FriStack – Modular System for Educational and Research Purposes

Andrej Šimkovič, Michal Kubaščík, Peter Šarafín, Peter Ševčík

***Abstract*—** This article introduces FriStack, a modular, stackable hardware system designed for IoT applications in educational and research environments. Inspired by existing systems like Seeed Studio's Grove, Adafruit's FeatherWings, and Espressif's M5Stack, FriStack aims to simplify module integration by using a standardized header block for communication. FriStack offers an accessible and less complex alternative to existing systems, while maintaining flexibility for future expansion through modular components. The system's future modules will include wireless communication and AI functionalities to broaden its potential applications in real-time data transmission and processing.

***Keywords*—** stackable system, modularity, ESP32, M5Stack, IoT

I. Introduction

Considering rapid development in the field of IoT applications and implementation in said solutions, we recognize the need to develop a modular, stackable system that can be used in a wide range of applications.

Modularity is a key factor that proves that there is no need to develop one specific hardware solution for one specific need. Instead, it is possible to develop your own solution to your problem using an already-developed system of stackable modules. With this approach it is simpler to create solutions and save time and cost.

While they are mainly used for hobby projects, there is an ambition to expand these systems further into fields of IoT such as smart factory or smart agriculture, where emphasis is laid on data gathering, processing and durability of the system in harsher conditions. Another use could be in education where students could learn embedded programming, IoT and learn to develop their own modules. Furthermore, its capabilities in data collecting and processing and rise of AI implementations could be beneficial in research environment.

II. Stackable Systems

This type of system consists of multiple compatible modules which can be connected without the need for additional soldering. They are used in IoT fields like smart factory or smart home. Additionally, they are used in education as a way to teach about IoT solutions and embedded programming.

The main element of a stackable system is the core which handles communication between modules and users. These modules vary widely in their applications. They can gather data from sensors and use wireless communication methods like Wi-Fi, Bluetooth, and Zigbee. More advanced modules can support AI functionalities such as voice assistants, image recognition, and general data processing. The core and modules are connected with a solderless solution like a header or cable so users can work with it immediately after obtaining it.

Andrej Šimkovič, University of Zilina, Zilina, Slovakia (e-mail: simkovic4@stud.uniza.sk).
Michal Kubaščík, University of Zilina, Zilina, Slovakia (e-mail: michal.kubascik@fri.uniza.sk)
Peter Šarafín, University of Zilina, Zilina, Slovakia (e-mail: peter.sarafin@fri.uniza.sk)
Peter Ševčík, University of Zilina, Zilina, Slovakia (e-mail: peter.sevcik@fri.uniza.sk)

A few of the systems present on the market are:

- Seeed Studio - Grove Ecosystem
- Adafruit - FeatherWings
- Espressif - M5Stack

A. Seeed Studio – Grove Ecosystem

Grove is a modular system categorized as a standardized connector prototyping system. Connections are made through header blocks. It consists of the Base unit which includes a microprocessor which provides communication between the Base unit and the modules using mainly the I2C bus, but some modules are using UART. By communicating through I2C, it is possible to use Grove modules with other systems such as Raspberry Pi or Arduino boards.

The Grove ecosystem offers a broad range of affordable products, making it highly accessible. Seeed Studio offers opportunities to design your own module and sell it on their website. It serves as a significant source of inspiration for our system design as to how this kind of system can work and grow thanks to its community [1].

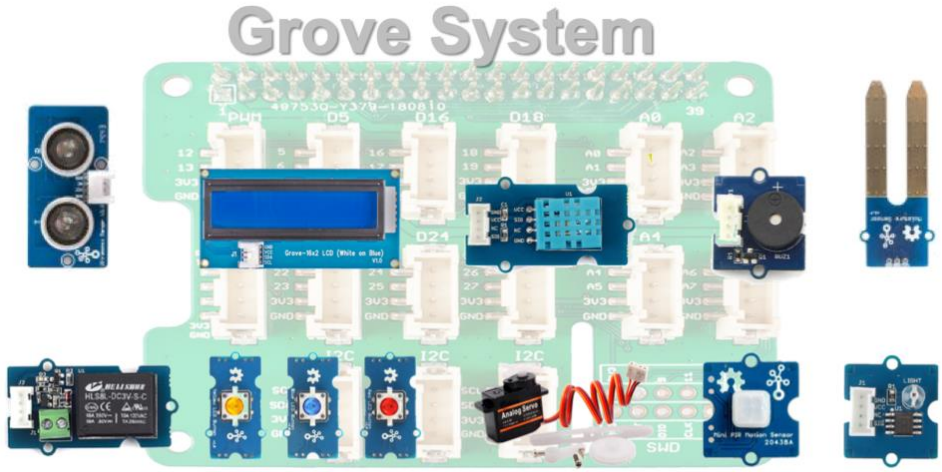

Fig. 1 Grove Ecosystem sensors and extender board [1]

B. Adafruit – FeatherWings

This system comprises the main boards (Feathers) and modules as shields or HATs called Wings. The Feathers have chipsets from various manufacturers such as Atmel, STM, Espressif, SemTech and more are to come.

Wings range from simple sensors to advanced modules like thermal cameras. Almost all Wings are compatible with all Feathers, but because of the usage of so many chipsets in their Feathers the means of available communication changes [2]. For example, GPS Wing is not compatible with Feathers with ESP8266 and nRF52 because this Wing uses UART for communication and these chipsets can't spare their UART as they have only one and are used for programming and debugging [3]. On the other hand, most of the wings use I2C and SPI.

As for programming, it consists of Arduino C/C++ example codes and libraries available for most of the Feathers and FeatherWings. Adafruit provides Feather boards that support CircuitPython, offering an alternative for beginners or those less familiar with Arduino's C/C++ programming language [2].

Unlike Grove Ecosystem this system does not have a standardized cable connector system. So, there is a problem with using different cables for different Wings, but they can be still connected through headers and this method is the default. Another difference is the price of all parts of this system. While Adafruit offers a broader range of chipsets and more complex boards, this level of complexity is beyond what we aim to achieve with our system.

C. Espressif – M5Stack

M5Stack began as an idea and personal project of Jimmy Lai and was later bought by the manufacturer of the chipset, which was used in the first M5Stack Core, Espressif. After the purchase, there has been steady growth of IoT solutions and a range of models [4].

The main controller core of the stackable system was M5Stack Core, but they expanded their selection of controllers with controllers of smaller sizes, Stick, Atom and Stamp, but still provide many possibilities of application in IoT [5].

Each of these controllers supports the use of their sensors and modules. Sensors are connected by cables mainly through the I2C bus, but when it comes to modules, they are connected through a universal header which contains all the possibilities of communication of ESP32-S3. However, this mainly applies to M5Stack Core as it is considered their flagship for IoT applications. There is a rich variety of these modules that vary from power supply through communication to camera modules. These modules are not truly stackable as you stack only your Core and then the module. You can use an extender, but you can connect only using connectors and cables.

Additionally, M5Stack solutions can be programmed using various languages like Arduino, MicroPython and UIFlow, which is a drag-and-drop visual programming tool, great for educational purposes and for beginners in embedded programming [5], [6].

This system has complex cores and modules like the FeatherWings boards, but they are more affordable and have unified casing. The casing of each core, sensor and module makes it suitable for harsher environments without the need to develop your own cases for your system [5].

Fig. 2 M5Stack CoreS3 [6]

III. FRISTACK

For our system, we plan to develop the core which will be less complex than the cores of previously mentioned systems while keeping all possible means of communication between modules. The main idea is that the core would have many uses which would broaden when modules are connected. Another feature would be stackability like FeatherWings by Adafruit. Theoretically, as many modules could be connected to the core until we would run out of power or pins.

The main communication will be through a standardized header block while there will be some I/O connectors for CAN(TWAI) and UART. Also, we plan to include the SPI bus header for possible connection of display or other components.

The power supply of the FriStack will be through USB-C and will be also used for programming and debugging to save space, and cost and fully utilize the properties of ESP32-S3.

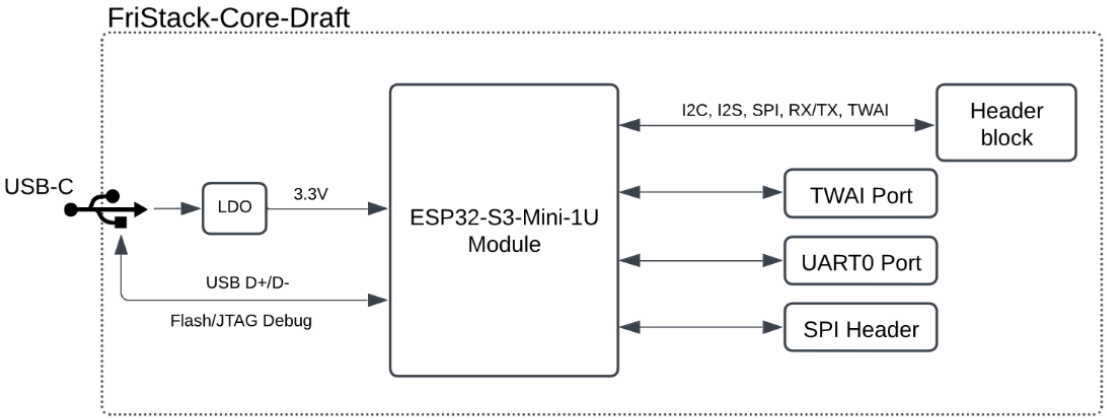

Fig. 3 FriStack block scheme

A. Future modules

To start the project FriStack we would like to offer, with the core of the system, some modules to showcase the possibilities of FriStack and its uses in future applications.

One of them would be a communication module using microcontroller ESP32-C6 thanks to its wireless communication properties. This module could be used for applications where data needs to be transmitted in real-time and cable connection is not practical. Another use could be to connect sensors through Bluetooth and gather data [7].

Another module we are thinking of could be an AI module using ESP32-P4, which is not yet a commercially released model, but it is designed for applications which include image and speech recognition. Due to its high computing power and offer of peripherals, it is a great opportunity to experiment with this microcontroller and its potential [8].

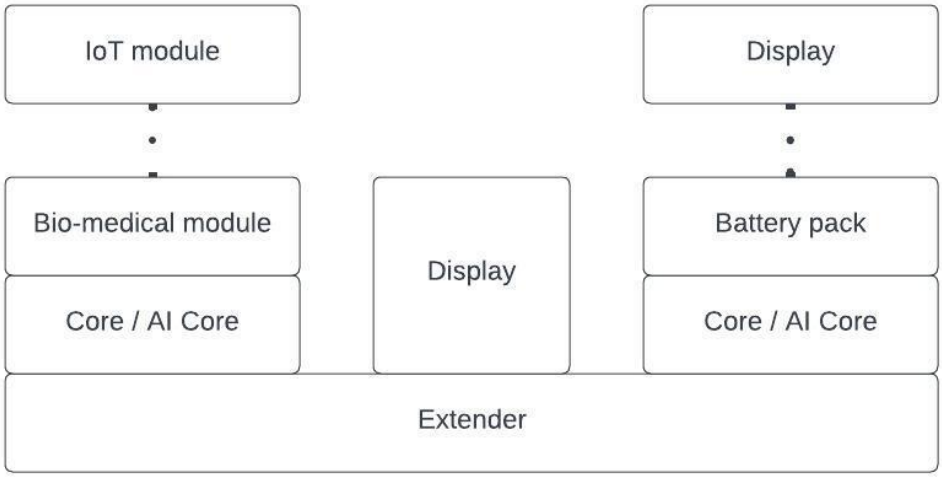

Fig. 4 Example build of FriStack system

B. Standardized header block

As for our project, we mainly get inspiration from Espressif-M5Stack, and we would like to make it compatible with FriStack. We would like to achieve it through an extended module to transform our header to theirs and vice versa.

The header block would consist of peripherals like UART, I2C, I2S and SPI also power and ground would be connected through the header. We also plan to include GPIO pins, pins for flashing core and connected modules as in M5Stack Core3. However, the M5Stack CoreS3 header consists of two 15x2 blocks, we would like to make our header block smaller and possibly just one to conserve the size of our Core and future modules [6].

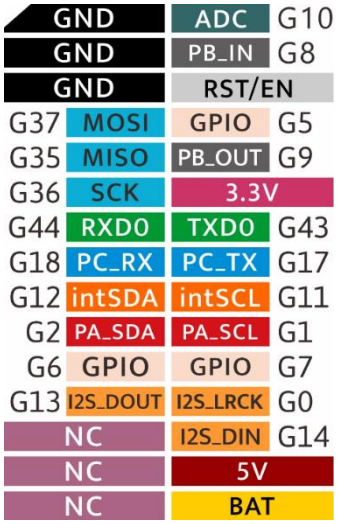

Fig. 5 M5Stack CoreS3 Header blocks

Fig. 6 Concept 3D-model of FriStack

IV. Conclusion

The ambition of our project is to provide a stackable system solution for education and research purposes. We draw inspiration from existing solutions and take a simpler approach to designing to make it more compact, affordable and effective. For now, we want to develop the core of the system that would communicate with all future modules through standardized header block. Additionally, develop a few modules and prepare documentation and methods for future modules development by community as it is going to be open-hardware solution.

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