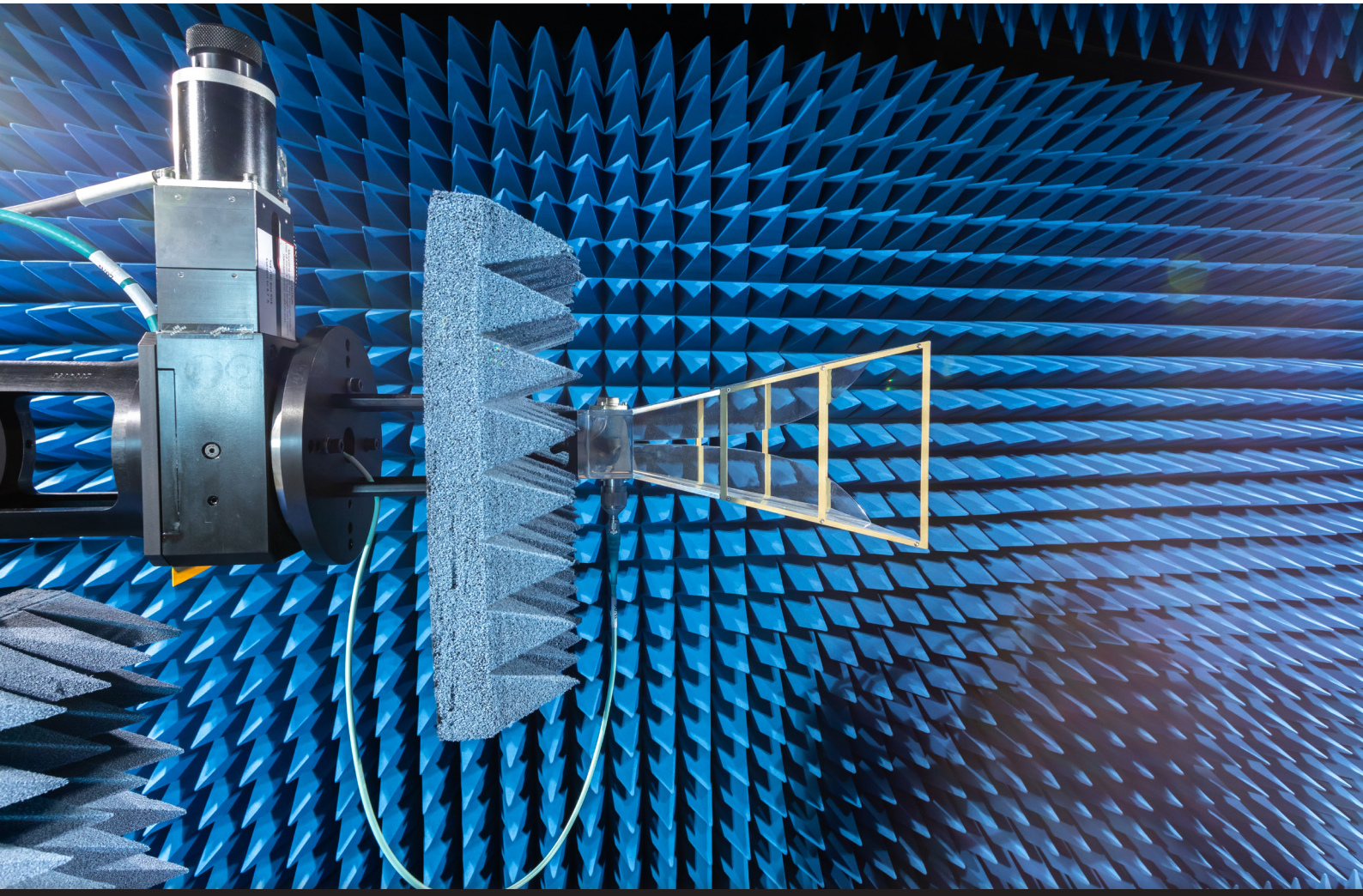
MIL GRADE EMC FILTER FOR DC/DC CONVERTERS



DC/DC-converters are electronic devices that can change a direct current (DC) voltage into another DC voltage. They can act like an isolating transformer or a step-up or step-down transformer but with direct current instead of alternating current (AC) supplies.

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ABOUT DC/DC-CONVERTERS

DC/DC-converters are electronic devices that can change a direct current (DC) voltage into another DC voltage—in other words, they can act like an isolating transformer or a step-up or step-down transformer but with direct current instead of alternating current (AC) supplies. As transformers only work with AC, all DC/DC converters are internally DC-to-AC-to-DC modules:

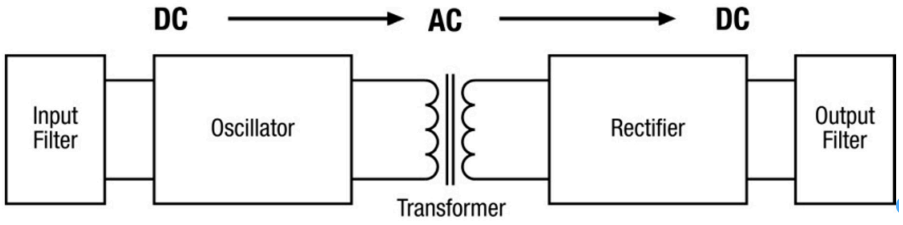

Figure 1:Basic layout of a DC/DC-converter

As DC/DC converters contain switching elements (transistors) to generate the internal AC waveform, their input and output currents are pulsating in nature which generates electromagnetic interference (EMI). Electromagnetic compatibility (EMC) filters are specialized circuits designed to ensure effective management of EMI and allow the converter to pass the EMC tests with sufficient margin below the maximum permitted limits. Their primary function is to suppress unwanted electromagnetic signals, preventing interference that could disrupt or degrade the performance of sensitive electronic equipment.

ABOUT MIL-STD-461G

Military-grade compliant EMC filters are engineered to meet stringent army, airforce and navy standards, with high-quality components and rigorous testing to ensure reliability in extremely harsh environmental and operating conditions. With their exceptional EMI-suppression capabilities, these filters play a crucial role in safeguarding critical military systems and optimizing their overall electromagnetic compatibility.
The United States Military Standard (MIL-STD) applicable for EMC is MIL-STD-461 (Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment). The current, most up-to-date version of this standard is referred to as MIL-STD-461G, although many legacy projects still use the older version, MIL-STD-461E.

CLASSES AND LEVELS OF MIL-STD-461G

MIL-STD-461G establishes classes and test levels to define the limits for EMC in various military platforms. These classes and their corresponding limits apply to a wide range of military vehicles, including:

Ground Vehicles:

Class A: Non-critical systems with moderate emission and immunity requirements.
Class B: Combat vehicles with intermediate emission and immunity requirements.
Class C: Mission-critical systems, such as command and control units, with the strictest emission and immunity requirements.

Aircraft:

Class A: Non-critical avionics and systems meeting moderate limits.

Class B: Critical avionics with intermediate emission control and immunity requirements.
Class C: Vital systems, including flight control and communication equipment, meeting the strictest limits for emission and immunity.

Submarines:

Class A: Non-critical systems with moderate emission and immunity requirements.
Class B: Critical subsystems with intermediate emission control and immunity requirements.
Class C: Vital systems such as navigation and communication equipment, subject to the strictest emission and immunity requirements.

REQUIREMENTS MATRIX

MIL-STD-461G specifies a comprehensive set of test procedures aimed to fulfill the US Department of Defense (DoD) specifications and requirements, depending on the sphere of operation.
The test procedures are broken up into four groups: radiated emissions (RE), conducted emissions (CE), radiated susceptibility (RS), and conducted susceptibility (CS). The name of a procedure consists of the two-letter abbreviation representing its group followed by a code, for example CS101 denotes the test "Conducted Susceptibility, Power Leads."

EQUIPMENT	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS114	CS115	CS116	CS117	CS118
Surface Ships	A	A	L	A	S	L	S	L	S	A	L	S
Submarines	A	A	L	A	S	L	S	L	S	L	S	S
Aircraft, Army	A	A	L	A	S	S	S		A	A	L	A
Aircraft, Navy	L	A	L	A	S	S	S		A	A	L	A
Aircraft, Airforce		A	L	A	S	S	S		A	A	L	A
Space Systems		A	L	A	S	S	S		A	A	L	
Ground, Army		A	L	A	S	S	S		A	A	S	
Ground, Navy		A	L	A	S	S	S		A	A	S	
Ground Airforce		A	L	A	S	S	S		A	A		

Table 1: MIL-STD Conducted Emissions and Susceptibility Matrix

EQUIPMENT	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	L	A	L
Submarines	A	A	L	L	A	L
Aircraft, Army	A	A	L	A	A	L
Aircraft, Navy	L	A	L	L	A	L
Aircraft, Airforce		A	L		A	
Space Systems		A	L		A	
Ground, Army		A	L	L	A	
Ground, Navy		A	L	L	A	L
Ground Airforce		A	L		A	

Table 2: MIL-STD Radiated Emissions and Susceptibility Matrix

A = Applicable
S = Specified in procurement
L = Limited applicability
Blank = Not applicable

EMC FILTER DESIGN

To comply with the strict MIL-STD emission and susceptibility limits, multiple stage filtering is required, with each stage focusing on a specific frequency band so that, in total, the filter is effective over the full frequency range of interest. For example, CE101 (Conducted Emissions, Audio Frequency Currents, Power Leads) limits are measured over the frequency range 30Hz – 10kHz, while CE102 (Conducted Emissions, Radio Frequency Potentials, Power Leads) limits are measured over the frequency range 10kHz – 10MHz.
For Surface Ships, both CE101 and CE102 tests are required for conformity, so the EMC filter must cover the very wide range of 30Hz to 10MHz, a range impossible with a single filter stage.

Test Setups

Due to the wide range of frequencies involved, the testing for MIL-STD-461G for the RECOM products RP60Q-RUW and RP40Q-RUW had to be carried out in a specialist EMC test facility.

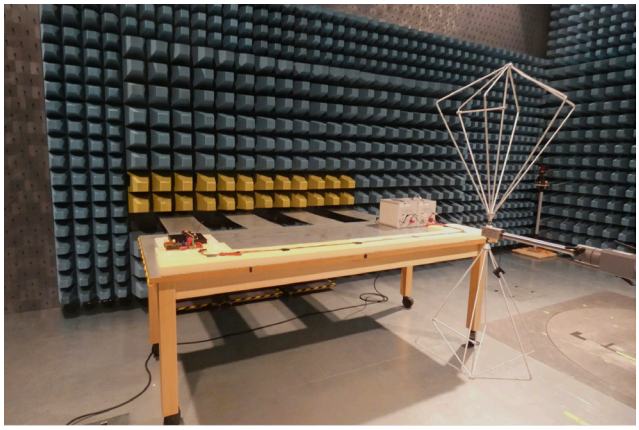

Figure 2: Radiated Emissions test setup

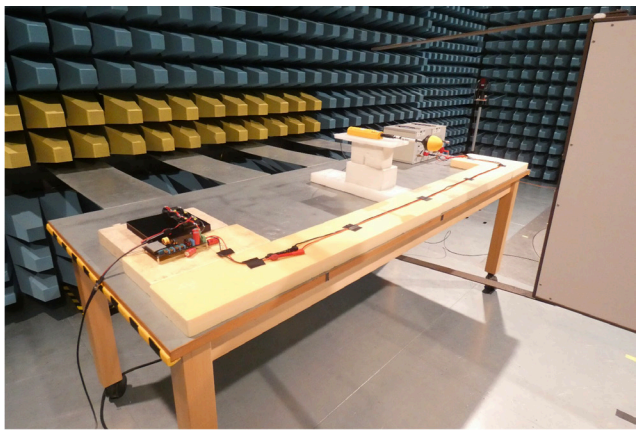

Figure 3: Conducted Emissions test setup

Schematics

An example of a multiple stage MIL-STD compliant EMC filter design is shown below:

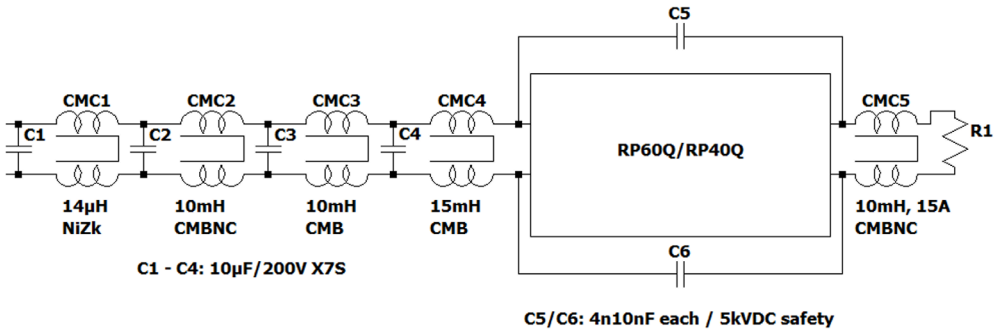

Figure 4: MIL-STD EMC Filter

Note that both the input and the output leads need to be filtered for compliance with the limits.

Other applicable standards

In addition to MIL-STD-461G, other performance standards such as MIL-STD-1275D (Characteristics of 28V DC Electrical Systems in Military Vehicles) may also be applicable for EMC filters. MIL-STD-1275D stipulates additional requirements for reverse polarity protection, transient suppression, and inrush current limiting. Thus, an EMC filter designed for military applications is more complex than a simple COTS (commercial off-the-shelf) EMI filter that could be used in industrial applications.

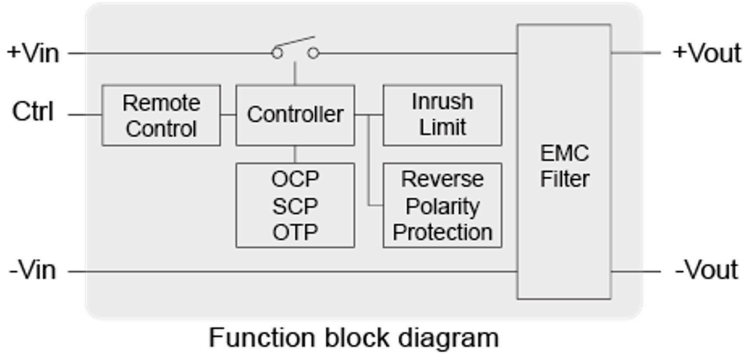

Figure 5: Combined MIL-STD EMC and Protection Circuit

KONTAKT:
RECOM Power GmbH
E-Mail: info@recom-power.com
www.recom-power.com