BACHELOR PAPER

Thesis submitted in fulfillment of the requirements for the degree of Bachelor of Science in Engineering at the University of Applied Sciences Technikum Wien - Degree Program Electronics and Business Distance Study (BEW-DL)

Wireless Button for FABI

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Munich, 13.02.2025

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Abstract

**Schlagwörter:** Puck.js, Raspberry Pi Pico W, FABI, Assistive Technologies

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Acknowledgements

**Keywords:** Puck.js, Raspberry Pi Pico W, FABI, Assistive Technologies

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# Introduction

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Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Proin pharetra nonummy pede. Mauris et orci.



Figure 1: Example of name and year printed on spine (Source).

Below there is a cross-reference to Table 1. The table format shown here serves as an example only. Tables may be formatted individually.

Tabelle 1: Schedule for “Applied Mathematics” (Quelle).

|  |  |  |
| --- | --- | --- |
| **Date** | **Subject** | **Room** |
| **20. 08. 2008** | Graph Theory | HS 3.13 |
| **01. 10. 2008** | Biomathematics | HS 1.05 |

This is a cross-reference to Equation (1):

|  |  |
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Bibliography references should be automated especially when there is a long list of books. This is a sample reference to The style of citation and the Bibliography format used here is one of several possible ways, depending on the discipline and the functionality of the word processor.

# State of the Art

Before implementing any ideas, it is important to gain an understanding of the current state of the art. This chapter will provide an overview of FABI and describe the current state of the art of the used hard- and software.

## FABI

According to the AsTeRICS Foundation, “[t]he FABI (Flexible Assistive Button Interface) is an interface box which allows the connection of up to 9 momentary switches (buttons) or self-made electric contacts to a computer, tablet or smartphone” [1]. The user may specify the actions of each button in a “web-based config manager” [2, 3]. Buttons are either “momentary switches or self-made electrical contacts” [2] or “sip-puff sensor[s]” [2], that have to be connected via wire to the FABI system. The FABI itself may either communicate via USB to the target computer, or utilize a Bluetooth connection, if the user attaches a Bluetooth module to the FABI. The FABI system is an open-source project, wherefore it is possible to build a device oneself, using the provided building guides and user manual [4-7]. The main processing unit of the FABI system is an Arduino Pro Micro microcontroller, that is based on the ATmega32U4 chip [8], according to SparkFun Electronics [9], a vendor of electronic components, whose Pro Micro board is recommended by the AsTeRICS Foundation in the construction of a FABI system The Pro Micro board has been chosen, as it supports the USB HID protocol, meaning the device can act as an interface device, such as a mouse or a keyboard, when connected via an USB port [5]. It features 12 digital I/O pins, and is “[s]upported unter Arduino IDE v1.0.1” [9]. However, the Pro Micro board does not feature an onboard Bluetooth or Wifi chip, wherefore the FABI currently relies on an external Bluetooth module for wireless connections. To make the external Bluetooth module obsolete, a different board will be chosen for this project. Hence, the following chapter explores the available options for alternative boards.

## Hardware

An alternative to the Pro Micro board has to be compatible with Arduino IDE, support the USB HID protocol and needs to have digital I/O pins. One such candidate is the RP2040 chip developed and produced by Raspberry Pi Ltd [10], that is the basis of microcontrollers such as the Raspberry Pi Pico W or the Arduino Nano RP2040 Connect [11].

### Raspberry Pi Pico W

The RP2040 present on the Raspberry Pi Pico W board features a dual-core ARM Cortex-M0+ processor running at up to 133 MHz [12], significantly outperforming the ATmega32U4, which has a single-core 8-bit AVR processor operating at 16 MHz [8]. This increased clock speed and 32-bit architecture allow the RP2040 to handle more computationally intensive tasks efficiently. Both chips support native USB support without needing any additional hardware [8, 10]. While the Pro Micro costs $12.50 from the vendor SparkFun [9] at the time of writing, the Raspberry Pi Pico W is significantly cheaper priced at 6.70€ ($7.04) from the official vendor BerryBase GmbH [13]. The key advantage of the Raspberry Pi Pico W over the Arduino Pro Micro is the inclusion of the Infineon CYW43439 [14]. This chip supports “Wi-Fi 4 (802.11n), Single-band (2.4 GHz)“ [14], as well as Bluetooth 5.4 [14], which both are necessary for the present project.

### Arduino Nano RP2040 Connect

The Arduino Nano RP2040 Connect features the same RP2040 chip as the aforementioned Raspberry Pi Pico W. The main differences are the replacement of the CYW43439 chip by the u-blox Nina W102 module, which also provides single-band 2.5GHz Wi-Fi operation and supports Bluetooth 4.2 [11, 15]. It is currently priced at 30.74€ ($31.35), meaning it is significantly more expensive than the Raspberry Pi Pico W. It is more advanced technically speaking, as it features various additional sensors, such as a gyroscope, microphone or a cryptographic co-processor, that are not relevant for this project [11].

### Raspberry Pi Pico 2 W

In August of 2024 Raspberry Pi Ltd announced a successor to the Raspberry Pi Pico W, the Raspberry Pico 2 W, that is based on the enhanced RP2350 chip [16-18]. While the new board is more powerful than its predecessor, featuring a dual core ARM Cortex-M33 processor running at up to 150MHz [18], the same CYW43439 is present on the board, leading to no changes in wireless connectivity. The price of the Raspberry Pi Pico 2 W is given at 7.90€ ($8.30) by the official vendor BerryBase GmbH [19].

### Puck.js

The Puck.js is a compact, energy-efficient Bluetooth Low Energy (BLE) development board designed for wireless applications. It is based on the Nordic Semiconductor nRF52832 chipset [20], featuring an ARM Cortex-M4 processor and integrated radio communication capabilities [21]. The onboard nRF52832 chipset supports BLE 5.0, allowing for reliable data transmission and interaction with other BLE-enabled devices such as smartphones, computers, and embedded systems [20-22]. The Puck.js board is equipped with various built-in sensors and features, most importantly for this project a push-button for user interaction [22]. The Puck.js is designed for long battery life, operating on a standard coin-cell battery (CR2032) for extended periods [22]. Unlike many microcontroller boards that require compiled firmware development, Puck.js can be programmed using JavaScript through the Espruino interpreter, which makes development highly accessible, as code can be written and executed directly from a web browser via Web Bluetooth [21]. It currently retails for £32.40 ($40.88) in the official Espruino webshop [22].

## Software

After delving into the state of the art hardware, this chapter shall give an overview of the state of the art of the used software.

### Earle Philhower Core

The Earle Philhower Core is an Arduino-compatible core designed specifically for the RP2040 and RP2350 families of microcontrollers [23]. By bridging the gap between the robust features of the RP2040 & RP2350 and the ease-of-use provided by the Arduino ecosystem, this core allows developers to write, compile, and deploy code using the Arduino IDE [23]

The core is designed to be compatible with a wide range of existing Arduino libraries [24]. This compatibility minimizes the need for extensive code rewrites and allows for the quick migration of projects from other Arduino boards, such as the Arduino Pro Micro, that is used in the FABI sytem. The Earle Philhower Core provides many SDKs, that are needed in this project, such as an SDK for BLE and Wi-Fi, that are used in this project [24]. Additionally, Philhower [23] provides many detailed examples on how to use the SDKs on his GitHub page.

### BLE

### WIFI

# Requirements

This chapter will give an overview of the requirements of this project, i.e. which features need to be implemented. First, the hardware on which the project must run will be stated. Afterwards, the required user features will be discussed.

## Required Hardware

As this project features BLE, the required hardware features both an BLE central and a BLE peripheral device. Both will be stated in the next parts.

### Raspberry Pi Pico W

To provide an update to FABI, the main processing board and the BLE central devide has to be the Raspberry Pi Pico W, introduced in Chapter 2.2.1. While the Raspberry Pico 2 W is an updated version, it is rather more expensive and does not provide any additional features, that are required for this project. While not explicitly testing for compatibility, it is assumed, that the project will work on the Raspberry Pi Pico 2 W as well, as the Philhower Core explicitly also covers the board, and the wireless communication chip has not changed from the predecessor.

### Puck.js

The BLE peripheral device, that recognizes the user induced button presses has to be the Espruino Puck.js, which was introduced in Chapter 2.2.4. As stated before, that device fulfills all needs of this project, as it features an onboard push-button and is able to establish a BLE connection.

## Required Software

After having introduced the required hardware, next the required software will be introduced. This includes both the programming language, as well as the IDEs.

### C++ and Arduino IDE

The software, that will run on the Raspberry Pi Pico W, has to be programmed in C++ using the Arduino IDE, analogous to the original FABI project. The required core is the Philhower Core, that has been introduced in Chapter 2.3.1.

### Javascript and Espruino IDE

## Functional Features

### User Interface

### Connection of Puck.js

### Button Presses

# Design

### Hardware

### Software

# Implementation

## Raspberry Pico W

### Setup

### Wifi User Interface

### BLE

### Button Mapping

### Key Presses

### Main Loop

## Arduino Nano RP2040 Connect

### Setup

### Wifi User Interface

### BLE

### Button Mapping

### Key Presses

### Main Loop

# Evaluation

## Test

## Limitations

### One Button vs Multiple Buttons

Multiple bottons are supported on the Arduino, but not on the Raspi

### Wifi vs BLE

Chip does not support both at the same time.

### USB HID vs BLE Periperal

If the Puck.js shall be connected via BLE, then the computer cannot be connected via BLE, as the Raspberry can be either LE Central or LE Peripheral

# Results and Discussion

## Comparing the requirements

### Required Hardware

### User Interface

### Connection of Puck.js

### Button Presses

## Discussing Future Work

# Conclusion

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List of Abbreviations

|  |  |
| --- | --- |
| FABI | Flexible Assistive Button Interface |
| USB HID |  |
| I/Os |  |
| BLE | Bluetooth Low Energy |
| GPIO? |  |
| SDK | Software Development Kit |
|  |  |
|  |  |

Documentation table of AI-based tools

|  |  |  |
| --- | --- | --- |
| **AI-based tools** | **Intended use** | **Prompt, source, page, paragraph...** |
| **DeepL Translate** | Translation of an article in English | Source (XXX), Chapter X on page X-X |
| **ChatGPT (4.0)** | Grammar and spelling | "Please list issues with spelling and grammar in the following text: ..." Entire document |
|  |  |  |

Appendix A: Code for Puck.js

Appendix B: Code for Raspberry Pico W

Appendix C: Code for Arduino Nano RP2040 Connect

Appendix D: Code for Puck.js (for the Connection with Arduino Nano RP2040 Connect)