MIL EMI and Transient Solutions

Written by: Jeffrey Ham
Principal Product Line Engineer
Contributions by: Robert Pauplis
Senior Principal Product Line Engineer; et al.

Contents **Page**

Introduction

28V defense applications must meet a number of noise and power related standards such as MIL-STD-461, MIL-STD-704, and MIL-STD-1275. To complicate matters, there are a number of revisions to these standards, any of which may be enforced by the application. Additionally, within each standard are subsections that apply as dictated by the end installation. This Application Note will review these standards and offer means of achieving compliance when using Vicor's MIL-COTS VI Chips® (MP028F036M12AL and MV036FxxxMxxx series).

MIL-STD-461

The latest revision of this standard is MIL-STD-461E. It is a comprehensive document addressing Conducted Emissions, Conducted Susceptibility, Radiated Emissions, and Radiated Susceptibility. Emission refers to the noise a device generates as it impacts the source to which it is connected. Susceptibility is the vulnerability of a system to incoming noise.

Table 1 shows the requirements for each substandard; and Table 2 illustrates the sections related to each of these and the applicability based upon installed platform. As can be observed from Table 2, not all sections are universally required. Hence, most power conversion suppliers focus on achieving compliance to the subset where all installations are affected and in particular to the conducted sections rather than the radiated. These standards are CE102, CS101, CS114, and CS116. Frequently, manufacturers will also reference CE101, as the switching frequency of most DC-DC converters are well beyond the frequency band of interest. Conducted emission and susceptibility requirements are quoted (and not radiated requirements) because radiated sections are significantly dependent upon the physical layout, external output circuitry and enclosure in which the power supply resides. A valid filter design and good PCB layout mean conducted requirements are easily met.

There is not much difference between revision E and the earlier revision D; in fact, of sections CE101, CE102, CS101, CS114, and CS116 only CS101 and CS114 are different.

The extent of the differences are:

CS101 - No change up to 5kHz; above 5kHz:

461D: Required level drops 20dB / decade to 50kHz

461E: Required level drops 20dB / decade to 150kHz

CS114 - No change up to 30MHz; above 30MHz:

461D: Required level drops 10dB / decade to 400MHz

461E: Required level drops 10dB / decade to 200MHz

Table 1
Summary of MIL-STD-461E Requirements

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30Hz to 10kHz
CE102	Conducted Emissions, Power Leads, 10kHz to 10MHz
CE106	Conducted Emissions, Antenna Terminal, 10kHz to 40GHz
CS101	Conducted Susceptibility, Power Leads, 30Hz to 150kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15kHz to 10GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30Hz to 20GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30Hz to 20GHz
CS109	Conducted Susceptibility, Structure Current, 60Hz to 100kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10kHz to 200MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10kHz to 100MHz
RE101	Radiated Emissions, Magnetic Field, 30Hz to 100kHz
RE102	Radiated Emissions, Electric Field, 10kHz to 18GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10kHz to 40GHz
RS101	Radiated Susceptibility, Magnetic Field, 30Hz to 100kHz
RS103	Radiated Susceptibility, Electric Field, 2MHz to 40GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

Now we have introduced the standard, how do we gain compliance? What follows is a general guide for EMI filter design. We will focus on CE102 for our discussion.

Basics of EMI

EMI measurement are separated into two parts:

- Conducted
- Radiated

Conducted measurements are measurements of either voltages or currents flowing in the leads of the device under test (as dictated by the standard). Common mode conducted noise current is the unidirectional (in phase) component in both the positive and negative inputs to the module. This current circulates from the converter via the power input leads to the DC source and returns to the converter via the output lead connections. This represents a potentially large loop cross-sectional area that, if not effectively controlled, can generate magnetic fields. Common mode noise is a function of the dV/dt across the main switch in the converter and the effective input to output capacitance of the converter. Differential mode conducted noise current is the component of current, at the input power terminal, which is opposite in direction or phase with respect to each other.

For our purposes we will concentrate on MIL-STD-461, CE102 that is a voltage measurement into 50Ω.

E-Field radiated emissions are due to conducted currents through a suitable antenna such as the power leads of the device under test. If we can greatly reduce the conducted emissions then we will reduce the radiated emissions as well. The enclosure of the device under test, lead geometry, and other devices running within the device under test will affect the emissions. Radiated emissions due to B-Fields are best addressed by shielding with a suitable material and proper layout.

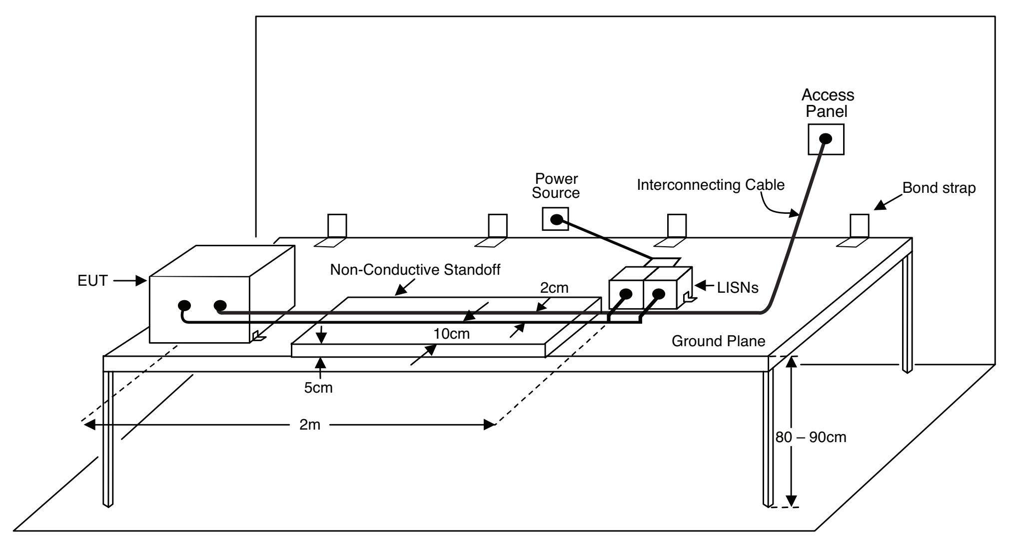
Table 2
Section Requirement Applicability

Equipment and subsystems installed in, on, or launched from the following platforms or installations:	Requirement Applicability																
	CE101	CE102	CS106	CS101	CS103	CS104	CS105	CS109	CS114	CS115	CS116	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships		A	L	A	S	S	S		A	L	A	A	A	L	A	A	L
Submarines	A	A	L	A	S	S	S	L	A	L	A	A	A	L	A	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S		A	A	A	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S		A	A	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S		A	A	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S		A	A	A		A	L		A	
Ground, Army		A	L	A	S	S	S		A	A	A		A	L	L	A	
Ground, Navy		A	L	A	S	S	S		A	A	A		A	L	A	A	L
Ground, Air Force		A	L	A	S	S	S		A	A	A		A	L		A	

Legend:
A Applicable
L Limited as specified in the individual sections of this standard
S Procuring activity must specify in procurement documentation

A defined test setup, known source impedance, and limits to which we can compare results are needed to get repeatable results. The standard test configuration is shown in Figure 1.

Figure 1
MIL-STD-461 Test Setup



The known impedance is realized with the use of Line Impedance Stabilization Networks (LISN) terminated into 50Ω (internal to the measurement device). One LISN per power lead is needed. This is illustrated in Figures 1 & 2.

Figure 2
LISN Schematic and Impedance Graph

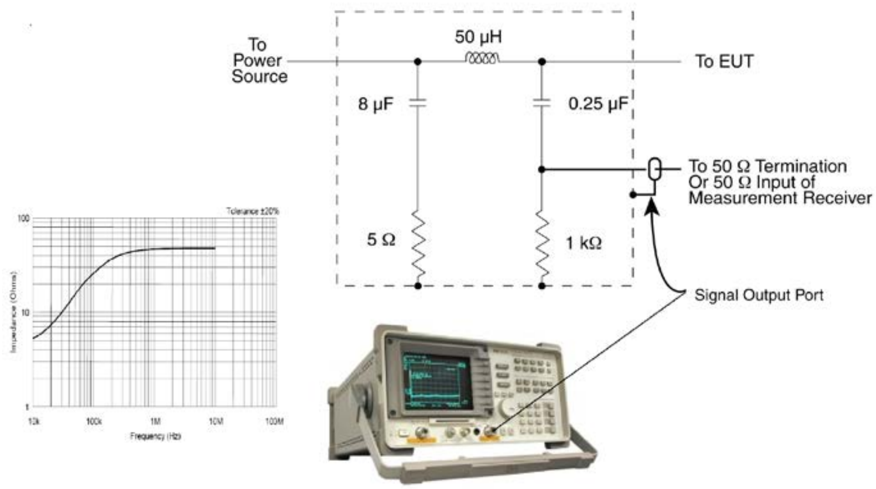
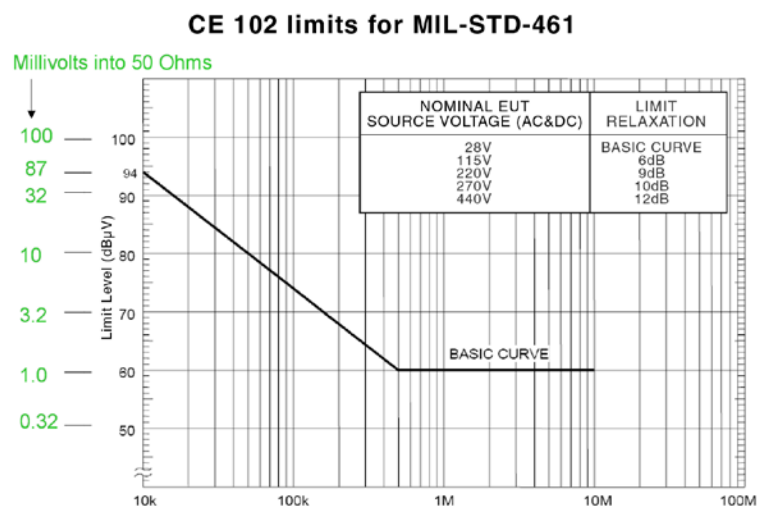


Figure 3 shows the spec limits. It is beneficial to translate the limits to millivolts in addition to the standard dBµV.

Figure 3



From the limits shown in Figure 3 for 28V systems, we can see that at 500kHz and above, the limit is 1mV into 50Ω. Given the limits, we will need to understand the source of the noise to determine the amount of attenuation required to stay below the limits. It is critical to understand the properties of the noise source in order to design a good filter.

Since in most cases the noise character of a device is unknown, the most effective solution is to have the device in hand prior to the development of a filter. The noise source can then be characterized through experimentation and, once characterized, amodel can be generated. A good series of noise voltage measurements are:

- Input to ground – open circuit.
- Input to ground – 100Ω shunt termination. (With DC blocking cap)
- Input to ground – 10Ω shunt termination. (With DC blocking cap)
- Input to ground – 1Ω shunt termination. (With DC blocking cap)
- Measurement of the short circuit common mode current input-output.

Let's assume the noise voltage measurements are:

Input to ground – open circuit.	10V P-P
Input to ground – 100Ω	4V P-P
Input to ground – 10Ω	580mV P-P
Input to ground – 1Ω	280mV P-P
Short circuit (50nH) current input-output.	290mA

The equivalent circuit (model) would be most nearly a 10V source as found from the open circuit test, with a series resistance of about 35Ω (10V from the open circuit test and 0.28A from the 1Ω test).

Let's now investigate adding "Y" capacitance (from Line to Ground). This 4,700pF device has an impedance of ~13Ω at 2.3MHz (an assumed frequency of the ring wave measured in the 1Ω termination test.) “Repeat” the measurement to observe the amplitude of the waveform. Let's also assume that the result of this measurement yields 1.3V.

We now need to check our results:

A 10V noise source with a series impedance of about 35Ω is the model for the source.

The “Y” capacitor has an impedance of 13Ω at 2.7MHz.

Solving for the voltage across the capacitor yields 2.7V. The "measured" value across the 4,700pF capacitor is 1.3V.

Although this looks like a huge difference in percentage, we are only off -6.3db from the calculations. The good news is the error is in the right direction.

So what do we know?

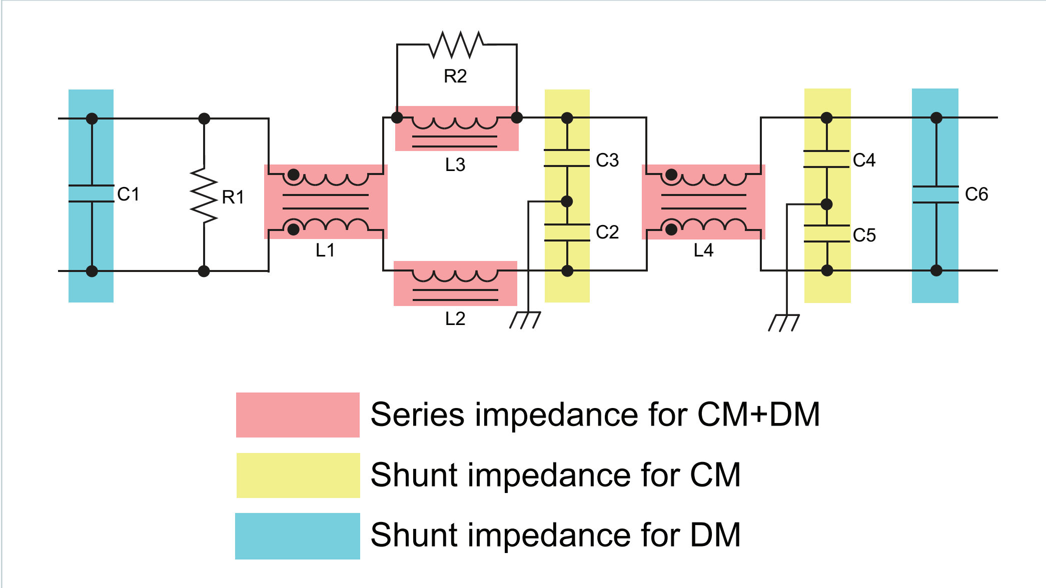
If we measure the conducted emissions using a LISN we would see a value of only slightly less than 1.3V. Our source impedance is still relatively low with respect to 50Ω. i.e., 1.3V_{OCV}, I_{SC} 0.29A = 4.5Ω.

Our target voltage measurement value is 1mV, we only need 63db of additional attenuation. Is it practical to continue to add shunt capacitance or impedances?

No, even if we could add as much shunt capacitance as we wanted the entire impedance, given an Isc current of 290mA, would require the total shunt impedance <3.4mΩ. This dictates that a practical filter must be constructed of a cascade of shunt and series devices forming an AC voltage divider. This is illustrated in Figure 4.

For a good design we need to understand the impedance of every part and the potential interaction. It is good practice to keep the "Q" of the inductors and the ESR of the capacitors low for good attenuation without creating a resonance or as it is sometimes called “peaking”. Layout of the filter is very important to avoid inadvertent parasitic coupling. For the example filter above, parasitic capacitance from input to output could easily be 1pF, which is about 60kΩ at 2.7MHz. If there were no shunt impedance looking back into the filter this would produce over 1mV at the LISN, putting us above the limit on its own.

Figure 4
Multistage Filter for MIL-STD-461 Compliance



The filter impedance (looking into the input) as well as additional "Y" capacitance either real or parasitic near C1 helps mitigate the effects of this parasitic. It is important to note that inductive coupling will have the same effect. Good layout practice is imperative so as to prevent input to output and stage to stage coupling.

Having a filter precede a power component has the added benefit of providing attenuation to transient fluctuations in the source voltage. Short duration, high dV/dt, events have little energy associated and the inductance and capacitance present in a filter is sometimes enough to integrate this energy by reducing the peak, and expanding the time as it appears at the output of the filter.

Unfortunately, the power supply to the application (as defined by the standard) can frequently exceed the capacity of the input filter to mitigate these power excursions; and so additional circuitry may be needed to transform them in such a way as to not affect the power device.

Transient Immunity

MIL-STD-704 and MIL-STD-1275 refer to aircraft and ground-based systems that describe the anticipated power quality of those systems, and the levels a device mustmeet or exceed in order to perform satisfactorily in the anticipated application. Other standards may be required but are not covered in this paper.

Tables 3 – 7 below give a summary of the most current revisions of $28V_{DC}$ system requirements.

Table 3
28V Transient Standard Summary

Specification	Test Description	V_{START} V_{DC}	Time Sec	V_{SURGE} V_{DC}	Tr ms	Duration ms	Tf ms	V_{NOM} V_{DC}	Time sec	Remarks	Interval sec
RTCA DO-160E Section 16 Power input Airborne Equipment Category Z	Normal Surge Par. 16.6.1.4	28	300	50	1	50	1	28	5	Repeat 3 times	5
		28	300	12	1	30	1	28	5	Repeat 3 times	5
	Abnormal Surge Par. 16.6.2.4	28	300	80	ns	100	ns	28	ns	Repeat 3 times	1
		28	300	48	ns	1,000	ns	28	ns	Repeat 3 times	10
DEF STAN 61-5, Part 6 $28V_{DC}$ Electrical Systems in Military Vehicles	Import Surge Generator Plus Battery	26.4	300	40	ns	50	50	26.4	1	Repeat 5 times	1
		26.4	300	20	ns	500	500	26.4	1	Repeat 5 times	1
	Import Surge Generator Only	26.4	300	100	ns	50	150	26.4	1	Repeat 5 times	1
		26.4	300	15.4	ns	500	150	26.4	1	Repeat 5 times	1
Mil-STD-1275D $28V_{DC}$ Electrical Systems in Mil Vehicles	Normal Import Surge Generator Plus Battery	28	300	40	1	50	1	28	ns	Repeat 5 times	1
	Generator Only	28	300	100	1	50	1	28	ns	Repeat 5 times	1
AIRBUS BD0100.1.8 Electrical Installation Conventional DC Network	Voltage Surge Normal Trans. Test 3.1 Test 3.2 Test 3.3 Test 3.4	27.5	300	40	ns	30	ns	27.5	5	Repeat each test 3 times	5
		27.5	300	17	ns	15	ns	27.5	5		5
		27.5	300	39	ns	50	ns	27.5	5		5
		27.5	300	19.5	ns	30	ns	27.5	5		5
		27.5	300	37	ns	100	ns	27.5	5		5
		27.5	300	21	ns	50	ns	27.5	5		5
		27.5	300	35	ns	200	ns	27.5	5		5
		27.5	300	23.5	ns	100	ns	27.5	5		5

ns = not specified

Table 4
28V Transient
Standard Summary

Specification	Test Description	V_{START} V_{DC}	Time Sec	V_{SURGE} V_{DC}	Tr ms	Duration ms	Tf ms	V_{NOM} V_{DC}	Time sec	Remarks	Interval sec
AIRBUS ABD0100.1.8 Electrical Installation Conventional DC Network	Voltage Surge Abnormal Trans.										
	Test 4.1	27.5	300	46	ns	100	ns	27.5	5	Repeat 3 times	5
	Test 4.2	27.5	300	38	ns	1,000	ns	27.5	5		5
		27.5	300	0	ns	5,000	ns	27.5	5		5
AIRBUS ABD0100.1.8 Electrical Installation NBPT* DC Network *No Break Power Transfer	Voltage Surge Normal Trans.										
	Test 2.1	27.5	300	36	ns	100	ns	27.5	5	Repeat 3 times	5
	Test 2.2	27.5	300	35	ns	200	ns	27.5	5		5
	Test 2.3	27.5	300	34	ns	300	ns	27.5	5		5
	Test 2.4	27.5	300	18.5	ns	5,000	ns	27.5	5		5
	Voltage Surge Abnormal Trans.										
	Test 3.1	27.5	300	36	ns	1,000	ns	27.5	5	Repeat 3 times	5
	Test 3.2	27.5	300	33	ns	3,000	ns	27.5	5		5
	Test 3.3	27.5	300	0	ns	5,000	ns	27.5	5		5
Mil-STD-704F and Mil-HDBK-704 Part 8	Normal Voltage Trans. Overvoltage										
	AA	29	300	50	<1	12.5	<1	29			
	BB	29	300	50	<1	12.5	70	29			
	CC	29	300	40	<1	45	<1	29			
	DD	29	300	40	<1	45	37.5	29			
	EE	29	300	50	<1	10	<1	29		Repeat 3 times	.0005
	FF	22	300	50	<1	12.5	<1	22			
	GG	22	300	50	<1	12.5	95	22			
	HH	22	300	40	<1	45	<1	22			

ns = not specified

Table 5
28V Transient Standard Summary

Specification	Test Description	V_{START} V_{DC}	Time Sec	V_{SURGE} V_{DC}	Tr ms	Duration ms	Tf ms	V_{NOM} V_{DC}	Time sec	Remarks	Interval sec
Mil-STD-704F and Mil-HDBK-704 Part 8 (cont.)	Normal Voltage Trans. Overvoltage										
	II	22	300	40	<1	45	62.5	22			
	JJ	22	300	50	<1	10	<1	22		Repeat 3 times	.0005
	Undervoltage										
	KK	29	300	18	<1	15	<1	29			
	LL	29	300	18	<1	15	234	29			
	MM	29	300	18	<1	10	<1	29		Repeat 3 times	.0005
	NN	22	300	18	<1	15	<1	22			
	OO	22	300	18	<1	15	85	22			
	PP	22	300	18	<1	10	<1	22		Repeat 3 times	.0005
	Combined Transient										
	QQ	29	300	18	<1	10	<1	29	<.001	Repeat 5 times	
		then		50	<1	12.5	70	29			
	RR	22	300	18	<1	10	<1	22	<.001	Repeat 5 times	
		then		50	<1	12.5	62.5	22			
	Repetitive Normal Voltage Trans.	28.5	.0025	18	30	$45V_{DC}$	2.5	28.5		Continuous for 30 min.	.0005

Table 6
28V Transient
Standard Summary

Specification	Test Description	V_{START} V_{DC}	Time Sec	V_{SURGE} V_{DC}	Tr ms	Duration ms	Tf ms	V_{NOM} V_{DC}	Time sec	Remarks	Interval sec
Mil-STD-704F and Mil-HDBK-704 Part 8 (cont.)	Abnormal Voltage Trans. Overvoltage										
	AAA	29	300	50	<1	50	<1	29			
	BBB	29	300	50	<1	50	15	45			
		then		45		decreasing	30	40			
		then		40		decreasing	60	35			
		then		35		decreasing	4,850	30			
		then		30		decreasing	1,000	29			
	CCC	29	300	50	<1	50	<1	29		Repeat 3 times	.5
	DDD	22	300	50	<1	50	<1	22			
	EEE	22	300	50	<1	50	15	45			
		then		45		decreasing	30	40			
		then		40		decreasing	60	35			
		then		35		decreasing	4,850	30			
		then		30		decreasing	8,000	22			
	FFF	22	300	50	<1	50	<1	22			
	Undervoltage										
	GGG	29	300	7	<1	50	<1	29			
	HHH	29	300	7	<1	50	15	12			
		then		12	30	increasing	na	17			
		then		17	60	increasing	na	22			
		then		22	4,850	increasing	na	28			
		then		28	1,000	increasing	na	29			
		then		29							

Table 7
28V Transient
Standard Summary

Specification	Test Description	V_{START} V_{DC}	Time Sec	V_{SURGE} V_{DC}	Tr ms	Duration ms	Tf ms	V_{NOM} V_{DC}	Time sec	Remarks	Interval sec
Mil-STD-704F and Mil-HDBK-704 Part 8 (cont.)	Abnormal Voltage Trans. Undervoltage										
	III	29	300	7	<1	50	<1	29	<1	Repeat 3 times	.5
	JJJ	22	300	7	<1	50	<1	22	<1		
	KKK	22	300	7	<1	50	15	12			
		then		12		increasing	30	17			
		then		17		increasing	60	22			
	LLL	22	300	7	<1	50	<1	22		Repeat 3 times	.5
	Combined Trans.										
	MMM	29	300	7	<1	10	<1	50			
				50	<1	50	15	45			
		then		45		decreasing	30	40			
		then		40		decreasing	60	35			
		then		35		decreasing	4,850	30			
		then		30		decreasing	1	29			
		then		29							
	NNN	22	300	7	<1	10	<1	50			
				50	<1	50	15	45			
		then		45		decreasing	30	40			
		then		40		decreasing	60	35			
		then		35		decreasing	4,850	30			
		then		30		decreasing	8,000	22			
		then		22							

As with MIL-STD-461 there are earlier revisions of 704 and 1275 that may be required depending upon the installation. Be certain you know which one is being imposed because the limits can vary greatly.

MIL-STD-704F is relatively easy to meet. The tables 8 – 10 below summarize the important variations between the revisions of 704.

Table 8
704 Revision Summary

		28V$_{DC}$ Steady State		
		NORMAL (V)	ABNORMAL (V)	EMERGENCY (V)
MIL-STD-704A	Cat. A	25 – 28.5	23.5 – 30	17 – 24
	Cat. B	24 – 28.5	22.5 – 30	16 – 24
	Cat. C	23 – 28.5	21.5 – 30	15 – 24
MIL-STD-704C		22 – 29	20 – 31.5	16 – 30
MIL-STD-704D		22 – 29	20 – 31.5	16 – 29
MIL-STD-704E		22 – 29	20 – 31.5	18 – 29
MIL-STD-704F		22 – 29	20 – 31.5	16 – 29

The Surge differences are:

Table 9
704 Revision Summary

		28V$_{DC}$ Surges							
		Normal Operation				Abnormal Operation			
		High Transients		Low Transients		High Transients		Low Transients	
		Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time
MIL-STD-704A	Cat. A	70	20ms	10	50ms	80	50ms	0	7S
	Cat. B	70	20ms	8	50ms	80	50ms	0	7S
	Cat. C	70	20ms	7	50ms	80	50ms	0	7S
MIL-STD-704C		50	12.5ms	18	15ms	50	45ms	0	7S
MIL-STD-704D		50	12.5ms	18	15ms	50	45ms	0	7S
MIL-STD-704E		50	12.5ms	18	15ms	50	50ms	0	7S
MIL-STD-704F		50	12.5ms	18	15ms	50	50ms	0	7S

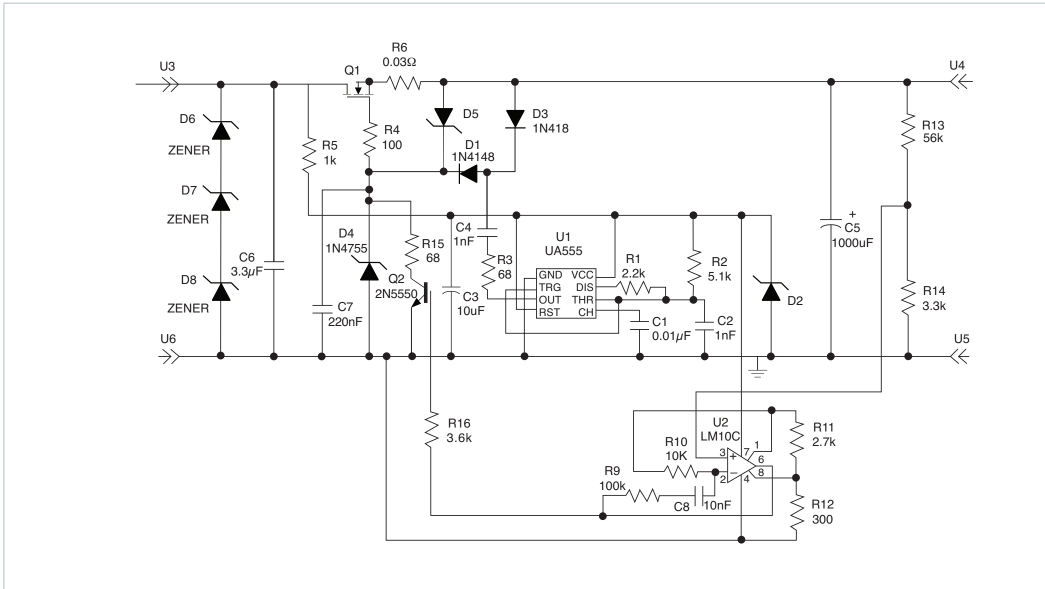
Table 10
704 Revision Summary

		28V$_{DC}$ Spikes			
		High Transients		Low Transients	
		Voltage (V)	Time	Voltage (V)	Time
MIL-STD-704A	Cat. A	600	50µs	–600	50µs
	Cat. B	600	50µs	–600	50µs
	Cat. C	600	50µs	–600	50µs
MIL-STD-704C		N/A			
MIL-STD-704D		Spikes less than 50µs are controlled by MIL-E-6051			
MIL-STD-704E		N/A			
MIL-STD-704F		N/A			

As can be seen from Tables 8 – 10, 704 F is readily met if the power device has a normalinput range of 16 -50V_{DC} - no special precautions or circuitry is needed. The Vicor M-PRM Model MP028F036M12AL has this input range, allowing for direct compliance to this standard.

If 704 A is required to be met, the MP028F036M12AL needs additional protection - usually an input shunt Transorb to clamp the spike to a reasonable level, followed by an active clamp circuit using FETs to reduce the voltage to the output to the maximum level the DC device can tolerate. Figure 5 below illustrates the concept.

Figure 5
Example Clamp Circuit



Q1 is the main clamping element and must be sized appropriately to handle the power dissipation needed during the 80V (for 50ms) abnormal requirement. Obviously if the downstream device can handle a higher voltage, less power must be dissipated in Q1. D6 – 8 are in this example 33V 600W devices.

MIL-STD-1275D is a more severe requirement in that the Surge amplitude and duration is 100V_{DC} for 50ms. Tables 11 – 13 list the variations in revisions for MIL-STD-1275. As can be seen from these tables, with the exception of the 600V spikes from 704 A, 1275D is more stringent. Therefore, if MIL-STD-1275D is met, 704 F is met and because the Transorb handles the 600V spike, 704 A is also met.

The circuit in Figure 5 could be built using discrete components, and an EMI filter could be designed using the methodology outlined earlier, but doing so requires iterations of build, test, evaluate, modify - dragging out the design phase of a project. To save time and ensure compliance, a ready-made product should be used, such as the Vicor M-FIAM7.

Table 11
1275 Revision Summary

	$28V_{DC}$ Steady State		
	NORMAL (V)	GEN ONLY (V)	BATTERY ONLY (V)
MIL-STD-1275A (AT)	25 – 30	23 – 33	20 – 27
MIL-STD-1275B	25 – 30	23 – 33	20 – 27
MIL-STD-1275C	25 – 30	23 – 33	20 – 27
MIL-STD-1275D	25 – 30	23 – 33	

Table 12
1275 Revision Summary

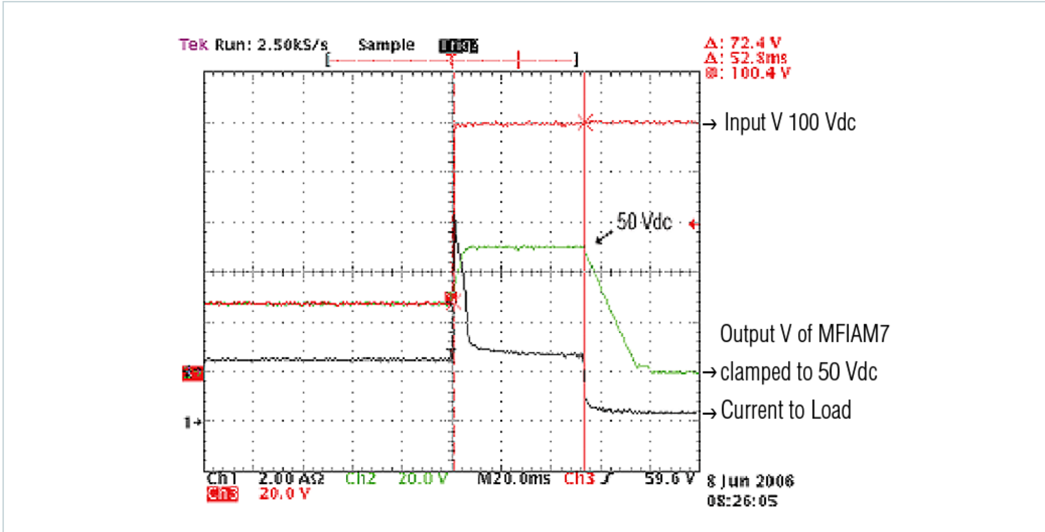
	$28V_{DC}$ Surges							
	Fault Free Operation				Single Fault Operation			
	High Transients		Low Transients		High Transients		Low Transients	
	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time
MIL-STD-1275A (AT)	40	50mS	18.5	100mS	100	50mS	15	500mS
MIL-STD-1275B	40	50mS	18.5	100mS	100	50mS	15	500mS
MIL-STD-1275C	40	50mS	18	100mS	100	50mS	15	250mS
	$28V_{DC}$ Surges							
	Normal Operating Mode				General Only Mode			
	High Transients		Low Transients		High Transients		Low Transients	
	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time
MIL-STD-1275D	40	50mS	18	500mS	100	50mS	15	500mS

Table 13
1275 Revision Summary

	$28V_{DC}$ Spikes							
	Fault Free Operation				Single Fault Operation			
	High Transients		Low Transients		High Transients		Low Transients	
	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time
MIL-STD-1275A (AT)	250	70uS	–250	70uS	250	70uS	–250	70uS
MIL-STD-1275B	250	70uS	–250	70uS	250	70uS	–250	70uS
MIL-STD-1275C	250	70uS	–250	70uS	250	70uS	–250	70uS
	$28V_{DC}$ Spikes							
	Normal Operating Mode				General Only Mode			
	High Transients		Low Transients		High Transients		Low Transients	
	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)	Time
MIL-STD-1275D	250	70uS	–250	70uS	250	70uS	–250	70uS

Figure 6 is plot of the transient protection behavior of the M-FIAM7.

Figure 6



The pre-filter Conducted Emission (CE102) plot for a raw PRM™/VTM™ pair is shown in Figure 7. Figure 8 shows the same plot after the addition of the M-FIAM7 with the measurement setup illustrated in Figure 9.

Figure 7
Note the Bulk of the Energy Needing to be Attenuated is at and Above the Switching Frequency of the PRM / VTM Pair

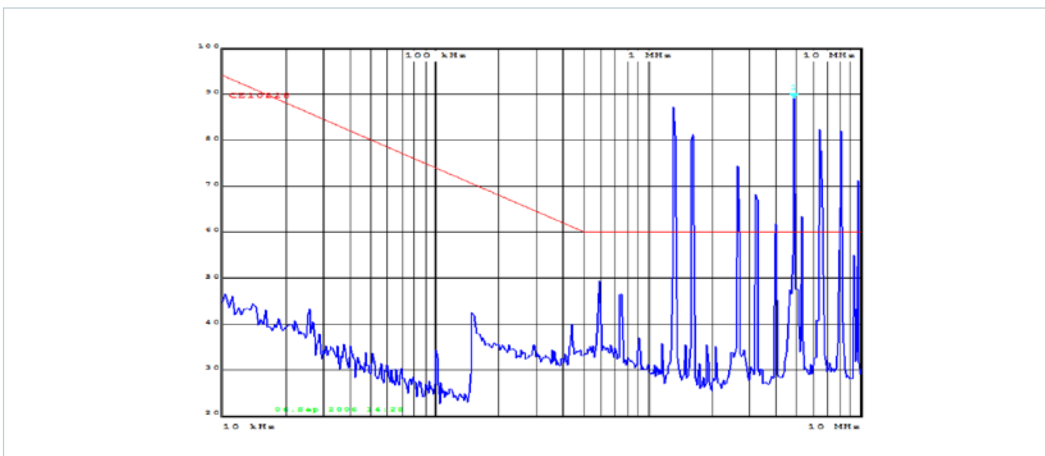
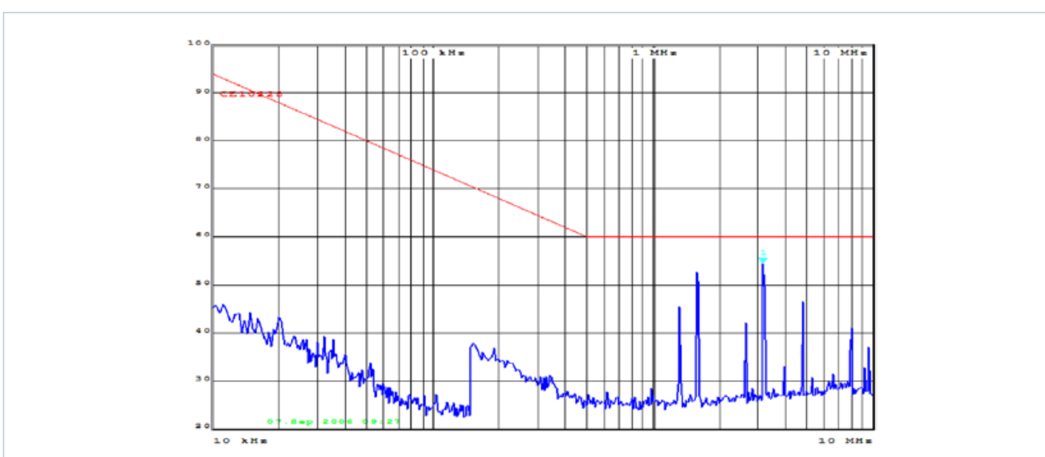
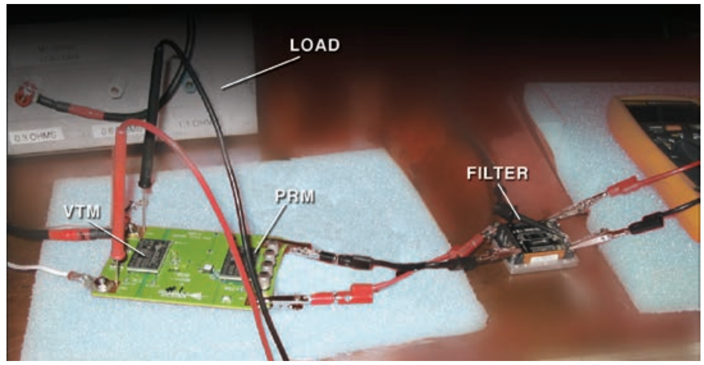


Figure 8
CE102 Plot After the Addition of M-FIAM7 and Y Capacitance





Conclusion

Meeting the Compliance limits for EMI and Transient protection can be a daunting task. The steps involved in designing a filter from scratch, while doable, are tedious and time-consuming. Nevertheless this can be done if the steps outlined in this document are followed. A better method is to use a component such as the M-FIAM7 that has been designed by the manufacturer of the power component. Doing so assures compatibility with the device and a huge reduction in the design effort.

Limitation of Warranties

Information in this document is believed to be accurate and reliable. HOWEVER, THIS INFORMATION IS PROVIDED "AS IS" AND WITHOUT ANY WARRANTIES, EXPRESSED OR IMPLIED, AS TO THE ACCURACY OR COMPLETENESS OF SUCH INFORMATION. VICOR SHALL HAVE NO LIABILITY FOR THE CONSEQUENCES OF USE OF SUCH INFORMATION. IN NO EVENT SHALL VICOR BE LIABLE FOR ANY INDIRECT, INCIDENTAL, PUNITIVE, SPECIAL OR CONSEQUENTIAL DAMAGES (INCLUDING, WITHOUT LIMITATION, LOST PROFITS OR SAVINGS, BUSINESS INTERRUPTION, COSTS RELATED TO THE REMOVAL OR REPLACEMENT OF ANY PRODUCTS OR REWORK CHARGES).

Vicor reserves the right to make changes to information published in this document, at any time and without notice. You should verify that this document and information is current. This document supersedes and replaces all prior versions of this publication.

All guidance and content herein are for illustrative purposes only. Vicor makes no representation or warranty that the products and/or services described herein will be suitable for the specified use without further testing or modification. You are responsible for the design and operation of your applications and products using Vicor products, and Vicor accepts no liability for any assistance with applications or customer product design. It is your sole responsibility to determine whether the Vicor product is suitable and fit for your applications and products, and to implement adequate design, testing and operating safeguards for your planned application(s) and use(s).

VICOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED OR WARRANTED FOR USE IN LIFE SUPPORT, LIFE-CRITICAL OR SAFETY-CRITICAL SYSTEMS OR EQUIPMENT. VICOR PRODUCTS ARE NOT CERTIFIED TO MEET ISO 13485 FOR USE IN MEDICAL EQUIPMENT NOR ISO/TS16949 FOR USE IN AUTOMOTIVE APPLICATIONS OR OTHER SIMILAR MEDICAL AND AUTOMOTIVE STANDARDS. VICOR DISCLAIMS ANY AND ALL LIABILITY FOR INCLUSION AND/OR USE OF VICOR PRODUCTS IN SUCH EQUIPMENT OR APPLICATIONS AND THEREFORE SUCH INCLUSION AND/OR USE IS AT YOUR OWN RISK.

Terms of Sale

The purchase and sale of Vicor products is subject to the Vicor Corporation Terms and Conditions of Sale which are available at: (http://www.vicorpower.com/termsconditionswarranty)

Export Control

This document as well as the item(s) described herein may be subject to export control regulations. Export may require a prior authorization from U.S. export authorities.

Contact Us: http://www.vicorpower.com/contact-us

Vicor Corporation
25 Frontage Road
Andover, MA, USA 01810
Tel: 800-735-6200
Fax: 978-475-6715
www.vicorpower.com

email
Customer Service: custserv@vicorpower.com
Technical Support: apps@vicorpower.com