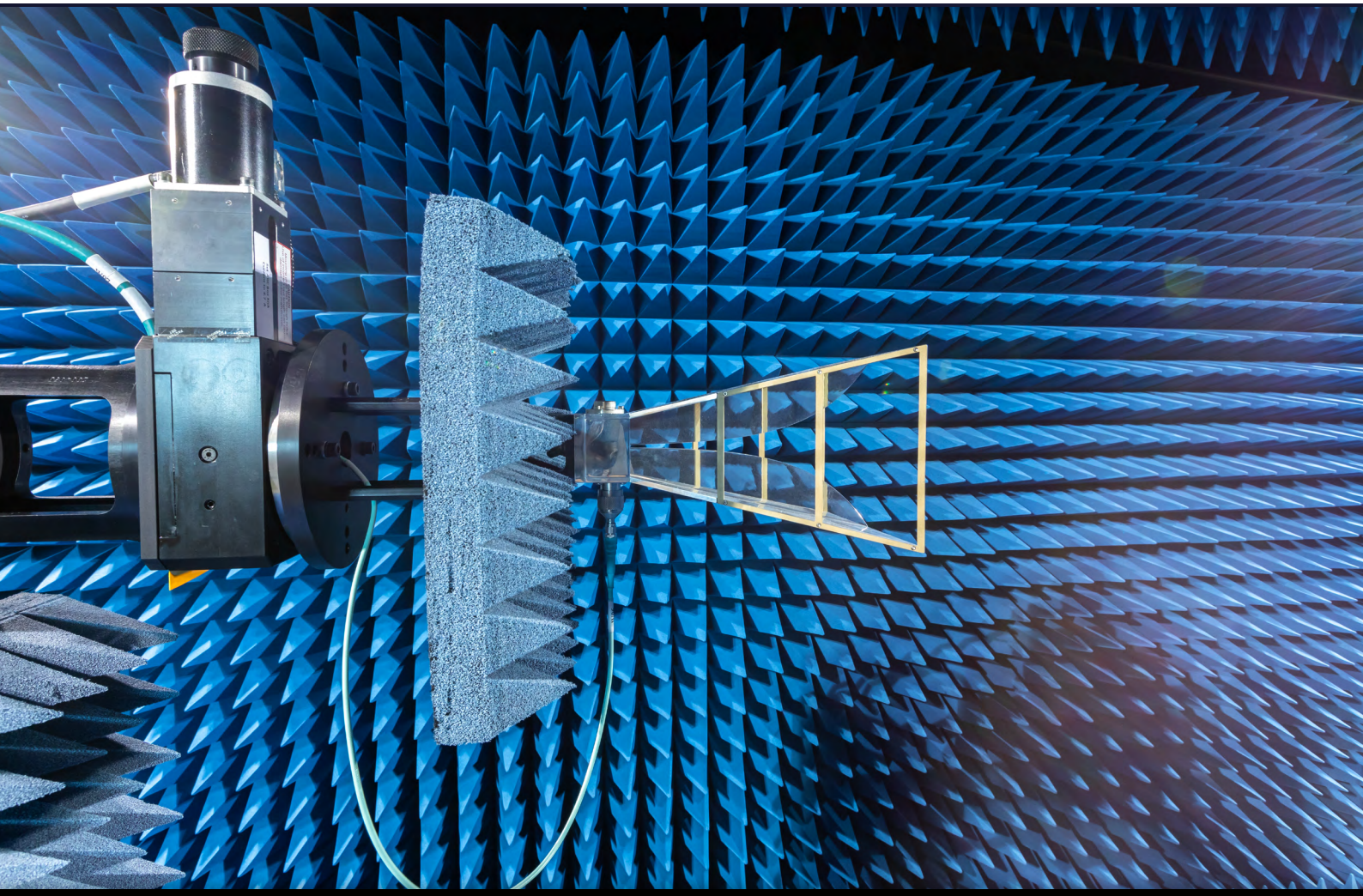
# MIL GRADE EMC FILTER FOR DC/DC CONVERTERS



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 convert one direct current (DC) voltage into another. In essence, they can function like an isolating transformer or a step-up/step-down transformer, but operate with direct current instead of alternating current (AC). Since conventional transformers only work with AC, all DC/DC converters internally operate as DC-to-AC-to-DC systems:

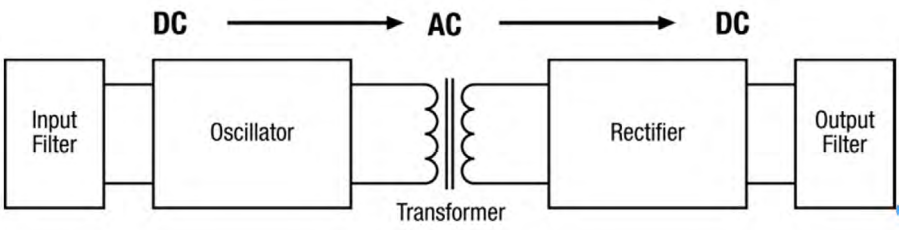


**Figure 1: Basic layout of a DC/DC converter**

Because DC/DC converters use switching elements (such as transistors) to generate the internal AC waveform, their input and output currents are inherently pulsating. This switching action produces electromagnetic interference (EMI). Electromagnetic compatibility (EMC) filters are specialized circuits designed to manage this EMI effectively, helping the converter meet EMC compliance standards with adequate margin below the permitted limits. Their primary role is to suppress unwanted electromagnetic signals, preventing interference that could affect or degrade the performance of nearby sensitive electronic equipment.

## ABOUT MIL-STD-461G

Military-grade compliant EMC filters are engineered to meet stringent Army, Air Force, and Navy standards, using high-quality components and undergoing rigorous testing to ensure reliability under extremely harsh environmental and operating conditions. With their exceptional EMI suppression capabilities, these filters play a crucial role in safeguarding critical military systems and enhancing their overall electromagnetic compatibility.

The United States Military Standard (MIL-STD) applicable to EMC is MIL-STD-461 (Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment). The most current version of this standard is MIL-STD-461G, although many legacy projects still follow the earlier 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 across various military platforms. These classes and their corresponding limits apply to a wide range of military vehicles and systems, 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 designed to meet the U.S. Department of Defense (DoD) specifications and requirements, depending on the intended operational environment.

These test procedures are divided into four groups: radiated emissions (RE), conducted emissions (CE), radiated susceptibility (RS), and conducted susceptibility (CS). Each procedure is identified by a two-letter group abbreviation followed by a numeric code—for example, CS101 refers to 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, multi-stage filtering is required, with each stage targeting a specific frequency band. This ensures the filter is effective across the full frequency range of interest. For example, CE101 (Conducted Emissions, Audio Frequency Currents, Power Leads) applies to the 30Hz – 10kHz range, while CE102 (Conducted Emissions, Radio Frequency Potentials, Power Leads) covers the 10kHz – 10MHz range.

For Surface Ships, both CE101 and CE102 tests are mandatory, meaning the EMC filter must be capable of suppressing emissions from 30Hz to 10MHz—a range too broad to cover with a single filter stage.

### Test Setups

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

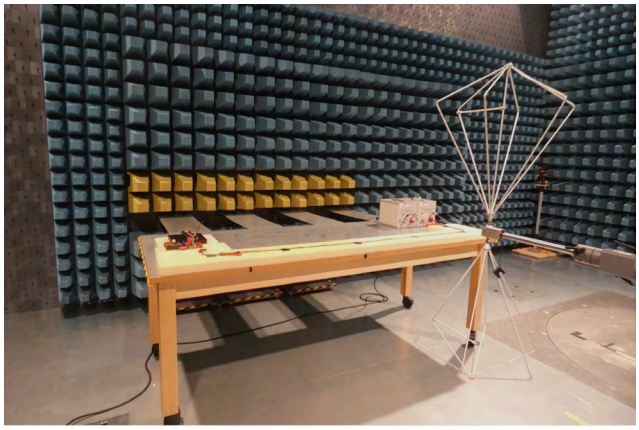

**Figure 2: Radiated Emissions test setup**

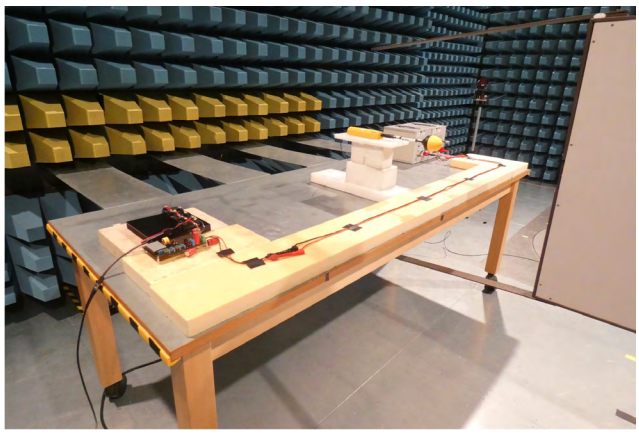

**Figure 3: Conducted Emissions test setup**

## Schematics

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

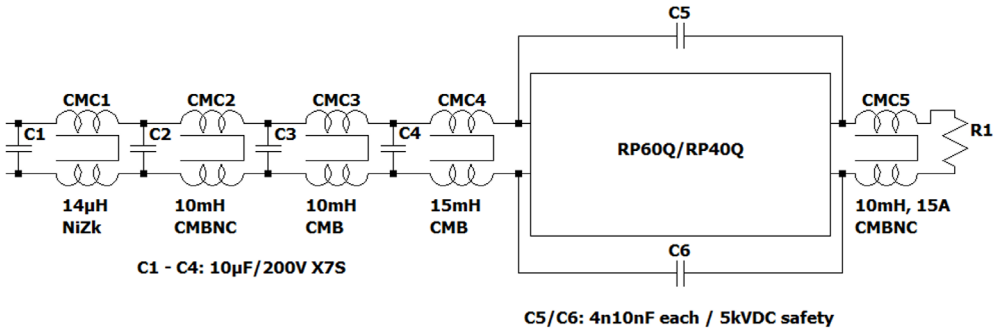


Figure 4: MIL-STD EMC Filter

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 28VDC Electrical Systems in Military Vehicles) may also apply to EMC filters. MIL-STD-1275D defines additional requirements including reverse polarity protection, transient suppression, and inrush current limiting. As a result, an EMC filter designed for military applications is more complex than a standard COTS (commercial off-the-shelf) EMI filter typically used in industrial settings. An example of a combined EMC and protection circuit, integrating both MIL-STD-461G filtering and MIL-STD-1275D protective features, is shown in Figure 5.

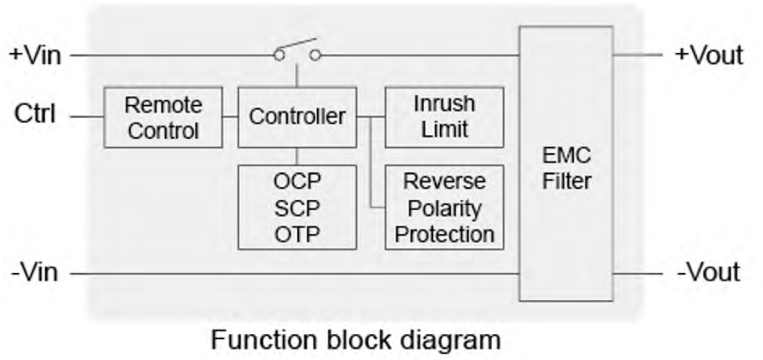


Figure 5: Combined MIL-STD EMC and Protection Circuit

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