ICUS – ADHA ICU System Controller Module Concept

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Advanced Data Handling Architecture (ADHA)

To contribute towards the European Space Agency's (ESA) objectives of reducing spacecraft development time, achieving cost efficiency, and promoting faster adoption of innovative technologies, the European Space Agency's On-Board Computer and Data Handling Systems section (TEC-EDD) is currently engaged with European industry partners in the development of the Advanced Data-Handling Architecture.

The Advanced Data Handling Architectures (ADHAs) aim is to provide a data-handling architecture based on standardized, interchangeable, and interoperable electronics modules equipped with the latest generation of microelectronics components. These modules can be assembled and re-assembled into numerous and diverse products for on-board data handling applications and services.

ADHA is intended for utilization in Low Earth Orbit satellites, particularly for Earth Observation missions.

ADHA Concept

Each ADHA system is based on a set of interconnected (ADHA) units composed of interoperable (ADHA) modules, communicating through a standardized backplane.

ADHA covers functional, technical, interface, and product assurance requirements at different abstraction levels to ensure combability between developed products and streamline integration and validation at all levels.

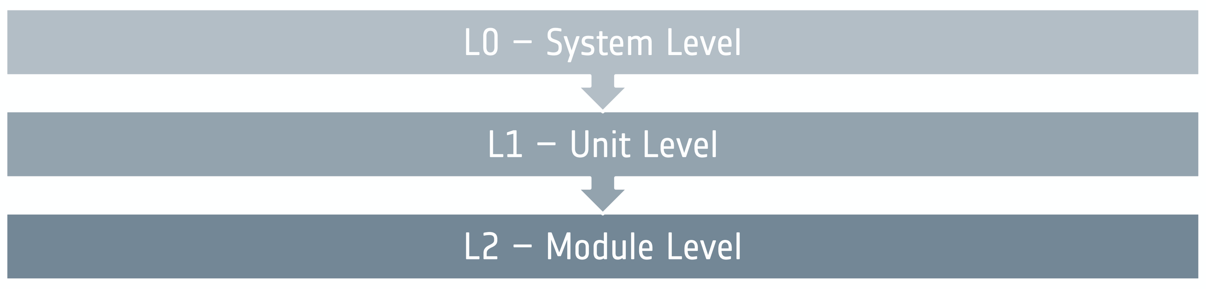

Figure 1: ADHA abstraction levels, adopted from [1]

ADHA Units

Two sizes of ADHA units are currently envisioned (3U, and 6U height), with different types of modules up to a maximum of 13 (14 for 3U) modules per unit, which communicate through a standardized compact-PCI-Serial-Space-based backplane.

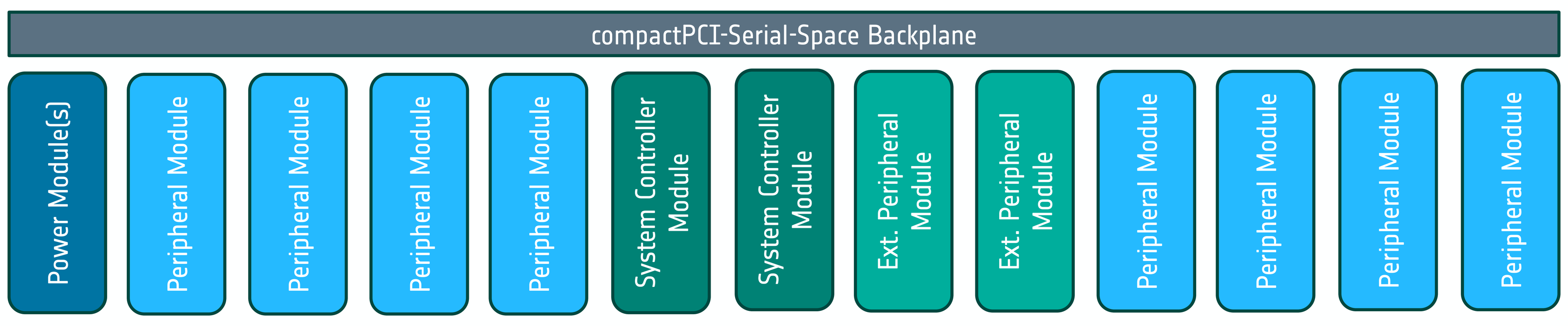

Figure 2: ADHA 6U example unit configuration, adapted from [2].

The backplane provides CAN as a low-speed, SpaceWire as a medium-speed, and SpaceFibre as a high-speed interface, all of which can be used for internal command & control and data routing. Furthermore, dedicated interfaces are implemented for synchronization and health monitoring of the modules.

The communication structure in an ADHA unit is centered around communication hubs (System controller/Ext. Peripheral Slot), which implement a star-like communication network for all point-to-point links to all other slots in the module.

ADHA units may be internally redundant at module level, or externally redundant at system level, based on mission needs. Additionally, ADHA modules may be internally redundant.

ADHA Modules

In ADHA four different standard module types exists, which are mapped to different slot profiles. The slot profiles differ in the available backplane connectors and in the available backplane interfaces.

Power Module	Provides nominal and redundant power to the unit
System Controller Module	Manages unit and internal modules, S/C interface, communication/processing hub or storage
Extended Peripheral Module	Communication hub or centralized processing/storage
Peripheral Module	Interfacing with external equipment, Dedicated internal functionality

(a) (b) (c)

Figure 3: Preliminary Renderings of ADHA module (a), ADHA unit with EMC cover (b), and fitted ADHA unit with modules (c), taken from [AD014]

Instrument Control Unit(s) within ADHA

ADHA was recently extended to also cover payload units and the instrument control unit provides an interesting case-study for the adoption of ADHA.

Based on existing ICU architectures, generic functional requirements can be derived for an ADHA ICU [3]:

1. Hosting and execution of the Instrument Control Software (ISW).
2. Interfacing with instrument sensor, either through dedicated front-end equipment or directly.
3. Routing science data, command and control message, and housekeeping telemetry.
4. Controlling, configuring, and managing all instrument functions, including lower-level equipment.
5. Mechanism control for operation of instrument, e.g., drive electronics control for filter wheel, alignment mechanism, or similar.
6. Power distribution, and optionally conditioning, for internal use and lower-level equipment.
7. Thermal management of the instrument, including heater control and temperature acquisition.
8. Local on-board time management including distribution to connected equipment.

Some functions may be implemented by dedicated units depending on mission needs.

Based on the requirements an ADHA-enabled ICU architecture will consists of the following modules:

ICU Controller Module	Central module, hosting of ISW, control of unit and equipment
Processing Module	(Pre-)process sensor data, provides buffering, communication hub
Front-End Module	Interfaces with instrument sensor electronics
Power Conditioning Module	Provides power conditioning to lower-level instrument electronics
Low Level Interface Module(s)	Control and interfacing of discrete electronics (i.e., motors, heater, sensors)

Figure 4 gives an overview of the resulting ICU architecture in spacecraft context. Most of the described modules are optional and can be omitted based on mission needs.

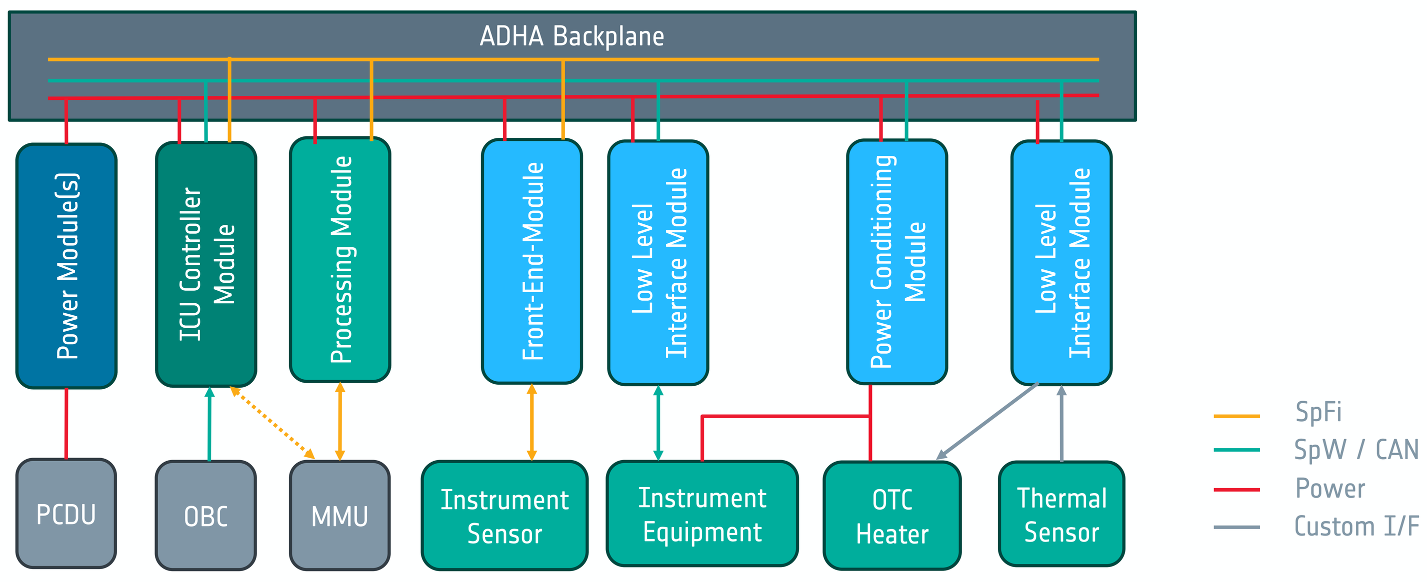

Figure 4: ADHA ICU concept. The slot profiles used for each described modules correspond to the colours in Figure 2.

The ICUS module

Of the described modules, the ICU Controller Module was chosen for prototyping to validate the ADHA ICU architecture and gain experience with ADHA in the context of payload units.
The ICUS module is currently being developed internally at the European Space Agency.

Figure 5 shows an overview of the architecture of the ICUS module. It consists of two FPGAs, one low-speed, but radiation-hardened supervisor FPGA (Microsemi proASIC3L), and one high-speed, but radiation-tolerant FPGA (Xilinx XRKU060).

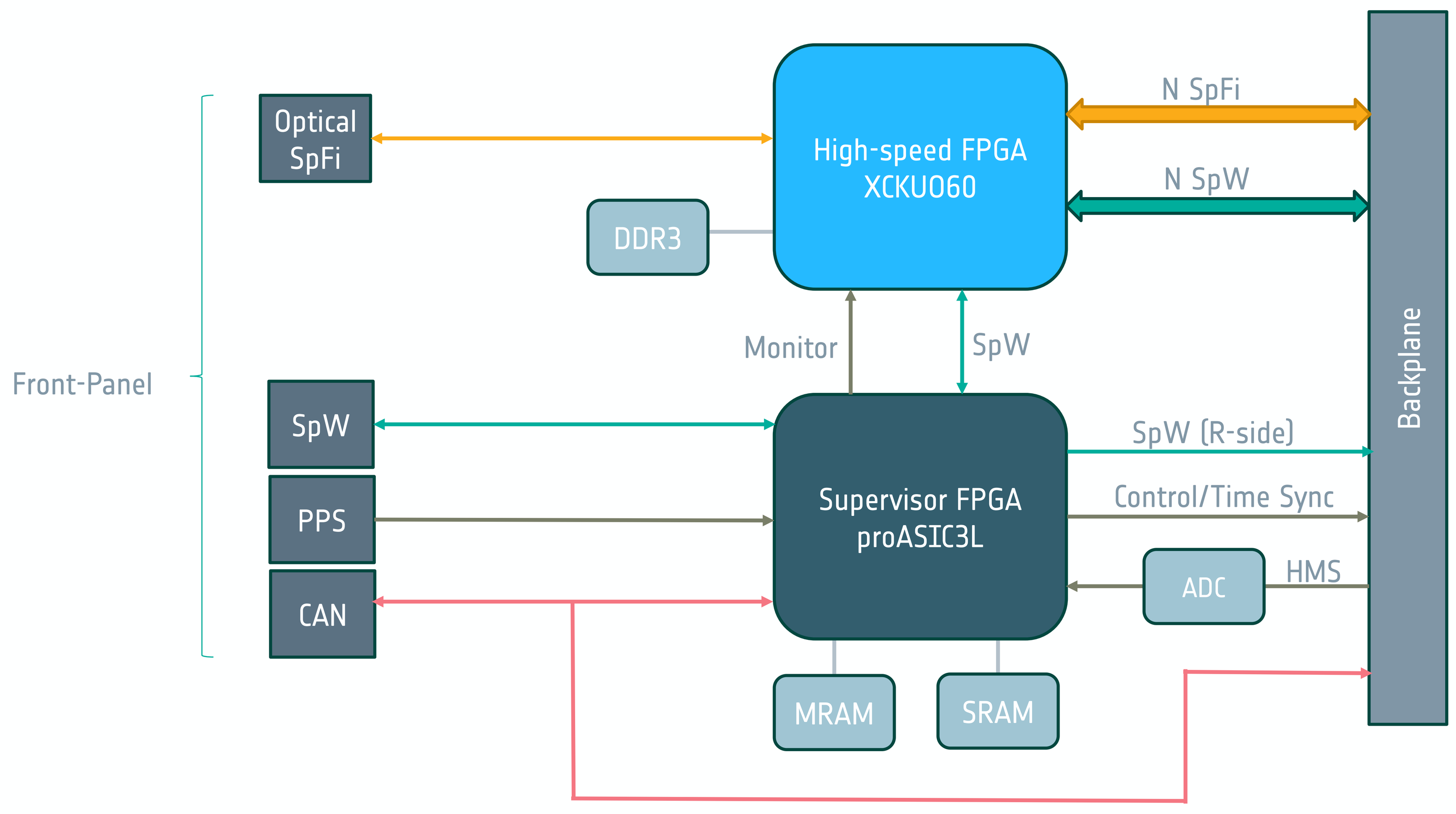

Figure 5: ICUS simplified architectural design.

Supervisor FPGA

On the supervisor FPGA, a RISC-V-based System-on-Chip (SoC) is implemented that is responsible for most of the unit and module management. Internally, it takes care of the configuration and monitoring of the high-speed FPGA. It additionally, implements telemetry, and telecommand interfaces towards the spacecraft platform, as well as local time-management, and other dedicated interfaces such as the ADHA health-management system. The supervisor SoC will also host the ISW, stored in the local MRAM and provide unit and module level fault-detection, isolation, and recovery for the ADHA ICU.

Data-Routing FPGA

The high-speed FPGA implements all data-routing functionality of the module. On the front-panel, it will provide data and command- and control routing towards and from the mass-memory unit through its optical high-speed links. Towards the backplane, it will implement the high-speed SpaceFibre and SpaceWire star-network as well as provide SpaceWire routing towards the supervisor FPGA for internal command and control routing. To minimize the implementation effort, a single SpaceFibre router will be employed to manage both SpaceFibre and SpaceWire backplane links. Due to this, only a single SpaceWire link is required between the two FPGAs.

Current Status

The first iteration of the module is implemented using commercial-off-the-shelf components; however, special care is taken to ensure that the module has a potential path to a future EM development. For example, space-qualified equivalents exist for all baselined components, and the PCB layout will respect the size-overhead of space-qualified equivalents where possible.

The module is currently in the architectural design stage. In parallel the internal power distribution network is being developed and prototyped.

Conclusion

In this paper, we have shown that the ADHA concept can be applied successfully to payload units such as the instrument control unit.
By decomposing ICU functionality into the pre-defined ADHA module profiles, it is easily possible to create generic architecture components such as the ICU controller module, which could be rapidly reused in different mission contexts, thus potentially reducing future development and qualification effort and cost significantly.

References

[1] "Advanced data handling architecture – product tree, terminology and acronyms", ADHA Standard, Issue 1.0, Oct. 2022
[2] "Advanced data handling architecture – ADHA-UX generic design description", ADHA Standard, Issue 1.0, Oct. 2022
[3] Bargholz, M., "ADHA-Ux-ICUS-M Design Description", Issue 0 Rev. 3, (unpublished), April 2023