



APPLICATION NOTE

Designing VME Power Systems from
Standard Modules

DC-DC CONVERTERS AND ACCESSORIES



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Introduction

Military electronics continue to push the performance envelope in all directions. With each new system design come the same challenges: more processing power, tighter specs, and shorter development time. Continual advances in system performance often require similar advances in the power system. VME architecture is common in many military applications, and can be readily built around standard or custom circuit cards. Off-the-shelf VME power supplies are available, but often don't meet your specifications, haven't kept up with recent performance advances, or require too many compromises. There is usually neither schedule nor budget for a full blown custom power supply development effort. An optimized VME power supply solution can almost always be built from standard off-the-shelf high-reliability or COTS DC-DC converter modules. This type of solution can be rapidly developed at minimal cost since most of the design effort is internal to the modules. Most input power bus requirements such as MIL-STD-704 and MIL-STD-1275 can be met by combining standard DC-DC converter, EMI filter, and transient protection modules, with custom interface and control circuitry. This modular approach can be made to fit almost any application, achieving the same end performance as a custom power supply with much lower risk.

For military, avionics and other high reliability applications it is best to choose DC-DC converters from a manufacturer who focuses on these applications. Look for high quality standards such as J-STD-001 and IPC-A- 610 class 3, or for the most critical applications, MIL-PRF-38534 class H or K. Products should have a wide temperature range, -55°C to 100°C or more, a wide input voltage range, and rugged mechanical construction. The environmental qualification should be to MIL-STD levels.

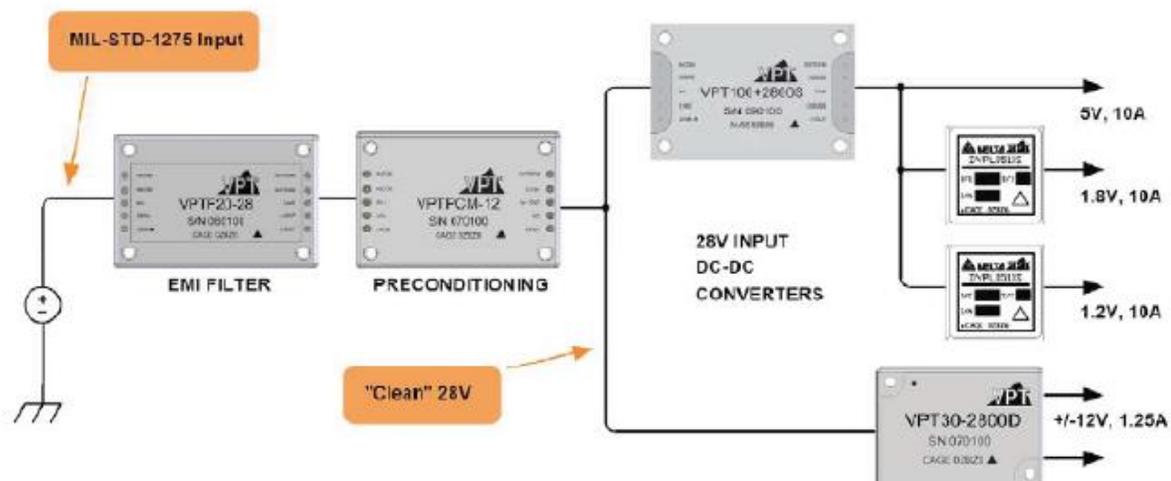


Figure 1. MIL-STD compliant 28V input power supply.



Meeting Output Voltage Requirements

The 28V DC power bus is common in military applications and there are several manufacturers who offer a wide variety of isolated DC-DC converters and accessory modules. The standard VME voltages such as 5V, 3.3V, and $\pm 12V$ are readily available, but also voltages down to 0.8V and up to 28V and everything in between, including single, dual, and triple output configurations. Some models will have output voltage trim capability to achieve nonstandard voltages, and some can be paralleled for higher output power. Other common features include primary or secondary referenced inhibit (on/off) control, as well as a frequency synchronization input.

Isolated converters can be configured in various ways to meet different output requirements. Outputs can be connected as positive or negative simply by reversing the output pins, or can be stacked to obtain higher output voltages. There are two options for low output voltages such as 3.3V and below. The first is an isolated converter which converts 28V directly to a low voltage output. The second is to use the isolated converter to provide 5V, then regulate the 5V down to a lower voltage with a non-isolated point-of load or POL converter. POL converters, recently available in high reliability versions, are optimized for very high efficiency and fast transient response. Some typical output configurations are shown in Figure 1.

MIL-STD 28V Input Requirements

While there are many DC-DC converters available for the 28V DC power bus, a robust system design is often not as simple as it sounds. The actual power requirements for most VME applications are usually defined by a government standard such as MIL-STD-704 for aircraft or MIL-STD-1275 for military vehicles. The power bus can vary widely and will include voltage ripple, surges, and transients. Some variation can be accommodated directly by the DC-DC converter, but some of it is quite severe and must be clamped or filtered externally to the DC-DC converter. There is usually also an EMI requirement such as MIL-STD-461 governing the conducted emissions and conducted susceptibility of the power supply. Proper selection of the DC-DC converter, EMI filter, and possibly input conditioning module or external circuitry will ensure compliance with the complete input requirements. A summary of some common power requirements is given in

Table 1.

MIL-STD-704			MIL-STD-1275	
Revision	A	F	Revision	D
Steady State			Steady State	
Normal	23 – 28.5V	22 – 29V	Normal	25 – 30V
Abnormal	21.5 – 30V	20 – 31.5V	Generator Only	23 – 33V
Emergency	15 – 24V	16 – 29V	Transients	
Transients			Normal	40V, 50ms 18V, 500ms
Normal	80V, 100ms	50V, 50ms	Generator Only	100V, 50ms 15V, 500ms
			Cranking	16V, 30sec
			Starting	6V, 1sec

Table 1. Summary of MIL-STD input requirements for 28V.

There are several versions of MIL-STD-704 still in use governing airborne power systems. The main differences between MIL-STD-704A and later revisions are a steady state voltage of 15V during emergency battery only and engine start operating conditions, and a transient surge voltage of 80V. Compliance to MIL-STD-704A usually takes one of two forms. The first is a DC-DC converter with a 15V to 50V continuous input range and 80V transient capability. The transient rating should be at least 1 second to encompass the full decay of the transient. The second is a DC-DC converter with a 16V to 40V continuous input range preceded by transient protection circuitry or a dedicated preconditioning module. Compliance to later versions of MIL-STD-704 can usually be obtained with the DC-DC standalone, assuming it has the standard 16V to 40V continuous input range and 50V transient capability.

For military vehicles, MIL-STD-1275D is somewhat more difficult to meet. It includes a 6V engine starting disturbance, $\pm 250V$ spikes, and a 100V surge. Most DC-DC converters do not have that wide of an input voltage range. Instead, transient protection circuitry or a dedicated preconditioning module typically enables compliance. In either case, a wide input range on the DC-DC converter, such as 16V to 40V, simplifies the design. A typical MIL-STD-1275 compliant power supply design is shown in Figure 1.

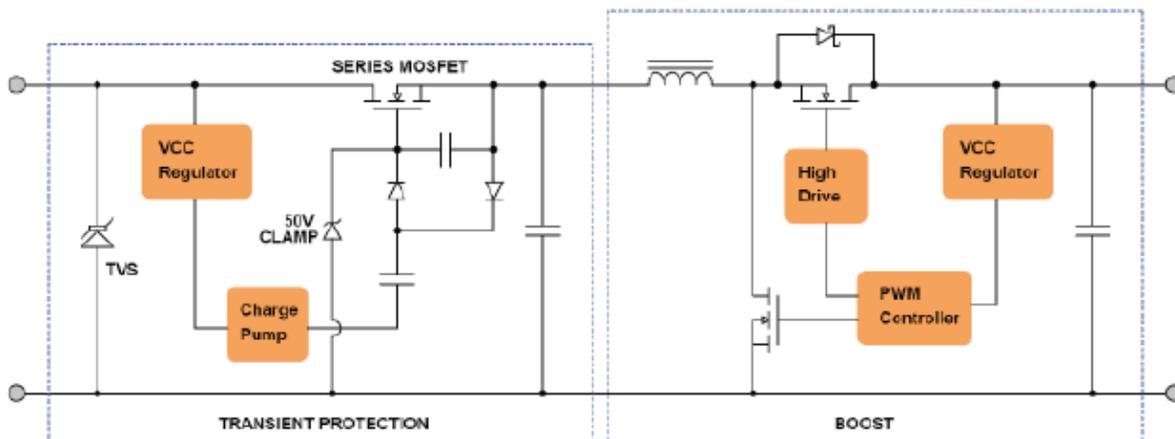


Figure 2. Input Voltage Conditioning Circuit.

Input Voltage Conditioning Techniques

A basic input voltage conditioning circuit is shown in Figure 2. This is a two-stage circuit that can accommodate input transients which extend both above and below the operating range of the DC-DC converter, such as in MIL-STD- 1275. The first stage is the transient protection function which activates when the input voltage exceeds the input range of the DC-DC converter. Low energy spikes such as the $\pm 250\text{V}$ spikes of MIL-STD-1275 are easily clamped with a transient voltage suppressor or TVS. The 100V transient is sufficient duration that it cannot be clamped, and must be limited with a series device. The best way to implement this is with a series pass MOSFET. The MOSFET is basically configured as a linear regulator, and regulates its output to less than 50V, which can be accepted by the DC-DC converter. An N-channel device should be chosen for low on-resistance and high power handling capability. Device selection is key as it dissipates very high instantaneous power, dropping 50V while passing several amps. Care should be taken to ensure the MOSFET stays within its safe operating area. To turn it fully “on” for low power loss during normal operation, a charge pump is used to drive the gate above the input voltage. A hard clamp on the gate at 50V will force the MOSFET to act as a source-follower during the transient and safely limit the output to less than 50V.

The second portion of the input voltage conditioning circuit is the “boost” stage. The boost is necessary if operation is required below the input range of the DC-DC converter, for example to operate through the engine starting “initial engagement surge”. Operation through this surge is not always required, in which case, the DC-DC converter can be allowed to cycle off and back on. The boost will remain off during normal operation at 28V input, but will maintain its output above 16V, within the operating range of the DC-DC converter, during a line drop. A traditional boost with a Schottky output rectifier is easiest to implement, but will suffer from increased power dissipation due to the voltage drop of the Schottky during normal 28V operation. A synchronous boost will result in improved efficiency but increased complexity with the need for a high side gate drive for the upper MOSFET. During 28V operation, the boost must operate at zero duty cycle, or basically off, for minimal power loss. This further complicates the high side gate drive since most such drive schemes rely on the switching action of the converter. The control loop of the boost circuit must also have very fast response transitioning out of its “off” mode in the event of a transient, otherwise its output could dip causing a glitch in the output of the downstream converter. Figure 3 gives a worst case envelope of the input voltage transients from MIL-STD-1275D along with the output envelope of the preconditioning circuit. Voltages above the range of the DC-DC converter are limited by the series pass MOSFET, while inputs below the input range are boosted. The resulting output is controlled within the operating range of the DC-DC converter.

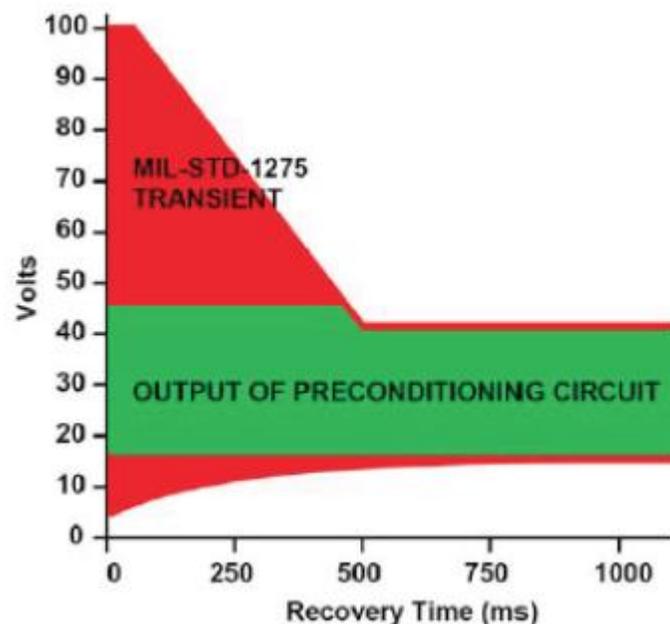


Figure 3. MIL-STD-1275 transients.

Accommodating Higher Voltage and AC Inputs

High voltage power buses, such as 270VDC or 115VAC can be dealt with in several ways. At the card or box level, it can be advantageous to first do a bulk conversion to 28VDC, then use individual DC-DC converters to regulate the individual low power outputs. This approach works with both DC and AC inputs, and can often result in a simpler overall system design, not only by minimizing the amount of high voltage wiring which must be accommodated, but also by taking advantage of the wide variety of 28V input products available. There is a much wider range of off-the-shelf DC-DC converters for 28V input than for 270V input, including lower power levels, more output voltages, multiple output configurations such as dual and triple outputs, and higher reliability levels. There are also more manufacturers, and products with better performance and more extensive feature sets.

A typical aircraft power system design is shown in Figure 4. The input shown is a 3-phase wye connected grounded-neutral system typical of MIL-STD-704 with a nominal voltage of 115Vac and a nominal frequency of 400Hz. A 3-phase six-diode rectifier and bulk capacitor is used to convert the 3-phase AC to a nominal 270VDC. A bus converter is used to convert the 270VDC into a 28V power bus which can then be converted to lower voltages with standard 28V input DC-DC converters. This bus converter can be implemented with a standard 270V input to 28V output DC-DC converter, or it can use a dedicated bus converter module. The dedicated bus converter, newly available for 270V input high reliability applications, takes advantage of the fact that it is powering downstream DC-DC converters. Its design is optimized with higher efficiency and higher power density than a typical DC-DC converter. The power system can maintain high overall efficiency and by capitalizing on the flexibility of the 28V input converters, possibly smaller size.

The 3-phase AC waveform is shown in Figure 5. The voltage on the bulk capacitor is the rectified value of the AC waveform. The bulk voltage can be approximated as:

$$V_{BULK} = V_{AC} \cdot \sqrt{2} \cdot \sqrt{3}$$

This is a DC voltage with ripple at six times the fundamental frequency of the AC input or 2400Hz. Its magnitude is determined by the size of the bulk capacitor, but is usually a few volts peak to peak. From the diagram of the six-diode AC rectifier, the negative side of the bulk capacitor is always connected to one of the AC phases. The result is a substantial ripple that appears on the negative input of the DC-DC converter with respect to the AC neutral, approximately 80V peak-to-peak at 1200Hz. The AC neutral is generally connected to the system ground along with the secondary output return of the DC-DC converter. As a result, this ripple shows up between the input and output returns of the converter as a common mode disturbance.

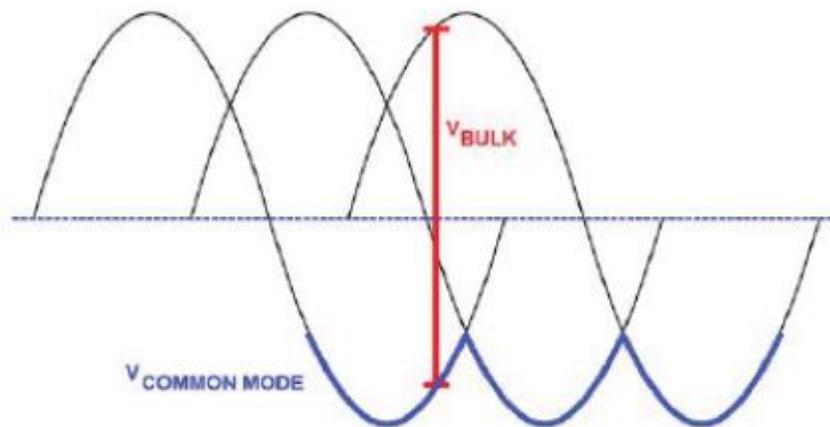


Figure 5. Diagram of 3-phase AC waveforms.

The converter must reject both the differential ripple present on the bulk capacitor as well as the common mode ripple present on its input return. Since both these applied ripples are large, the DC-DC converters must have significant rejection at 1200Hz and 2400Hz to prevent ripple from appearing on the low voltage outputs. With two DC-DC converters in series and an intermediate 28V bus, the two-stage approach shown in Figure 4 will have essentially twice the rejection of a single 270V input DC-DC converter. In this way the input bulk capacitor size could be reduced, allowing more ripple on the input, while still maintaining reduced noise on the outputs. It is now also possible to locate some of the bulk capacitance on the 28V bus. This could be beneficial for applications which require holdup.

With proper system design, standard 28V input DC-DC converters can satisfy a variety of input power bus requirements. The DC-DC converters, EMI filters and accessory modules are readily mounted to a PCB and packaged in a conduction or convection cooled housing. Power modules with a temperature rating of -55C to +100C can easily meet a final power supply specification of -55C to +85C rail temperature. Additional discrete circuitry can be added for enable signals, input and output monitoring, over temperature protection, status LEDs, and even output sequencing and timing.

The VPTVME-28, shown in Figure 6, is a highly configurable VME power supply built from VPT Series COTS modules. It can accommodate various input and output requirements. The output voltages and power levels, as well as the number of outputs and I/O signals, can be configured for almost any application.



Figure 6. VME power supply built from off-the-shelf DC-DC converter modules.



Contact Information

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