Modular Power Bus for Space Vehicles (MPBus)

Luis Moreno, Eduardo Remirez*, Berta Pérez**, Javier Alonso**, Pablo Ortiz**, Yaniv Seri***, Yair Maryanka***, Arnaud Debaize**** and Nicolas Martin****
*JMP Ingenieros S.L.
26371 Sotés, La Rioja (Spain)
**Najera Aerospace S.L
26371 Sotés, La Rioja (Spain)
***Yamar Electronics Ltd.
6249220 Tel Aviv (Israel)
****Centre Spatial de Liège
4031 Angleur (Belgium)*

Abstract
The rapid growth of the private satellite launchers sector is leading the space race. Hence, with the privatization of the sector, all the companies are racing for a more efficient and reliant way to set satellites in orbit. Having detected the current needs for power management in the launcher vehicle industry, the Modular Power Bus is proposed as a technology to revolutionize power management in current and future Launcher Vehicles. The MPBus Project is committed to develop a new power bus architecture combining ejectable batteries with the main bus through intelligent nodes. These nodes are able to communicate between them and a battery controller using an improved, data over DC line technology. This would result in less weight for each launch stage increasing the operational satellite payload and reducing cost. These features make the system suitable for a number of launchers.

1. Introduction

The current launchers power management systems are able to provide power control, power distribution, power bus monitoring, etc.; but it implies a significant increase in the number of wires with impacts on systems weight and space allocation. The proposed solution to this problem is to use a unique path wire to transmit power and data.

The MPBus consists on a new concept that suggests two main ideas:

- A system with **distributed batteries** which allow to activate only one power source at the time to provide power to the whole launcher system.

- To transmit **battery status telemetry and another purposes** through the power bus line communication.

In this concept, as many nodes (sensors, actuators, batteries) as needed would be distributed along the system. Connection with all these nodes will be done with the main power bus using DataBus over DC line technology. Therefore, system management, provided by a specific node, would flow through the power bus thus avoiding the use of complex additional wire harness.

With the development of this new system, new advantages appear over traditional Bus technologies:

- **Reduce the total weight of the final stages**. The current battery systems sweep along depleted batteries (or with low power), during the launch. However, the MPBus approach has a decentralized battery system where depleted batteries can be jettisoned resulting in minimum battery weight at the final stage.

- **Reuse of a part of the batteries**. In case of a part of the stages could be rescued and reused in future missions, the MPBus system distribution would allow reuse batteries for a determinate number of cycles.

- **Use the main power bus communication to transmit battery status telemetry and another uses**. At least for now, the main power bus provides energy to the loads and has no other uses. This new concept of the MPBus proposes the use of the same main power bus line to provide a data link along the launcher. This data link will not be intended to serve as a critical bus because it hasn't got the latency, availability and speed required to the communication between some sensors/actuators. However, it will be designed to be a fully functional bus to transmit battery telemetry and another purposes with a medium transfer rate (3Mbps). Note that, as it said, it does not replace the main bus where critical data will be sent.

However, increasing the complexity of the battery management system will result in the necessity to develop a battery management device; this will manage the status of all the batteries along the launcher from the On Board Computer (OBC). This OBC will be in charge of taking the decision of which battery must be connected to the MPBus according to the status of each battery, the bus and the launcher. In the framework of MPBus, a battery management system developed in the PC will simulate a real battery management system, simulating its behaviour (connection/disconnection, load changes …)

To summarize, the goal of the MPBus solution is to provide a bus that ensures the transmission of data while it's possible the management of different batteries at the same wire.

2. MPBus Structure

The MPBus structure is based on a modular three-stage launcher like Ariane 5 [1] and other launchers with similar characteristics, with the batteries distributed along the different stages.

The main control of the MPBus will be done with a solution based on a PC connected to the Bus Controller by a dedicated bus. Bus controller serves as a gateway between the PC and the MPBus communication system. The system will manage the different actuators, sensors, and batteries connected along the bus, being possible to simulate a simple mission where some batteries are disconnected from the MPBus while the controller reads values from the sensors and operates the actuators.

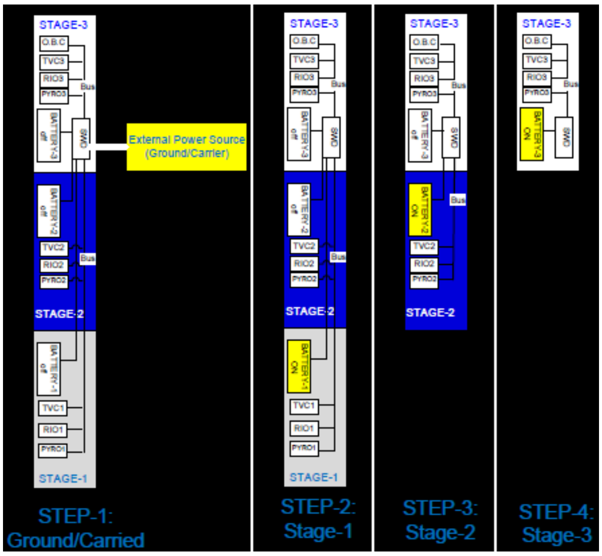

Figure 1: MPBus Structure

According to Fig. 1, the system starts powering on an external power source called carrier. Due to the battery management system of the MPBus solution, it is possible to connect/disconnect batteries at will. It means that the systems is able to ensure the best transition during batteries switching at different stages. Hence, when a battery of a stage will be connected, the battery of the previous stage can be disconnected.

3. MPBus Prototype

The building of the MPBus is mainly focused on the design of two components: the data bus (modulation technique, AC/DC coupling, study of a bus controller) and the intelligent nodes (components, control logic, battery switching system). The test of these subsystems must encompass MPBus functionality, correct communication between control logic and communication module, stability of all the system to high temperatures, and correct flow.

3.1 Data Bus Design

The MPBus modem operates as part of a network consisting of multiple modems. Each can transmit messages to other devices over the power lines at selectable communication rates for enhanced robustness by selecting the right ECC according to the channel conditions

The entire modem is implemented on a FPGA board with an Analog Front-End (AFE) to fit later on into aerospace environment. The modem is based on the DC-BUS technology from Yamar [2] that combines Phase modulation with Forward Error Correction codes (ECC) mechanism to allow error free operation under impulse noisy powerline conditions.

The Modem is divided into the following main building blocks;

- Protocol handling block, interprets the host protocol.
- Transmit and Receive internal FIFOs, each has 128 bytes, providing a buffer between the host and the powerline.
- CODEC block, encodes/decodes the data according to the channel protection selected.
- Modem block, phase modulates and demodulates the data to and from the powerline.
- CSMA/CA mechanism allow Carrier sense and arbitration capabilities to the modem

Figure 2: Communication modem

Modem Main Features:

- Communication over DC
- Bit rate of 3Mbps
- Combined Modem, ECC and Synchronization
- Multiplex CSMA/CA mechanism
- Selectable communication robustness

3.2 Intelligent Nodes Design

The Intelligent Node is defined as a device composed for a Control Logic and an Analog Front-End to the communications. The control logic is based on a FPGA where is running a Cortex M3 and the communication modem.

Furthermore, the Intelligent Node can assume different roles into the Bus, just depending on the additional hardware developed around the control logic. Their main function is battery management (main objective of the project), thus a

Node which is working as battery management includes the necessary hardware to be able to connect and disconnect batteries from the bus according to instructions received through the MPBus. On the other hand, the bus controller manages the battery system sending messages to the battery node to connect/disconnect batteries according to the programmed mission.

In addition, switching device is the subsystem included in the battery management node and it's responsible for connect/disconnect the batteries to the main bus. In the case of the MPBus system, the battery switching is based on a "make before break" concept. This concept ensures the best transition since a new battery is connected to the bus before the old one has been removed.

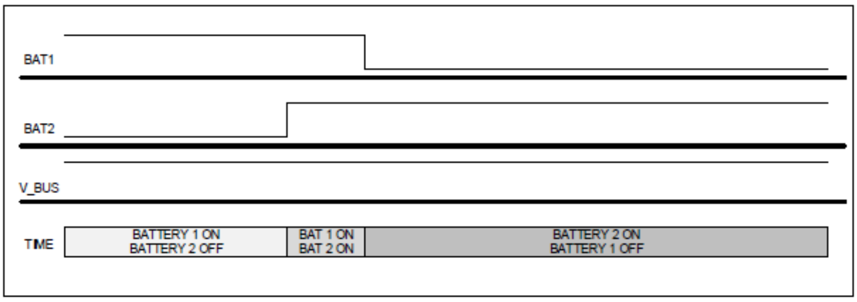

Figure 3: Make Before Break Concept

The second main role of the Intelligent Nodes is acting as gateway between the MPBus and sensors/actuators. The control logic can acquire info from some sensors and, once it's processed, it's sent to the bus controller. The same can happens with actuators, info about state of one actuator can be received from the Bus controller and the control logic of the Node will manage the actuator according to the data received. For this proposal, the necessary hardware for connect the sensor/actuator with the FPGA is necessary.

A shared memory between the Bus controller and the Node allocated in the node is used to read parameters from the node as could be, battery parameters, connect/disconnect battery and read/write parameters of the devices connected to the Node. Furthermore, as Fig.5 shows, the Node includes the Analog Front-End (AFE) from Yamar, the power conditioning and the Switching Device.

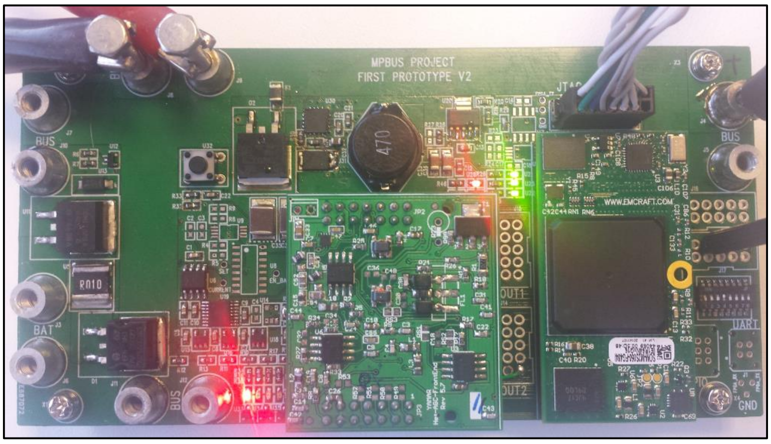

Figure 4: Intelligent Node

3.3 Whole System

Once the individual components are tested, the system is assembled and integrated as a whole. Hence, the system must provide:

- Data bus over DC line communication.
- Ejectable batteries with intelligent nodes that are able to manage the different system.

Figure 4: Panel Demonstrator

During the MPBus project, two prototypes will be developed: the First MPBus Prototype and the Final MPBus Prototype. Currently the First Prototype is developed and tested, and it constitutes the most essential input for the final prototype design phase. Based on the actual system performances, the merits and issues associated with each of the technological solutions implemented in the first-prototype are being analysed and discussed in order to identify the key technological choices for the Final Prototype which will be an improved design.

There are two kind of tests performed to the whole system: functional tests and endurance tests. The first ones check the proper behavioural of the system; and the second ones are oriented to test the system in a more real way, where environmental conditions such as extreme temperatures, vibrations, EMC and radiations have been taken into account. Therefore, endurance tests try to emulate the launch environment conditions for different launch scenarios. In conclusion, results of the First Prototype indicate that the behaviour of the MPBus solution meets the goals defined at the beginning of the project.

3. Conclusion

The MPBus solution is, to our knowledge, the first project that involves an intelligent battery management system and data and power transmission over a unique path wire in space shuttles. To summarize, the implementation of the MPBus in the launching platform will create direct and indirect weight reductions with the added benefit of reducing the installation and maintenance complexity.

The project scope aims for completing implementation of the MPBus from basic level at design phase up to validation of a final prototype technology for power management in two years current and future Launcher Vehicles. At project, completion is expected to lie in TRL-5 (Component and/or breadboard validation in relevant environment).

References

[1] Arianspace (2011). Ariane 5 User's Manual Issue 5 Revision 1. Online at *http://www.arianespace.com/launch-services-ariane5/Ariane5_users_manual_Issue5_July2011.pdf*

[2] YAMAR (2007). DCB500 – Transceiver for Powerline Communication. Online a *http://www.yamar.com/datasheet/PO-DCB500.pdf*