PIN INJECTION LIGHTNING TEST

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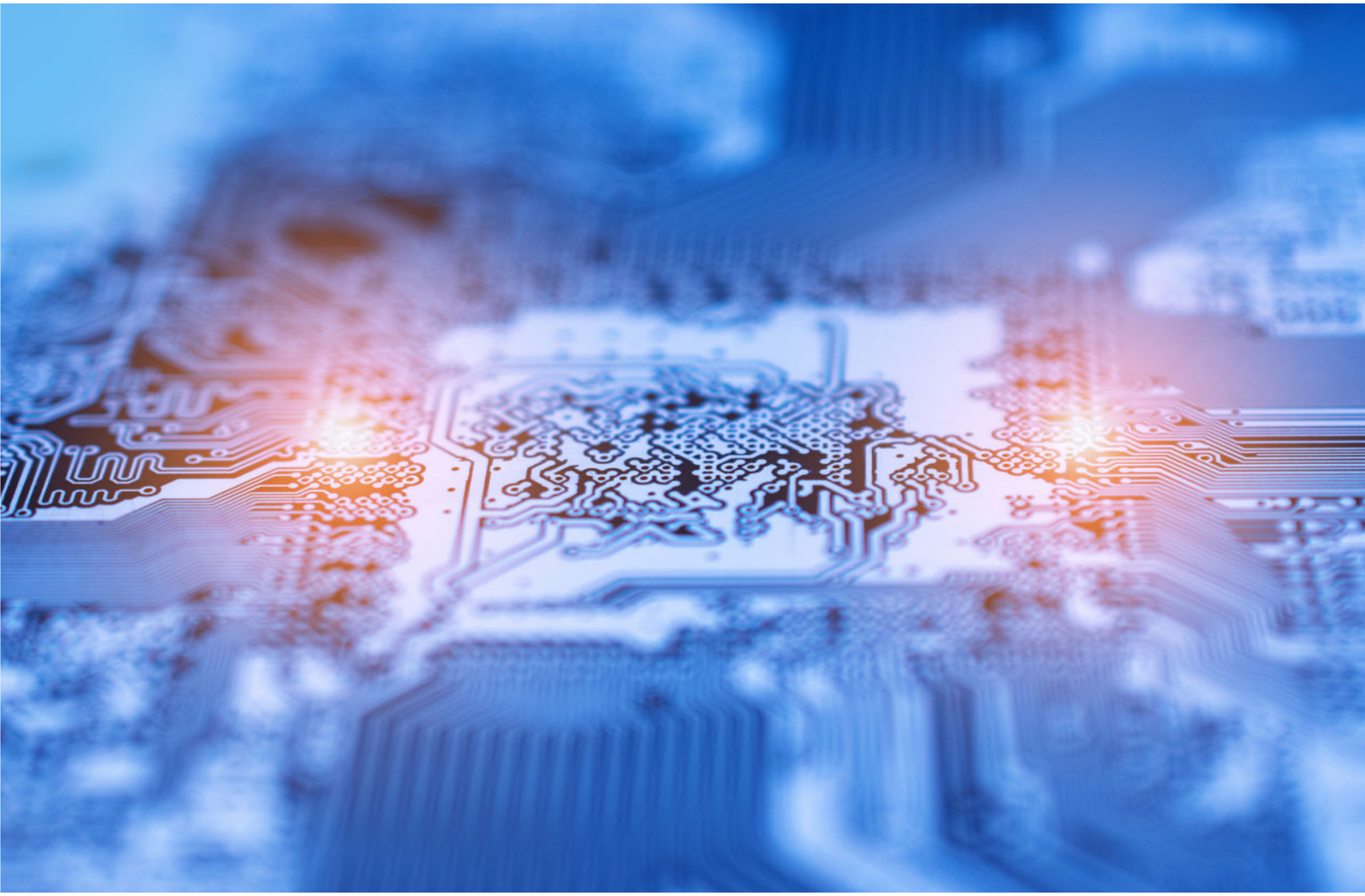
emccons0@gmail.com



ABSTRACT
Circuits are described which effectively protect RF, receiver, analog and control line input circuits from three types of transient injection, described in DO-160, directly into the input pin of the connector.

The goal was to achieve a circuit which would not adversely affect the performance of the RF circuit over an input frequency range of 20MHz to above 1GHz with zero attenuation. The analog input was designed to have no more than 1dB of attenuation from dc to 20MHz. The RF circuit was tested both for RF performance and with the three types of transient specified by DO-160 injected into the input circuit.

Index terms - DO-160 pin injection test.
RF and receiver input protection. 20MHz to above 1GHz operating frequency range, low VSWR, low attenuation. Analog input dc to 20MHz with low attenuation.

1. RF AND RECEIVER CIRCUIT INTRODUCTION

When a significant series impedance can be inserted in the RF circuit followed by diodes to the supply rail and power return this can provide adequate protection. However the goal is that the circuit has only 0.27dB total loss, which includes attenuation and mismatch loss, and so precludes the addition of any series impedance.

Low capacitance Transient Voltage Suppressor (TVS) which includes a low capacitance series diode in series with the TVS are available but even the low capacitance results in an unacceptable VSWR loss above about 100MHz.

These and other devices for protection are described in reference 1.

The DO-160 pin injection is conducted between the pin and chassis with the Equipment Under Test (EUT) powered up.

If the RF ground is isolated from chassis with a sufficiently high impedance over the frequency range typical of the pin injection waveforms, then both the input circuit and the RF ground will rise in potential above the chassis to the test level. If this technique is used it is thus important that any circuits, such as the input of isolated switching power supplies, are able to withstand the voltage, of up to 600V. In most RF circuits, the RF ground is chassis ground, and that is the assumption used in the design of the protection circuit, so isolation is not feasible.

The DO 160 pin injection waveforms are transient current waveforms 1/ 3, 4 and 5A or 5B with waveform 5A more common than type 5B. These waveforms are shown in figures 1, 2 and 3. The test levels are specified from 1-5 with 3 the most common maximum level and this was used in the development of the protection circuit. The peak open circuit voltage and peak short circuit current at level 3 are shown in table 1.

DO-160 also specifies a cable bundle test which is used to evaluate the functional upset tolerance of equipment when transients are applied to interconnecting cables. As the majority of RF circuit interface cables are shielded, and often analog interfaces, and use shielded connectors the level of shielding effectiveness thereby achieved means that it is highly unlikely that the input circuit will be damaged by the transients, although an upset may occur, depending on the RF signal level. An input impedance of 50 Ω is used in the development of the protection circuit as this is the most common input impedance for RF circuits.

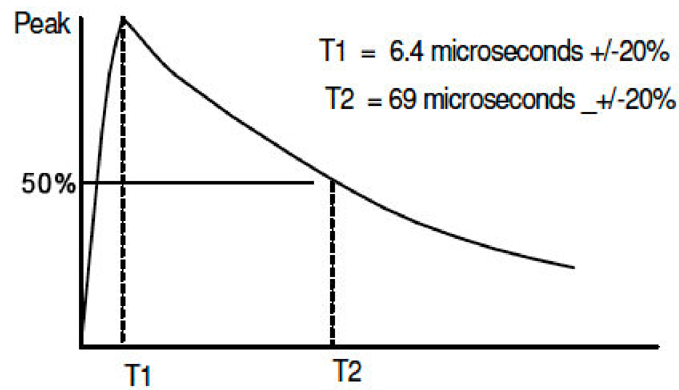


Figure 1: Waveform 1 and 4

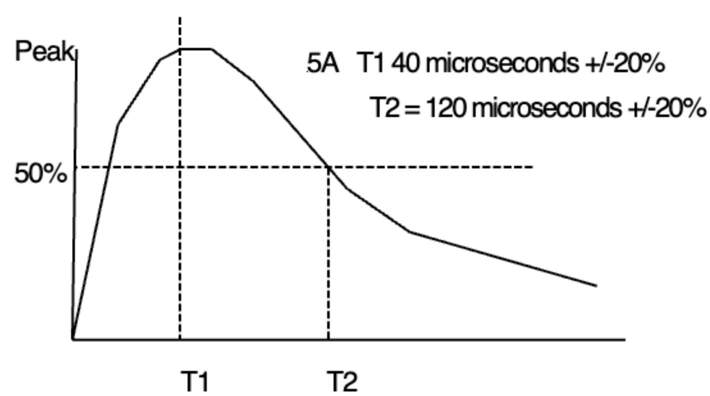


Figure 2: Waveform 5A

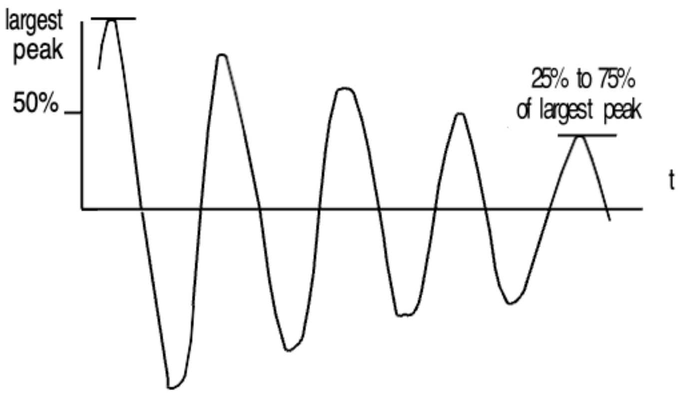


Figure 3: Waveform 3

Table 1: Level 3 peak open circuit voltage and peak short circuit current

Waveform 3	Waveform 1 and 4	Waveform 5A
600V/24A	300V/60A	300V/300A
+10%-0%	+10%-0%	+10%-0%

2. RF PROTECTION CIRCUIT

Adding an inductor in parallel with the 50 Ohm input impedance can represent a low impedance to waveform 1, 3 and 5A but a high impedance from 20MHz and above to the RF signal. Above some frequency the inductor will modify the VSWR of the input. An arbitrary maximum VSWR of 1.1 was used in selecting the inductors.

The inductors chosen were designed for power as they are most likely to withstand the high transient current. They are rated for dc current and no information was available on the transient current carrying capability. Instead the inductors which were found ideal, based on their RF performance, were tested with 50 positive and 50 negative transients and the dc resistance and inductance were measured before and after exposure. All of the inductors tested were unchanged after this testing.

The inductors tested had values of 220nH, 470nH, 1μH, 1.5 μ H, 2 μ H, 4.7 μ H,10 μ H and 23 μ H.

The 1.5 μ H part number 744314150 measured 48Ω or higher from 20MHz to 337MHz.

The 1.5μ H part number DR73-1R5-R1 Measured 48Ω or higher from 20MHz to 380MHz.

The 744314150 inductor is manufactured b Wurth and the DR73-1R5-R by Eaton Electronics Division.

The DR73-1R5-R1 saturates at a current of 6.52A and then it is the dc resistance of 0.013 Ohm which is across the input circuit.

The dimensions of this inductor are 7.5mm x 7.5mm with a height of 3mm.

The DR125-1R5-R, also manufactured by Wurth, is also 1.5uH in value but has an even lower resistance of 0.0029 Ohm. This inductor was not tested.

The Wurth and Eaton inductors were both tested and passed the transient injection test and it was decided to proceed testing with the 1.5 μ H DR73-1R5-R1 inductor. The impedance of the DR73-1R5 in parallel with 50Ω is shown in table3 and the maximum VSWR is 1.0417.

To increase the frequency range further a 11 turn air core coil was wound with a diameter of 6.5mm and a length 9mm and with an inductance of 0.495 μ H. This was added in series with the 1.5 μ H DR73-1R5-R1 inductor, as shown in figure 5. The impedance of both inductors when in parallel with a 50Ω resistor was 48.5Ω at 500MHz and 49.2Ω at 1GHz thus the useful frequency range of the combination 0.495uH and 1.5uH was 20MHz to 1GHz.

The 220nH and 470nH fixed power inductors did not perform any where near as well as the air wound coil.

The voltage developed across the 50Ω load and 1.5 μ H inductor with the 6.9 μ S/69 μ S 300V/60A waveform 1 / 4 was 61V. The voltage developed across the 50Ω load and 1.5 μ H inductor with the 40 μ S/120 μ S, 300V/300A waveform #5A applied was 35V with a 9 μ S pulse width at 50% amplitude.

These levels are still too high. Also the damped sine wave, waveform 3, is usually tested at 1MHz and 10MHz and the impedance of the 1.5 μ H inductor is too high at 10MHz to reduce the test level sufficiently. However due to the short duration of the resultant damped sine wave transients the electrical energy is much lower than in the applied pulse test transients as the half cycles in the 1MHz and 10MHz damped sine wave have a short duration.

The use of a limiter to further reduce the transient across the inductor was examined. The 1N5711 and BAT81S small signal schottky diodes in parallel with the 1.5 μ H inductor were tested and both failed with the 40 μ S/120 μ S pulse applied.

Mini-Circuits manufacture small limiters

An application engineer at Mini-Circuits suggested the RLM-43-5W+ which can handle 37dBm (5W) but could not predict the performance with the transients generated across the 1.5 μ H and 0.495uH inductors. The frequency range of the RLM-43-5W+ is 20MHz to

4000MHz.

The loss and VSWR are shown in table 2.

Table 2: RF performance of RLM-43-5W

Frequency (MHz)	Loss	VSWR
20	0.15	1.36
50	0.05	1.13
90	0.04	1.06
200	0.04	1.03
500	0.05	1.02
1000	0.09	1.02

Table 3: DR73-1R5-R1 in parallel with 50 Ω

Frequency (MHz)	Z
20	48
66	50
103.6	50
141	50
174	50
199	51
258	49
315	50
368	50
380	48

The Mini-Circuits engineer's recommendation was to test it and that is what was done.

The final protection circuit is shown in figure 4 A photo of the 1.5μ H in series with the 0.495μ H inductor is shown in figure 5.

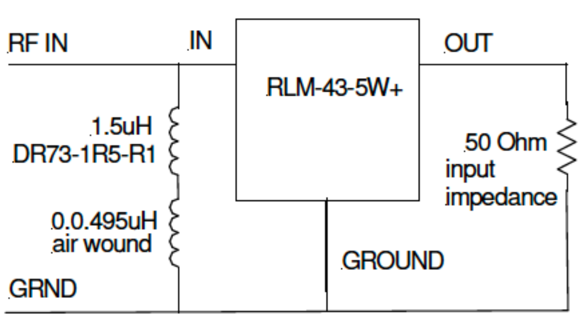


Figure 4: Final protection circuit

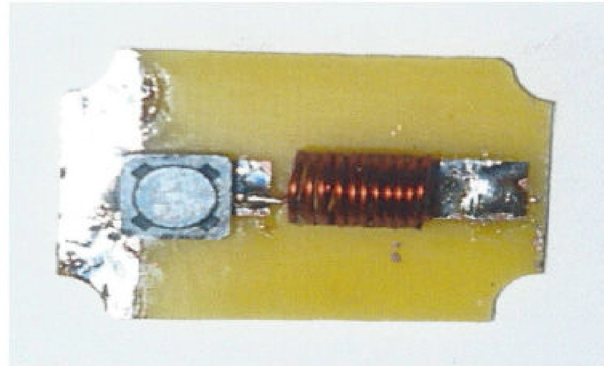


Figure 5: Photo of 1.5μ H and 0.495μ H inductor

To prove that the 1.5μ inductor is necessary the RLM-43-5W was tested without the 1.5μH inductor but as expected failed open circuit.

3. TEST RESULTS WITH FINAL CIRCUIT

The circuit was tested with 50 positive and 50 negative transients for each of the four tests and the resultant induced transient remained the same throughout.

Table 4 shows the amplitude of the induced transients for each test

Table 4: Induced response with the final protection circuit

Waveform	Peak voltage
1	4.72
5A	13V
3 (1MHz)	13.8
3 (10MHz)	16

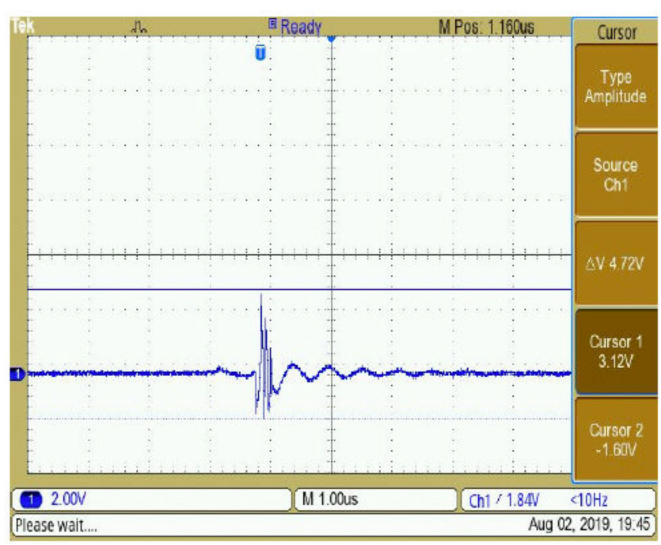


Figure 6: Induced voltage with waveform 1 6.9μ S/69μ S 300V/60A Probe x10 V=4.72V

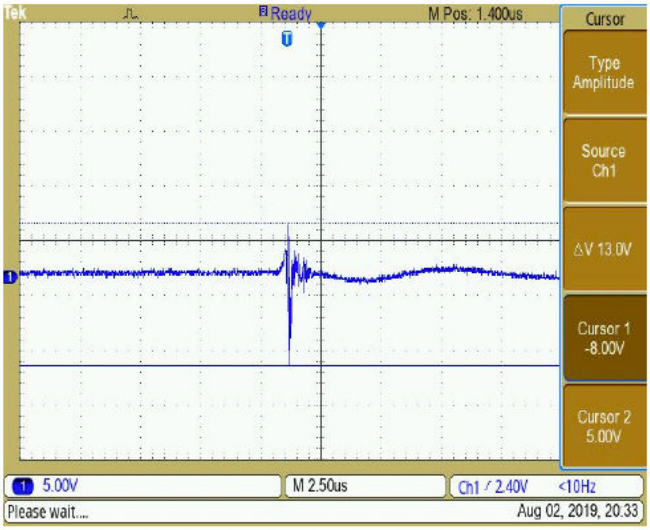


Figure 7: Induced voltage with waveform 5A 40μ S/120μ S 300V/300A Probe x10 V=13V

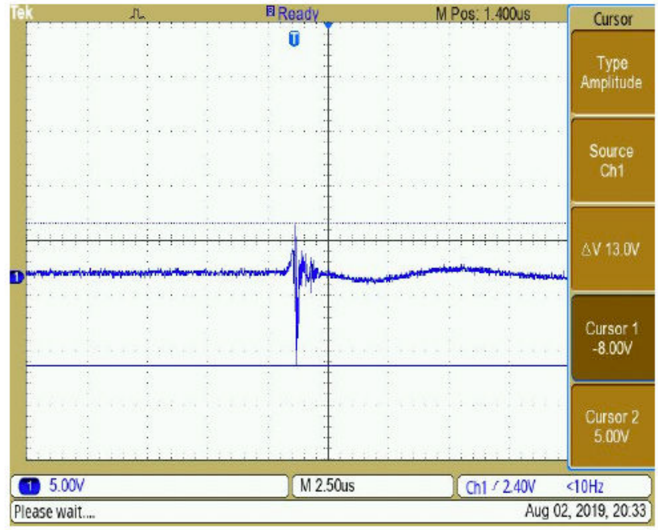
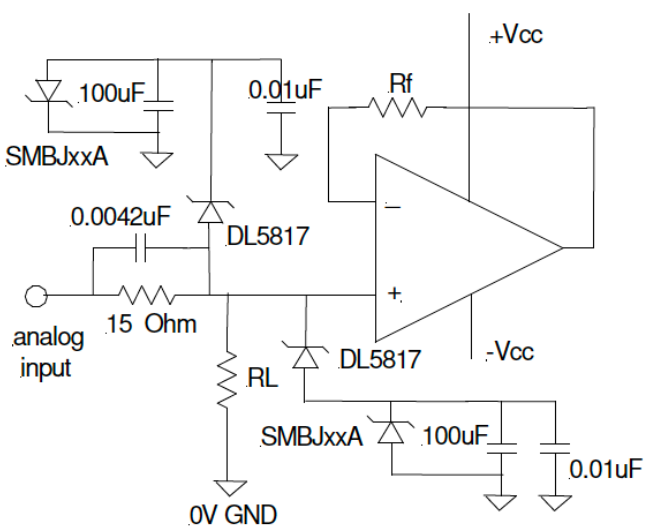


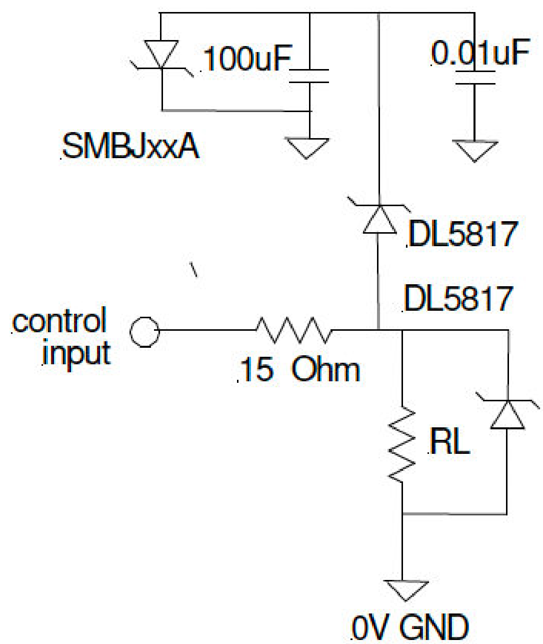
Figure 8: Induced voltage with waveform 3 Damped sine wave frequency = 1MHz Probe x100 voltage = 13.8V

4. ANALOG AND CONTROL LINE

The circuits are shown in figure 5. and 6



5. ANALOG CIRCUIT INPUT PROTECTION



6. CONTROL LINE CIRCUIT PROTECTION

The DL5817 Schottky diodes are used to clamp the input transients to just above the positive supply voltage and the negative transient to just below 0V or below -Vcc. The DL5817 Schottky diode could be connected to +Vcc and -Vcc and the SMBJxxA Transorb removed. However this means that the power supplies must sink the transient current. With a 600V 24A transient applied the generator source impedance and the 15 Ohm resistor will limit the current through the diode to 15A, With 300V 60A applied, the current through the diodes is maximum 15A and with 300V 300A supplied the current through the diodes is maximum 19A. Instead of sinking the current the supplies output voltages are likely to increase above the rated power supply voltage. The circuits in figures 5 and 6 shows the protection circuit disconnected from the supply voltages and instead connected to the Transorb.

On application of the transient the 100uF capacitor begins to charge up and at some voltage the Transorb clamps the voltage. If the DL5817 is connected from the input to ground, as shown in the control circuit, then the peak current is 19A with a duration (from 0A to 0A) of approximately 300uS. The DL5817 is rated at peak 25A for 8.3mS half sine and so is well derated.

For a 12V supply the SMBJ10A would be a good choice with a breakdown voltage of 11.7V at 1ma. Adding the DL5817 approximate forward voltage drop of 0.3V at 1mA, the input voltage will be 12V. With the longest duration transient, the 40/120uS, the maximum current through the SMBJ10A will be 8.5A and the approximate voltage drop is 13V. Adding the voltage drop of the DL5817 at 8.5A of 0.8V the input voltage is limited to 13.8V. The maximum rated current of the SMBJ10A for a 10/1000uS pulse is 60A and so is well derated. The attenuation at low voltage is due to the divider resulting from the 15 Ohm series resistor and the load resistor. Assuming the load resistor is 1kOhm then the attenuation at low frequency is 0.13dB.

The typical SMBJ10A diode junction capacitance is 300pF at 0.1V. Due to the 0.0042uF capacitor in parallel with the 15 Ohm resistor the attenuation at 20MHz with a high impedance load or a 1kOhm load is then approximately 0.6dB.

David A. Weston has worked on EMI problem solving and the EMC design of Space, aircraft, rail, military and commercial equipment, subsystems and systems over the last 41 years. He is author of the third edition of the 1200 page book Electromagnetic Compatibility: Methods, Analysis, Circuits and Measurements, Published August 2016 as well as numerous articles and papers.

REFERENCES

1. Electromagnetic Compatibility: Methods, Analysis, Circuits and Measurements, third edition, D. A. Weston, CRC Press, Taylor and Francis Group, 2016

REFERENCES

(ARTICLE LINKS, DIRECTORIES, CONFERENCES, & LINKEDIN GROUPS)

LINKS TO LONGER ARTICLES

"MIL-STD-461G – The Compleat Review"
https://interferencetechnology.com/mil-std-461g-compleat-review/

"Selecting the Proper EMI Filter Circuit For Military and Defense Applications"
https://interferencetechnology.com/selecting-proper-emi-filter-circuit-military-defense-applications/

"Why is there AIR (In MIL-STD-461G)?"
https://interferencetechnology.com/air-mil-std-461g/

"Overview of the DO-160 standard"
https://interferencetechnology.com/overview-of-the-do-160-standard/

"Review of MIL-STD-461 CS118 - Electrostatic Discharge"
https://interferencetechnology.com/review-of-mil-std-461-cs118-electrostatic-discharge/

"Design for DO-160 pin injection for indirect lightning"
https://interferencetechnology.com/design-for-do-160-pin-injection-for-indirect-lightning/

"DO-160 cable bundle testing for indirect lightning"
https://interferencetechnology.com/do-160-critical-sections-cable-bundle-for-indirect-lightning/

TEST HOUSE DIRECTORY

Test House Directory – 2016 Test and Design Guide
https://interferencetechnology.com/wp-content/uploads/2016/11/2016_IT_Test-Design-Guide.pdf

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http://www.icmst.org/

IEEE AESS Events:
https://ieee-aess.org/

Jane's Events:
www.janes.com/events

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Defense and Aerospace

EMP Defense Council

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Radio, Microwave, Satellite, and Optical Communications

RF/Microwave Aerospace and Defense Applications

RF and Microwave Community

TABLE OF NEW EQUIPMENT ALLOWED/REQUIRED IN MIL-STD-461G

Tony Keys
EMC Analytical Services

Ken Javor
EMC Compliance

The following table was compiled by Ken Javor, of EMC Compliance. The updated changes to MIL-STD-461G require some new equipment. One of these changes allows the use of time domain EMI receivers, which will help speed up the testing, due to their fast FFT-based signal acquisition. Following is a list of some specific changes and equipment requirements:

CS101 *(Conducted Susceptibility, Power Leads) - There is now a requirement to measure induced AC power line ripple. This requires a new "*power ripple detector", which is a specially designed isolation transformer that matches the power line to 50 ohms.

CS114 *(Conducted Susceptibility, Bulk Cable Injection) - This injection probe test now requires the use of a current probe calibration fixture to validate the test level durin*g pre-calibration.

CS117 *(Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads) - This* is a new test added to MIL-STD-461G and requires a lightning transient simulator.

CS118 *(Conducted Susceptibility, Personnel Borne Electrostatic Discharge) - This* is a new test added to MIL-STD-461G and requires a standard electrostatic discharge simulator.

RS103 *(Radiated Susceptibility, Electric Field) - This test requires an E-field antenna that can go down to 2 MHz.*

Table of New Equipment Required for Latest Updates to MIL-STD-461G			
Requirement	Equipment Type	Vendor(s)	Websites
General	Time Domain EMI Receivers*	Gauss Instruments Keysight Rohde & Schwarz	http://www.gauss-instruments.com/en/products/tdemi http://www.keysight.com/en/pdx-x201870-pn-N9038A/mxe-emi-receiver-3-hz-to-44-ghz?cc=UG&lc=eng https://www.rohde-schwarz.com/us/products/test-and-measurement/emi-test-receivers_105348.html
CS101	Frequency Domain Ripple Monitoring Transducer* High-voltage Differential Probe, 100 MHz, 1k V(RMS) Digital Oscilloscopes (200 MHz - 4 GHZ, 5/10 GSa/s)	Pearson Electronics Rohde & Schwarz Rohde & Schwarz	https://www.pearsonelectronics.com/ https://www.rohde-schwarz.com/us/product/rtzd01-productstartpage_63493-34629.html https://www.rohde-schwarz.com/us/product/rto-productstartpage_63493-10790.html or https://www.rohde-schwarz.com/us/products/test-and-measurement/oscilloscopes_63663.html (with Option RTO-K17)
CS114	Current Probe Calibration Fixture	ETS/Lindgren Fischer Custom Communications Pearson Electronics Solar Electronics	https://www.ets-lindgren.com/products/probes-monitors/current-probes/9006/900602?page=Products-Item-Page (fixture not listed on web site but should be part of current probe/injection clamp line-up) https://www.fischercc.com/type/current-monitor-probe-fixtures/ https://pearsonelectronics.com/pdf/8705C.pdf (fixture holds both injection clamp and current probe) http://www.solar-emc.com/RFI-EMI.html (scroll to bottom of page)
CS117	Indirect Lightning Test Systems	HV Technologies Thermo Scientific Solar Electronics	https://www.hvtechnologies.com/emc-test-equipment/military-avionics-test-equipment/avi-lv3-indirect-lightning-test-system/ http://www.thermoscientific.com/en/product/ecat-lightning-test-system-lts.html http://www.solar-emc.com/2654-2.html
CS118	ESD Gun	EMC Partner EM Test Haefely LISUN Group Noiseken Thermo Scientific TESEQ	https://www.emc-partner.com/products/immunity/esd/esd-generator http://www.emtest.com/products/productGroups/ESD_generators.php http://www.haefely-hipotronics.com/product/product-category/electrostatic-discharge-test-systems-esd/ http://www.lisungroup.com/product-id-318.html http://www.noiseken.com/modules/products/index.php?cat_id=1 http://www.thermoscientific.com/en/product/minizap-15-esd-simulator.html http://www.teseq.com/product-categories/esd-simulators.php
RS103	1 – 18 GHz Electric Field Probe (most test facilities already have one)	Amplifier Research ETS/Lindgren NARDA	https://arworld.us/field-analyzers-field-monitoring/ https://www.ets-lindgren.com/products/probes-monitors?page=Products-Landing-Page https://www.narda-sts.it/eng/products/probes/

* Specified as acceptable for use, but not required.

MILITARY RELATED DOCUMENTS AND STANDARDS

The following references are not intended to be all inclusive, but rather a representation of available sources of additional information and point of contacts.

MIL-HDBK-235-1C Military Operational Electromagnetic Environment Profiles Part 1C General Guidance, 1 Oct 2010.

MIL-HDBK-237D Electromagnetic Environmental Effects and Spectrum Certification Guidance for the Acquisition Process, 20 May 2005.

MIL-HDBK-240A Hazards of Electromagnetic Radiation to Ordnance (HERO) Test Guide, 10 Mar 2011.

MIL-HDBK-263B Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), 31 Jul 1994.

MIL-HDBK-274A Electrical Grounding for Aircraft Safety, 14 Nov 2011.

MIL-HDBK-335 Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance Systems, Notice 4, 08 Jul 2008.

MIL-HDBK-419A Grounding, Bonding, and Shielding for Electronic Equipment and Facilities, 29 Dec 1987.

MIL-HDBK-454B General Guidelines for Electronic Equipment, 15 Apr 2007.

MIL-HDBK-1004-6 Lightning Protection, 30 May 1988.

MIL-HDBK-1195, Radio Frequency Shielded Enclosures, 30 Sep 1988.

MIL-HDBK-1512 Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods, 30 Sep 1997.

MIL-HDBK-1857 Grounding, Bonding and Shielding Design Practices, 27 Mar 1998.

MIL-STD-188-124B Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communications-Electronics Facilities and Equipment, 18 Dec 2000.

MIL-STD-188-125-1 High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions Part 1 Fixed Facilities, 17 Jul 1998.

MIL-STD-220C Test Method Standard Method of Insertion Loss Measurement, 14 May 2009.

MIL-STD-331C Fuze and Fuze Components, Environmental and Performance Tests for, 22 Jun 2009.

MIL-STD-449D Radio Frequency Spectrum Characteristics, Measurement of, 22 Feb 1973.

MIL-STD-461F Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 10 Dec 2007.

MIL-STD-461G Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 11 Dec 2015.

MIL-STD-464C Electromagnetic Environmental Effects Requirements for Systems, 01 Dec 2010.

MIL-STD-704E Aircraft Electric Power Characteristics, 12 Mar 2004.

MIL-STD-1310H Standard Practice for Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility Electromagnetic Pulse (EMP) Mitigation and Safety, 17 Sep 2009.

MIL-STD-1377 Effectiveness of Cable, Connector, and Weapon Enclosure Shielding and Filters in Precluding Hazards of EM Radiation to Ordnance; Measurement of, 20 Aug 1971.

MIL-STD-1399 Section 300B Interface Standard for Shipboard Systems, Electric Power, Alternating Current, 24 Apr 2008.

MIL-STD-1541A Electromagnetic Compatibility Requirements for Space Systems, 30 Dec 1987.

MIL-STD-1542B Electromagnetic Compatibility and Grounding Requirements for Space System Facilities,

MILITARY RELATED DOCS AND STANDARDS CONTINUED

15 Nov 1991. MIL-STD-1605 Procedures for Conducting a Shipboard Electromagnetic Interference (EMI) Survey (Surface Ships), 08 Oct 2009.

MIL-STD-1686C Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices). 25 Oct 1995.

ADS-37A-PRF Electromagnetic Environmental Effects (E3) Performance and Verification Requirements, 28 May 1996.

DOD-STD-1399 Section 070 Part 1 D.C. Magnetic Field Environment, Notice 1, 30 Nov 1989.

DoDI 3222.03 DoD Electromagnetic Environmental Effects (E3) Program, 24 Aug 2014.

DoDD 4650.01 Policy and Procedures for Management and Use of the Electromagnetic Spectrum, 09 Jan 2009.

DoDI 6055.11 Protecting Personnel from Electromagnetic Fields, 19 Aug 2009.

AEROSPACE STANDARDS

AIAA Standards
http://www.aiaa.org/default.aspx

S-121-2009, Electromagnetic Compatibility Requirements for Space Equipment and Systems

RTCA Standards
https://www.rtca.org/

DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment

DO-160G Change 1, Environmental Conditions and Test Procedures for Airborne Equipment

DO-233, Portable Electronic Devices Carried on Board Aircraft

DO-235B, Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band

DO-292, Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band

DO-294C, Guidance on Allowing Transmitting Portable Electronic Devices (T-PEDs) on Aircraft

DO-307, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance

DO-307A, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance

DO-357, User Guide: Supplement to DO-160G

DO-363, Guidance for the Development of Portable Electronic Devices (PED) Tolerance for Civil Aircraft

DO-364, Minimum Aviation System Performance Standards (MASPS) for Aeronautical Information/Meteorological Data Link Services

DO-363, Guidance for the Development of Portable Electronic Devices (PED) Tolerance for Civil Aircraft

DO-307A, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance

SAE Standards
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ARP 5583 – Guide to Certification of Aircraft in a High Intensity Radiation (HIRF) Environment http://standards.sae.org/arp5583/

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