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DESIGNING A RASPBERRY PI LAB PC

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ABSTRACT

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Sasken Finland Oy is a design and engineering firm specialising in global and domestic design and development of hardware and software products. In the development of its projects Sasken uses Lab PC's every day from which to help develop its prototypes. These Lab PC's are therefore an important and integral tool for all engineers within Sasken. A desire to create a more versatile and portable system led to the idea behind this thesis.

Within this thesis the author focuses mainly upon the designing of a Lab PC with a Raspberry Pi as its base. The author firstly establishes the needs and requirements before moving on to describe and discuss the Raspberry Pi and its suitability. The author then takes a look at some of the suitable hardware available from which to expand it, and the software possibilities, based upon the established requirements. The author also produces a basic proof of concept prototype and gives some examples of its possible uses. Finally, the author evaluates the practicality of creating such a system and offers ideas on further research and development of the prototype produced within it.

Key words

GPIO, Hardware, HAT, Prototyping, Raspberry Pi, Software

CONCEPT DEFINITIONS

GPIO

General Purpose Input Output. GPIO is a standard interface that is used to connect microcontrollers to other electronic devices such as sensors and displays.

HAT

(Hardware Attached on Top) hardware add on designed for use with Raspberry Pi series

HW

Hardware

IDE

Integrated development environment

OS

Operating system

RPi

Raspberry Pi

SPI

Serial Peripheral Interface

SW

Software

ABSTRACT

CONCEPT DEFINITIONS

CONTENTS

APPENDICES

FIGURES

TABLES

1 INTRODUCTION

The idea for this thesis was given by Sasken Finland Oy. Sasken Finland Oy is a design and engineering company with offices located in Kaustinen and Tampere. It specialises in the design and development both of hardware and software products. It also provides many services for the telecommunication industries, defence, medical industry, and satellite communications serving. Sasken Finland Oy has developed a strong and successful record in the delivery of R&D programs with a particular expertise in wireless technology. (Sasken 2022.)

Within its projects, Sasken uses many Lab PC's from which to test its prototypes and control other testing equipment. Each department speciality has its own unique uses for a Lab PC. The ability to test and develop prototypes reliably, and to a high standard, is an important and integral part of R&D prototyping to ensure the continuation of quality products. As well as being reliable, a Lab PC needs to be durable and withstand the environment in which it is used. An idea was proposed that a more portable and affective design could be made by basing a system around a Raspberry Pi (RPi) and using HATs (hardware attached on top), to expand it and meet the differing and specific needs. Therefore, a need to research and test the possibility of such as system arose.

1.1 Objective

The objective of this thesis is to explore the possibilities and design a small, portable, and robust Lab PC for use with prototyping (hardware and software) within Sasken Finland. The PC is to use a RPi as its base and utilise HAT's where possible to expand it as needed. The RPi Lab PC is not meant to be a replacement for the day-to day working laptop but is rather an addition to the tools that the engineers can use within their projects. A Lab PC based upon a RPi is hoped to bring greater portability, usability, customisations, and control over the various devices required and used in prototyping, whist also being cost affective.

1.2 Scope of the thesis

The main scope of this thesis will be in the designing of such a PC, focusing in particular in the hardware and software requirements. It will look at and assess a selection of the various hardware available to best meet the needs of the project. A basic proof-of-concept prototype of a RPi Lab PC will be made if possible, incorporating the main basic required features as available. The design will be assessed to establish if it would be a viable option for use within Sasken. Issues on connection to the network drives, security and the possibility of custom-made casing will not be addressed within the scope of this thesis.

1.3 Structure of the thesis

The thesis will firstly establish the requirements and determine the essential features required for the Lab PC. This involves looking at what the current uses and methods are and gathering requirements from the users, paying attention to the hardware, as well as software that will be required. Secondly the thesis will then look more in depth at all the different and possible hardware available to fulfil the requirements. It will look at the suitability of the hardware for its use and compare options where appropriate. It will consider any potential conflicts between hardware and take this into account when designing. It will then continue to look at the software available starting with the operating system and continuing to the software currently used and its suitability and availability for use with the RPi. Lastly it will look at the possible ways in which the RPi could be used within Sasken.

1.4 Research methods

Due to the nature of the project much of the research information will be taken from technical specifications for the hardware or software, other technical publications, forums, hardware reviews and articles. Discussion with manufacturers on product suitability and use will be used where necessary. Informal meetings and questionnaires with key engineers will also be used to gather requirement information.

2 ESTABLISHING REQUIREMENTS

To design such a system, it is important to understand the current system and how it is used, what its downfalls are and what improvements are needed or desired from a new Lab PC. The requirements gathering was therefore the first step on this thesis project. To establish the requirements, questions were asked from key engineers within Sasken on what and how they currently use their Lab PC. They were asked particularly what they feel is essential and what they would desire in a new Lab PC with a view to making it easier to perform their testing tasks. The results were then analysed, and the requirements established along with potential problems that could affect the project.

2.1 Requirements Gathering

Different engineers in different department specialities, will have different priorities and needs when it comes to a Lab PC. Therefore, a selection of key engineers representing the different department specialities were asked for their requirements. In all eight key engineers from different specialities including Hardware, Software, Mechanics, and R&D, were asked firstly for information on their current system and then for their opinions on what would be essential requirements for such as system. They were also asked what would be desirable to have in such a system.

The requirement gathering was done via email and a meeting held at Sasken Finland premises. In the meeting five key engineers attended in person, and one attended online via Teams from the Tampere branch. In addition, responses were also received via internal email where they were unable to attend, or where there were additional thoughts after the meeting.

The attendees (and those via email) were asked to consider the following questions,

1. What do you use your current Lab PC for?

2. The RPi 4 comes with 2x USB 2 ports and 2x USB 3 ports, 2x HDMI, Gigabit Ethernet, Wi-Fi, and Bluetooth connections. What other types of connections would you require as essential?

3. What software do you currently use and would require in a new system?

4. Are there any features (connections or software etc) you would like to have that would make it more appealing to you to use over your current Lab PC?

5. Are there any other thoughts/information on what you feel would be important? or any problems you would have to use this type of Lab PC?

2.2 Requirement results and analysis

Responses to the requirements gathering were given from six key engineers from different specialities and the responses (APPENDIX 1). Overall, the responses were insightful and gave a good overall view of the basic features required and what would be desirable. The results were however as anticipated. It was clear that the different departments/specialities had vastly differing needs and requirements from each other. It was also noted that the needs can greatly differ from project to project, regarding both the hardware needed and software needed. In this respect the results were also disappointing as no real clear use cases could be given.

With such a variety of potential requirements coming from the different departments, and the unknown variables of each project's needs, to build a prototype with all options or eventualities available would neither be cost effective or feasible. Therefore, to keep the project and thesis manageable, it was necessary to narrow the scope of the project. Finding a middle ground from which to develop a basic prototype will mean concentrating on the more commonly used aspects.

Despite some very differing requirements and unknowns, there were still similarities. Most felt that remote access was a must and SPI, UART connections along with some control over the GPIO being desirable and ability to communicate or have some type of connection with LabVIEW.

2.3 Design Requirements

After analysis of the requirements the general requirements that cover the common aspects required are relatively few, and are given below,

1. The Lab PC shall design be kept as small and durable as possible.
2. The Lab PC design shall make use of HATS or other modules to ensure as many of the required connection types are available. Mainly RS232, RS485.
3. The Lab PC shall allow for remote access and operation.
4. The Lab PC shall include the appropriate basic software.
5. The lab PC shall be designed with the needs of different departments and project needs in mind.

2.4 Potential Problems of Design Phase

There were a few anticipated problems that could arise and affect the progress of the project. Problems with the availability of desired parts is one of the main concerns in projects such as this. This includes not just the physical availability but also the location and reliability of those available parts. The global chip and component shortage that began with the Covid pandemic is still at this point in time impacting on the manufacturing of many goods and potentially may affect the ability to get some HATS/modules (Pennisi 2022, 41-49).

Incompatibility with required software and the RPi OS could mean finding alternative software causing training and ease of use issues. Connection to the company's internal network drive may also be problematic, although for the scope of this project/thesis that will not be addressed.

Finding suitable HATs that can be used together may be an issue. It is not recommended to stack HATs, although in some cases it is able to be done, it can potentially result in damage to the RPi or the HAT. Many HAT's have pin conflicts that cause them to be incompatible with each other for stacking without some kind of modifications. Other problems may be the ability to find a suitable case once HATs are installed. It may be that the case will need to be custom made to meet the needs.

3 RASPBERRY PI OVERVIEW

The main requirement of this project is to use a RPi as a base for a Lab PC. RPi is a series of microcontroller boards and single board computers that have been developed by the UK based charity Raspberry Pi foundation, with collaboration from Broadcom. The Pi's single board computers function essentially as a minicomputer. As such, along with a display, keyboard, and mouse, can perform the same tasks as that of any other computer. The RPi is Linux based and utilizes open-source operating system and applications. It also supports many different programming languages which has made it an ideal choice in recent years for use in embedded system projects and industrial applications. (Raspberry Pi Foundation 2022.)

3.1 History of the Raspberry Pi

The concept for the RPi was first born in 2006 with Eben Upton. Eben was at the time, the Computer Studies Director of St Johns College of Cambridge, when he began to notice a drop in the numbers and abilities of those enrolling to become computer engineers. Eben therefore embarked on a mission to increasing those dwindling numbers and improve upon their abilities. Upton and a group of researchers, set out to create an affordable computer in the hopes of improving the situation. The first prototype was named ABC Micro and its design was inspired by the BBC micro. In 2009 Upton and his fellow researchers set up the Raspberry Pi Foundation and continued with their mission, creating various prototypes along the way. (Severance 2013.)

In 2012 the first RPi was launched. Since then, there has been several new releases of the RPi, comprising of a variety of versions and iterations. The very first Pi comprised of a mere 700MHz CPU and had only 256 RAM. Today its latest model the RPi 4, comprises of a quad core CPU of 1.5GHZ and up to 8 GB Ram. The advantage the RPi holds over many other single board computers, is that its price is notably low making it a realistically affordable option to those who otherwise would not be able own a computer. The RPi however can also be used for more than a cheap computer, its GPIO pins also make it possible to add and control electronic components making it an option also within embedded system projects. Today the Pi is used worldwide to learn programming skills as well as being used in many different embedded system projects from hardware, automation, and industrial applications. (opensource.com 2022.)

3.2 Advantages of the Pi

The Pi as mentioned previously, offers a cheaper alternate to that of conventional laptops and PC's. It is small and compact, with its latest iteration the Raspberry Pi 4 Model B, being around the size of a credit card. Being so small it also offers a much lower power consumption to that of a standard PC. It is easy and simple to use and its GPIO pins make for easy connection to a wide range of other hardware devices and peripherals. This makes it particularly customisable and useful. (Raspberry Tips 2022.)

3.3 Disadvantages of the Pi

The RPi lacks the internal memory of a regular PC, and the use of an SD card is required for internal storage. This can lead to boot time being slower due to the read and write speeds of the SD card. It also lacks a Graphics processor rendering it ineffective in cases of heavy video or photo editing. There is also the problem of overheating; the processor is still quite powerful, yet the board does not have heatsink or fan integrated into it. For this reason, average use time is only approximately 6-7 hours for continual use without some kind of cooling fan. Another major disadvantage is that Windows OS is not made for, or rather not supported for, use on the RPi. This may lead to compatibility issues with some of the software's that may be needed and with the ease of use for those more accustomed to the Windows OS. (Hirak, Solanki & Sahu 2021.)

3.4 Choosing the Raspberry Pi - Raspberry Pi 4 Model B

There are numerous versions of the Raspberry Pi and therefore which model to use needed to be decided. Considerations when deciding which to use were the processing speed, memory, performance, and life cycle. The Raspberry Pi Foundations official magazine, The MagPi, in its issue 83, conducted benchmarking tests comparing the performance of the various types of Pi's. The tests compared CPU speeds, responsiveness of web browser running a web application, memory bandwidth and much more (APPENDIX 2). The RPi 4 Model B excelled in all areas. (Zwetsloot R, 2019.)

The Pi selected for use within this project is the Raspberry Pi 4 due to it being the newest addition to the Pi family and its exemplary benchmark testing performance compared to the others. The Raspberry Pi 4 is described by its creators as a tiny, dual- display, desktop computer. Figure 1 shows the Raspberry Pi 4 Model B with its main parts and connections. A link to the full list of specifications for the RPi4 can be found from appendix 4.

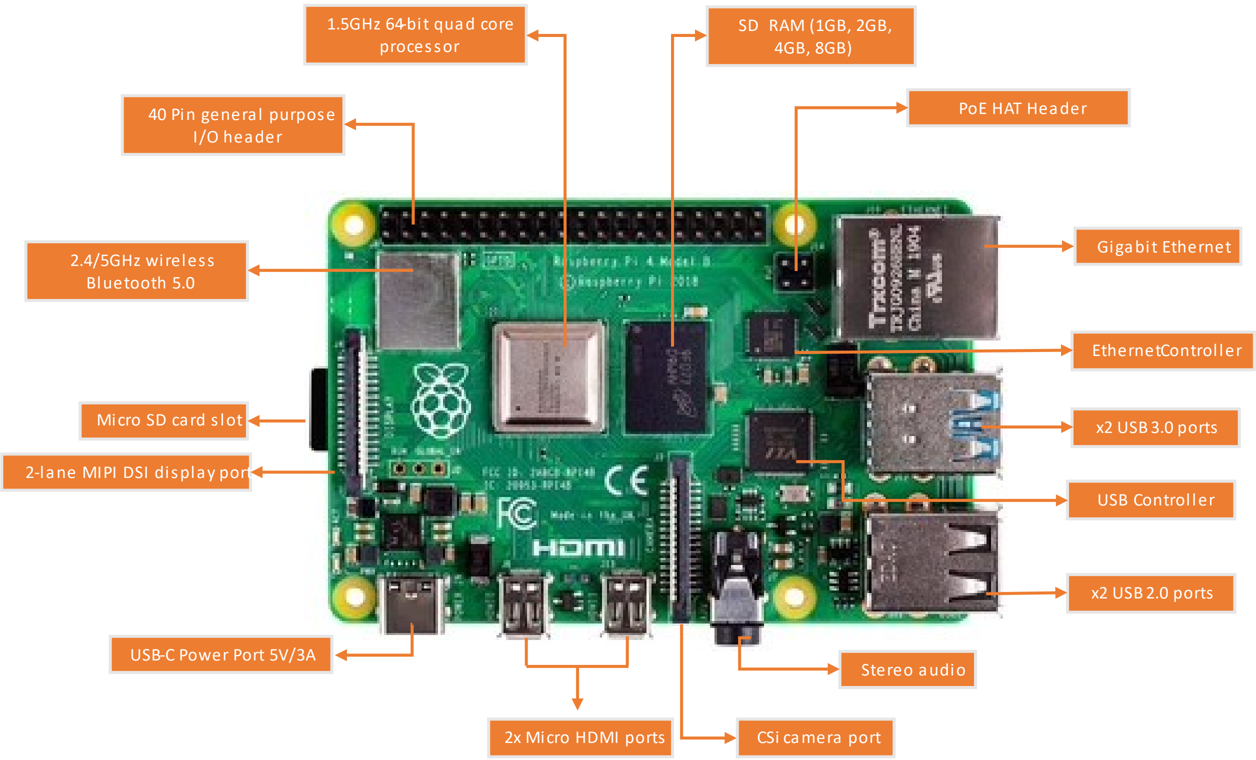

FIGURE 1 Raspberry Pi 4 Model B main board parts (Raspberry Pi 2022e).

This latest model differs to the older ones in that it now comprises of two mini-HDMI ports, allowing two 4K monitors to be run at once. It also claims to be much more energy efficient and cost effective than other machines. This model also offers, for the first time in its iterations, a choice of SD RAM sizes. The RPi 4 offers models of 1GB, 2GB, 4GB and 8GB. (Raspberry Pi 2022a.)

There is presently however a supply problem with all versions of the Pi 4 Model B, especially the 4GB and 8GB, with a severe lack of availability and long wait times on stock. A recent article in techcrunch.com, touches the issue of these shortages as stemming from the previously mentioned global supply shortage, which is causing global supply chain distribution problems, with many products on backorder until 2023 (Lomas 2022).

Fortunately, a Pi 4 was already available for use within Sasken, and the model used for this project is the 8GB version. The inability to purchase another board however should this one fail means avoiding unnecessary risks with its prototype build and therefore HAT's/module choices must be made wisely as to avoid any damage to the Pi.

3.5 GPIO Header

GPIO pins are what aids the RPi to perform various functions, with some pins acting as inputs and other outputs. Each pin on the RPi is assigned a specific function or functions.

By running the **pinout** command in the command line of the RPi, it is possible to see the position of the pins on the board as well as other useful information about the Pi. Running the command `raspi-gpio get` will return the status for all GPIO pins and running the command `raspi-gpio <gpio pin number>` will return the status for the GPIO pin requested, (FIGURE 2.)

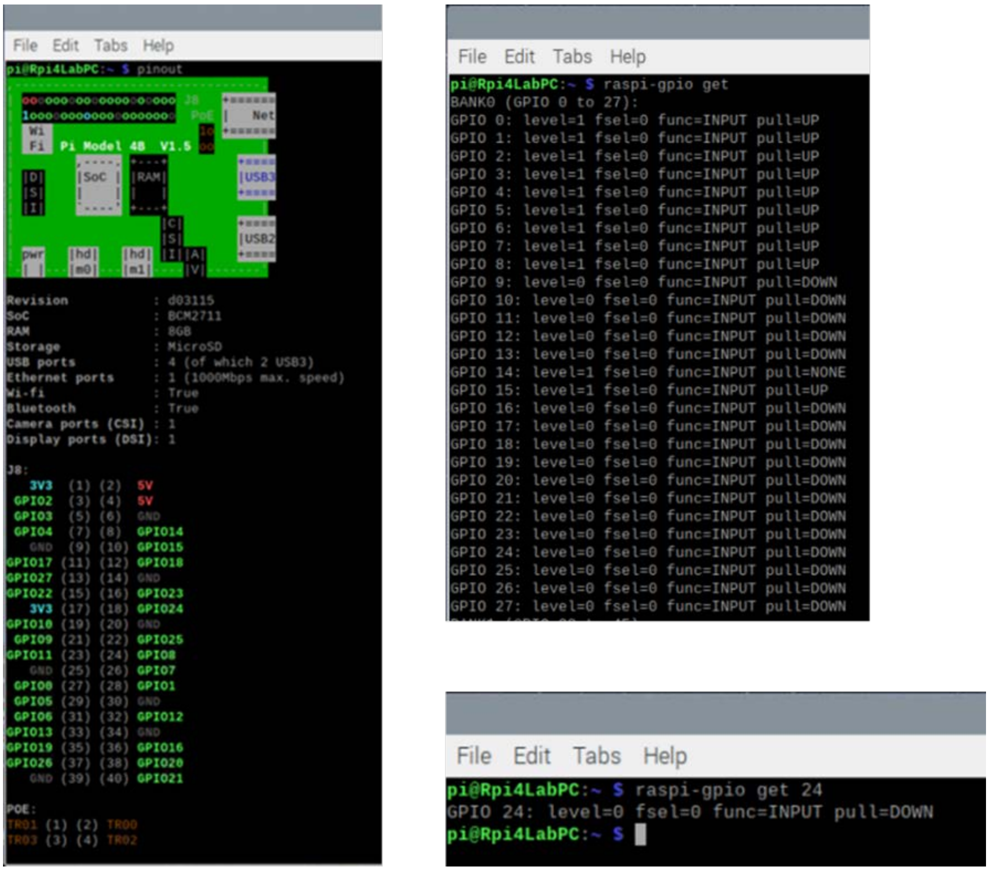

FIGURE 2 GPIO Pin commands

The GPIO of the RPi 4 has 40 pins and from those 40, 26 are GPIO pins. Of the 14 remaining pins there are,

- 8 ground pins (Pins: 06, 09, 14, 20, 25, 30, 34 and 39),
- 2x 5V DC power pins (Pins: 02, 04),
- 2x 3.3V DC power pins (Pins: 01, 17) and,
- 2 reserved pins for I2C and EEPROM (Pins: 27, 28)

Of the 26 GPIO pins, all can be used for software Pulse Width Modulation (PWM), where a digital signal is converted into an analog signal, but only 4 are able to perform hardware PWM. Other pins are used for Serial Peripheral Interface (SPI) communication which allows communication between attached devices such as sensors. 2 pins are reserved for use with Universal Asynchronous Receiver Transmitter (UART) communication. One of which is used for the transmitting of data, and the other for the receiving of data. There are also an additional 4 more pins that can be enabled for use with UART. (Khan, A. 2022.)

FUNCTION	BCM	PIN#	PIN#	BCM	FUNCTION
3.3V		1	2		5V
GPIO/SDA1(I2C)	2	3	4		5V
GPIO/SCL1(I2C)	3	5	6		GND
GPIO/GCLK	4	7	8	14	TX UART/GPIO
GND		9	10	15	RX UART/GPIO
GPIO	17	11	12	18	GPIO
GPIO	27	13	14		GND
GPIO	22	15	16	23	GPIO
3.3V		17	18	24	GPIO
MOSI (SPI)	10	19	20		GND
MISO (SPI)	9	21	22	25	GPIO
SCLK (SPI)	11	23	24	8	CE0_N (SPI)
GND		25	26	7	CE1_N (SPI)
RESERVED		27	28		RESERVED
GPIO	5	29	30		GND
GPIO	6	31	32	12	GPIO
GPIO	13	33	34		GND
GPIO	19	35	36	16	GPIO
GPIO	26	37	38	20	GPIO
GND		39	40	21	GPIO

Note: RESERVED are for EEPROM usage

FIGURE 3 Map of GPIO pins for the RPi 4 (ElectronicWings 2022)

Figure 3 details a map of the GPOI pins, their BCM and board numbers, and their intended purpose. The reserved pins shown are reserved for the EEPROM. The label names of the pins are a little disorganised and this can lead to some confusion when needing to write them into programs. The GPIO numbering refers to the Broadcom (BCN) pins of the system chip to which they are connected, and this is why it does not follow a logical order. However, sometimes they may also be referred to by their physical/board number. Therefore, it is essential to ensure you are connecting any hardware to the correct pins and that they are referred to correctly and the numbering system in use declared in the program to avoid any damage to the Pi or hardware.

GPIO pins can be configured as either input or output. Output is set at either high or low and input is read as high or low. High being 3.3V and low 0V. Voltages between 1.8V – 3.3V are read as high and lower than 1.8V read as low. It is important not to use a voltage above 3.3V for input to avoid damage to the RPi. (Future Learn 2022.)

4 HARDWARE AND BASIC REQUIREMENTS

This section looks at other hardware and basic peripherals that will be needed for the project. It addresses them from the basic I/O devices required to the potential HATs and other hardware modules that can be utilised to fulfil the requirements. It describes the various hardware options available and give reasons for its consideration where appropriate. It also touches on the availability of the part if necessary and any compatibility issues. Additional technical information and descriptions on all the hardware and HATs mentioned can be found from the links in Appendix 4.

4.1 Power supply

The RPi 4 requires 5V/3A Power Supply with USB C connection, and it is recommended to use the official Raspberry Pi Power Supply. The supply has the following basic specifications,

- 5.1V / 3.0A DC output
- 96-264Vac operating input range
- Short circuit, overcurrent and over temperature protection
- 1.5m 18 AWG captive cable with USB-C output connector

However, if this is to be truly portable, it is a good idea to have some kind of portable battery/power bank. There are numerous onboard solutions available to use with the RPi. One such solution is the PiJuice HAT shown in figure 4. This attaches to the RPi board and can utilize many different size batteries. It is also available as a 6- or 12-Watt Solar Panel option. The charge time will last for around 6-12 hours at the basic 1820mAh and up to 24 hours or more with the 5000mAh or 12000mAh batteries. It offers multiple power management options for all situations and uses.

One advantage of this HAT is that it is possible to disable its EEPROM and change its I2C address to enable compatibility and use with other HATs. The PiJuice costs around 70€ so is not a cheap option, but it does seem to offer a good solution to making the Lab PC truly portable. However, the RPi uses a USB C connection so it is also an option to use any power bank such as would be used with a smartphone.

FIGURE 4 PiJuice rechargable battery HAT for RPi (Pi Supply 2022)

4.2 Keyboard, Mouse, and Display

Any USB, wireless or Bluetooth keyboard and mouse can be used with the RPi 4. The idea is that this would be portable and could be used with the keyboards and mouse found already in the Labs if not needed to run remotely. The RPi 4 has 2 Micro-HDMI ports and therefore requires a Micro-HDMI to HDMI cable to enable use with any monitors with HDMI connection. It is hoped that again this would be able to be connected to existing equipment found in the Lab if needed.

4.3 Cooling Fan

As discussed earlier, the RPi does not have any type of cooling. Once the Pi's built in temperature sensor exceeds a threshold of 82 degrees, thermal throttle will then begin. This works by reducing the clock speed of the CPU in a bid to prevent overheating and prolong the lifespan of the Pi, making the Pi lag or even shutdown. Where the risk of overheating may not be a problem for some basic short-term usage if it is to be used more regularly and for prolonged periods of time, then a cooling fan may be of some benefit. (Bardwell 2022.)

Therefore, the addition of a cooling fan to the Lab PC would be a cheap solution in extending the efficiency and lifespan of the Lab PC. When choosing a fan consideration needs to also be given to another HATs that is onboard and how it can be integrated to be most effective. There are numerous types of fans available both available individually and as part of casing. Figure *5* shows an option that also comes with an aluminium case as well as a simpler bolt on option.

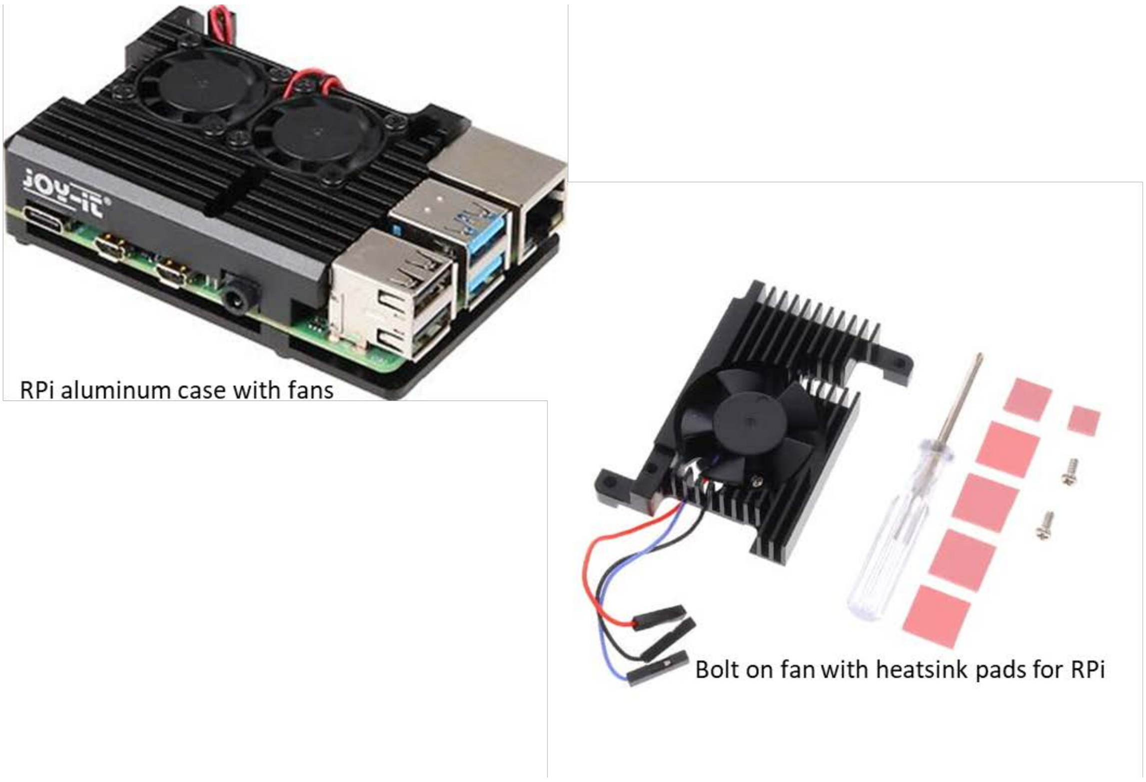

FIGURE 5 Example of the types of fans available for RPi 4 (Tom's Hardware 2022)

4.4 Storage

The RPi 4 does not have onboard storage and therefore a good quality and high-capacity microSD card is required. Alternatively, a USB SDD can be used from which to boot the Pi and address any larger storage needs; or it can be used alongside the SD card. For this project a 32GB microSD card was used. The ability to connect the Pi to the internal network would also allow for more storage solutions. It would also be an option for to backup and save project specific OS images upon the project's completion.

4.5 Hardware Attached on Top (HAT)

Firstly, it should be defined what HAT is and its uses. HAT, or Hardware Attached on Top is additional hardware that extends the functionality of the RPi and is designed to fulfil a specific purpose. There are numerous HATs available for a variety of purposes and functions such as taking measurements from attached sensors or receiving Power over Ethernet (POE). HATs have been designed especially for use with RPi Model B+ boards. They are as it says, hardware attached on top and are simply plugged into the GPIO of the RPi without the need for any soldering making it easy for to customise any project. (OKdo 2022.)

The RPi model A and B differ in the amount of GPIO connector pins they have, with the A there is 26 and B models 40. With the model A, using any add-ons usually meant having to work around and edit drivers to make them loadable from boot so that the RPi knows that a board is there and make it usable. This often led to mistakes and problems due to its complexity especially for those inexperienced. The model B+ design took these previous challenges on board, most importantly the one being the issue of identifying and configuring the board. With the model B+, HATs drivers are automatically loaded and its GPOIs configured. The B+ boards 40 pin GPIO header is what gives it this ability. It utilises 2 dedicated pins reserved for I2C EEPROM. It is the EEPROM that contains the information of the board such as, manufacturer, GPIO set up and device tree fragment. It basically contains all the information needed about the attached hardware so that the Linux based OS can load the drivers automatically. (Adams 2014.)

For all the EEPROM has made the use of HATs easier regarding drivers and configuration it also brings a set of problems regarding compatibility. As noted previously, HATs are not designed to be stacked, and the Pi design allows for only one EEPROM. Stacking HATs each with their own EEPROM will lead to conflicts upon boot and result in the 'Rainbow Screen of Death'. There are however ways around this problem, as long as there are no pin conflicts, but to do this means losing the auto configuration. (Watkins 2020.)

4.5.1 Waveshare Isolated RS485 RS232 HAT For Pi

One of the main common requirements was for SPI. In the prototyping phase particularly, many projects require some kind of serial interface connection for communication purposes. There are numerous options available for RS232 or RS 485 individually, but this HAT offers both RS232 and RS485 connections together on one HAT. It has been specifically designed by Waveshare for use with the Raspberry Pi series boards (FIGURE 6).

At under 25€ this would also be a cost-effective addition and solution to the often-required connections during prototyping. Amongst many other features its main features are listed as,

- A standard RPi 40Pin GPIO header supporting Pi boards.
- Converts SPI to one RS485 and one RS232.
- Features an onboard resettable fuse and protection diodes ensuring stability of output for RS485 current and voltage.
- Breakout SPI control pins, for connecting with Arduino and other host control boards.

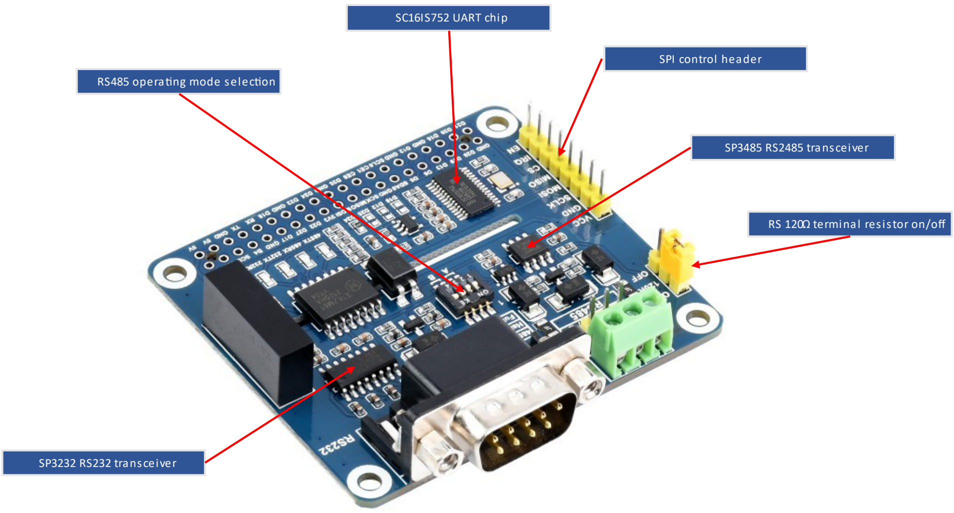

FIGURE 6 Isolated RS232 RS485 Hat and its main components (Waveshare 2022a)

4.5.2 Waveshare USB TO RS232/485/TTL Interface Converter, Industrial Isolation

This module is given as an alternative to the previous one that offered RS232/RS485. This is not a HAT, but rather an external module enclosed in an aluminium case that offers RS232, RS485 and TTL (UART) via bidirectional USB conversion. It comes in two versions, the FT232RL or CH343G, which differ only in the type of chip used, the basic functionality remains the same for both (FIGURE 7). This could be a suitable alternative to still providing serial connections in issues where the previous RS485 RS232 HAT causes pin compatibility issues with other HATs.

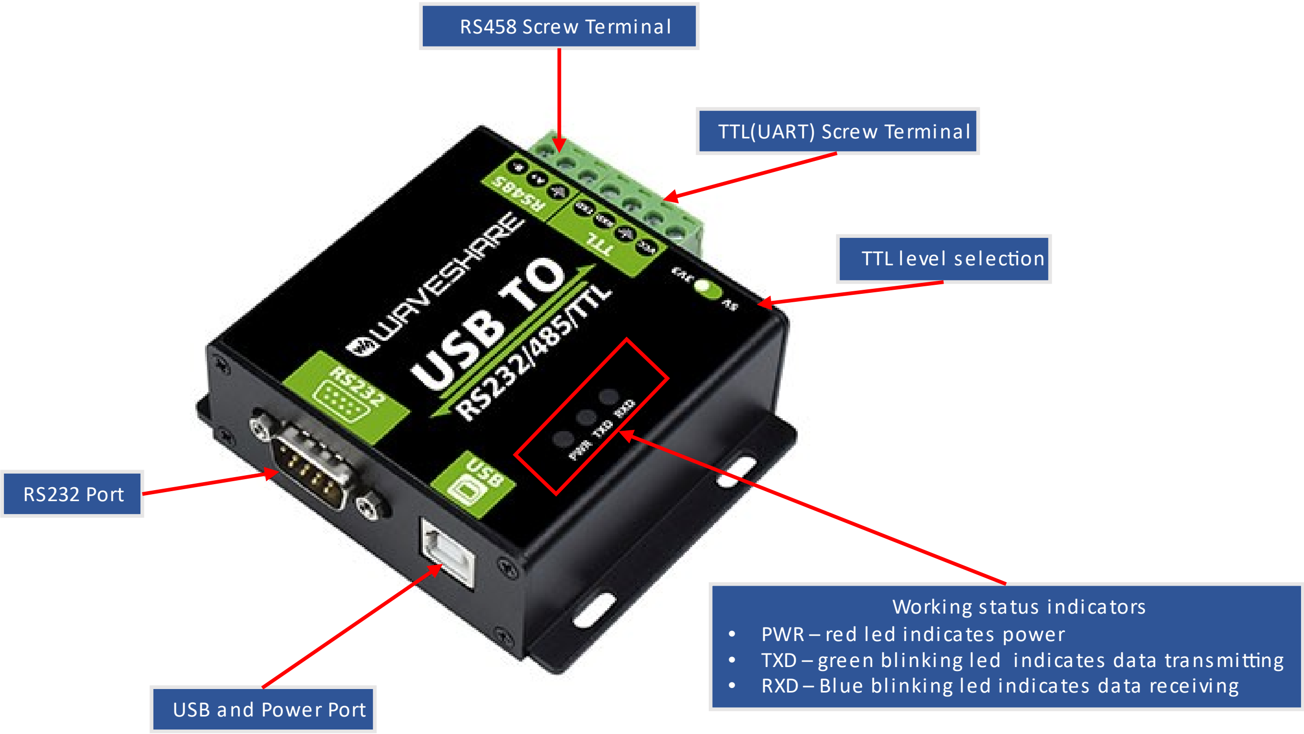

FIGURE 7 USB to RS232/485/TTL convertor (Waveshare 2022b)

4.5.3 Waveshare Analogue to Digital Converter HAT (ADC)

An ADC was one request that falls into the grounds of desirable and also department/project specific. This HAT allows you to enable high precision AD conversion and it was reasoned that such a module could be useful for some cases in that it would allow the signals to be measured instead of just the ability to monitor the GPIO high/ low states. Figure 8 shows the ADC HAT module and its main features.

The Raspberry Pi is based on digital logic and as such works with binary signals having only two discrete states of a logic "1" or logic "0". Analogue signals, in contrast, have continuously changing values. Therefore, a way from which to convert between these two different types of changing signals and discrete states is required. An ADC does this by taking a kind of snapshot of the analogue voltage at an instance of time and then creating a digital output code representing that analogue voltage. (Electronics Tutorials 2022.)

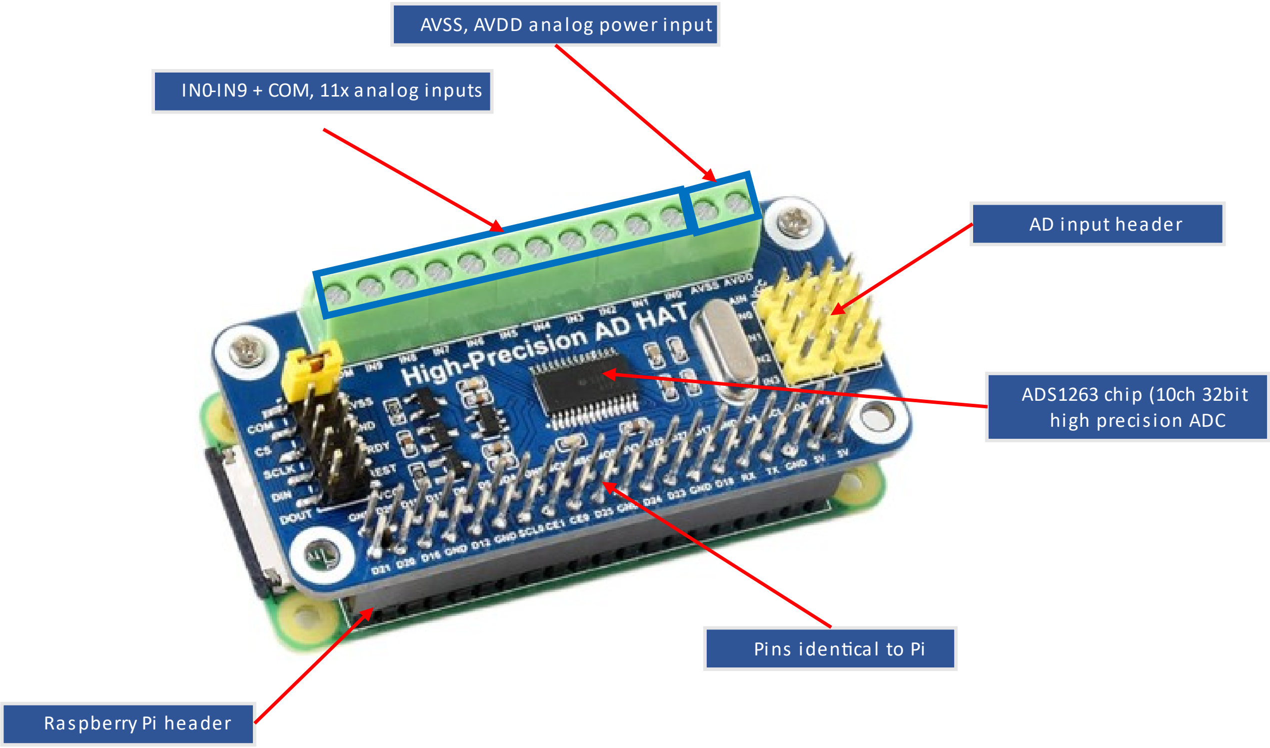

FIGURE 8 ADC HAT Main Features (Waveshare 2022c)

There are compatibility issues however between this HAT and the previous RS232/RS485 HAT. After discussion with the manufacturers (email can be seen in Appendix 3) it seems that they are not stackable in the traditional sense due to pin conflict. There is a way around this by making changes to the hardware, but it is not recommended. It could also defeat the object of the project by making the features not as easily controllable as desired, therefore a few other options should be explored. The previous USB to RS232/485/TTL converter discussed earlier would be one such module that could give a possible solution to the problem. There is a small problem of availability for this HAT with few places stocking it and none of which are within Finland.

4.5.4 PiStack by SB Components

One other possible solution that was explored to combat the stacking problem was the PiStack from SB Components. The PiStack is described as an I/O expansion kit specifically designed for the Raspberry Pi as a means of stacking HATs (FIGURE 9). It provides space for the Pi and up to 3 additions HATS to be added, as well as reserved jumper pads on the underside allowing pin connections to change with soldering. (sb Components 2022.)

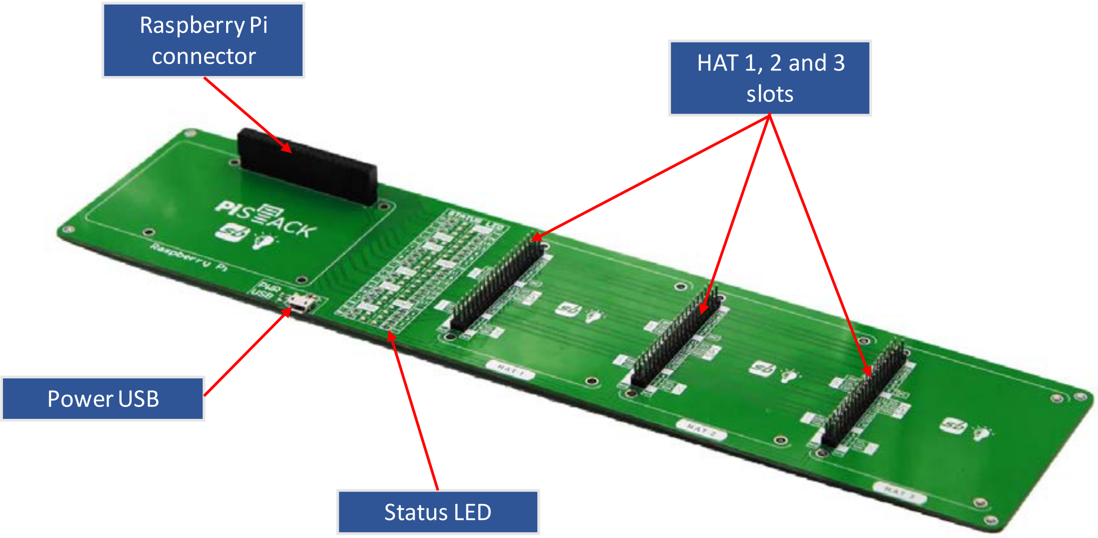

FIGURE 9 PiStack expansion board for Raspberry Pi (sb Components 2022.)

However, after discussion with the manufacturer it seems that this offers no real solution to the conflict problem. It could however make it potentially easier to do stack HATs that do not have such pin conflicts. It would allow for hats to be stacked horizontally as opposed to vertically in the case where multiple hats were needed. This could also help with reducing the risk of overheating when more than one HAT is in use, and also make creating a custom case with access to the necessary parts easier.

4.5.5 Audio interface– Babyface Pro

Currently the audio department is using the Babyface Pro FS as an audio interface (FIGURE 10). This is a 24channel 192kHz bus powered USB 2.0 audio interface. It offers a comprehensive set of connectivity and features for audio work. Although there are various audio hats available non seem to offer such a comprehensive range of features. Therefore, this would be one such area where a RPi Lab PC and HAT is maybe not so feasible.

FIGURE 10 Babyface Pro FS audio interface (RME 2022)

However, it would still be possible to use the Babyface Pro with the RPi 4. Although its driver downloads only support Mac OS and Windows, it also offers class compliant mode making it possible to still connect it with a RPi running a suitable OS.

4.6 Casing

The RPi will also need a case from which to keep it protected from the environment. When considering what type of case to use it is necessary to know what HATs will be used with the RPi and also consider if access is needed to the GPIO header. Cooling as mentioned earlier is also another consideration to consider when deciding. The decision to go for a fan built into the case or a fan as an extra, or maybe even a case with heatsinking to it. There are numerous options when it comes to cases, but most are for use with the basic board or for use with a specific HAT attached. Those that do allow for stacking of

HATs appear to only have the base and top and no encasing for the sides. Although this should still be ok in such an environment as it is to be used it may not offer the robustness required. An RPi tower case is one possibility also for use with hats. This would however, although still small, make it larger than desired. It will most likely be that for this project a case would need specifically designing to suit the needs. However as stated in the introduction, this is not part of the scope of the thesis.

5 OPERATING SYSTEM

Most of the operating systems available for the RPi are Linux based. The official and recommended OS for the Raspberry Pi is the Raspberry Pi OS, which was previously known as Raspbian, but there are also numerous other Linux based options available. Which one to choose will often depends on what its final use will be. Windows is also now possible to install to the RPi but there is no official version of it made for RPi.

One major advantage of the RPi is that you can easily change the OS by simply changing the SD card. It is possible for example to have Ubuntu on another SD card. This could be a solution to use where software is not supported by the RPi OS. It also makes it possible to easily store the full OS image for a particular project when completed.

5.1 Windows 10/ Windows 11

An ideal operating system to ensure that current testing software would be compatible would be to use Windows 10 or 11. It is possible to run Windows 10 or 11 on the Raspberry Pi, but it is not supported officially or recommended to do so. The installation process is a little more complicated also than installing the RPi's own, but there are tools available to help with the process and guide you through it. There is a problem in that many tech forum users that have installed Windows to their RPi, although reporting no major issues, have still found issues with some drivers not working, and report that it tends to run slowly and lag even when not running any large programs. For this project there is also the added concern that it may then be problematic with the functionality, or at least the ease of use of the HATs.

5.2 Raspberry Pi OS

The RPi OS is similar in many ways to Windows OS. Raspberry Pi OS, which was previously known as Raspbian was first released in 2012 and is the recommended OS for use with the RPi. In contrary to its Raspbian predecessor which was available only as 32-bit, the new Raspberry PI OS also offers a

64-bit version. This 64-bit version is Debian ARM64-based and no longer uses any of the former Raspbian code. It is especially aimed for use with the 8GB version of the RPi 4. (Long 2020.)

RPi OS is based upon Debian, which is one of the most popular and well-known Linux packages. The Raspberry Pi OS has also been optimised especially for the Raspberry Pi HATs hardware (Raspberry Pi 2022b).

For this project the official Raspberry Pi OS was installed due to it being the most supported for use with the Pi and for ease of use with configuration and HATs. The version that has been installed to the Raspberry Pi is the 64-bit version (FIGURE 11).

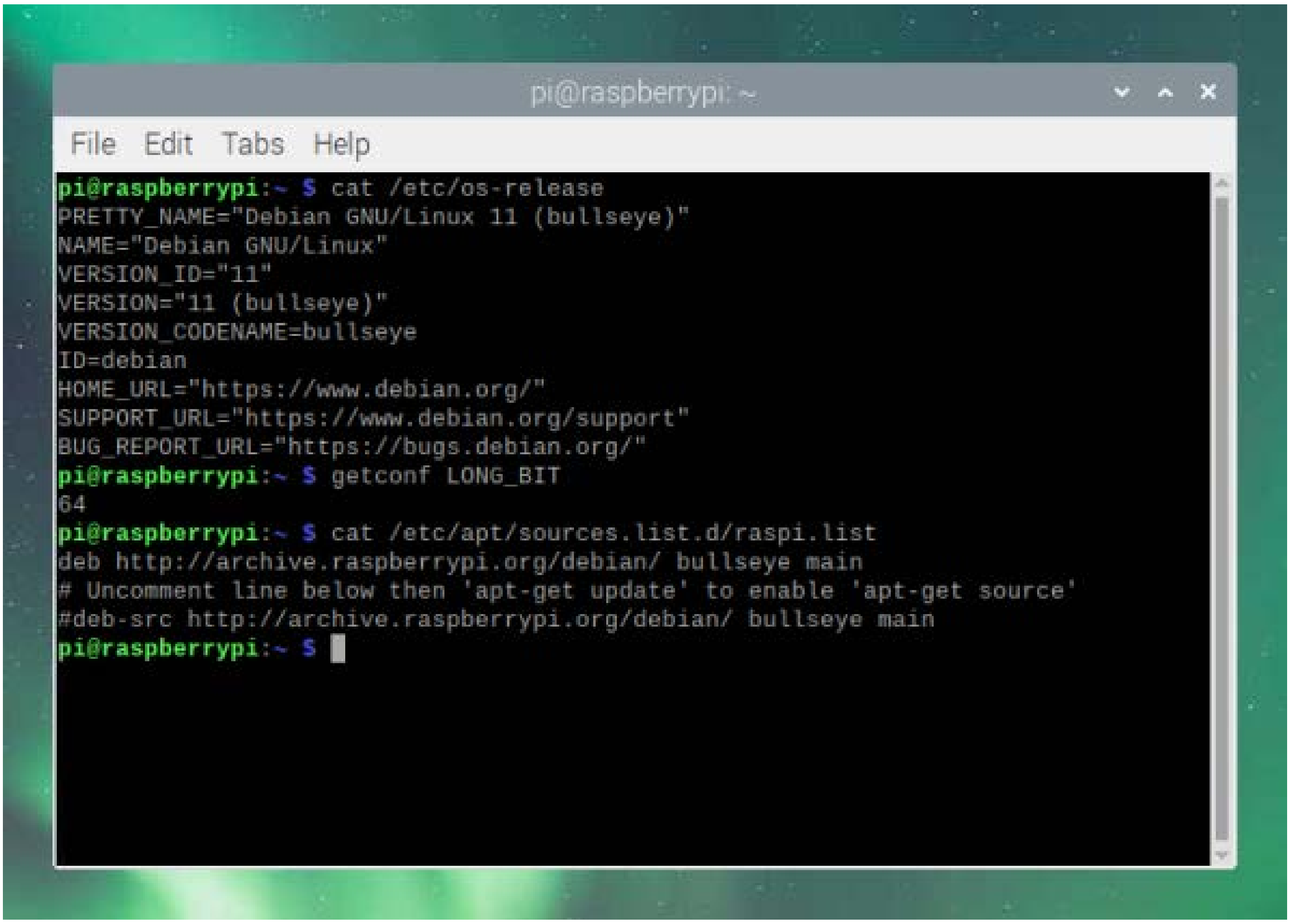

FIGURE 11 Raspberry Pi OS version information

It is also worth noting that it is possible to use the RPi OS image between different RPi models, although where the newest version of RPi OS is backwards compatible for the older versions, the older Raspbian versions may not always be forward compatible with the newer of the RPi’s

6 REMOTE ACCESS

One requirement was that of remote access and it is possible to easily control the Raspberry Pi remotely. The decision on which to use will depends on what is required by the engineer or project. An SSH can be set up if only access to the command line is needed, but it is also possible to control it with a remote desktop. Both can be turned on or off with ease. With the RaspController App it is also possible to control the Pi from your mobile phone. Where all the methods listed below work with ease whilst connected to the same server for the host and remote machines, if wanting to connect from outside of the network then it will require a few extra permissions and settings or the installation of an app such as or Socket XP.

6.1 Headless Installation

It is possible also to install Raspberry Pi OS and set up ssh headless, without ever connecting a keyboard, mouse, or monitor to the Pi. To do this you use Raspberry Pi Imager as you would for the normal installation and access settings menu. From the settings it is possible to set hostname, enable SSH, set authentication type, set username and password, and configure the LAN or WIFI as shown in figure 12. When the SD Card is written and then be placed in the Pi and the Pi powered up all the necessary settings are already there. To connect via shh the IP address is needed.

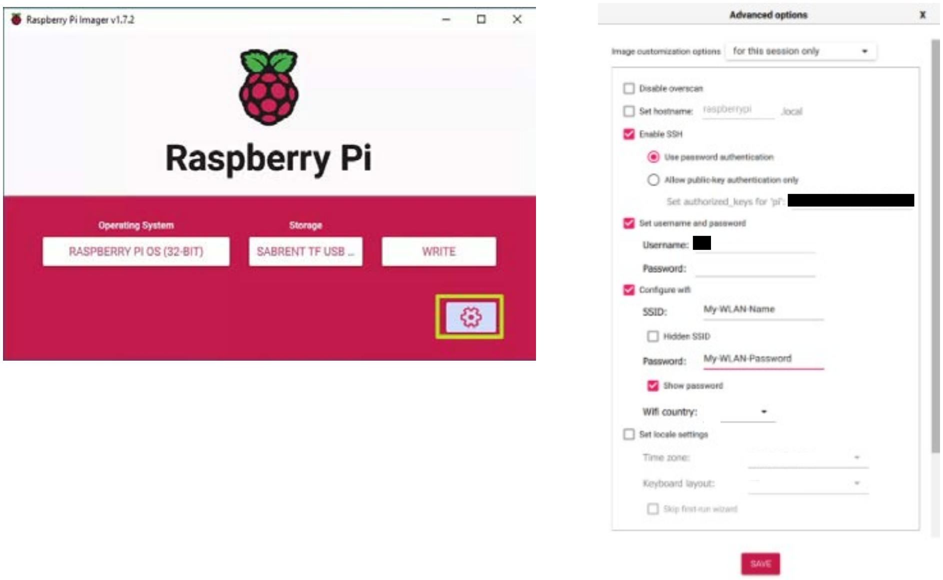

FIGURE 12 Advanced settings for Raspberry Pi Imager - OS headless installation

As long as both computers are on the same network this can be found by opening the command prompt from the operating PC and typing, `ping hostname. local;` replacing hostname with the one selected when setting up the Raspberry Pi OS. SSH can then be used to gain access to the RPi a described previously. When you have access, VCN can then also be turned on by accessing the configuration settings via the command line.

A problem with headless installation and remote access may occur if the Pi is used on a different WI-FI network, for example at a customer's premises. The new network can be added by taking a copy of the file `/etc/wpa_supplicant.conf`, and adding the text as shown in figure 13.

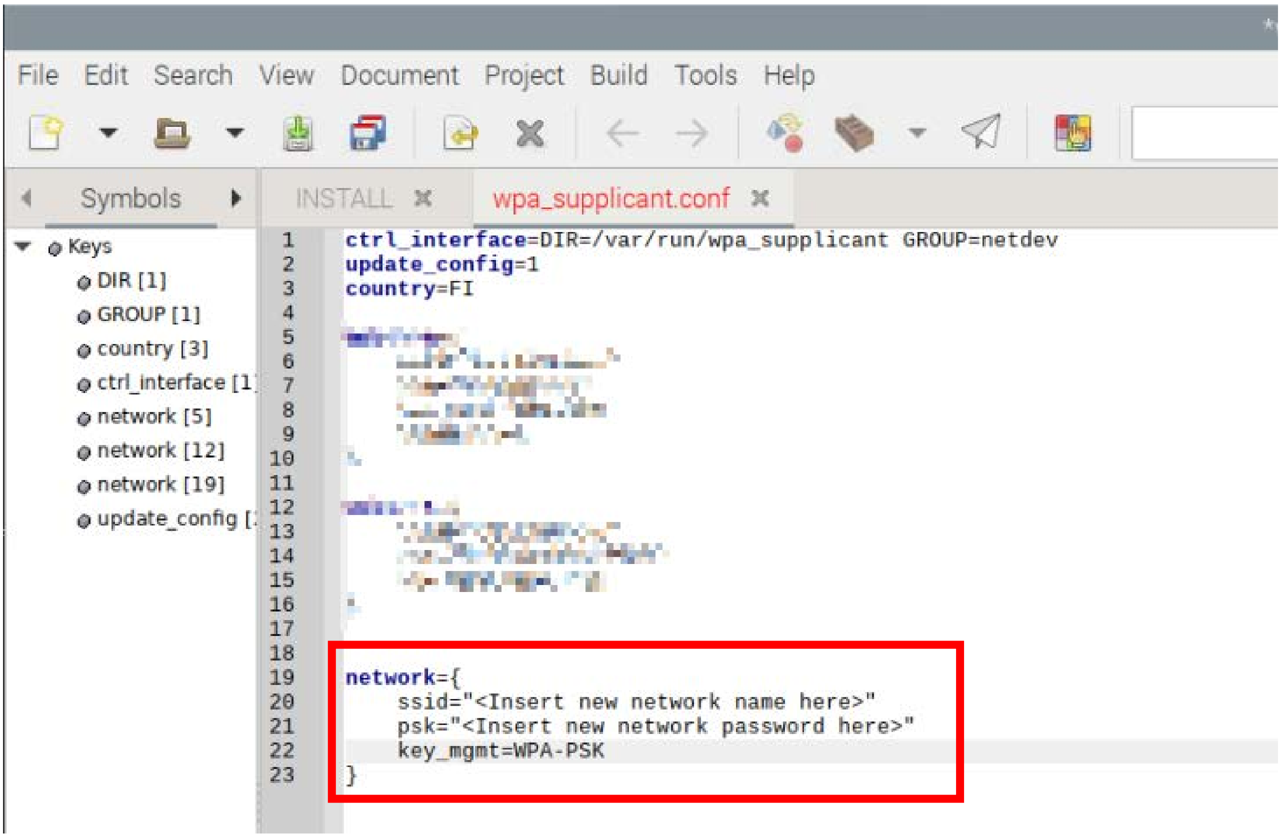

FIGURE 13 wpa_supplicant.conf file containing network information

It is possible to include many different Network configurations to this file to allow the RPi to connect to any of the WiFi networks included. This file is then placed inside the root directory of the microSD card or USB SSD that is used to boot the Pi where it is moved to the correct folder the next time the system is booted and used.

If you are not using Raspberry Pi imager to write the OS to the card it is still possible to configure the ssh headless by placing a copy of the `wpa_supplicant.conf` file containing the network information, as described above, into the boot folder along with a file named `ssh.txt`. This `ssh.txt` file does not need to contain anything and is there to simply enable the ssh.

6.2 VNC Server and VNC Viewer

VNC Server is a software from RealVNC which is included with Raspberry Pi OS. It allows the user to access the graphical desktop of the Pi and control it as if they were using the Pi itself, but from another device. The VNC Server must be enabled from the Raspberry Pi Configuration Interfaces to be used. The RPi OS makes it easy to tun the VCN Server on without the need to use the command line. The computer from which the Pi is to be controlled must have the VNC Viewer installed, which is available from RealVNC. It is necessary to create an account with RealVNC to use the cloud connections. This cloud connection is recommended for ease of use and security purposes as opposed to connecting over the internet. RealVNC is free of use for non-commercial use or educational purposes but requires a licence otherwise. (Raspberry Pi 2022c.)

It uses RFB (remote framebuffer) protocol from which to transmit the screen data between computers. The desktop image from Server computer is captured in real time and then sent and displayed to the Viewer computer. The VCN Viewer then captures and takes any input and sends it to the Server computer to be inserted. This gives the Viewer user full remote control of the Server computer. (REALvnc 2019)

For this project the free use account version was created and permission from the IT department was given to install upon the company laptop. If the Lab PC was taken into general use for protype testing, then a valid licence must be acquired. VNC server was turned on from the RPi configuration interfaces section, and the Viewer application installed on the work laptop and personal home PC for testing (FIGURE 15). The RPi was then connected via the Windows Laptop (FIGURE 14). VNC also allows you to also hear audio from the Server computer and record sessions. With the paid licence versions, you can also use the chat function to communicate between users of Server and Viewer computers.

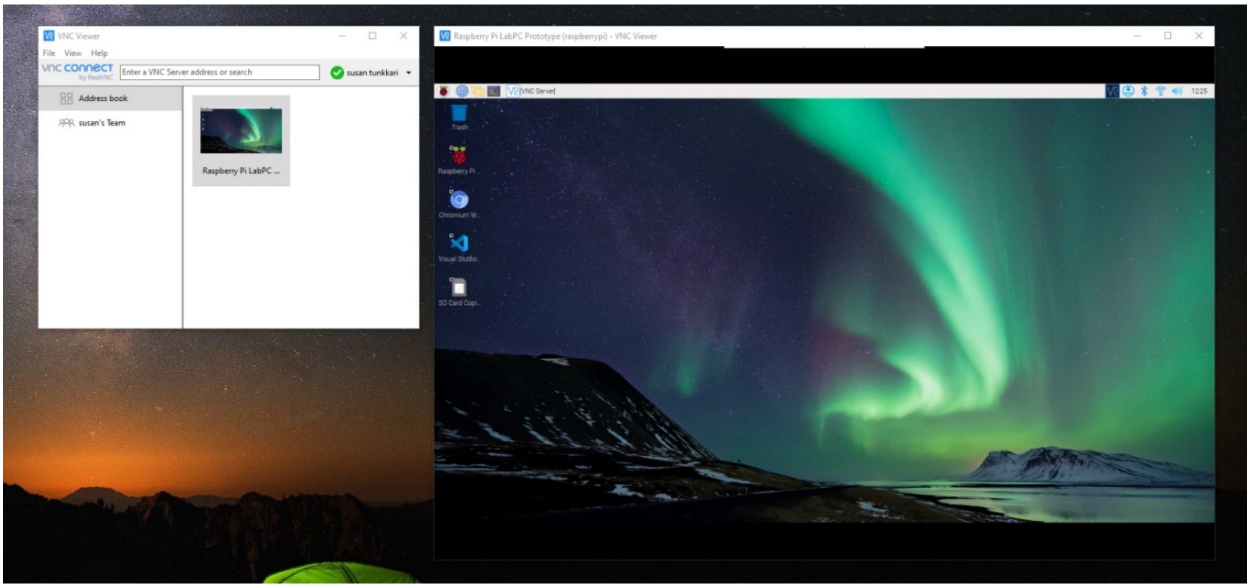

FIGURE 14 Raspberry Pi desktop accessed remotely using VNC Server and VNC Viewer

6.3 SSH

Raspberry Pi OS makes setting up the SSH simple. As with the VCN all that is required is to activate it from the configuration interfaces section (FIGURE 15). Then from the controlling computers command line insert the appropriate command. (Raspberry Pi 2022d.)

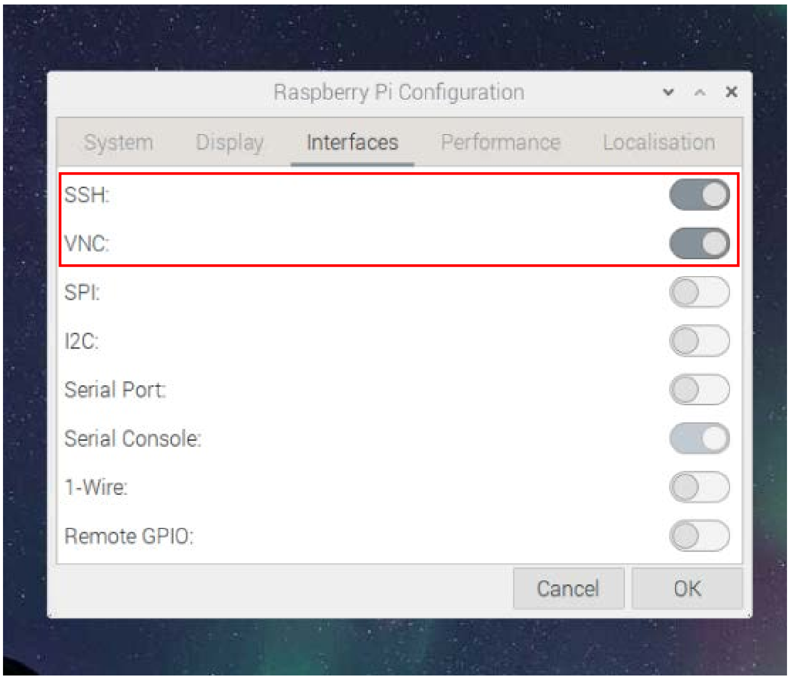

FIGURE 15 SSH and VCN turned to ON Position in RPi configuration

Once turned on from the controlling computers command line a connection can be made by using the command, `shh pi@<Pi-IP>` and entering the Password when prompted. The default username, or at least the default password for the Pi, should also be changed for security. Figure 16 demonstrates a successful SSH connection to the RPi from the Windows Laptop.

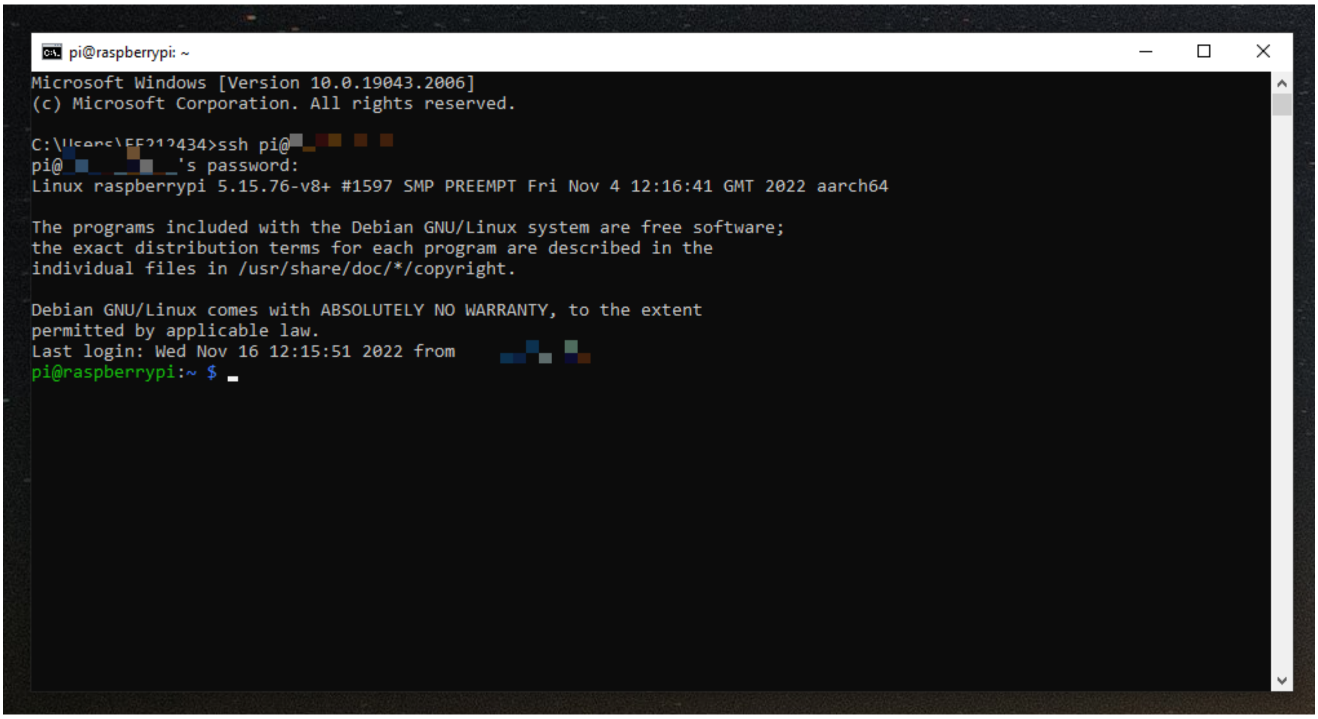

FIGURE 16 SHH connection to RPi

6.4 RaspController for Android

RaspController is a free app for the android phone available from the Google Play store. The RaspController allows you to access and manage your RPi remotely with our phone. It features the ability to manage files, control GPIO and access the terminal window. With the app you can view images on your phone from any cameras attached to the RPi and read data from any attached sensors. It also includes some wiring diagrams and information for the pins and their correct usage. RaspController is easy to set up and navigate. Figure 17 shows a screenshots of the RaspController installed on an Android device connecting to the RPi 4.

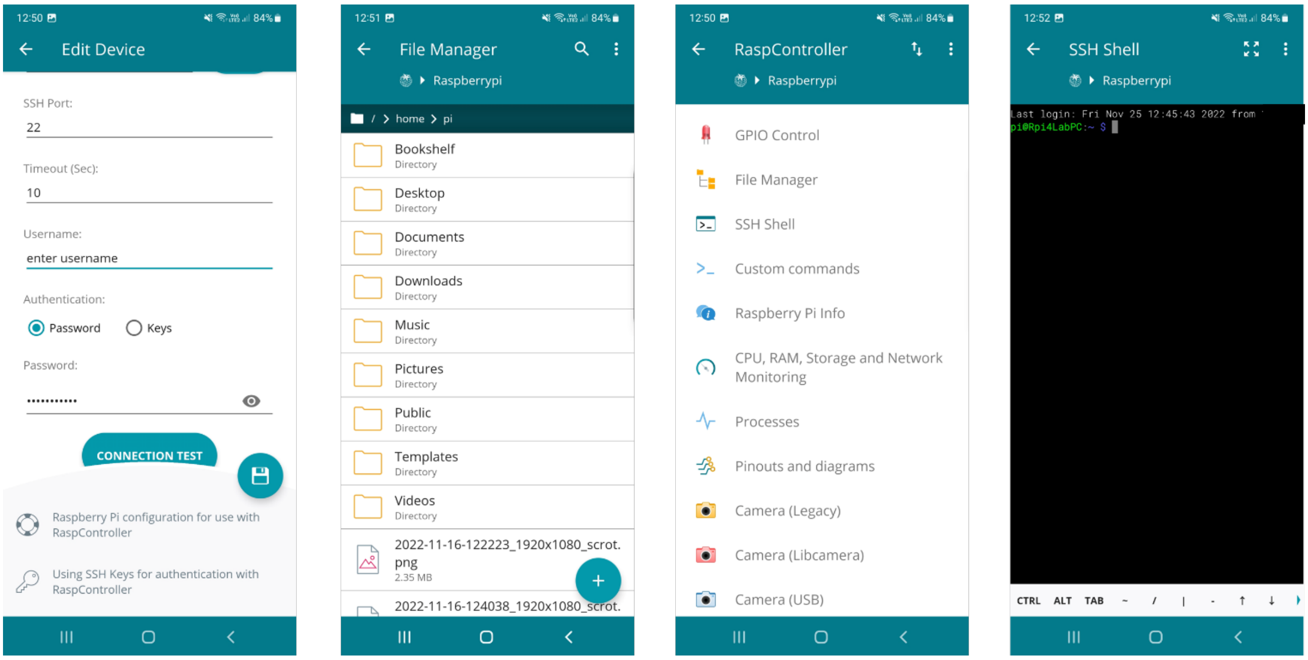

FIGURE 17 screenshots of RaspController controlling the RPi 4

7 SOFTWARE

There will be a few software requirements that will need to be met within this project. This ranges from simple office tools for the documentation and recording of test results, to the testing software required. As was noted from the requirements different projects will require the use of different software, so it is not possible to predict or cover all the various possibilities This chapter will therefore discuss the different options available for office tools and the basic testing software installed and commonly used on most lab PC's.

7.1 MS Office / 365

Microsoft Office desktop application sadly will not run on the RPi OS as there is no Linux version available. The main reason for the incompatibility being that MS Office is designed for x86 architecture and the RPi is Advanced RISC Machine (ARM) based architecture (Fromaget. 2022).

It is however possible to use the online version of Office 365 through the web browser as demonstrated in figure 18. Although the online version offers slightly less features to its desktop version the required basics are still there and functional. Word, Excel, PowerPoint, One Note, Outlook, Calendar can be accessed with this solution.

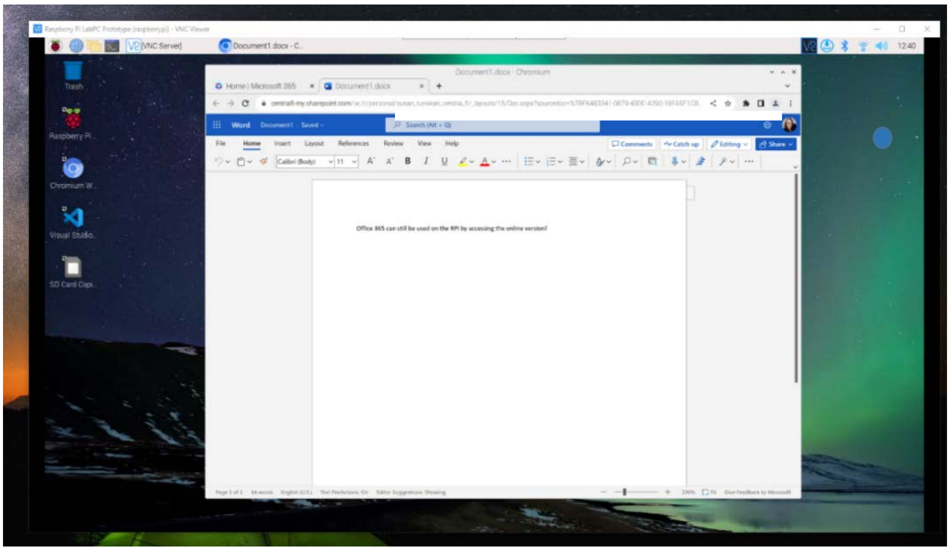

FIGURE 18 MS Office 365(Word) on RPi accessed via the web browser.

7.2 LibreOffice

LibreOffice is a free and open-source office suit and comes as part of the latest RPi OS package. Its latest version includes Writer (word processing), Calc (spreadsheets), Impress (presentations), Draw (graphics and flowcharts), Base (database) and Math (formula editing). These features make it a suitable alternative to MS Office. It is also compatible with MS Office document formats as well as many others. Some formatting issues may arise with some features of word that are not supported in Libre such as themes used. One disadvantage is that LibreOffice itself does not have an Email program although as mentioned previously Outlook can still be used online via the browser. If not already installed, or if using another LINUX operating system, it can be easily installed by running the command **sudo apt install libreoffice** in the command line of the Pi. (LibreOffice 2022.)

7.3 LabVIEW

LabVIEW, or Laboratory Virtual Instrument Engineering Workbench, is a graphical programming environment. It is used in data acquisition such as acquiring sensor measurements, testing automation, signal processing, analytics, instrument control, design of embedded systems and much more. LabVIEW is a licensable software to which Sasken has a subscription to its 2017 SP1 edition. The Community Version is free for non-commercial use and can be used in personal projects.

LabVIEW uses VI's which is simply code that is saved with the .vi extension. Whilst LabVIEW is available for Linux systems, the RPi is not supported and therefore LabVIEW full designer software cannot be installed upon the RPi running the RPi OS. With the use of the LabVIEW LINX toolkit, it is possible to communicate with and run VI's on the RPi. This is however only compatible with versions of LabVIEW 2020 and newer. The option for the version used in Sasken is then to use Digilent LINX from which to communicate and run the VI's on the RPi. This solution again poses a problem for this thesis in that it only supports the deployment of code to run headless on RPi's up to the RPi 3 and not the RPi 4. If Sasken was to take the RPi Lab PC into general use it would need to update its version of LabVIEW, or another possibility would be to use one of the supported LINUX based OS upon the RPi 4. (National Instruments 2022.)

To demonstrate communication between LabView and the RPi a simple LED on/off circuit was made using a breadboard, LED, resistor, and jumper wires. The circuit was connected to the RPi via the GND and GPIO 18 (board number 8). A simple VI was written in LabVIEW using a trial version for testing purposes, and deployed to the RPi4. Once deployed it was then possible to toggle the LED between on (FIGURE 19) and off state (FIGURE 20).

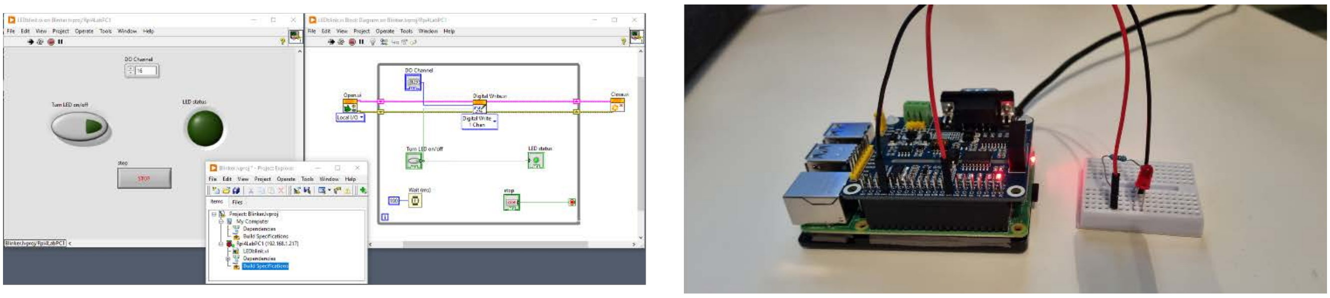

FIGURE 19 LabVIEW VI and control panel, LED off

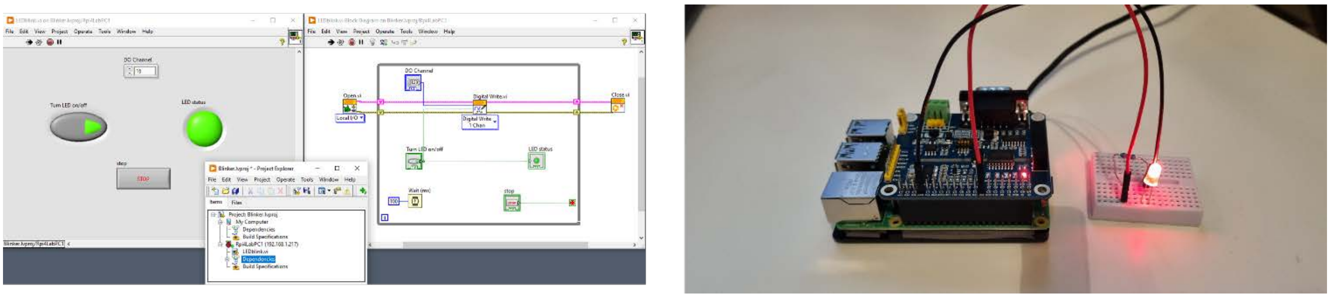

FIGURE 20 LabVIEW VI and control panel, LED on

7.4 Python and GPIO Zero

One requirement was to have some control over the GPIO pins of the RPi. Although it is possible to use C/C++ the Pi typically uses Python as a means of interaction. The GPIO pins of the RPi can easily be controlled using Python and GPIO Zero. These are both already pre-installed with the latest Raspberry OS. The GPIO Zero website offers some very comprehensive documentation and basic tutorials to help with its usage. The code can be written and deployed using the command line or Thonny Python IDE, which is also pre- installed on the Raspberry OS, or by installing any other preferred IDE. By turning GPIO remote on from the RPi configuration it is also possible to remotely control the GPIO pins of the RPi. It is also worth noting that GPIO Zero uses the BCM pin numbering system as default. If the board number is used it must be declared. Table 1 shows the different ways in which the pin number can be declared. It is also worth noting that if the state of a device is requested in the command line that it will always be reported back in the BCM numbering scheme (GPIO Zero 2022).

TABLE 1 Ways of declaring GPIO pin numbers in GPIO Zero

Assigning Pin Number	Description
led = LED(17)	Sets pin number according to BCM number
led = LED(“GPIO17”)	Sets pin number according to BCM number
led = LED(“BCM17”)	Sets pin number according to BCM number
led = LED(“BOARD11”)	Sets pin number according to board number
led = LED("J8:11")	Sets pin number according to board number “J8:11” means physical pin 11 on header J8

A simple circuit was made to turn on an LED from which to test the ability to control the GPIO pins (FIGURE 21). The LED was connected to the board via the GND pin (black wire) and the GPIO 27 Pin (red wire) and a 220Ohm resister and red LED were used.

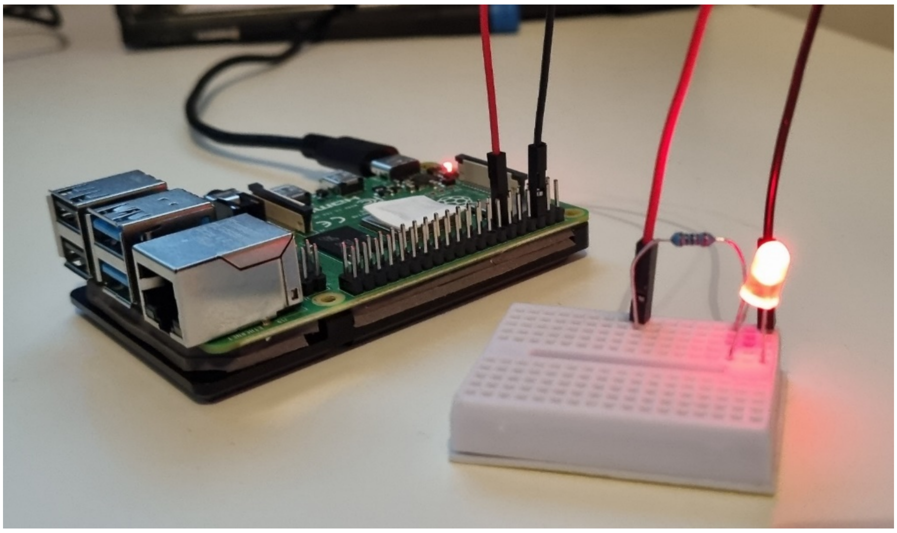

FIGURE 21 Using the GPIO header pins to control an LED

A simple basic program was written using the Thonny Python IDE that would turn the LED on and off when ran. The program could be written one of two ways to achieve the same result, either by using the blink and pause functions, or the LED on/off with sleep functions of the GPIO Zero library. Figure 22 illustrates the code using the GPIO Zero library blink and pause functions. Figure 23 shows the code using GPIO Zero library on/off and sleep functions.

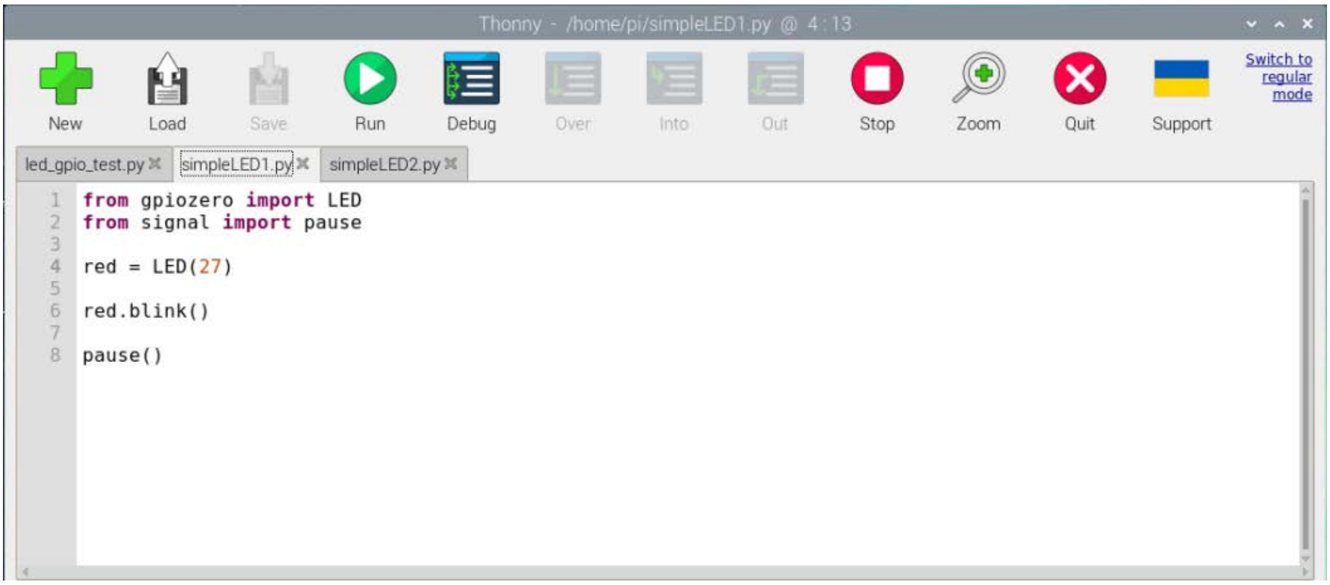

FIGURE 22 Example program using blink and pause function of GPIO Zero Library

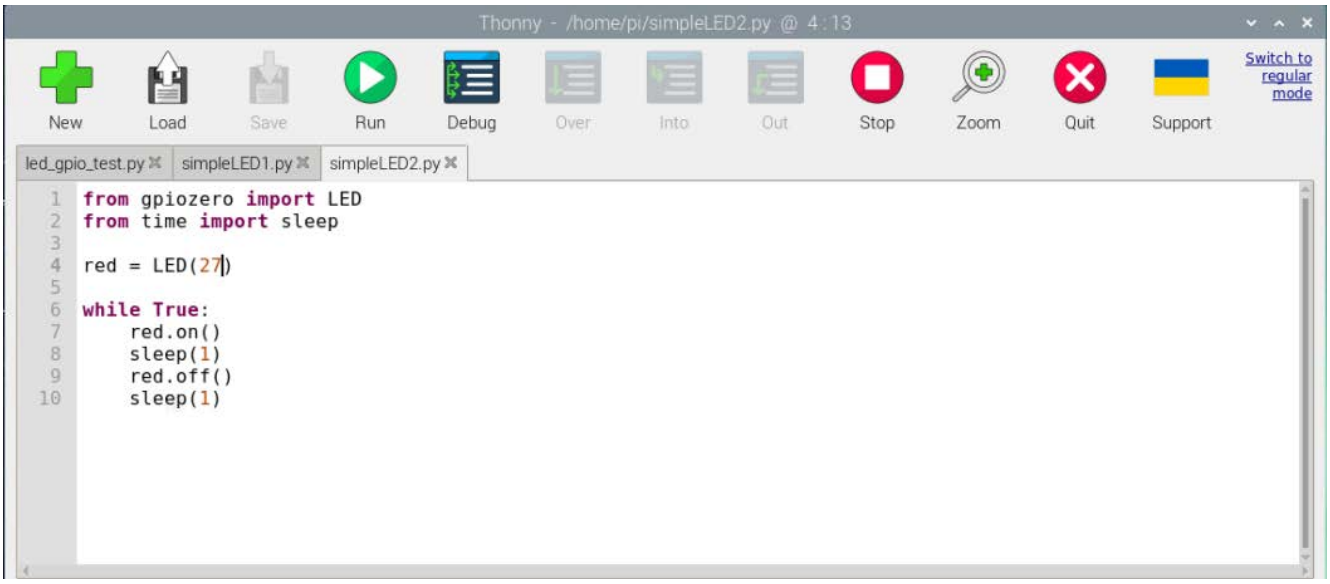

FIGURE 23 Example program using on/off and sleep function of GPIO Zero Library

As can be seen from the codes the GPIO Zero library makes it easy to have some control over the GPIO pins and can also be used to read from and write to sensors attached to them.

By using other GPIO Zero supported pin libraries, such as pigpio, it is also possible to gain control of the GPIO pins remotely over a network. Essentially it makes it possible to use GPIO Zero to remotely control the devices that are connected to the RPi within the network from a PC or another RPi. This library is already installed with the Raspberry OS and needs only to have the remote GPIO turned on from within the configuration settings of the RPi.

7.5 Security

Security is an important issue to address when using any IT equipment within Sasken. Most projects are confidential in nature and both Sasken and the customers intellectual property must be protected. Customers need to be assured that their sensitive information is dealt with appropriately. Therefore, before taking any Lab PC into general and customer use, the system must be protected. Sasken has its own security policy, and as such the issue of security would need to be addressed by the IT department to ensure that the security methods meet the internal policy standards, as well as the international standards they adhere too.

8 PROTOTYPE

In this section the prototype that was built will be discussed and detailed as well as a brief overview of its possible uses within prototyping of hardware and software here in Sasken. The prototype includes the basic requirements as presented from the requirements gathering phase and does not include all the possible requirements that may arise within specific projects.

8.1 Raspberry Pi Lab PC prototype

As discussed earlier the RPi chosen for a base for this project was the RPi 4. For its operating system the Raspberry OS was chosen and installed. The Raspberry OS includes with its instillation many of the necessary software that may need to be used such as LibreOffice, Python 3, libraries for use with Python and C as well as their IDE's.

For the prototype only one HAT was used in the form of the RS232 and RS485 use, in the form of the Waveshare Isolated RS485 RS232 HAT For Pi (FIGURE 24). For the purpose of a basic prototype, this was all that was needed from which to firstly evaluate its usefulness. A cooling fan and battery power supply was not purchased at this stage. A 32GB mini-SD card was also used for the OS and storage. An official RPi charging cable was used from which to power the RPi.

Any available monitor, keyboard and mouse was utilised when required, however for this project remote connection was mainly used via the VCN viewer or ssh connection. No suitable casing was found for the RPi to accommodate the Waveshare HAT and would need to be custom made whist also considering the future expansion possibilities for use with other HATs. Connection to the internal network were not established for the purposes of this basic prototype.

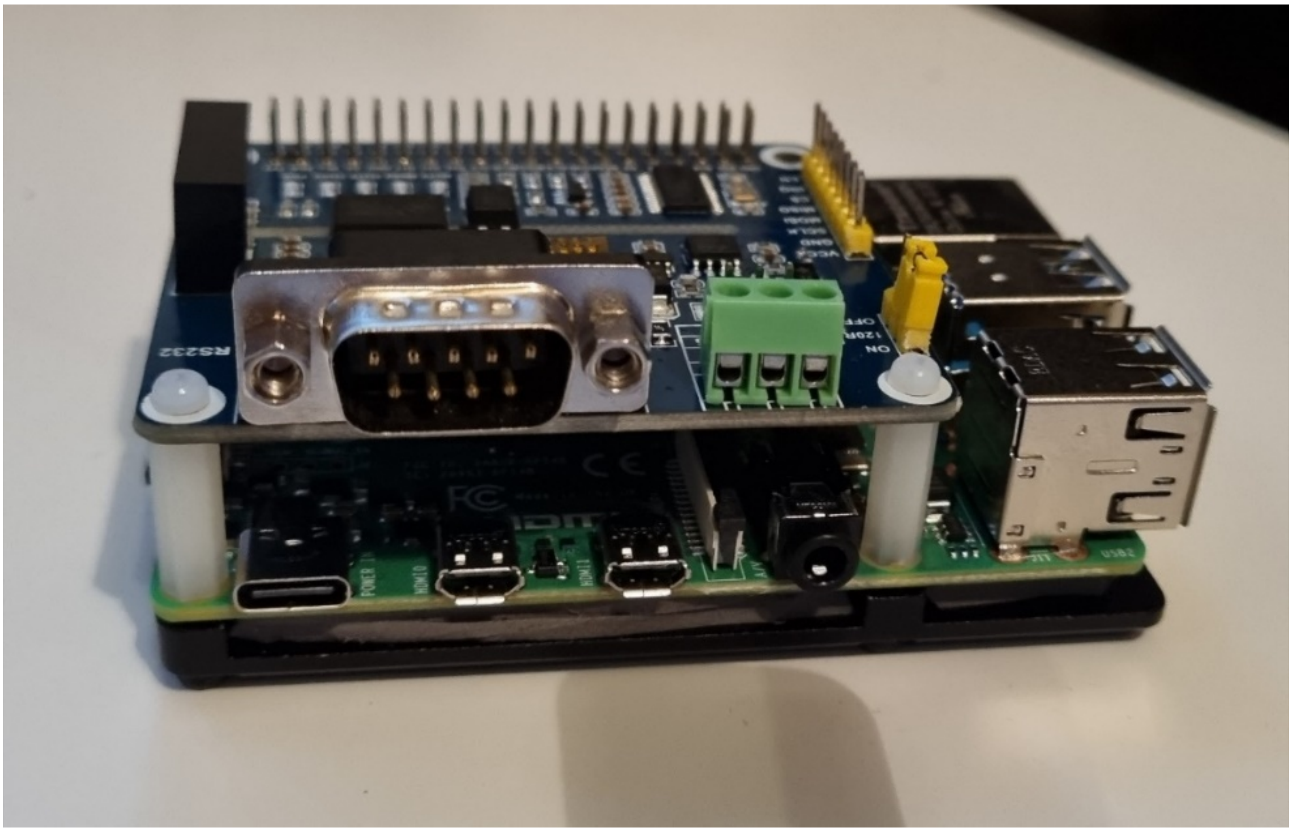

FIGURE 24 RPi 4 with Waveshare Isolated RS485 RS232 HAT installed

The Hat was attached to the RPi 4 via the attached header. The pins of the Waveshare Isolated RS485 RS2323 are connected to the GPIO pins of the RPi as presented in table 2. The table details the pin function name, its GPIO interface number where appropriate, as well as a brief description of its function.

TABLE 2 Waveshare Isolated RS485 RS232 HAT pin configuration

Function of Pin	RPi GPIO interface (BCM)	Description
VCC	5V	3.3V/5V power supply (positive)
GND	GND	Ground
SCLK	D21 (SPI1 SCLK)	SPI – clock input
MOSI	D20 (SPI1 MOSI)	SPI – data input
MISO	D19 (SPI MISO)	SPI – data output
CS	D18 (SPI1 CS)	SPI - Chip select
IRQ	D24	Interrupt output, can also be switched to D16, D12 or D25 pins
EN	D22	RS485 transceiver. Enable: high level – transmit enable Enable: low level - receive enable

The drivers for the HAT was installed per the instructions. This involved firstly entering the config.txt file and adding a line to initialise the pin according to the welding method of the HAT (FIGURE 25).

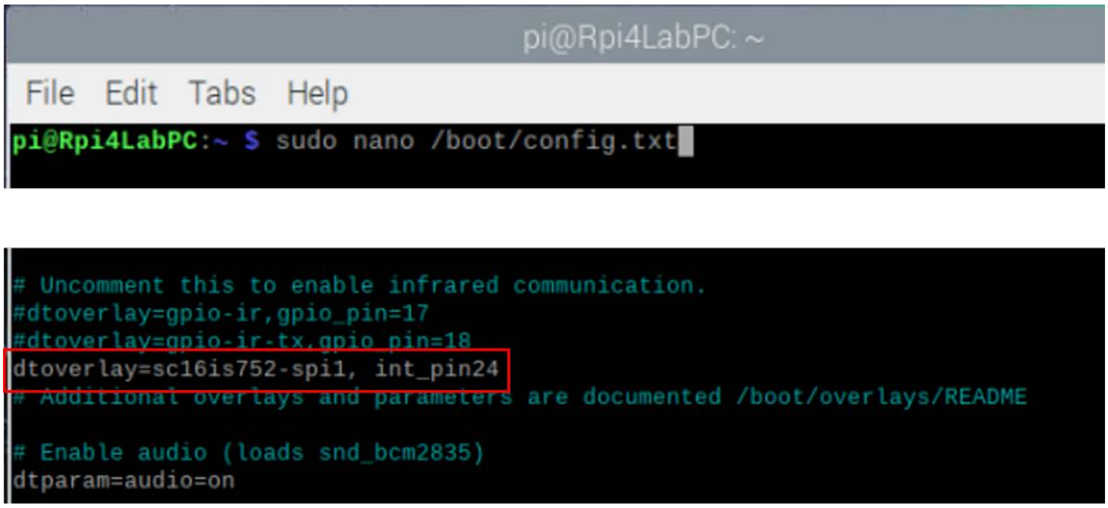

FIGURE 25 Editing the Config file

Once edited the system was rebooted and the driver for the UART with I2C /SPI interface part of the HAT was then also loaded to the kernel. It was then checked by issuing the `ls /dev` command (FIGURE 26).

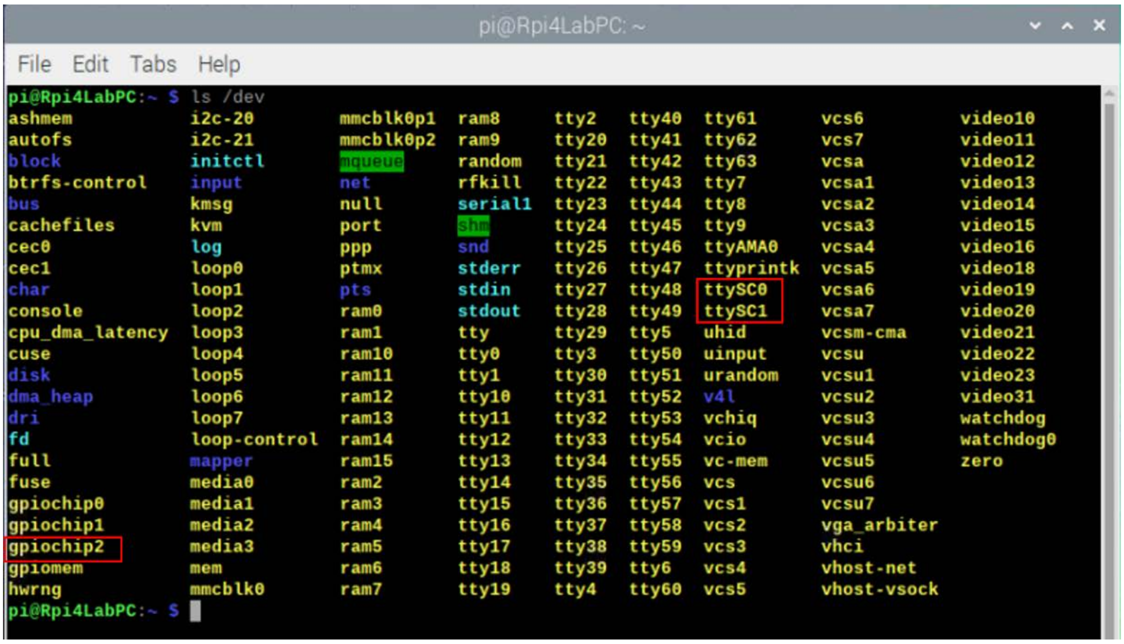

FIGURE 26 HAT installation check

A few applications and libraries needed to be installed if not already installed, BMC, wiringPi, Python 2 library and python3 library. The test routine for the HAT were then downloaded and ran to ensure that communication was functional on the RS485, RS232 and that RS485 and RS232 could communicate with each other.

8.2 Problems with prototype phase

A major problem with the prototype revolves around software. Most software requires a licence for commercial use, and therefore in order to assess the software and check its compatibility and appropriateness for use with the Pi Lab PC, free trials were needed to be used and under circumstances not related to any project work at Sasken.

8.3 Uses

As already demonstrated earlier the GPIO header of the Pi makes it ideal for the development of embedded systems. It can be a handy tool to from which to update software on hardware systems and investigate any problems with the hardware. It can also be more easily controlled and used to look at the data of sensors and other measuring devices attached to it. The RPi could also be used to control other testing equipment. As a debugging tool it can be of use within software development. In essence the RPi Lab PC would be able to do much the same as the present lab PC's with some exceptions where software and compatibility are an issue. However, it does offer some added uses due to its ability to be more customisable with the HATs and its GPIO pins.

9 CONCLUSION

This project firstly briefly looked at the ways in which Lab PC’s are currently used and what would be the main requirements in implementing a Lab PC built around a RPi. It focused mainly on the designing of such a Lab PC, describing the RPi and looked at some of the options for hardware and software requirements. Throughout this a basic proof of concept prototype was built with the required basic connections, software installed, remote connections established, as well as the GPIO pins demonstrated for their uses. It lastly gave a brief look at the possibilities in which it could be utilised within Sasken for prototyping.

The project has shown that there are numerous possibilities for how to build a Lab PC around the RPi 4. There is an abundance of HATs and modules that can be added to make it suitable for almost any situation or need that could arise. Presently there are many problems in acquiring the RPi 4 and some HATs, which hindered this project, but this is expected to improve throughout 2023 and is already beginning to see some improvement.

It also became apparent that a one size fits all option is neither practical nor cost effective. There are HATs that would be usable by some departments that another would never use, and needs differ according to the project. Incorporating all possibilities would also mean the Pi being not so portable as hoped. It would therefore seem that if this was to be a valid option then it would make more sense to be made more departmental or project specific. A base system with only the basic of needs as standard on the Pi, such as RS232, RS454 connections, OS system with remote access, and any other departmental needs being addressed individually would be more prudent to do. With the HATs in general being easy to install and also the OS image being easily interchangeable this is a viable option.

The prototype created within this project fulfilled the basic minimum requirements set out in the requirements gathering phase. It addresses the remote access needs, connections and offers control of the GPIO pins as requested. The basic base software and libraries needed are also installed.

The advantages of a RPi Lab PC lie in its small size and portability but mostly in its customizability. The use of its numerous available HATS, and the ability to also easily change between OS to suit the needs of the project or individual, is a major plus to this type of Lab PC. It also makes it possible to easily use the OS upon another Pi, or to backup and store the whole project OS image along with all its programs and data upon completion for future use or reference.

The biggest disadvantage to a RPi Lab PC seems to lie in the software area. Where the RPi OS made it easy to set up remote connection, install HATs, and gave some control of the GPIO via its desktop, it failed in that there is very little industrial software compatibility. This could be, as mentioned earlier, be somewhat circumvented by using another Linux based OS that is supported for the software needed for the project. However, this option could make the use of the HATs not quite as easy as with the Raspberry OS and also make it expensive if needing to buy multiple licences for different types of OS. This is another area that will require further research and discussion with the IT department in order to take the project further.

In conclusion, overall, it would seem that the idea of a Lab PC created around a RPi offers a cheap and versatile option, and presents a good argument for further research, prototyping and testing within real project situations. The idea has good foundation, and the Pi is much more customisable and offers greater control options within the testing environment than the normal PC. As each project would have different needs it makes it difficult to completely predict and evaluate its effectiveness as an alternative to the present Lab PC’s right now. More research is certainly needed into the software availability aspects and alternatives, as well as more project specific testing conducted over a longer period of time. This project is a one that will continue to be developed and assessed for its suitability.

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APPENDIX 1

RECEIVED EMAIL REQUIREMENTS RESPONSES

Two responses were received by email from those unable to attend the meeting or provide a different time to speak face to face.

Response 1

1. What do you use your current Lab PC for?
    - In SW work lab PC's or other external devices are usually needed for tracing and/or debugging the functionality of an embedded device
    - In my current project we are using lab PC's in Kaustinen through Windows Remote desktop connection
        i. For actual development work we are using the installed Windows software (+webcam) to control the attached satellite modem via UART/ETH and to view the spectrum outputs etc of measurement devices connected to the modem
        ii. For more supportive stuff, we update the SW on devices used by the HW guys in Kaustinen, investigate stuck units, program devices through JTAG etc
2. The Raspberry Pi 4 comes with 2xUSB 2 ports and 2x USB3 ports, 2x HDMI, Gigabit Ethernet, WiFi, and Bluetooth connections. What other types of connections would you require as essential?
    - Importance and priority of course changes from dev to dev and project to project. So, I'll just toss out some magic words based on my embedded gut feelings:
        i. UART. Most embedded devices usually have a debug serial connection available at least during the development phase of the device
        ii. SPI
        iii. I2C
        iv. As an extra bonus, it would be nice to have low level control of some GPIO pins. Configurable as input or output etc
3. What software do you currently use and would require in a new system?
    - SW required often changes from project to project, so it's a bit difficult to give a good answer here

   i. Drivers for the interfaces mentioned in 2. so that it would be relatively easy and simple to write scripts/programs for project purposes
   ii. Python and maybe Lua or Perl to interpret the scripts
   iii. Standard RPi probably covers most of the SW needs (terminal, SSH, standard C libraries etc etc etc)

4. Are there any features (connections or software etc) you would like to have that would make it more appealing to you to use over your current Lab PC
   - As a SW guy the main selling point would probably be the size of the device and the available interfaces. I could have a tiny lab PC with a powerful debug toolset on my desk next to my laptop
   - My personal preference would be to have good remote connection capabilities so that I don't need extra keyboard/mouse/display etc

Response 2

1. What do you use your current Lab PC for?
   a. Adb logging for android device
2. The Raspberry Pi 4 comes with 2xUSB 2 ports and 2x USB3 ports, 2x HDMI, Gigabit Ethernet, WiFi, and Bluetooth connections. What other types of connections would you require as essential?
   a. USB likely with some I/O interface card (?) so that voltage monitoring (high/low) information can be added and synced with the abb log timestamps. Maybe 1-2 inputs would be nice. Not sure if this kind of inputs are already available or does it require some external IO card.
3. What software do you currently use and would require in a new system?
   a. We run adb log in CMD window
4. Are there any features (connections or software etc) you would like to have that would make it more appealing to you to use over your current Lab PC?
   a. Current PCs don't have such synchronization capabilities (adb log + HW inputs)
5. Are there any other thoughts/information on what you feel would be important? or any problems you would have to use this type of Lab PC?
   a. No additional comments

RESPONSES IN MEETING

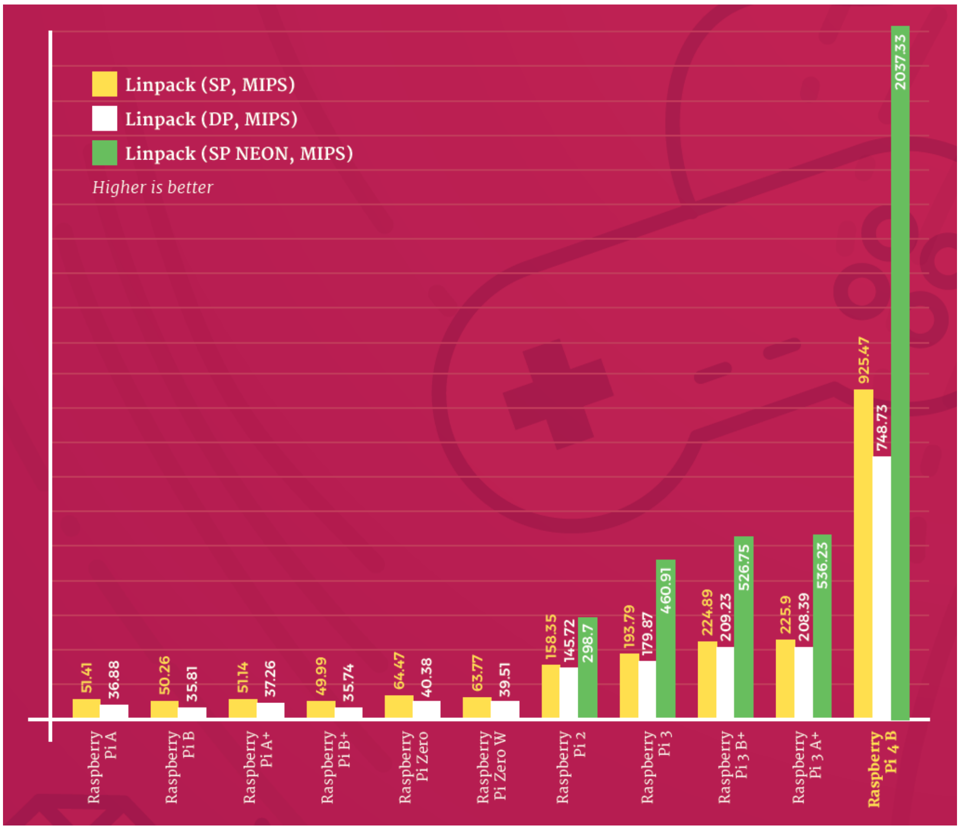
1. What do you use your current Lab PC for?
    a. Simple test runs
    b. Reading of hardware, writing to hardware
    c. Depends on project
    d. Debugging
    e. Testing purposes
2. The Raspberry Pi 4 comes with 2xUSB 2 ports and 2x USB3 ports, 2x HDMI, Gigabit Ethernet, WiFi, and Bluetooth connections. What other types of connections would you require as essential?
    a. SPi
    b. Remote connection
    c. Depends from project to project but serial connection is often used.
3. What software do you currently use and would require in a new system?
    a. LabView
    b. Again, depends on the project
    c. I am using LabView NI-MAX and NI-VISA
4. Are there any features (connections or software etc) you would like to have that would make it more appealing to you to use over your current Lab PC?
    a. As mentioned before the remote connection would be a great plus
    b. Some control over the GPIO
5. Are there any other thoughts/information on what you feel would be important? or any problems you would have to use this type of Lab PC?
    a. Connectivity to company network folders
    b. Ability to get the software needed to run on the Pi.

Extra thoughts received in a later email.

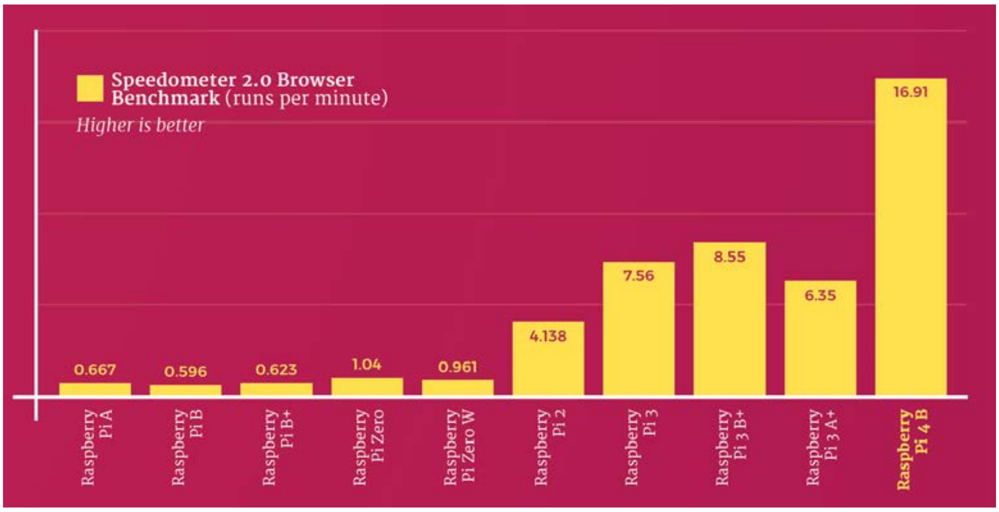
External ADC card would be useful for some cases. Instead of just monitoring GPIO (high/low) info, we could measure the signals.

APPENDIX 2/1

Raspberry Pi benchmarking tests taken from issue 83 of The MagPi Magazine. (Zwetsloot R. 2019)

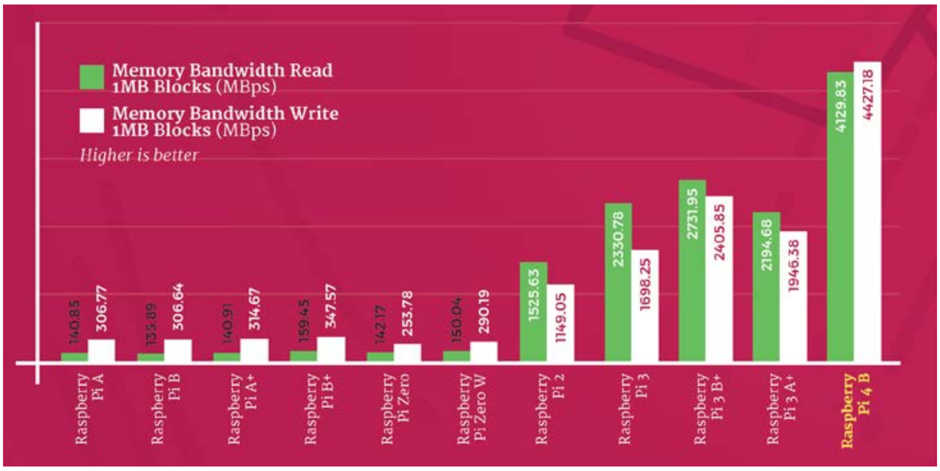


Comparison of Raspberry Pi's CPU speed conducted using LINPAC.

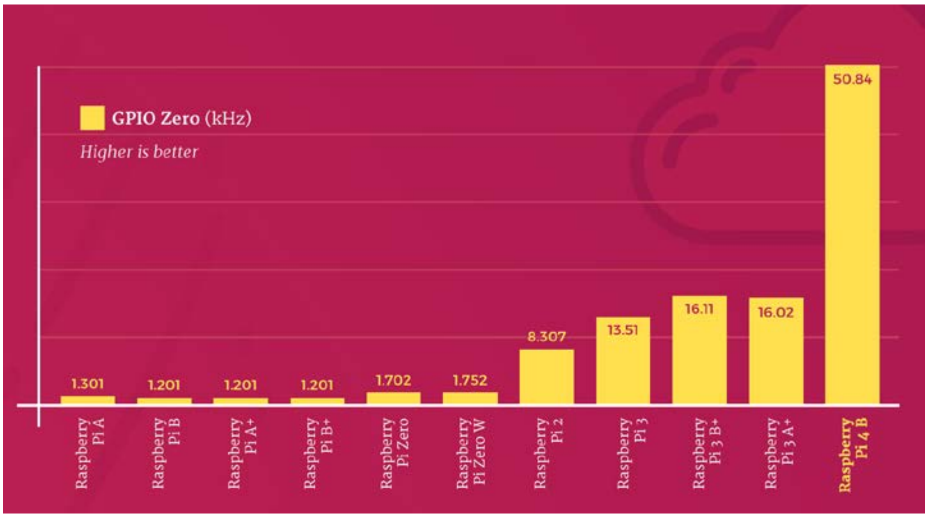


Comparison of Raspberry Pi browser speed test

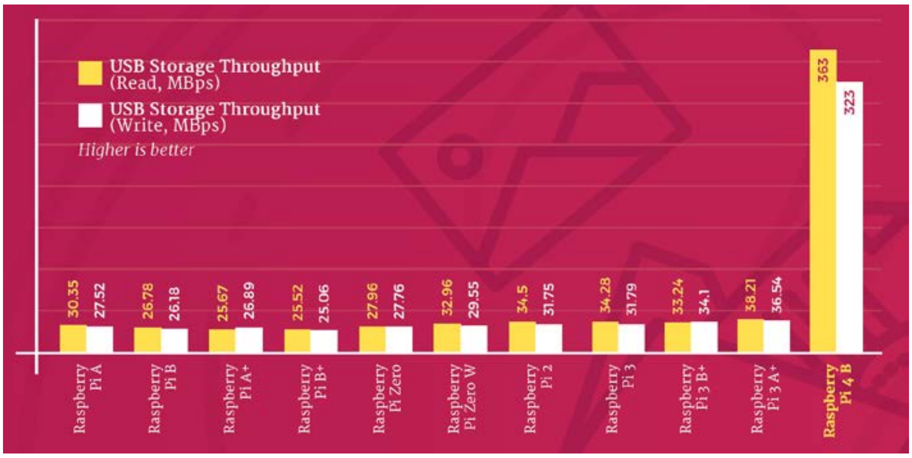
APPENDIX 2/2



Comparison of Raspberry Pi memory bandwidth

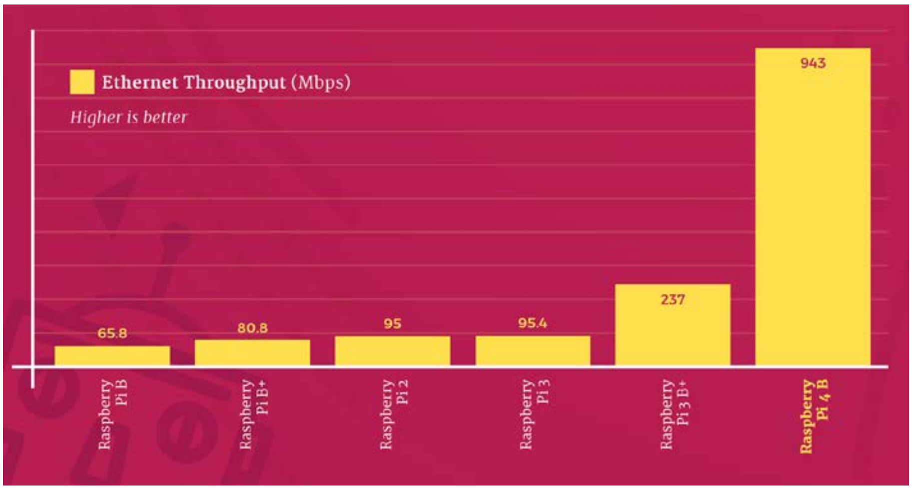


Comparison of GPIO toggle speed using Python GPIO Zero

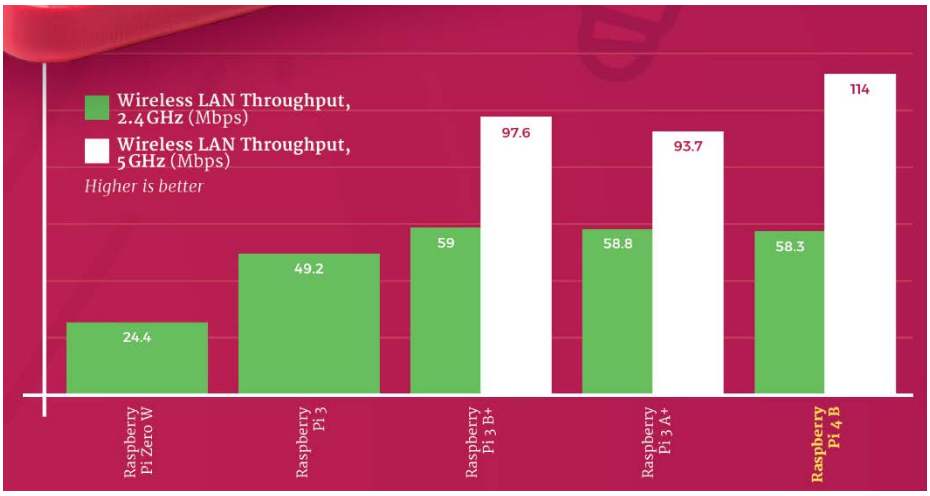


Comparison of Raspberry Pi USB read/write throughput

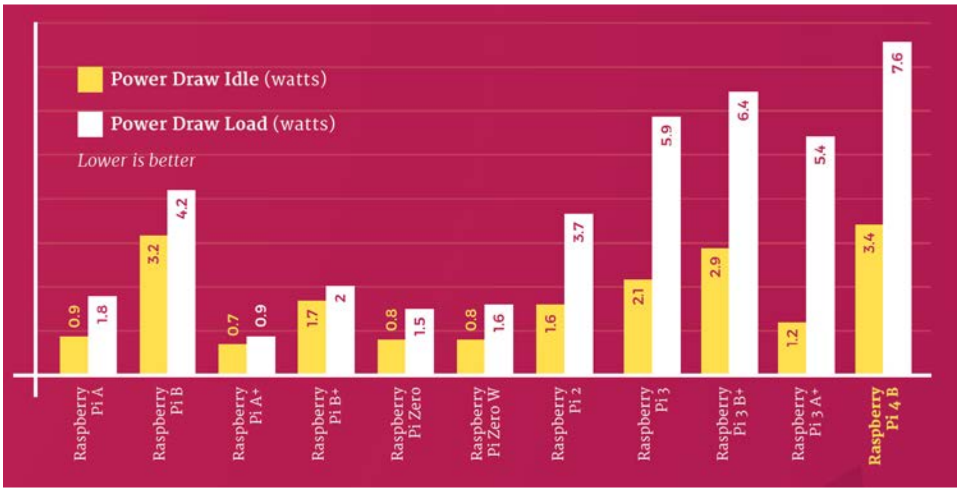
APPENDIX 2/3



Comparison of Raspberry Pi Ethernet throughput



Comparison of Raspberry Pi, WLAN throughput



Comparison of Power Draw

APPENDIX 3

Email communication with Waveshare

Hi, I am wanting to add both High-Precision AD HAT For Raspberry Pi, ADS1263 10-Ch 32-Bit ADC and the Isolated RS485 RS232 Expansion HAT for Raspberry Pi, SPI Control to the Raspberry Pi 4. Is this possible? I understand it is possible to stack HATs but that some may have issues.

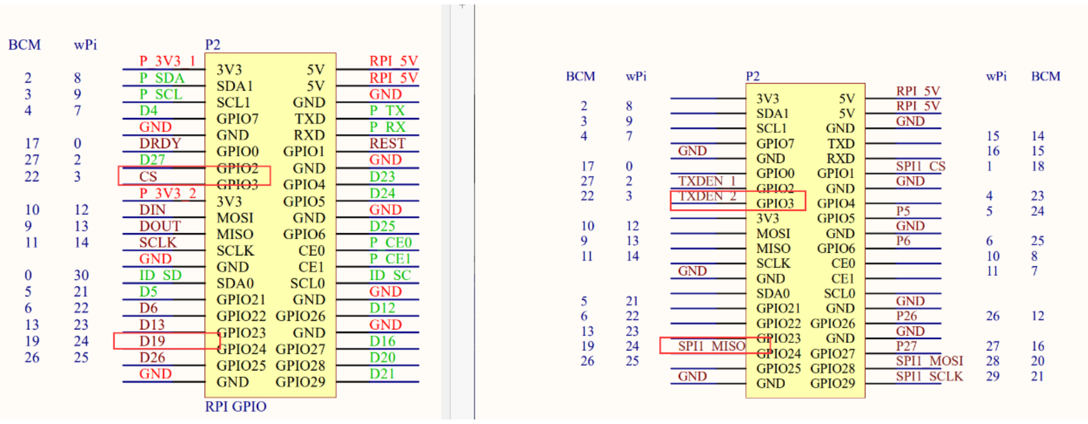
Thank you in advance,
Susan Tunkkari

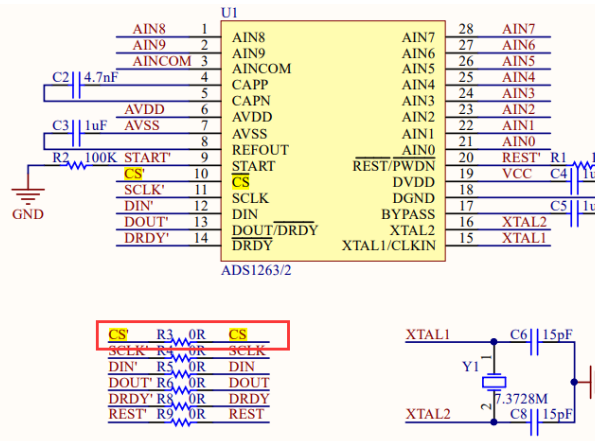
Huang Kangxin (Waveshare)

Oct 13, 2022, 19:32 GMT+8

Hi,sorry for replying late.

It is not recommended to use superposition, some pins have conflicts, if you must do so, you need to change the hardware, you can change the CS side of AD HAT or disconnect the TXD_EN side of RS485 (automatic mode is not available, you can disconnect the corresponding resistance, please see the schematic diagram for details) :





APPENDIX 4

Technical Specifications / Information Reference Links for Hardware and HATS

Hardware	Technical specifications / information link
Raspberry Pi 4	https://www.raspberrypi.com/products/raspberry-pi-4-model-b/specifications/
Power supply for RPi4	https://www.raspberrypi.com/products/type-c-power-supply/
PiJuice	https://uk.pi-supply.com/products/pijuice-standard
Waveshare isolated RS485 RS232 HAT	https://www.waveshare.com/wiki/RS485_RS232_HAT
Waveshare USB to Rs232/485/TTL interface	https://www.waveshare.com/wiki/USB_TO_RS232/485/TTL
Waveshare high precision AD HAT	https://www.waveshare.com/wiki/High-Precision_AD_HAT
PiStack	https://shop.sb-components.co.uk/products/pistack-stack-hat-for-raspberry-pi-stack-upto-3-hats?_pos=1&_sid=561d0d58f&_ss=r
PiJuice	https://uk.pi-supply.com/products/pijuice-standard
Babyface Pro FS	https://www.rme-usa.com/babyface-pro.html