Rugged Power supplies for harsh and defense applications – what to consider?

Defense applications are among the most demanding applications in the world, and so it goes without saying that the successful design of defense power systems demands a full understanding of the complex performance requirements, testing, and the environmental conditions to which the intended product will be subjected to.

Reliability and high performances a must!
At first glance and especially given that their basic function to convert a variable source AC or DC voltage to a stable usable voltage are the same, it may appear to the casual observer that power supply products used in the defense sector may seem similar to those used in other sectors such as industrial and telecommunications - but it is far from being comparable. Power solutions for the military sectors must have enhanced ruggedness, durability and must be highly reliable to a level perhaps higher than any other. In the defense sector, power equipments must perform seamlessly across a range of intense climates and harsh terrains. They must also be able to provide many years of service with minimal maintenance.

Military power supplies are generally manufactured to very high standards and to provide the best quality performance in diverse and often harsh deployment environments. Such power supplies can withstand ambient temperatures as high as 80 degrees and as low as -40 degrees Celsius. They have specific voltage ranges to provide the various military-grade aircraft and vehicles operating the different operational modes. The power supplies can handle considerable vibration, shock and jostling, the levels of which are much more intense than those occurring on commercial trains and aircraft. So make no mistake, the required reliability level of power supply systems is very high in defense sectors. They are able to operate in a

wide range of temperatures as well as in extreme shock and high impact conditions. MIL-STD requirements are found in most military power system units, and they work smoothly without hiccup in harsh environments.

Uniqueness of the military and defense market segment

Because of the nature of the military and defense business segments, which for most of the final applications are classified, highly confidential, and covered by trade secret protection regulations, it is very difficult to accurately estimate the overall market size related to power supplies. However market analysts' estimates which including batteries, generators, UPS and power supplies is estimated to be about 8 billion USD in 2023.

If we focus on power supplies (AC/DC, DC/DC), in its latest report Market Analyst Micro-Tech Consultants estimated this segment to represent close to 3 billion USD. This is composed of 60% designed in-house by military equipment manufacturers (Captive), and 40% from the merchant market, where part of it is custom designed, based on customers' specifications, and specific to a unique application (Figure 01).

Figure 01 – Example of a PRBX custom power supply designed to meet harsh environmental requirements (Source: PRBX)

Custom power solutions still represent a large portion of this segment though, and as it has been for other segments, when designing a new equipment, military and defense manufacturers are considering the benefits of using commercial and military off-the-shelf (COTS/MOTS) power supplies (Figure 02) in the very early

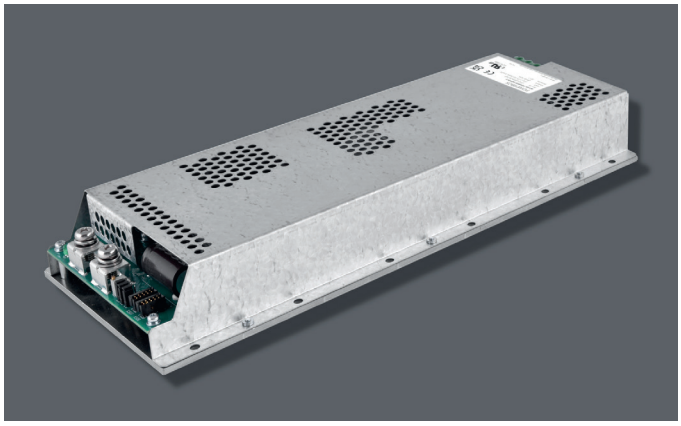

Figure 02 – PRBX COTS/MOTS OFD1200A AC/DC converter for defense and demanding industrial applications (Source: PRBX)

stages of their projects in order to reduce cost, resources allocation and time to market.

In terms of design, i.e., custom or standard power solutions, power electronics designers must consider a number of standards specific to the military and defense industry, which is a very interesting part of the design process.

Designed to meet stringent standards

From the ground to outer space, power supplies must comply with specific standards defining the level of ruggedness required to meet the final requirement. As the range of applications is extremely large, power designers must take into consideration the most appropriate standard covering the breadth of the application. Standards are specifying all possible environmental conditions that the final equipment will be exposed to e.g., extreme temperatures from -40 to +80 degree centigrade, the need for noise reduction due to tactical requirements, shock and vibration resulting from handling, transportation and operational impacts.

The Military and Defense industries are using the so called Military Standard (MIL-STD) (Figure 03). This standard was established after WWII to provide standard, uniform requirements and to ensure interoperability for the military and its secondary industries, explicitly focusing on engineering and technical requirements, processes, procedures, practices, and methods. First used by branches of the military, MIL-STD certification now represents the ability to withstand extreme conditions

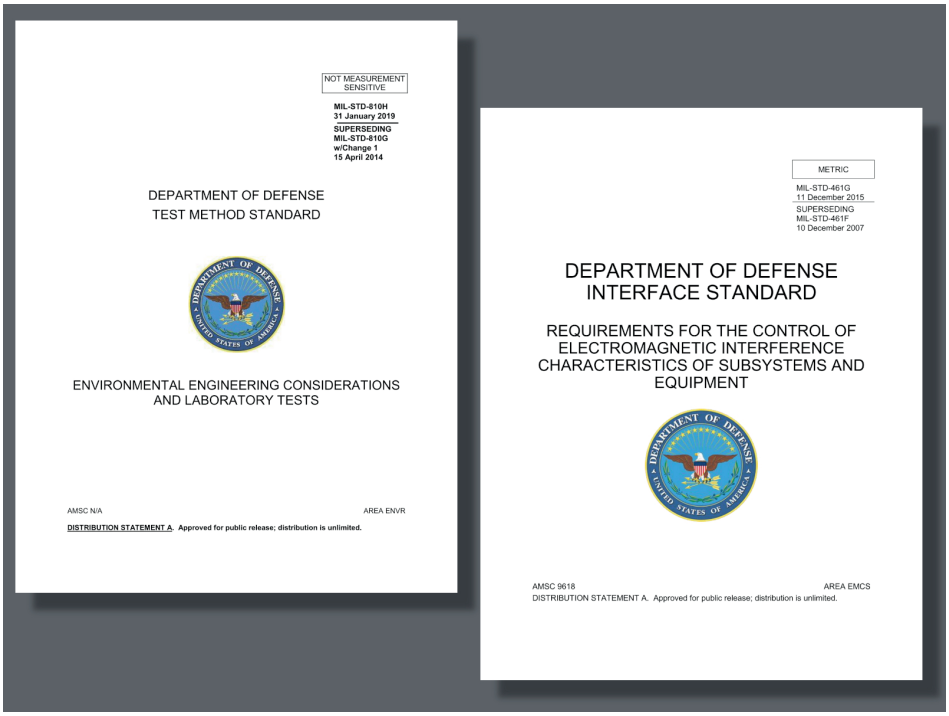

Figure 03 - The Military and Defense industries are using the so called Military Standard (MIL-STD) (Source: PRBX/DoD)

and is used as a reference by other demanding industries. Whilst it would be impossible to mention all of these standards we can list a few examples of what power supply designers must consider when designing product for military and defense applications.

When silence is golden MIL-STD-461 is the norm.
The basic principle of a power supply is to transform a DC voltage to AC and then to rectify it to return to a usable DC voltage. This process is achieved by switching the DC voltage, a process that generates radio emissions and conducted noise. These are very critical in defense application because they could be detected or interfere with critical systems. To reduce such disturbances power supply manufacturers are implementing different technologies from soft switching to noise cancelation, or to simplify, similar to what you are using in your headset to listen music in noisy environment.
To ensure that power supplies do not generate high levels of conducted or radiated noise, and also that the power supply itself is not affected or damaged by external signals, it should be tested in accordance with MIL-STD-461. This norm establishes the electromagnetic interference (EMI) and electromagnetic compatibility (EMC) requirements for military ruggedized power supplies. Compliance with the standard is key to ensuring the satisfactory performance of all equipment within a system. The tests performed under MIL-STD-461 include: conducted emissions ; conducted susceptibility ; radiated emissions and radiated susceptibility.

Depending on the application e.g., ground, air force, navy, or submarine frequency spectrum, the level of susceptibility and tests might vary as defined in the tables IV and V of the MIL-STD-461 (Figure 04).

Power to military vehicles: the MIL-STD-1275
Most of the military equipments onboard vehicles are powered by a 28V internal distribution BUS voltage from the main battery or power generator, with MIL-STD-1275 being the standard for the electrical power distribution system on military ground vehicles. This standard defines the operating voltage limits and transient voltage characteristics of the 28Vdc power supply at the input of

TABLE IV - Emission and susceptibility requirements.

Requirement	Description
CE101	Conducted Emissions, Audio Frequency Currents, Power Leads
CE102	Conducted Emissions, Radio Frequency Potentials, Power Leads
CE106	Conducted Emissions, Antenna Port
CS101	Conducted Susceptibility, Power Leads
CS103	Conducted Susceptibility, Antenna Port, Intermodulation
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation
CS109	Conducted Susceptibility, Structure Current
CS114	Conducted Susceptibility, Bulk Cable Injection
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads
CS117	Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads
CS118	Conducted Susceptibility, Personnel Borne Electrostatic Discharge
RE101	Radiated Emissions, Magnetic Field
RE102	Radiated Emissions, Electric Field
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs
RS101	Radiated Susceptibility, Magnetic Field
RS103	Radiated Susceptibility, Electric Field
RS105	Radiated Susceptibility, Transient Electromagnetic Field

TABLE V - Requirement matrix.

Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations	Requirement Applicability																		
	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS109	CS114	CS115	CS116	CS117	CS118	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	A	S	L	S	L	A	S	A	L	S	A	A	L	L	A	L
Submarines	A	A	L	A	S	L	S	L	A	S	L	S	S	A	A	L	L	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S		A	A	A	L	A	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S		A	A	A	L	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S		A	A	A	L	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S		A	A	A	L			A	L		A	
Ground, Army		A	L	A	S	S	S		A	A	A	S	A		A	L	L	A	
Ground, Navy		A	L	A	S	S	S		A	A	A	S	A		A	L	L	A	L
Ground, Air Force		A	L	A	S	S	S		A	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.

MIL-STD-461G - Emission and susceptibility requirements, limits, and test procedures.

Figure 04 - MIL-STD-461 tables IV and V with the classification of EMI and EMS test vs. applications (Source: PRBX/DoD MIL-STD-461G)

the utilization equipment. The DC/DC or DC/AC power conversion system must be able to operate when exposed to the defined voltage transients, both surges and spikes, and supply well-regulated, clean power to its loads. This standard covers all possible disturbances the power supply will face during its operation, guaranteeing it will always deliver on promise.

MIL-STD-810 or the Environmental engineering considerations and laboratory tests

First introduced in June 1962, MIL-STD-810 has been through a number of revisions, and released in January 2019 was its eighth version, MIL-STD810H. MIL-STD-810H describes detailed testing procedures designed to determine how equipment holds up under a variety of conditions, such as temperature, impact, vibration and humidity levels that the equipment may encounter while being used, transported and stored. Even though MIL-810H is a military standard, it is important to note that many ruggedized industrial products are tested to this standard. MIL STD 810H has more than 20 different test methods ranging from Low Pressure (Altitude) to Mechanical vibrations of shipboard equipment, including gunfire shock, and acid atmosphere. Most power supplies do not need to be tested according to all of the test methods, and power supplies designers select the relevant parts relevant to the final application. Some of the test methods are general and commonly used e.g., test method 516.8 for shock, and test method 514.8 for vibration. These tests simulate the effect of jolts, drops and other similar actions that can occur during transit and operations.

Designing with commercial and military off-the-shelf in mind!

Because COTS/MOTS power supplies can be used in a large range of applications, power designers must consider a broad range of environmental aspects.

A number of defense applications require power supplies to operate with limited, or indeed no ventilation cooling. In this respect we are mainly referring to those operating in harsh environments where electronic equipment is installed in a sealed box, in radio communication systems subject to adverse weather conditions, outdoor

surveillance and access control equipment, and indoor equipments subject to very strict audible noise restrictions. In addition to environmental requirements, reliability and cost of maintenance are motivating systems designers not to use fans and blowers, and to privilege conduction cooling.

Conduction cooling requires very specific building practices and the power supplies must be designed to guarantee optimal heat transfer from the dissipating components to the baseplate in order to deliver a high level of performance within an almost obscene operating temperature range of -40 to +95 degrees centigrade at baseplate. In such applications the baseplate can be used to cool the power supply when operating in high temperature environments, but also to warm-up the power supply when operating at low temperatures. Indeed some power supplies include a Peltier element powered by a small battery and used during the startup phase or peak cooling conditions.

When considering COTS/MOTS, customers often require power supplies to be extremely flexible and able to power a large range of applications. For example, some defense applications such as battery chargers require the power supply to deliver a constant current, and this must not only be easily adjustable but at the same time the power supply may be required to be used for other purposes e.g., monitoring when not charging, and to switch from constant current to constant voltage. Often such equipments are operated in environments requiring the electronics to be enclosed and protected from hazards. This necessitates the power supply to offer an external control to adjust the output voltage and/or current from the maximum allowed down to near zero. Depending on the final requirement, such functions can be controlled by analog or digital communication BUS. Flexibility is also needed for applications requiring redundancy or for higher power customers requiring power supplies to be designed for paralleling, where to maintain high efficiency often includes active ORing circuitry.

All of that without forgetting the need to meet the higher levels of shock and vibration above those required by conventional power supplies, and highly efficient EMC filtering such as specified by MIL-STD 461E CE102, MIL-STD 1399-300A and MIL-STD 810H.

The Bridge!

As mentioned, benefiting from the best practices to design ruggedized power solutions to meet MIL-STD810H specific tests, military and defense COTS/MOTS power supplies are rapidly gaining interest from end users in demanding industrial applications operating in harsh environments. In this article we have not mentioned extreme applications such as ones exposed to high levels of radiation. Whilst these applications might be considered marginal, with the number of nuclear power plants being refurbished to prolong their lifetime there is a demand to develop power supplies able to sustain exposure to high radiation levels with a longer lifetime than previously required. From research conducted on military power supplies able to sustain high radiation levels, and the implementation of the latest generation of Wide Bandgap semiconductors developed for hostile environments, it is obvious that demanding industrial applications will benefit from such research and from the availability of COTS/MOTS power supplies.

Developing power supplies for military, defense and high demanding industries is a very interesting area for power supply designers to explore and to discover new technologies making them even more robust, versatile and energy efficient.

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About Powerbox
Founded in 1974, with headquarters in Sweden and operations in 15 countries across four continents, Powerbox serves customers all around the globe. The company focuses on four major markets - industrial, medical, transportation/railway and defense - for which it designs and markets premium quality power conversion systems for demanding applications. Powerbox's mission is to use its expertise to increase customers' competitiveness by meeting all of their power needs. Every aspect of the company's business is focused on that goal, from the design of advanced components that go into products, through to high levels of customer service. Powerbox is recognized for technical innovations that reduce energy consumption and its ability to manage full product lifecycles while minimizing environmental impact. Powerbox a Cosel Group Company.

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Chief Marketing and Communications Officer for Powerbox, Patrick Le Fèvre is an experienced, senior marketer and degree-qualified engineer with a 40-year track record of success in power electronics. He has pioneered the marketing of new technologies such as digital power and technical initiatives to reduce energy consumption. Le Fèvre has written and presented numerous white papers and articles at the world's leading international power electronics conferences. These have been published over 450 times in media throughout the world. He is also involved in several environmental forums, sharing his expertise and knowledge of clean energy.

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