



APPLICATION NOTE

Selecting the Correct Level of DC-DC
Converter for Your Application

DC-DC CONVERTERS AND ACCESSORIES



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Introduction

Most power systems for high reliability applications can be constructed from standard power modules. The typical scenario requires various DC output voltages and power levels, and is usually met with standard DC-DC converters, EMI filters and accessory modules. A modular power system can be developed quicker and at lower cost than a full custom approach. This is true even for critical applications and reliability can often be as high as or higher than that of a custom design.

Critical applications range from undersea to military ground to commercial and military avionics to deep space. DC-DC converters, point of load converters, EMI filters and other power modules are offered by various manufacturers, all claiming high reliability. The question is, how do you know what level of quality and reliability you are getting, and how do you select the correct level for your application?

What Is High Reliability?

High reliability is more than just a claim from the manufacturer. High reliability DC-DC converters must meet certain standards for electrical and environmental performance, as well as defined quality requirements. Those requirements depend on the reliability grade of the product. They can be divided into three categories: high reliability COTS, Mil Spec or true military grade, and space grade.

The differences between these reliability grades can be subtle, and can be concealed with clever marketing. The product literature must be studied carefully to determine exactly what the product is, and, equally important, what it is not. Basic things to look for are temperature rating, hermeticity, military specification compliance, and a rigorous environmental qualification. The ultimate test of reliability beyond that is official qualification and certification by the US Department of Defense.



Defining High Reliability COTS

High Reliability Commercial Off-the-Shelf (Hi-Rel COTS) DC-DC converters came about in response to acquisition reform spearheaded by Secretary of Defense William Perry in the 1990s commonly referred to as “The Perry Initiative”. Perry’s COTS initiative sought to improve the Department of Defense’s access to state of the art technology and reduce costs while foregoing military standards for commercial specifications and standards. The intent was not to use commercial hardware in military applications. Rather, the intent was to use commercially available or non-developmental hardware where possible and reduce the need for full Mil Spec compliance.

The VPT Series of Hi-Rel COTS DC-DC converters meet the original intent of The Perry Initiative. They are intended for military applications and are commercially available but they are not fully Mil Spec compliant. The VPT Series of Hi-Rel COTS use commercial grade components, commercial best practices, and are specifically designed to achieve high reliability in military applications and harsh environments. Hi-Rel COTS are intended for cost sensitive applications that impose harsh conditions and require high reliability including avionics, UAVs, ground systems, ground vehicles, shipboard, weapons, and other similar type applications.

Several important considerations for COTS DC-DC converters are listed below. These characteristics will differ between manufacturers, so it is important to carefully evaluate the product you are selecting. How that product addresses each item can affect the final reliability of your system.

- Temperature Range. A wide operating temperature range is essential for most high reliability systems. If the system is required to operate over a -40°C to 85°C range, it is safest for the DC-DC converter to have a wider range than that. Full power, continuous operation to 100°C, and startup at -55°C is standard for Hi-Rel COTS.
- Input Voltage. A wide input voltage range and high transient capability will greatly simplify system design, accommodating line drops, transients, and noise often present in military electrical power systems.

- No Optocouplers. The performance properties of optocouplers vary widely. It is difficult to design a linear optocoupler feedback circuit that can be shown with a worst case analysis to operate properly over the full temperature range and life required by Hi-Rel applications. Hi-Rel DC-DC converters typically use magnetic feedback isolation, usually in the form of a pulse transformer, whose properties vary little over temperature and life.
- Fixed Frequency. All DC-DC converters utilize a switching topology which generates EMI at the fundamental switching frequency. The switching frequency can be fixed or variable, varying with line and load conditions. A fixed frequency is almost universally preferred when it comes to the system design. A fixed frequency greatly simplifies EMI compliance, input and output filter design, worst case analysis, and interaction analysis with other parts of the system.
- Metal Packaging. A six-sided metal package reduces the radiated emissions of the DC-DC converter and the radiated susceptibility of the EMI filter. It will facilitate the system EMI design and greatly reduce the likelihood of board level noise problems compared to open frame or plastic packaged DC-DC converters.
- Tin Whisker Mitigation Strategy. Tin whiskers are hair-like crystalline structures that can grow from a pure tin finish. Tin whiskers are electrically conductive and can produce electrical shorts and device failures. Hi-Rel COTS products will invariably contain pure tin finishes internal to the product, often in the form of semiconductor or passive component termination finishes. There will be a risk of tin whisker formation, making a mitigation strategy essential. A typical strategy prohibits bright tin, uses tin/lead solder, restricts the use of fine pitch components and utilizes a conformal coating.
- Compliance. When a DC-DC converter is designed into a critical application, it will be required to comply with system specifications. Common electrical specifications for DC-DC converters are MIL-STD-461 for EMI, MIL-STD- 704 for aircraft electrical power and MIL-STD-1275 for military vehicle power. Always select DC-DC converter that are designed to meet these specifications from the outset, with such features as wide input voltage ranges, high transient ratings, and accessory products including EMI filters, transient suppressors, and line conditioners.



- Qualification. Hi-Rel COTS are usually qualified to a manufacturer-specific qualification plan which can include both military and commercial standards. Typical standards used for qualification include MIL-STD-883, MIL-STD-810, MIL-STD-202 and JESD-22. In the absence of a governing military standard, the manufacturer's qualification plan is critical. Look for a qualification plan which includes temperature cycling, mechanical shock, random vibration and a steady state temperature humidity life test.
- Quality System. Hi-Rel COTS are assembled to commercial standards such as J-STD-001 and IPC-A-610. The manufacturer should have a quality system that is certified to ISO-9001, but experience with higher quality levels or additional certifications will directly benefit product quality. The manufacturer should also have an aggressive counterfeit parts control plan.

There is one more important point to consider when selecting COTS DC-DC converters. COTS does not imply using a commercial or telecom DC-DC converter outside its recommended operating range, whether that range is voltage, temperature or another parameter. It also does not intend the upscreening of commercial DC-DC converters. Upscreening, where a device is screened for use beyond its design limits, requires detailed knowledge of its internal stresses. Either of these practices can result in compromised system reliability. Qualification failures, compliance issues, field failures due to vibration and temperature cycling, and erratic operation at cold temperatures are typical examples of what can happen when a product is used outside of its intended application. Instead, use a Hi-Rel COTS DC-DC converter specifically designed for avionics, military or other rugged applications.

The VPT Series of Hi-Rel COTS DC-DC converters are based on VPTs MIL-PRF-38534 hybrid converter designs with 20 years of heritage. The VPT Series blends proven electrical designs with commercial components and assembly techniques in a rugged package, passes a rigorous environmental qualification, and offers a reliable solution for cost sensitive applications.



Defining True Mil Spec DC-DC Converters

A true military grade DC-DC converter is defined as a Mil Spec component. The governing specification for DC-DC converter modules is MIL-PRF-38534, General Specification for Hybrid Microcircuits. MIL-PRF-38534 certification is granted and audited by the Defense Logistics Agency (DLA) Land and Maritime, formerly DSCC, an agency of the US Department of Defense. A true military grade DC-DC converter will be qualified to this specification and listed on a Standard Microcircuit Drawing (SMD). A true military grade EMI filter will be listed on a DLA Land and Maritime Drawing.

MIL-PRF-38534 governs not only the end product, but the components, materials and processes used to build it. This means the converter is built on a DLA qualified manufacturing line, it has passed a DLA approved qualification, and it is available to a DLA SMD. This strict process ensures that quality is built into the product from the start, not added later.

Mil Spec DC-DC converters, governed by MIL-PRF-38534, are the default choice for any critical reliability application. Class H is the “go to” quality level for any application which imposes harsh environmental conditions or is required for high reliability platforms. Examples of these would include flight critical avionics, UAVs, ground systems, ground vehicles, defense weapons, shipboard, submarine, down hole, high temperature, undersea, high altitude and other similar applications.

The military grade DC-DC converter brings several additional characteristics above what you will find in a COTS grade product. These are dictated by MIL-PRF-38534 and they can drastically increase the long term reliability of the system.



- Wide temperature range. MIL-PRF-38534 class H devices are specified to operate continuously over the full military temperature range of -55°C to +125°C. High temperature operation is enabled with bare die power semiconductors and high thermal conductivity ceramic and metal packaging. True continuous full-power 125°C operation is impossible to achieve with plastic encapsulated ICs and PCB construction. When specifying converters for this temperature range, make sure your supplier does not derate the power at 125°C
- Hermetic Packaging. Qualified hybrid DC-DC converter modules are hermetically sealed, usually in welded metal packages with glass or ceramic seals. Hermeticity protects internal semiconductor devices from moisture related failures. Hermeticity is verified by MIL-STD-883 Method 1014 for fine and gross leak. Internal water vapor is monitored using MIL-STD-883 Method 1018. Hermeticity also allows the device to tolerate liquid cleaning processes during assembly. A true hermetic package should not be confused with packages that appear hermetic, or with datasheets using ambiguous terms such as “sealed” or “near hermetic” that do not meet the hermetic definition of conditions in MIL-STD-883.
- No Pure Tin. MIL-PRF-38534 specifically prohibits the use of internal and external pure tin finishes, with >97% tin, which can produce tin whiskers. Ensure the manufacturer has in place an aggressive program to screen components and eliminate pure tin.
- Component Element Evaluation. All materials and components used in the DC-DC converter module are evaluated in accordance with MIL-PRF-38534 to verify they meet their specifications and are suitable for the intended application. Element evaluation differs from qualification in that it is performed on each lot of material.
- Qualification. True military DC-DC converter modules are qualified in accordance with MIL-PRF-38534. Test methods are dictated by MIL-STD-883. The qualification is reviewed and final approval is given by DLA. This type of qualification differs from that of a commercial manufacturer where the test plan and final approval are self-determined. Upon successful qualification, the DC-DC converter can be put on a DLA controlled SMD.
- Qualified Manufacturing Line. The qualified DC-DC converter will be built by a QML listed manufacturer on a qualified manufacturing line. All processes used in the manufacture of the product are qualified and audited by DLA.



At the Mil Spec quality level, some of the characteristics mentioned for COTS products are taken as a given. Manufacturers are certified to ISO-9001 and above that, to MIL-PRF-38534. A counterfeit parts control plan is required. With regard to the products themselves, optocouplers are generally not used at this level, and fixed frequency and full six-sided metal shielding are standard. Mil standard compliance with regard to EMI and input voltage range and transient capability is also standard for this level of product.

MIL-PRF-38534 qualified DC-DC converters can often be procured to a manufacturer datasheet with reduced screening. This option can take advantage of the qualified manufacturing line and processes, and the reliability of the hermetic hybrid construction, without full Mil Spec compliance, and therefore at a reduced cost.

VPT's hermetic hybrid DV Series of Avionics / Military DC-DC Converters are built on a DLA certified manufacturing line and are fully qualified to MIL-PRF-38534 class H and K. VPT continues to push the technology envelope for hybrid DC-DC converters with high efficiency, low voltage point of load DC-DC converters, high efficiency isolated converters with synchronous rectification, higher power densities, lower noise, better regulation, and a continued release of new product technologies.

Defining Space Grade DC-DC Converters

Space level hybrid DC-DC Converters, radiation tolerant or radiation hardened, are also governed by MIL-PRF-38534. The manufacturer will have a radiation hardness assurance plan certified by DLA to MIL-PRF-38534 Appendix G. Space level DC-DC converters are available on SMDs and are typically procured to Class K. Space grade DC-DC converters are intended for space applications including satellites, launch vehicles and other spacecraft from low earth orbit to deep space for both commercial and military applications. Typical characteristics of space grade DC-DC converters include:

- Total Ionizing Dose (TID) Radiation. All space applications will require some level of TID radiation guarantee. TID radiation is affected by shielding. For low earth orbits or where the DC-DC converter is adequately shielded, a 30 krad(Si) guarantee is often sufficient. For higher orbits or longer missions, a 100 krad(Si) guarantee may be required. TID performance should be verified by the manufacturer with component test data or guarantees, worst case analysis, and test data on the complete DC-DC converter. Additional test margin can sometimes be substituted for analysis. Test reports should be available.



- Enhanced Low Dose Rate Sensitivity (ELDRS). TID testing is normally performed at high dose rates to shorten test time and reduce test cost. Testing at lower dose rates, closer to those seen in actual space environments, has shown increased sensitivity to radiation in some components, especially bipolar technologies. Modern space programs will almost certainly have an ELDRS requirement, usually to the same level as the TID requirement. Older DC-DC converter designs may not have an ELDRS guarantee, so be sure to inquire about this. ELDRS performance is proven through testing and analysis. VPT has performed extensive ELDRS verification of its SV series designs.
- Single Event Effects (SEE). Single event effects are caused by energetic particles which interact with the semiconductors internal to the DC-DC converter. SEE cannot be shielded and must be dealt with in the DC-DC converter design itself. SEE can cause simple transients on the output, dropout, shutdowns and restarts, latch offs or hard failures. Hard failures in a DC-DC converter are often caused by failure of the power MOSFET. An SEE rating of 44 MeV-cm²/mg covers most particles that a spacecraft may encounter in its lifetime and is sufficient for most programs. An SEE rating of 85 MeV-cm²/mg covers essentially all particles spacecraft will encounter during its lifetime. SEE performance is verified primarily with testing of the complete DC-DC converter. Testing should include high temperature latch up testing.
- Worst Case and Radiation Analysis. A guarantee of end-of-life post-radiation performance of the DC-DC converter is usually required. The manufacturer will have completed a detailed worst case analysis for circuit performance including both end-of-life and radiation effects. Radiation degradation of components is fed into analytical and simulation models to predict post radiation performance. Extreme value, root sum square, and Monte Carlo analysis methods are used.
- MIL-PRF-38534 Class K. Space grade DC-DC converters are typically procured to MIL-PRF-38534 class K. Class K includes additional element evaluation and additional screening beyond Class H. Most space level DC-DC converters are procured to an SMD. Procuring to a Class KSMD is less costly than procuring to a custom source Control drawing (SCD).



- No Optocouplers. Although isolation of the feedback control in a DC-DC converter can be accomplished with an optocoupler operating in the linear region, the LED within an optocoupler is sensitive to displacement damage from proton radiation. A reliable space grade DC-DC converter will not use optocouplers. Magnetic feedback, which is insensitive to radiation effects, should be used instead.
- Aerospace TOR. Some space programs are governed by The Aerospace Corporation report, "Technical Requirements for Electronic Parts, Materials, and Processes Used in Space and Launch Vehicles," commonly referred to as the "TOR." The TOR specifies additional quality requirements above and beyond MIL-PRF- 38534 Class K. These requirements can often be met on a custom basis with a modified or modified flow Class K hybrid DC-DC converter. Space level DC-DC converters are specially designed for radiation tolerance. Upscreening by test or even substituting a few radiation hardened components into an existing design will not meet the stringent analysis and testing requirements of modern space programs. VPT's SV Series space level DC-DC converters are specifically designed for space applications. They are built on the electrical and mechanical designs of VPT's proven DV Series of hybrid DC-DC converters, which already have an extensive space flight heritage, and backed up by full worst case analysis and radiation testing including both radiation lot acceptance testing (RLAT) at the component level and converter level testing. VPT leads the way in ELDRS performance with every SV Series DC-DC converter guaranteed for TID including ELDRS. These products are ITAR controlled and subject to export restrictions.

Conclusion

It can be difficult to determine the quality specifications listed in manufacturer datasheets, but it is critical to do so when selecting the right level of DC-DC converter for your application. To optimize your system reliability and control costs, it is important to be able to fully understand the products you plan to utilize in your design. Temperature range, performance specs, Mil Spec compliance and quality systems all must be considered. Design heritage and program heritage are also important factors to review. Select a reputable manufacturer with proven experience in high reliability applications. Choose Hi-Rel COTS for cost sensitive applications, a MIL-PRF-38534 Class H qualified DC-DC converter for critical avionics, or a Class K radiation hardened hybrid with an ELDRS guarantee for your next space mission. VPT is the only QML listed manufacturer which offers every quality level of DC-DC converter from COTS to space. VPT understands your next mission and offers three distinct product lines to ensure you receive the reliability and performance optimized for your application.

Parameter	Hi-Rel COTS Series	Avionics/Military Series	Space Series
Operating Temperature Range	-55°C to +100°C with no customer derating required	-55°C to +125°C with no customer derating required	-55°C to +125°C with no customer derating required
Environmental Screening	Rugged environmental per MIL-STD-883 test methods	To MIL-PRF-38534 Class H and Class K	To MIL-PRF-38354 Class H and Class K
Packaging	Six-sided metal package	100% hermetic metal packaging	100% hermetic metal packaging
Element Evaluated Components	No	Yes	Yes
Materials	Tin whisker mitigation strategy, anti-counterfeit materials policy	No pure tin, anti-counterfeit materials policy	No pure tin, anti-counterfeit materials policy
Optocouplers	No	Yes	No
Fixed Switching Frequency	Yes	No pure tin, anti-counterfeit materials policy	Yes
Radiation Tolerance	N/A	N/A	To 30 or 100krads (Si), including ELDRS
On DLA SMDs	N/A	Yes	Yes
Typical Compliances and Certifications	<ul style="list-style-type: none"> • MIL-STD-1275 • MIL-STD-704A input voltage requirements • MIL-STD-461 C-F when used with a VPT EMI Filter • DO-160 • ISO-9001 • DEF-STAN 59-411 • Testing to JESD22, MIL-STD-810, MIL-STD-883, J-STD-001, ISO-9001 • IPC-A-610 manufacturing 	<ul style="list-style-type: none"> • Products available qualified to MIL-PRF-38534 Class H and Class K • MIL-PRF 38534 Class H and Class K certified manufacturing facility • MIL-STD-704A input voltage requirements • DO-160 • ISO-9001 • MIL-STD-883 environmental screening • MIL-STD-461 C-F when used with a VPT EMI filter 	<ul style="list-style-type: none"> • Products available qualified to MIL-PRF-38534 Class H and Class K • VPT's Radiation Hardness Assurance (RHA) Plan certified by FLA to MIL-PRF-38534 Appendix G • MIL-PRF-38534 element evaluated components • MIL-STD-704A input voltage requirements • MIL-PRF-38534 Class H and Class K facility manufacturing • ISO-9001 • MIL-STD-883 environmental screening • MIL-STD-461 C-F when used with a VPT EMI filter

Table 1. Similarities and Differences to Understand When Selecting Between VPT's Three Series of DC-DC Power Converters and Accessories



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