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DEVELOPMENT OF A MODULAR OPEN SYSTEMS APPROACH TO ACHIEVE POWER DISTRIBUTION COMPONENT COMMONALITY

Jason Holmstedt[1]

[1] Intellisense Systems, Inc., Torrance, CA

ABSTRACT

The hybridization and electrification of military vehicles coupled with the desire to reduce fuel consumption has led to the need for an increase in power distribution controls including electronic circuit breakers (ECBs).The Department of Defense's approach to tactical systems development and acquisition has aligned to a Modular Open Systems Approach (MOSA) strategy. Currently, no established form-factor standards exist to apply to power distribution to conform to MOSA. Intellisense proposed and chairs the VITA 85.108 Power Distribution and Controls Study Group to establish a common standard for ECB solutions to further commonality of the components, increase competition, and mitigate proprietary solutions. This paper describes the progress and activities to develop this standard.

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1. INTRODUCTION

The hybridization and electrification of military vehicles coupled with the desire to reduce fuel consumption has led to the need for an increase in power distribution controls. Furthermore, the need for greater levels of historic data to facilitate prognostic and predictive maintenance (PPMx) has increased to ensure mission readiness of fleet equipment. Currently, no standards exist to achieve these functions.

The publicly available SOSA Reference Architecture 1.0 states that power distribution is a Power Module responsibility. However, the only underlying VITA standard supporting power is VITA 62 [1], and there are no VITA standards that directly address power distribution, including electronic circuit breaker (ECB) functionality.

ECBs, sometimes referred to as solid-state power controllers (SSPC) have been successfully applied to commercial aircraft and provide pilots with the ability to view breaker status on their flight displays and provide direct control over ECBs distributed throughout the aircraft remotely. Furthermore, this electronic control provides an opportunity to increase automation of power systems, thus reducing warfighter workload. ECBs have also been successfully deployed in commercial and defense fixed-wing aircraft.

2. DEVELOPMENT OF A POWER DISTRIBUTION MOSA SOLUTION

To establish a MOSA standard that can be flowed down for power distribution systems, Intellisense proposed and chairs the VITA 85.108 Power Distribution and Controls Study Group. This study group is exploring the technical trade-offs and analysis towards developing a set of requirements. These requirements will serve as the basis of the standard document that will be ratified with industry and government input.

As noted in Figure 1, the MOSA landscape for power standards focuses primarily on power supplies, which functionally convert incoming voltage to specified output voltages (see Figure 2(a)). This function necessitates allocating high current pins for returns. This is distinct from the operation of ECBs (see Figure 2(b)), which act as a high-side switch and do not need the return to pass through the module. Typically, the return can be routed or coupled external to the line-replaceable unit (LRU). Note that the return will still be used as a reference, but it is not required to carry high currents in and out of the LRU unless used for power conversion.

This MOSA standard is intended to facilitate advanced power management and power awareness functionality for evolving ground vehicle power architectures. As indicated in Figure 3, the ECB LRU can provide intelligent power management functions including real-time power usage data. This data can be used to support PPMx by analyzing load power draw for anomalous characteristics that could indicate imminent failures. These LRUs can also provide load shed capabilities by rapidly cutting off power to predetermined loads that are not mission critical. Thus, ECB LRUs are critical to advancing tactical vehicles to the next stage of intelligent power management.

However, not all applications will require or utilize a module standard for development of a power distribution system. Nevertheless, defined and standardized module-level interfaces and functions can be used to support commonality for box-level solutions, including software interfaces, power control services, and external connectorization.

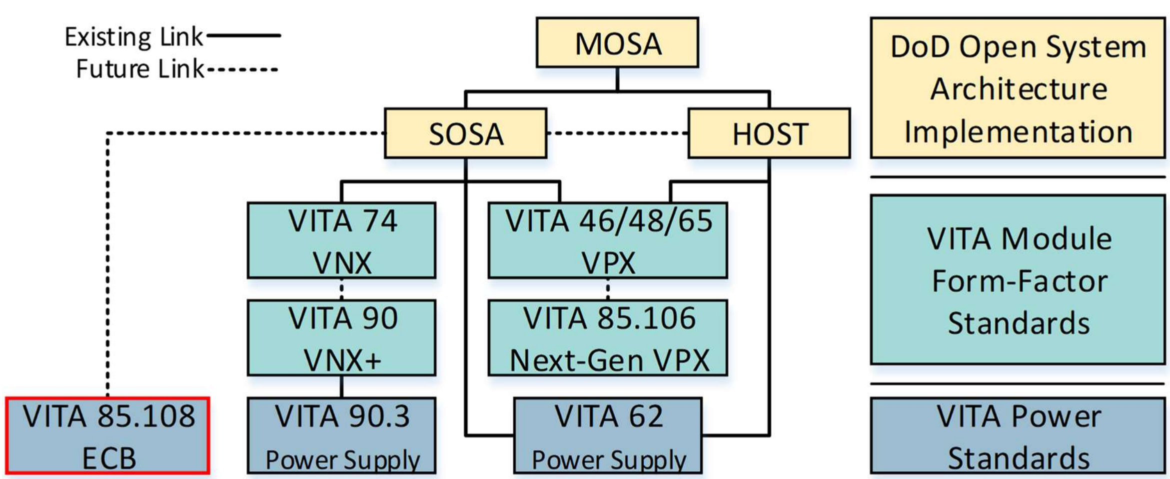
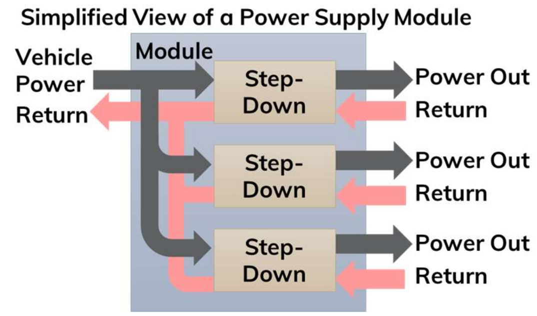
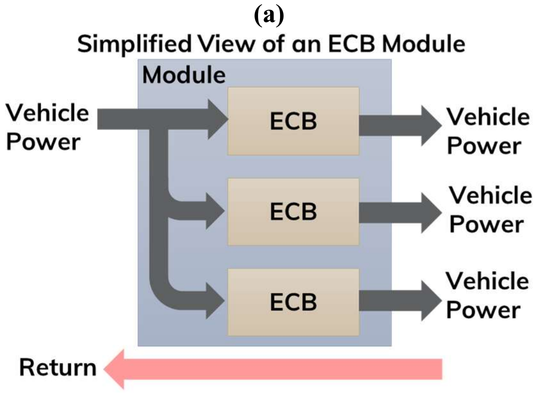


Figure 1: Overview of the landscape of MOSA standards for power, indicating the need for a new power distribution standard to support advanced power controls and PPMx data collection.



(a)



(b)

Figure 2: Functional differences between (a) typical power supply module and (b) an ECB module indicating the need for a distinct standard.

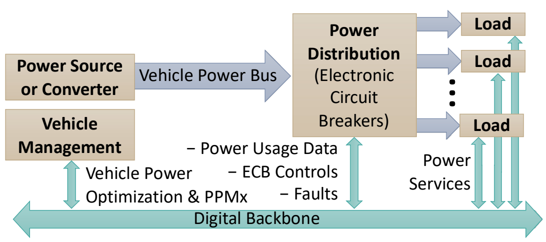


Figure 3: Vehicle power architecture enhancements made possible using intelligent ECB subsystems.

3. ECB MODULE DEFINITION AND ARCHITECTURE

To expedite the development of the MOSA ECB standard, existing mechanical definitions including VITA 48.2 [2] for conduction cooling are being leveraged. In general, ECBs are designed to provide very low resistance and thus are not significant contributors to heat generation when compared to other types of VPX functions including power supplies. Furthermore, for design flexibility, existing 3U and 6U form-factors are being leveraged. As shown in Figure 4 these modules realize a circuit breaker LRU through the integration of multiple modules with a system controller and external connections. As a result, the principal details left to define are the logical definition tied to the functional architecture and the module and backplane connectors.

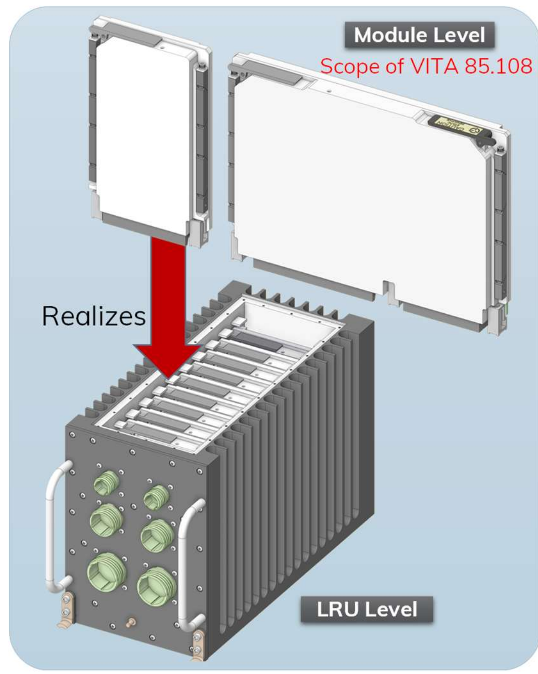


Figure 4: At the module level, the utilization of VPX 3U and 6U definitions help to realize an LRU supporting providing power distribution functionality.

3.1. Logical Interface Definition of the ECB Module

The goal of establishing the logical definition was to determine what functions and controls were necessary for interfacing to the ECB module. Primarily, the interface must enable the ECBs to be configured (e.g., set trip currents) and read back status including current draw. Secondly, the interface needs to support the standard VITA 46.11 [3] chassis management functions. Thus, to address these interface needs, the generalized module architecture of Figure 5

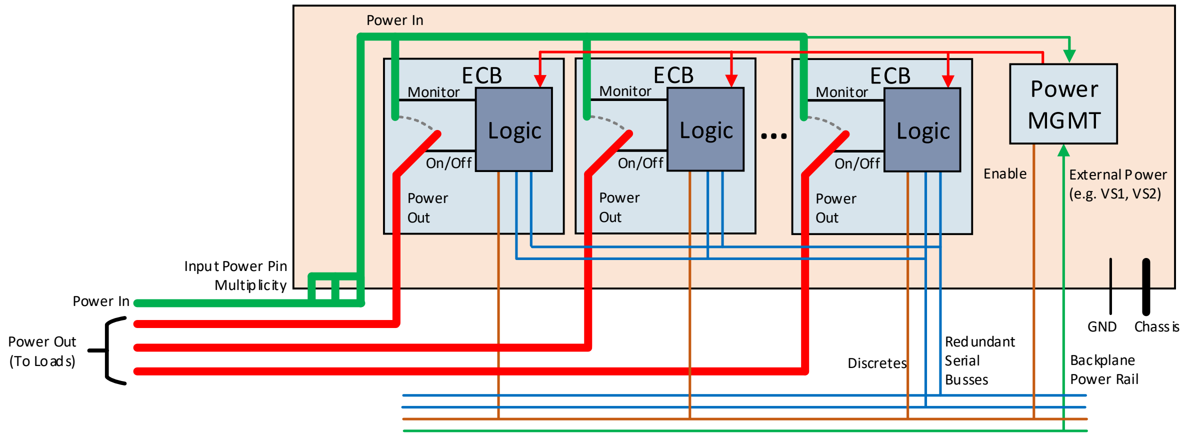


Figure 5: ECB module architecture incorporating the interfaces necessary to meet functional needs of intelligent power management.

was conceived. In addition to the data and control interfaces, it is noted on the diagram that the input power will have multiple inputs to account for the need to support the summation of all the current delivered to the loads.

The architecture also includes a combination of serial and discrete signals, as well as provisions of local VITA 62 power rails. The serial interface is a redundant I^2C bus to support high availability and leverage the Intelligent Platform Management Bus (IPBM) functions. The discrete signals include standard VITA 46.11 signals including global address (GA), FAULT, SYS_CON, EN/INHIBIT, and SYS_RESET.

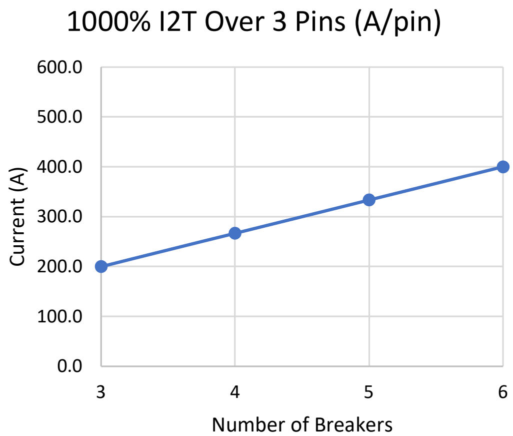
Table 1: ECB Module Interface Signal Pin Descriptions

Signal Pin	Description
ECB_EN (xN)	Individual ECB on/off controls
IPMB (x2)	Redundant I2C control/status bus
SHED	Sheds multiple preconfigured loads
GA[2:0]	Three geographic address pins allowing up to 7 modules
GAP	Global address polarity selection
FAULT	Output indicating a fault in the module
SYS_CON	Output indicating presence of module
EN/INHIBIT	Input enabling or disabling the entire module
SYS_RESET	Input to initiate a reset of the module
Logic Power	Ex: VS1 for internal logic power

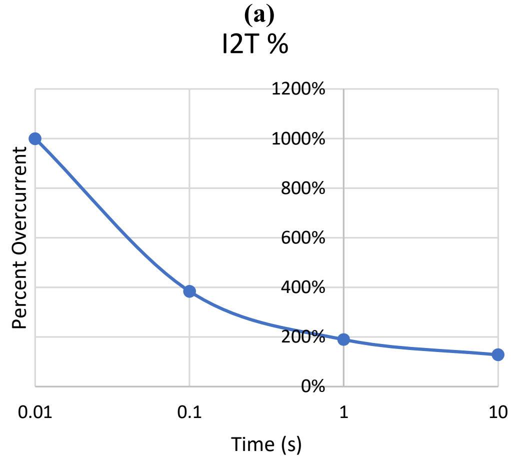
In addition, we have specified new ECB-specific pins including individual ECB on/off controls and a SHED input to facilitate rapid shedding of preconfigured non-essential loads. These signals are listed in Table 1 along with functional descriptions.

3.2. Logical Interface Definition of the ECB Module

The connector will ultimately be the limiting factor for performance of any ECB module. The mating connection must endure not only high steady-state current but withstand overcurrent events up to 1000% for 10 ms typically. The need for support for 1000% overcurrent events is required per MIL-PRF-83383E [4] and is often referenced as a limit in product requirements to allow for surge conditions. Hence, for 20 A rated ECBs the contacts would need to support 200 A surges before tripping. Furthermore, as each 3U or 6U module is intended to house multiple ECBs, the input current to the module will scale with the number of ECBs. For example, with a 6 ECB 3U with three pins allocated to input power, the worst-case steady state would be 120 A total of 40 A per pin with the worst-case overcurrent event of 1,200 A or 400 A per pin as indicated by Figure 6(a). The current VITA 62 high power pins support 58 A per pin when derated for four adjacent contacts. Thus, there is little concern regarding steady state.



(a)



(b)

Figure 6: (a) Maximum overcurrent per pin when allocating three pins for module input.
(b) Example I^2T curve overcurrent as a percentage of specified max ECB steady-state current.

However, the primary issue is preventing degradation in connector pin performance for overcurrent events.

In addition to 1000% overcurrent limits, the curve that generally governs circuit breaker energy withstanding is referred to as I^2T. The principle is that the product of the time and current squared is constant. This is represented in the graph of Figure 6(b) where the amount of overcurrent decreases with an increase in the time spent in an overcurrent condition. The key here is to also note that the current will exceed 100% for well beyond several seconds. The maximum steady-state current will often be derated to accommodate the extended overcurrent duration. Otherwise, a specified time can be used to trip the ECB at an arbitrary time.

Again, based on the existing VITA 62 family of power supply connectors, we can leverage the modular tooling capabilities of the connectors developed by TE Connectivity to define a 3U module connector. As shown in Figure 7, this connector configuration allocates three pins for input power and six pins for each ECB. Given that this module can be used in high voltage applications, provisions for dielectric barriers are included. A chassis connection is included to maintain compliance to existing low-impedance chassis connection requirements. The signal interface is intended to couple directly to the system controller module, which will manage the data from each module and communicate power usage and load faults to the vehicle management system.

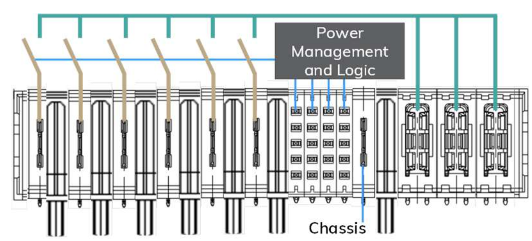


Figure 7: Functional allocation of the connector pins used to define the VITA 85.108 module profile.

4. ALTERNATIVE HIGH CURRENT CONFIGURATIONS

The existing 3U and 6U VITA 85.108 modules are meant to support direct connections to load elements and provide the greatest level of power data granularity. However, there are still requirements for upstream power management where high currents of 100 A or more are needed to protect the integrity of the power system and support configurabilty. Furthermore, while ECB modules can be parallelized to provide increased current capacity, this may not result in the most optimal size and weight.

As a result, recognizing the need for a higher current single or dual ECB to provide the same level of MOSA conformance and access to real-time power usage over the vehical's digital backbone, we have developed a high-current concept as shown in Figure 8. This concept derives from the short VPX (sVPX) form-factor that is permissible under VITA 48.2 and reduces the 3U height to 100 mm. This module uses a 100 A per pin connector configuration allowing up to four pins to be allocated for input and four for output, thus theoretically allowing for up to a 400 A breaker. However, some derating would likely be considered, and testing would need to be completed to validate the performance in austere conditions.

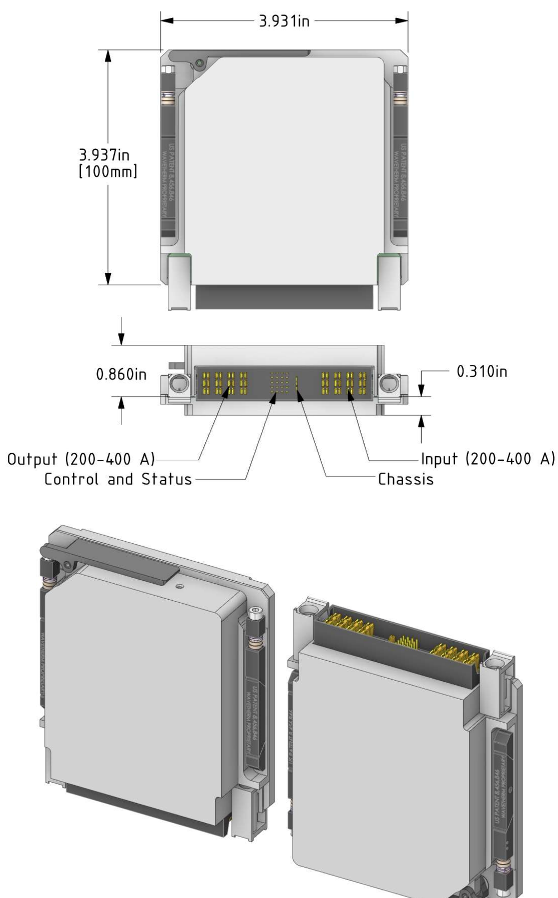


Figure 8: High-power sVPX ECB concept for front-end power distribution and controls with lower size and weight over standard 3U.

5. NEXT STEPS IN THE ECB MOSA STANDARD DEVELOPMENT

The VITA 85.108 standard is actively being developed as a study group. The study group is currently focused on gathering industry and user inputs and defining requirements. Additionally, analysis and testing are also being performed to validate performance assumptions including ability to withstand overcurrent events. After requirements have been sufficiently developed and validated, the study group will create a working group to develop and ratify the standards document. Critical to the applicability and adoption of the standards will be power component provider and user community input and feedback to refine the requirements and implementation. We anticipate the study and working group activities to conclude in 2023 calendar year allowing for products to be produced in conformance to the published standard.

6. CONCLUSION

The need for active management of vehicle power to achieve significant fuel savings, support PPMx, extend mission duration, and reduce soldier workload is becoming critical. To achieve this goal, Intellisense established and chairs the VITA 85.108 Study Group with the goal of establishing MOSA standards that can be used to produce power distribution components that can be leveraged across all services, as well as support dual-use applications.

These common building blocks achieve the intent of MOSA acquisition and ensure increased competition and availability of components. Furthermore, this standard establishes common boundaries for suppliers to implement innovations while limiting risk of adoption due to legacy proprietary interfaces and bespoke designs.

The ability to access real-time power usage throughout the vehicle provides critical insights into vehicle system usage and power characteristics. The availability of this data enables optimization of the vehicle power usage and PPMx to facilitate repairs before breakdowns occur.

7. ACKNOWLEDGMENT

The MOSA technology presented here was shaped with support of the VITA Standards Organization and members of the VITA 85.108 Study Group. For more information on how to join and contribute to the development of the standard, visit: https://www.vita.com/join.

8. REFERENCES

[1] *Modular Power Supply Standard*, ANSI/VITA 62.0, 2016.

[2] *Mechanical Specification for Microcomputers using REDI Conduction Cooling Applied to VITA 46*, ANSI/VITA 48.2, 2020.

[3] *System Management on VPX*, ANSI/VITA 46.11, 2022.

[4] Performance Specification, Circuit Breakers, Remote Control, Thermal, Trip Free General Specification For, MIL-PRF-83383 (Rev. E), 2004.