IMPORTANT FACTORS IN VEHICLE POWER DISTRIBUTION

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**Introduction**

A common trend in today's military vehicle and aircraft architectures is “electrification,” defined as *the conversion of a machine or system to the use of electrical power*. Many of us have seen it; the growth of the platform power budget requiring a larger alternator on the engine, the introduction of electrical components which were traditionally hydraulically driven, and the introduction of higher voltage power buses. Platforms, such as the M109A7 *Paladin* 155mm artillery system, as an example, have been in the news in recent years with various power upgrades to support this concept of *electrification*.

No matter the power generation scheme, some form of power distribution is necessary to protect the electrical harnesses and loads. This is typically in the form of a power distribution unit (PDU), also referred to as solid state power control (SSPC) or remote power control (RPC), offering electronic circuit breaker technology to replace old mechanical circuit breakers.

There are a number of advantages of introducing an electronic circuit breaker-based power distribution unit (PDU), and a few key features all electrical engineers, systems engineers, and supply chain professionals should be aware of when sourcing a PDU, no matter the application.

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Flexibility & Customization is Important

In any product development or certification effort, product flexibility and customization assist the design engineer to achieve compliance to the design specification or standard. Flexibility and customization are important factors when defining a power architecture and implementing a power distribution solution.

For example, the number of loads in a system, and therefore the number of channels necessary in a PDU, is different from platform to platform. Two input channels each controlling four output channels may be implemented for a redundant system of high reliability in an aircraft. Comparably, a single input managing 32 output channels, which can protect architectures with a large number of loads, may be necessary in a different architecture in a ground vehicle. Flexibility to support differing power architectures can be achieved with a modular PDU design, where building blocks are implemented to reduce the development time and the probability for design errors. A scalable design in the PDU is advantageous in this scenario.

Further, when implementing a hierarchical approach to PDU design, the available current budget is reduced with the addition of each output port. Configuring the current trip thresholds by output port enables the PDU designer to design for such a system with a wide range for the threshold and allows for use of the same key building blocks in several locations in the design. Thresholds should be tailorable by the integrator to meet the needs of their unique platform requirements. For example, when considering DO-254 compliance during the design of complex airborne electronics, this flexibility plays an important role. Again, a scalable PDU solution with flexible user-defined settings is advantageous.

Figure 1. Overload Protection: Configurable I²C Trip Curve 2-25A, per channel/pole
Similarly, flexibility and customization can be more readily achieved by changing the system architecture from mechanical to a more state-of-the-art electrical circuit breaker-based PDU. Table 1 highlights a number of advantages of electronic circuit breakers over their older mechanical counterparts.

### Table 1 - Mechanical vs. Electronic Breaker Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mechanical</th>
<th>Electronic</th>
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<tbody>
<tr>
<td>Reliability</td>
<td>≈1k - 10k switching capability</td>
<td>Only based on temperature and time. Reliability exceeding one million operations</td>
</tr>
<tr>
<td>Environmental</td>
<td>Mechanical shocks can trip the switch</td>
<td>Not sensitive to mechanical shocks</td>
</tr>
<tr>
<td>Remote Operation</td>
<td>Needs a motor to enable. Motor’s reliability is questionable</td>
<td>Achieved inherently.</td>
</tr>
<tr>
<td>Output voltage</td>
<td>Can bounce when turns on</td>
<td>Turning on is engineered with soft start</td>
</tr>
<tr>
<td>Current rating</td>
<td>Fixed</td>
<td>Programmable</td>
</tr>
<tr>
<td>Volume</td>
<td>~1.5 cu-inch</td>
<td>~1 cu-inch</td>
</tr>
<tr>
<td>Weight</td>
<td>&gt;1.4 oz.</td>
<td>0.5 oz.</td>
</tr>
<tr>
<td>Software Programmable</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In summary, it is critical that an engineer, supply chain professional, or program manager understand the importance flexibility and customization play in sourcing a power distribution solution and identifying a power architecture for an aircraft or ground vehicle platform.

As an example, the Milpower Source MILPDU family of power distribution products offer such a scalable and flexible approach. Built around the same electronic power circuit, any number of output channels can be rapidly configured, in various form factors, to meet the unique needs of the platform. As shown in Figure 1, 8 channels are independently configurable by the integrator. Similarly, other important factors are incorporated into the MILPDU product family, offering flexibility and customization, as discussed below.

![Figure 2. MILPDU 8 Channel Power Distribution Unit](image-url)
Sourcing a PDU – Key Factors & Features

A number of PDU products are available on the market today, each with unique features and functionality. A number of such functions are critical for the safe and reliable integration of a PDU to airborne or ground vehicle power architectures. When sourcing a PDU, the following list of features should be strongly considered. If incorporated into the PDU solution, features such as current limits, reverse voltage protection, and sequencing dramatically increase the chances of a seamless integration into the system, thereby maximizing protection for expensive computing, fire control, and sensor loads integrated to the platform. Further benefits include support to hazard analyses and straightforward failure mode effects analyses when working to achieve DO-254 compliance.

Current Limiting

Limiting the current for short circuit conditions turns a wild, uncontrolled, and dangerous event into a secure, safe, and predictable one. A massive short circuit condition can drop the voltage for the entire system, causing a partial or full system reset. In response, that can cause the system to repeat the erroneous condition and thus entering a dangerous lasting loop of short circuits. When working with a current limit feature in a PDU, the design and systems engineers can design the system such that power source current capability will be higher than the switch’s current limit setting. When doing so, the power source will never drop due to current limit.

Another useful benefit of current limit functionality in a PDU is evident when implementing power distribution in a daisy-chained type architecture, as represented in Figure 2. Without current limit functionality, a short circuit can trip multiple switches, compromising the selectivity needed for the system, because all the switches in the chain experience the same uncontrolled current. With a proper current limiting feature in the PDU, the system architect can set a lower current limit at every stage (similar to the overload disconnection). In this configuration, a short circuit at one switch will not forward more than the defined current-limit to its previous stage, thereby not forcing the higher stages to trip. In our example shown in Figure 2, the short circuit will be limited by 25A, which will flow from the power source. This current will not trip any of the other switches experiencing the current until the fault disconnection, allowing unaffected channels to operate as normal.
Reverse Voltage Protection

The intent of a power distribution solution is to protect itself, the wiring harnesses, and loads from negative voltage conditions. Unfortunately, not all power distribution products available in the marketplace offer reverse voltage protection, a critical safety feature. The importance of reverse voltage protection is due to human error; we make mistakes. Incorporating reverse voltage protection within the PDU will not only protect the PDU electronics, but also will protect the devices connected to its output channels. Incorporating this feature into the PDU reduces systems architecture and eliminates the need for a reverse protection at each load. It also reduces the risk of inadvertently reversing the wiring connection by a technician, maintenance team, or user, thereby harming the components in the system. Any PDU integrated into a military platform should offer reverse voltage protection.
**Soft Start**

Soft start is controlling the rise time of a switch or converter’s output, thus lowering the inrush current into capacitors. The current feeding a capacitor is equal to its voltage ramp multiplied by its capacitance figure, so for higher rise times, we will get lower inrush currents.

Incorporating a soft start mechanism, along with a current limit feature described previously, results in low in-rush currents to the PDU, enabling a healthier electrical environment. While some products on the market offer soft start capability, it may not be sufficient. As an example, a leading product’s soft start feature is approximately 300µs rise-time, a relatively short duration which allows for a harsh start up environment. Each 100µF capacitor at the output of the switch will result in 10A of inrush current! Repeated high pulses of current is an unhealthy environment for both the capacitors and the overall electrical system, resulting in poor reliability. The bottom line, higher capacitance support soft start requires a higher rise time to maintain the same inrush current.

The ideal way to control the inrush current within a PDU is by combining the soft start mechanism of the switch *together* with the current limit capability. The effect ensures a controlled environment for the capacitors in the PDU, limiting the amount of current and total duration, due to the constant current charging functionality. Any PDU integrated into a military power architecture should offer a robust soft start functionality paired with current limiting.

**Sequencing**

An often-overlooked function critical to the longevity and reliability of an electrical system is the sequencing of processes during power up scenarios. By implementing discrete enabling functionality within a PDU, stress is reduced on the entire electrical system. Not to mention, sequencing functionality also provides improved flexibility and customization referenced previously.

Sequencing and soft start functions, together, provide the most complete solution. As previously discussed, soft start functionality with current limiting by channel, alone, introduces risk to the electrical system, as current limits will add up and thereby introducing stress to the system and the power source. By incorporating a user-specified sequencing feature with the soft start design, startup currents across time can be implemented to reduce current peaks. When sourcing a PDU for military application, sequencing functionality is a critical feature that should be incorporated.
Surge Protection

In the case of ground vehicles, the surges defined by MIL-STD-1275D and revision E are significant. Surges are defined as transients that last longer than 1ms. For example, the recommended test in MIL-STD-1275D specifies that five 100V pulses of 50ms duration should be applied at the system input with a 1s repeat time.

Demanding that each component within the electrical system comply to these surges conditions will produce significant wasted volume with excess components to clamp the surge. This unnecessary volume negatively impacts the SWaP efficiencies industry has sought over the past few years. Not to mention, each component in the system will cost more to produce and maintain.

A more elegant solution is to centralize the surge protection feature at the input of the PDU and electrical architecture. This will ease the demands for the devices powered by the PDU, reducing overall lifecycle cost and improved reliability. Not all PDU solutions available in the market offer surge protection at levels acceptable to real world surge scenarios. Take caution when reviewing product specifications, specifically for surge protection.

Conclusion

Electrification of today’s military ground vehicle and aircraft power architectures drives the need for power distribution technology which offers important safety features. Engineers, supply chain professionals, and program managers should seek out products which offer the surge protection, configurable current limiting, sequencing, soft start, and reverse voltage protection to ensure the power architecture is adequately protected. Such features are available in today’s rugged, military PDU products, and provide the flexibility and customization a platform requires to meet the needs of our brave Warfighters.
About Milpower Source, Inc
Milpower Source is an industry leading manufacturer of rugged power conversion solutions for defense and aerospace applications. Milpower Source offers a family of power distribution unit (PDU) products, MILPDU, conforming and qualified to a wide range of military and industry standards. We excel at delivering off-the-shelf power conversion solutions to meet our customer’s demanding specifications, including rapid modification of our large catalog of baseline power supply designs. Contact us today to challenge Milpower Source with your demanding power distribution requirements.

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SBA Certified Small Business

M9516 Power Distribution Unit (PDU)
• Single Input, 8 ECB Outputs
• DC INPUT 6 TO 33 VDC Steady-State
• User Configurable Channels
• Customizable Modular Design
• Control VIA CAN BUS AND RS-485
• Adjustable Trip and Short Circuit Limit
• Robust 33V, 3mΩ Solid-State Switches
• Input spike and reverse-voltage protection
• -55°C to +85°C Typical Operating Range
• MIL-STD-1275D, MIL-STD-704, Def Stan 61-5
Compliant