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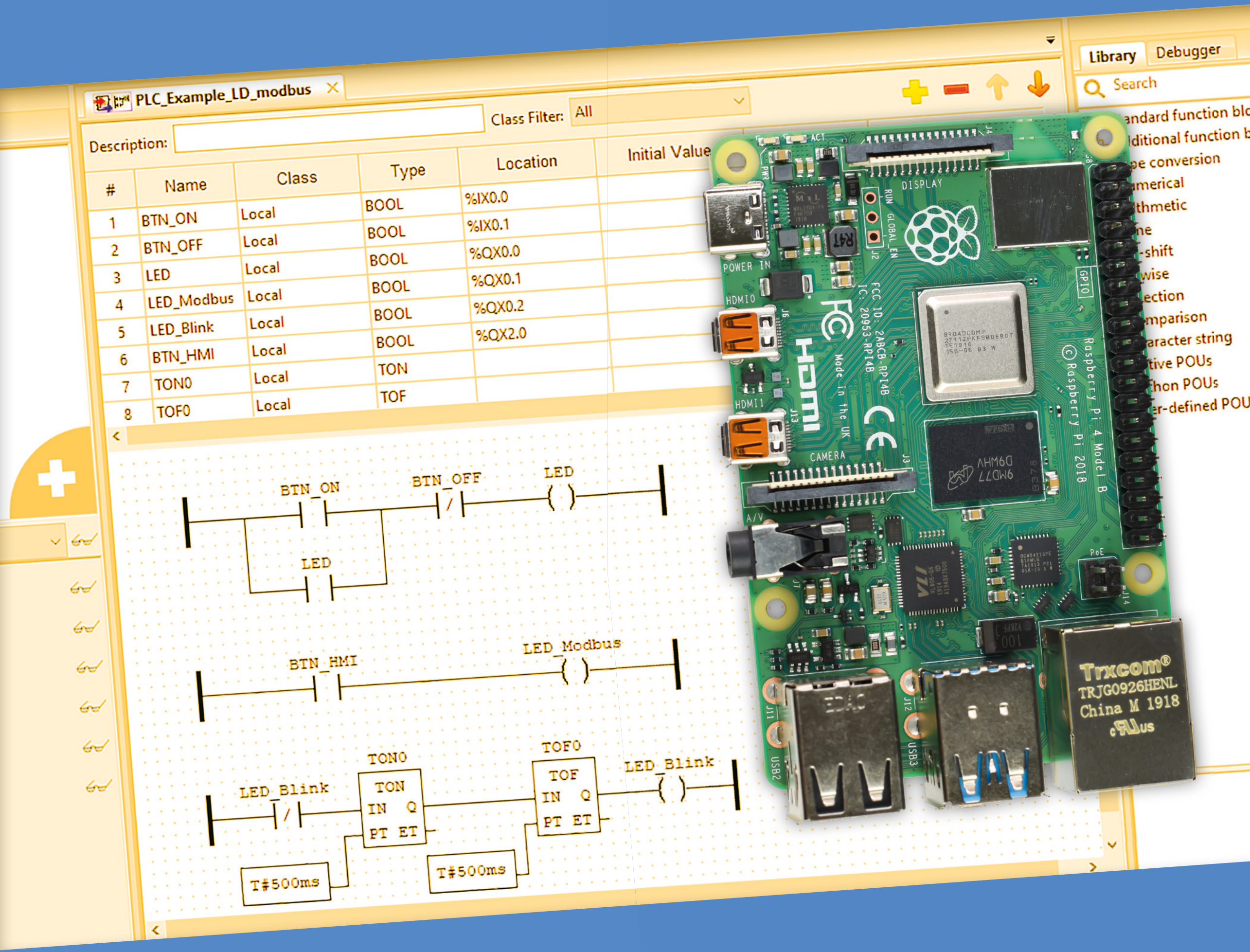
PLC Programming with the Raspberry Pi and the OpenPLC project

ModbusRTU and ModbusTCP examples with the Arduino Uno and ESP8266



PLC_Example_LD_modbus

Description:

Class Filter: All

#	Name	Class	Type	Location	Initial Value
1	BTN_ON	Local	BOOL	%IX0.0	
2	BTN_OFF	Local	BOOL	%IX0.1	
3	LED	Local	BOOL	%QX0.0	
4	LED_Modbus	Local	BOOL	%QX0.1	
5	LED_Blink	Local	BOOL	%QX0.2	
6	BTN_HMI	Local	BOOL	%QX2.0	
7	TON0	Local	TON		
8	TOF0	Local	TOF		

Josef Bernhardt

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Preface

This book is intended to provide readers with a practical introduction to using the Raspberry Pi computer as a PLC (programmable logic control) for their projects.

The project is indebted to programmers Edouard Tisserant and Mario de Sousa. They started the "Matiec project" after the introduction of IEC standard 61131-3 in 2003. This made it feasible to translate the programming languages introduced in the standard into C programs.

Later, when the Raspberry Pi became increasingly popular, Thiago Alves started the "openplcproject". He extended the editor from the "Beremiz" project and wrote a runtime library and a web interface for the Raspberry Pi and the PC. From then on, it was possible to write programs on the PC and install them on the Raspberry Pi.

Many Raspberry Pi users are now able to realize their own controls and regulation systems using their own hardware. The hardware and software are also excellent for training purposes because it abides by the IEC standard.

Beginners will also learn everything about installation and programming in the five programming languages in order to build their own control systems.

In a later chapter, the visualization with AdvancedHMI is discussed to display processes on the screen.

Circuits with the Arduino and ESP8266, which are necessary for Modbus, are also explained.

I wish you lots of success in reading and using the book.

Bad Abbach, May 2021
Josef Bernhardt

Introduction

Programmable logic controllers (PLCs) have revolutionized industrial control technology. PLCs have been used primarily in industrial control systems and home automation since their invention by Richard E. Morley about 50 years ago.

Here is the definition of "PLC" according to EN61131-3:

> "A PLC is a digitally operating electronic system for use in industrial environments with a programmable memory for internal storage of user-oriented control instructions to implement specific functions such as logic control, sequence control, timing, counting, and arithmetic functions to control various types of machines and processes through digital or analog input and output signals."

The Raspberry Pi is perfectly suitable for an application as a PLC because of its architecture with the GPIO connector, as well as its low price.

Various ready-made PLCs based on the Raspberry Pi are available on the market.

A big advantage of PLC programming is that the programmer does not have to learn the hardware details of I/O lines. The analog and digital outputs and inputs are like variables. This is also possible with modules that are connected to the Raspberry Pi via a network using a protocol such as Modbus-TCP.

Another advantage of PLC programming is the inter-compatibility of PLC systems. Programs for a PLC from manufacturer "A" can generally be used for PLCs from manufacturer "B" without much effort.

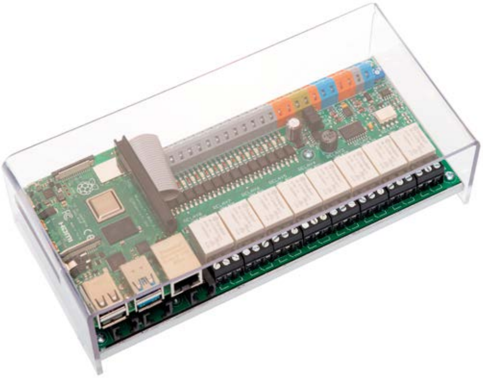


Figure 0.1: Raspberry Pi PLC Unipi 1.1.

Figure 0.1 pictures a PLC with 24 V inputs and relay outputs attached to a Raspberry Pi.

Most PLC systems support graphical and textual programming languages. The "openplcproject" fully supports the IEC 61131-3 standard, which defines basic software architecture and programming languages for PLCs.

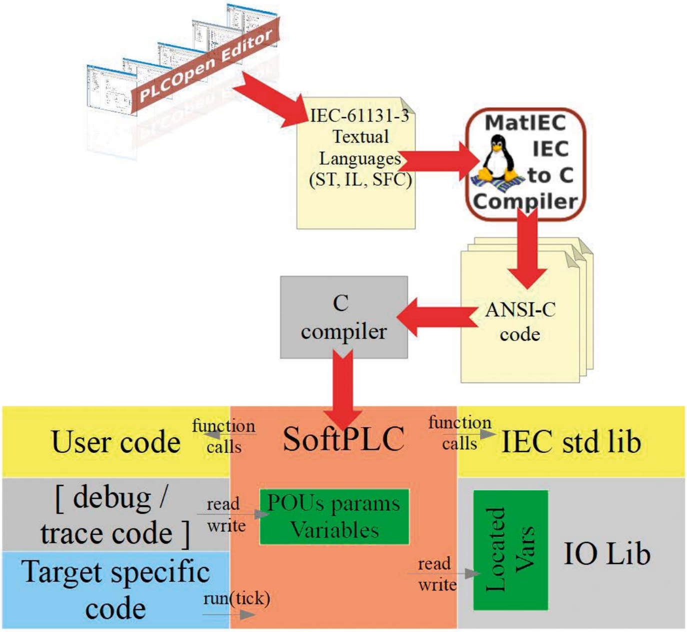


Figure 0.2: Overview OpenPLC.

The system consists of a runtime component, which is basically the software installed on the Raspberry Pi. This executes the PLC program. The program editor is installed on the PC under Windows or Linux to write the PLC program according to the IEC 61131-3 standard.

The following PLC languages are supported:

Programming language	Abbreviation
Ladder Logic	LD
Function Block	FBD
Instruction List	IL
Structured Text	ST
Sequential Function Chart	SFC

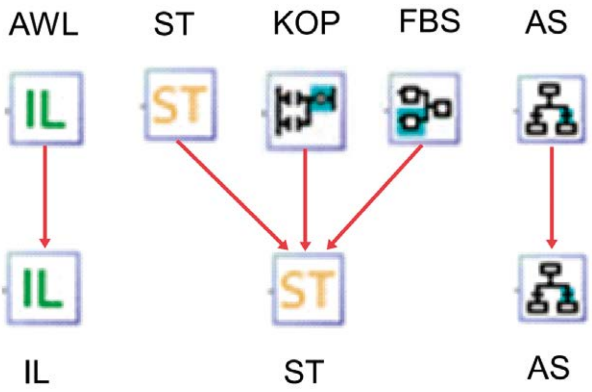


Figure 0.3: IEC programming languages.

Graphical languages KOP and FUP are translated to ST by the Matiec compiler.

Chapter 1 starts with the installation of the runtime component on the Raspberry Pi. After downloading the installation program, you will create a micro SD card with the operating system. After commissioning, you will install the PLC Runtime and perform the first test.

Next, you will deal with the editor and its user interface in Chapter 2. You'll get to download a finished example and translate it into a program for transferring to the Raspberry Pi.

In Chapter 3 you start programming with the PLC editor from "openplcproject". You will create your programs in various programming languages, translate, and upload them to the Raspberry Pi for testing.

Visualization should not be neglected in the process, and Chapter 4 examines the AdvancedHMI project which allows you to visualize processes running on the PLC via Modbus, on a PC.

Chapter 5 examines the possibility of communicating with external modules. You'll be using the popular Modbus/RTU protocol for Arduino UNO and the Modbus/TCP protocol for ESP8266 via WLAN. Also, circuits and layouts for this hardware are presented.

All program examples can be downloaded from the author's website. The links to the website are in the Appendix under "Web Links".

Chapter 1 • Installing the Raspberry Pi 4

1.1 Hardware description

The Raspberry Pi is now a well-known minicomputer, which, thanks of its low price, is widely used by hobbyists and industrial companies alike.

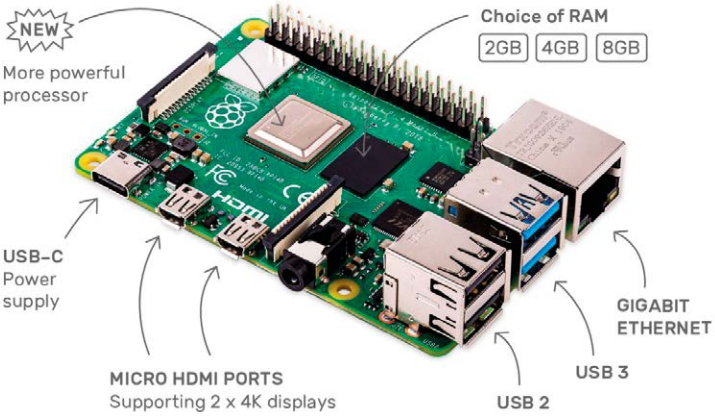


Figure 1.1: The Raspberry Pi 4.

The RPi 4 has enough interfaces to be used as a PLC. In addition to standard interfaces such as HDMI, USB, Ethernet, and audio, it has a 40-pin GPIO connector strip to connect to the outside world. Relays, buttons, switches, etc. can be connected to this connector via suitable interfaces. Hardware aspects are not discussed further for now — the Raspberry Pi website is host to several detailed tutorials about this minicomputer.

If you are looking for a more compact solution, you could also use the Raspberry Pi Zero W. After a first test by the author, everything turned out to work fine. If you can tolerate the lengthy installation process which takes several hours, the "W" is a good, low-priced alternative to the Raspberry Pi 4.

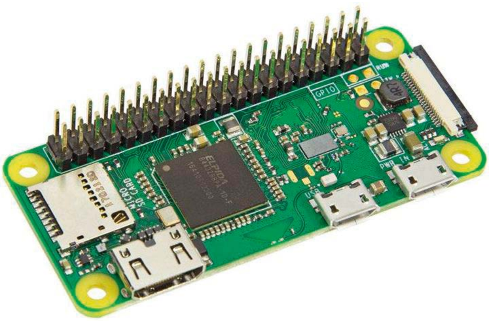


Figure 1.2: Raspberry Pi Zero W.

To use the Raspberry Pi as a PLC, first install the operating system, which can be found on the Raspberry.org website. Link: Raspberry Pi OS – Raspberry Pi.

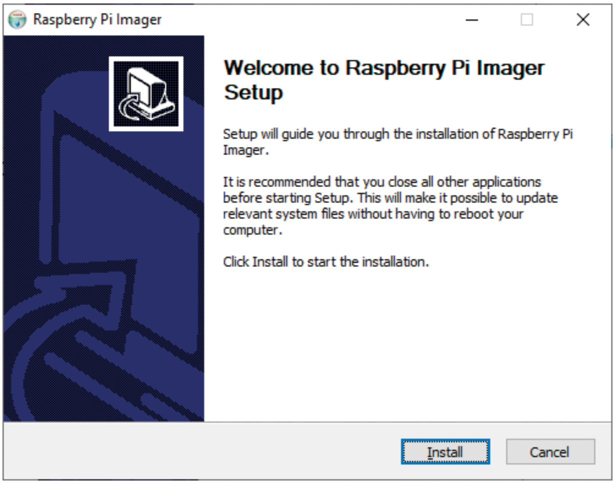
1.2 Installing the operating system

Download the Raspberry Pi Imager here. This is a simple and quick way to install the operating system on a Micro SD card. There is also a video about this on YouTube. Link:

https://www.youtube.com/watch?v=J024soVgEeM

After downloading, change to this directory and start the imager.

Link: https://downloads.raspberrypi.org/imager/imager_1.5.exe



Welcome to Raspberry Pi Imager Setup

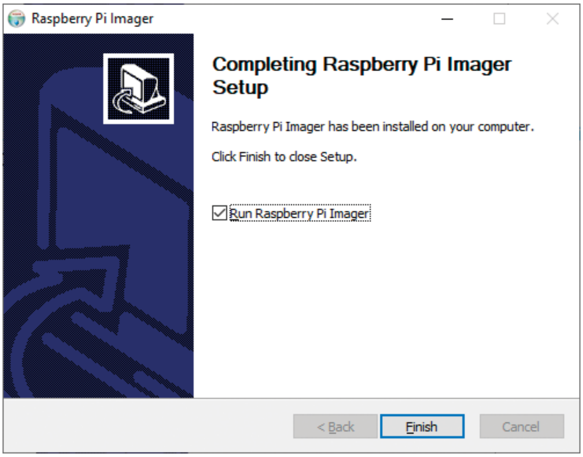
Setup will guide you through the installation of Raspberry Pi Imager.

It is recommended that you close all other applications before starting Setup. This will make it possible to update relevant system files without having to reboot your computer.

Click Install to start the installation.

Figure 1.3: Raspberry Pi Imager launched.

After clicking on "Install", the installation of the Imager program will commence. The Imager is used to install our Micro SD card.



Completing Raspberry Pi Imager Setup

Raspberry Pi Imager has been installed on your computer.

Click Finish to close Setup.

☑ Run Raspberry Pi Imager

Figure 1.4: Raspberry Pi Imager Setup.

With a click on the checkbox "Run Raspberry Pi Imager" the program launches after successful installation.

Select the Raspberry Pi OS (32-bit) as the operating system. Then select the drive where the Micro SD card is connected. Here, that's drive G:

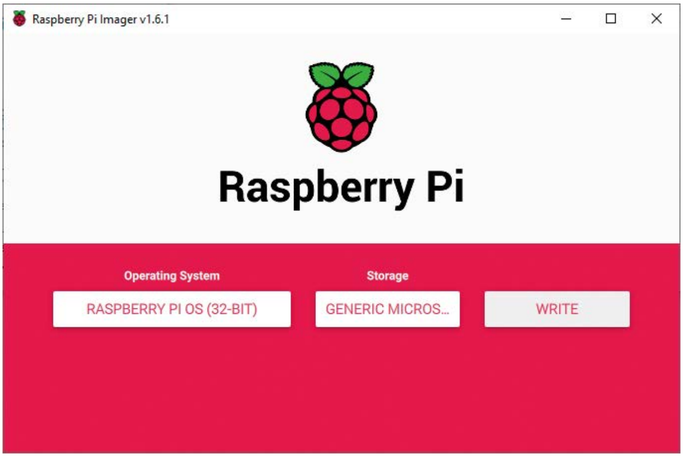
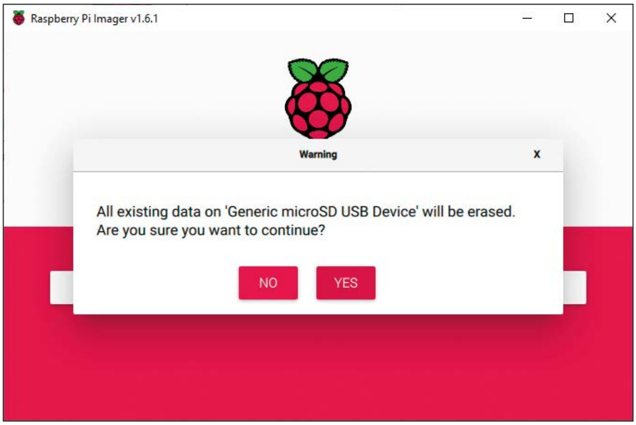


Figure 1.5: Raspberry Pi Imager OS selection.

Click the "Write" button to launch the installation.



All existing data on 'Generic microSD USB Device' will be erased.
Are you sure you want to continue?

Figure 1.6: Raspberry Pi Imager startup.

Confirm the security prompt with "YES".

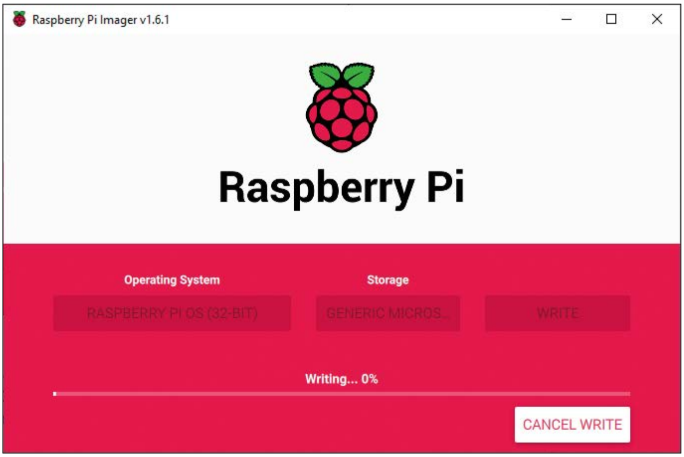


Figure 1.7: Writing to the SD card using the Raspberry Pi Imager.

Now the operating system is downloaded and written to the micro SD card. This can take about 30 minutes, depending on the computer. After the signal that writing to the card has been completed, exit the Imager with "CONTINUE".

Documentation for installation and usage can also be found here. Link: Raspberry Pi Documentation

The next step is to set up the Raspberry Pi. Insert the programmed Micro SD card into the Raspberry Pi. Next, plug in a monitor, keyboard, and mouse for the first setup of the Raspberry Pi. Now connect the 5 V power supply to the Raspberry Pi. The operating system should boot.

After the initial start, the operating system prompts for the country and time zone selection. Enter your details here. Now the settings are installed. After this, the password is requested. The default username is "pi", and the password is "raspberry".

If there is no Ethernet connection, set up the network access via WLAN. In the upper right corner between the Bluetooth and the speaker icon, click on the WLAN icon. Select your WLAN network and enter the access code. After a few seconds, the connection to the home or office WLAN is established. Continue with the installation of the updates. This can take several minutes. After this, a reboot is performed. When you click on the WLAN icon, you will also see the IP address. Make a note of it for later use with VNC and the PLC software, which is yet to be installed. Here, the IP is: 192.168.178.89.

Later, when the Raspberry Pi is used as a PLC, it will be easier to access it through VNC Viewer.

Follow: Menu → Settings → Raspberry Pi Configuration. Next, under Interfaces, the VNC Viewer can be enabled.

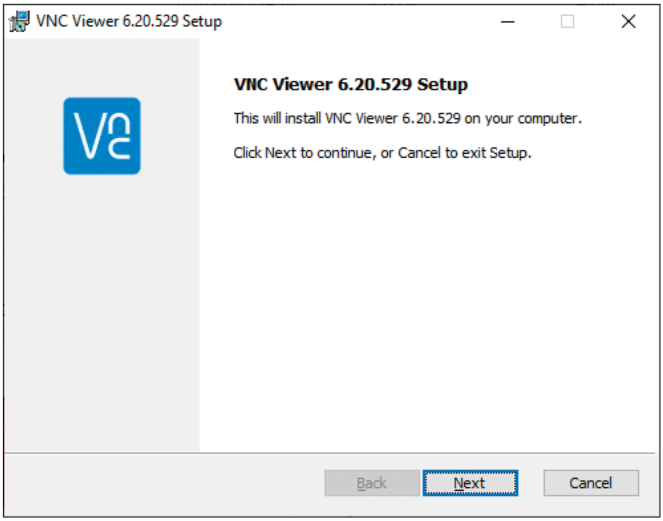
1.3 Installing the VNC Viewer

VNC is a graphical desktop sharing system allowing you to remotely control the desktop interface of a computer, in this case the Raspberry Pi (VNC Server) from another computer or mobile device using VNC Viewer (Client). VNC Viewer transmits keyboard, mouse, or touch events to VNC Server and in return receives information for screen updates. This can be downloaded and installed on a PC for now.

Link: https://www.realvnc.com/en/connect/download/viewer/.

The appropriate viewer can be downloaded at this url. We're using the latest version for Windows 10, but an Android version is also available.

After downloading, start the installation.



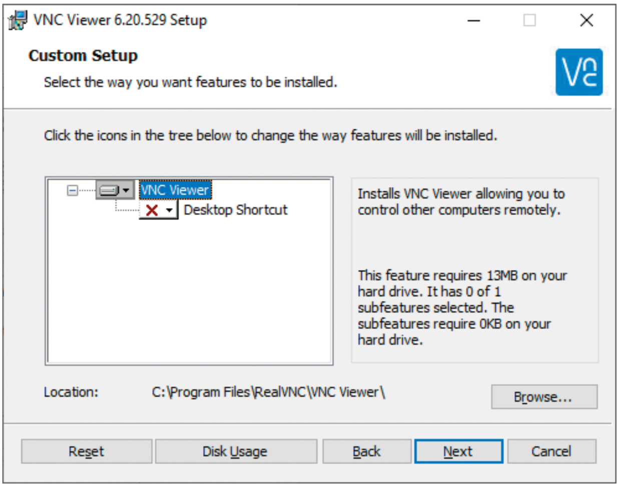
VNC Viewer 6.20.529 Setup

VNC Viewer 6.20.529 Setup

This will install VNC Viewer 6.20.529 on your computer.

Click Next to continue, or Cancel to exit Setup.

Figure 1.8: VNC Viewer installation.



VNC Viewer 6.20.529 Setup

Custom Setup

Select the way you want features to be installed.

Click the icons in the tree below to change the way features will be installed.

Installs VNC Viewer allowing you to control other computers remotely.

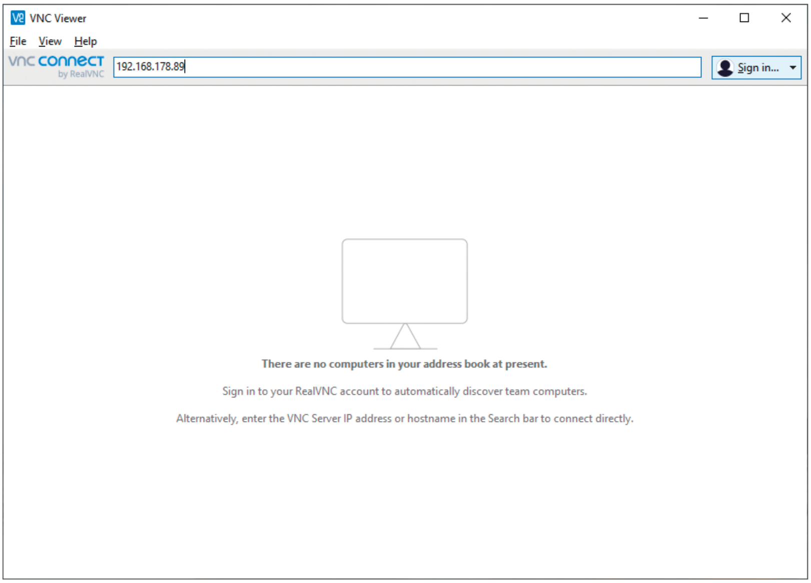
This feature requires 13MB on your hard drive. It has 0 of 1 subfeatures selected. The subfeatures require 0KB on your hard drive.

Location: C:\Program Files\RealVNC\VNC Viewer\

Figure 1.9: VNC Viewer installation.

Continue the installation by clicking on "Next". Click on "Install". This will launch the installation of the Viewer.

Start VNC Viewer and connect to the Raspberry Pi.



192.168.178.89

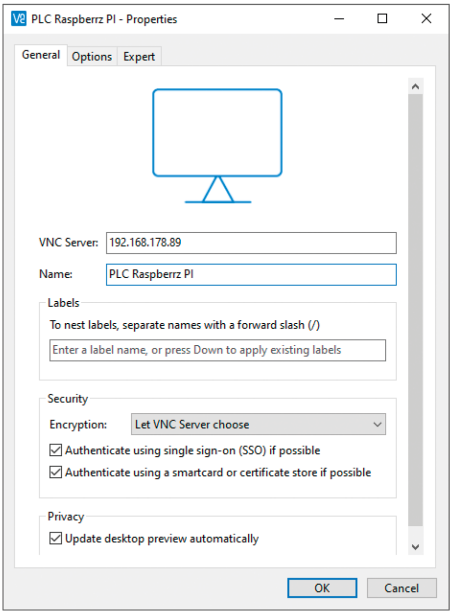
There are no computers in your address book at present.

Sign in to your RealVNC account to automatically discover team computers.

Alternatively, enter the VNC Server IP address or hostname in the Search bar to connect directly.

Figure 1.10: VNC Viewer start menu.

Under "File", and then "New Connection", enter the access data from your Raspberry Pi.



PLC Raspberrz PI - Properties

VNC Server: 192.168.178.89

Name: PLC Raspberrz PI

Labels

To nest labels, separate names with a forward slash (/)

Enter a label name, or press Down to apply existing labels

Security

Encryption: Let VNC Server choose

☑ Authenticate using single sign-on (SSO) if possible

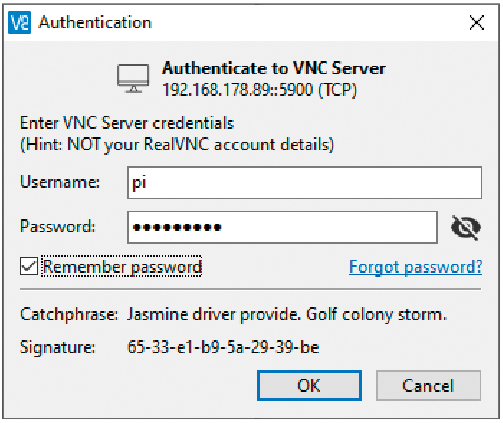
☑ Authenticate using a smartcard or certificate store if possible

Privacy

☑ Update desktop preview automatically

Figure 1.11 VNC Viewer configuration.

Enter the IP address and a suitable name. Afterwards, confirm the "Properties", "General" window with "OK".



Authentication

Authenticate to VNC Server
192.168.178.89::5900 (TCP)

Enter VNC Server credentials
(Hint: NOT your RealVNC account details)

Username: pi

Password: ●●●●●●●●●

☑ Remember password Forgot password?

Catchphrase: Jasmine driver provide. Golf colony storm.

Signature: 65-33-e1-b9-5a-29-39-be

Figure 1.12: VNC Viewer credentials

Enter the username "pi" and password "raspberry" and confirm with "OK". Shortly, the Raspberry Pi desktop will appear on your PC screen.

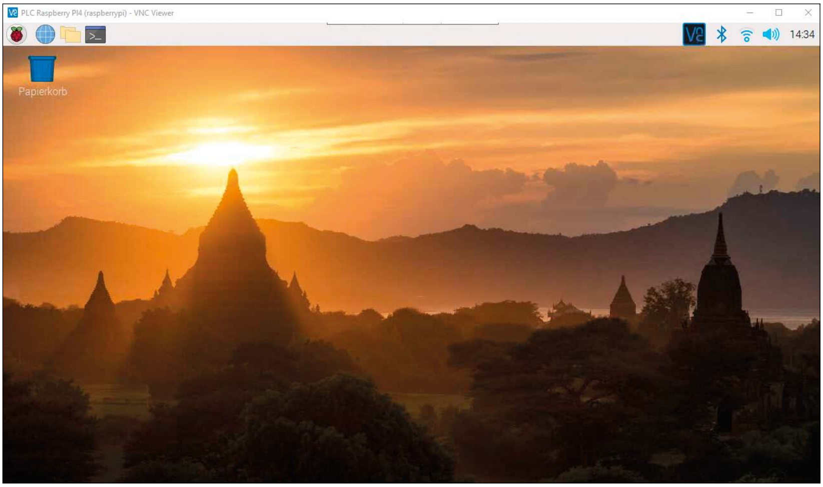
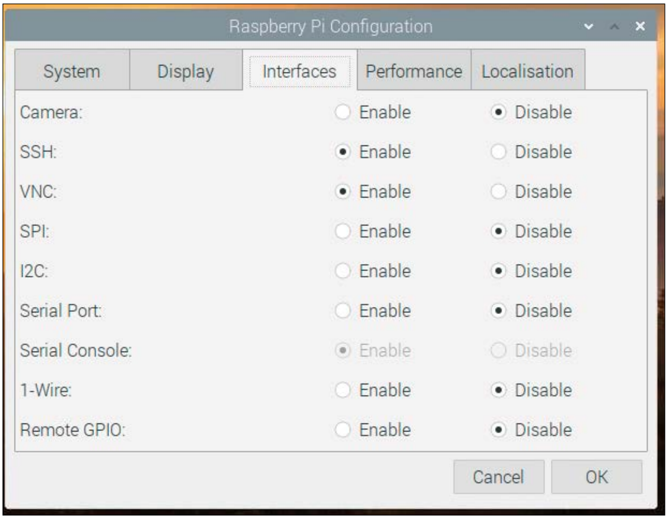


Figure 1.13 Raspberry Pi OS Desktop.

1.4 Installing the File Transfer Software WinSCP

WinSCP is an open-source SFTP and FTP client for Windows, needed to transfer files between a PC and Raspberry Pi.

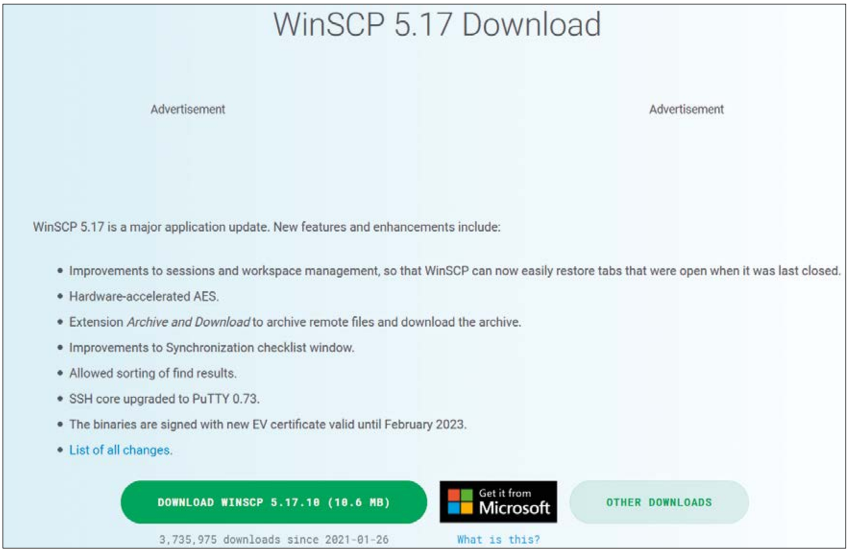
To get access, enable SSH on the Raspberry Pi under Settings → Raspberry Pi Configuration Interfaces.



Camera:	○ Enable	● Disable
SSH:	● Enable	○ Disable
VNC:	● Enable	○ Disable
SPI:	○ Enable	● Disable
I2C:	○ Enable	● Disable
Serial Port:	○ Enable	● Disable
Serial Console:	● Enable	○ Disable
1-Wire:	○ Enable	● Disable
Remote GPIO:	○ Enable	● Disable

Figure 1.14: SSH configuration.

Firstly, download and save the installer.



WinSCP 5.17 Download

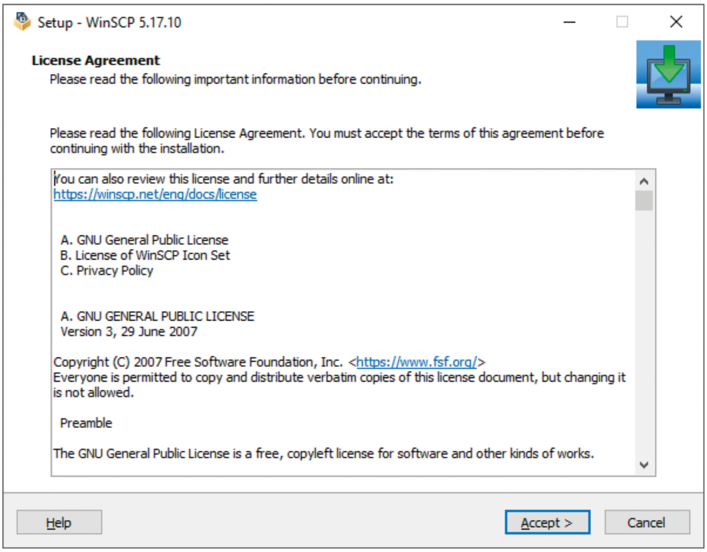
WinSCP 5.17 is a major application update. New features and enhancements include:

- Improvements to sessions and workspace management, so that WinSCP can now easily restore tabs that were open when it was last closed.
- Hardware-accelerated AES.
- Extension *Archive and Download* to archive remote files and download the archive.
- Improvements to Synchronization checklist window.
- Allowed sorting of find results.
- SSH core upgraded to PuTTY 0.73.
- The binaries are signed with new EV certificate valid until February 2023.
- List of all changes.

DOWNLOAD WINSCP 5.17.10 (10.6 MB)
Get it from Microsoft
OTHER DOWNLOADS
3,735,975 downloads since 2021-01-26
What is this?

Figure 1.15: WinSCP Download.

Now change to the download directory and start the installation.



Setup - WinSCP 5.17.10

License Agreement
Please read the following important information before continuing.

Please read the following License Agreement. You must accept the terms of this agreement before continuing with the installation.

You can also review this license and further details online at:
https://winscp.net/eng/docs/license

A. GNU General Public License
B. License of WinSCP Icon Set
C. Privacy Policy

A. GNU GENERAL PUBLIC LICENSE
Version 3, 29 June 2007

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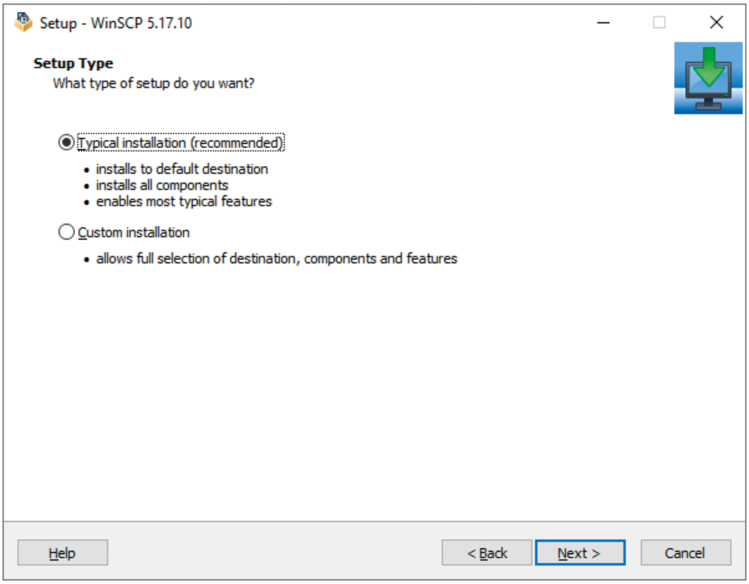
Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The GNU General Public License is a free, copyleft license for software and other kinds of works.

Figure 1.16: WinSCP installation

Accept the license agreement by clicking "Accept".



Setup - WinSCP 5.17.10

Setup Type

What type of setup do you want?

● Typical installation (recommended)

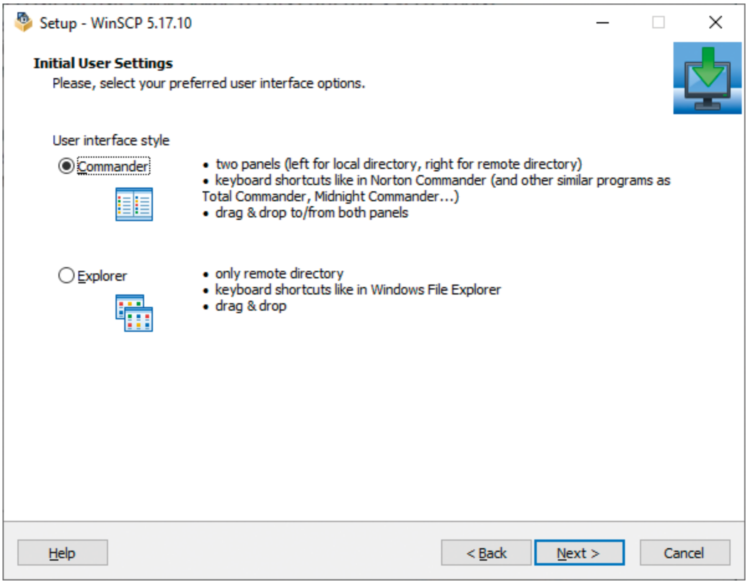
- installs to default destination
- installs all components
- enables most typical features

○ Custom installation

- allows full selection of destination, components and features

Figure 1.17: WinSCP installation.

Confirm with "Next".



Setup - WinSCP 5.17.10

Initial User Settings

Please, select your preferred user interface options.

User interface style

● Commander

- two panels (left for local directory, right for remote directory)
- keyboard shortcuts like in Norton Commander (and other similar programs as Total Commander, Midnight Commander…)
- drag & drop to/from both panels

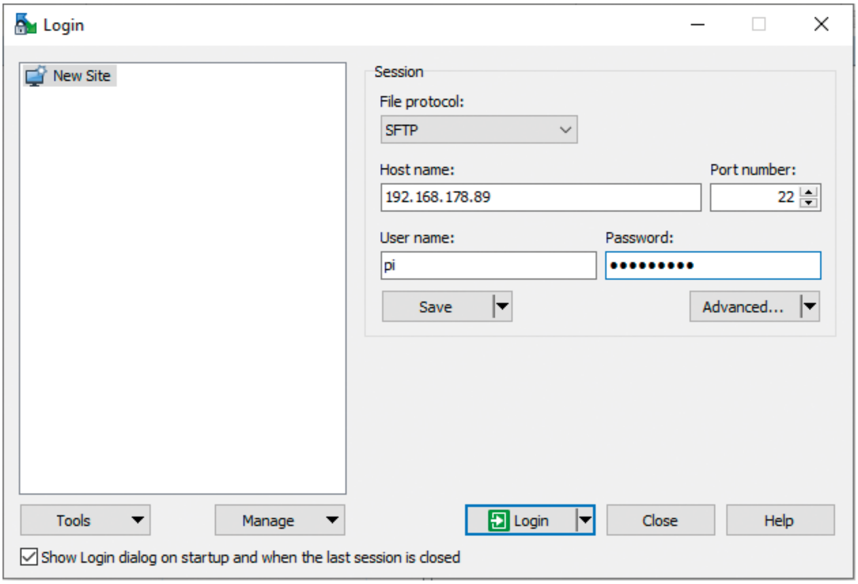
○ Explorer

- only remote directory
- keyboard shortcuts like in Windows File Explorer
- drag & drop

Figure 1.18: WinSCP installation.

Select the user interface "Commander", go to "Next" and confirm with "Install".

Start WinSCP and set up a new connection with the Raspberry Pi's IP address. As an example, the IP address was 192.168.178.89 with access data.



Login

Session

File protocol: SFTP

Host name: 192.168.178.89

Port number: 22

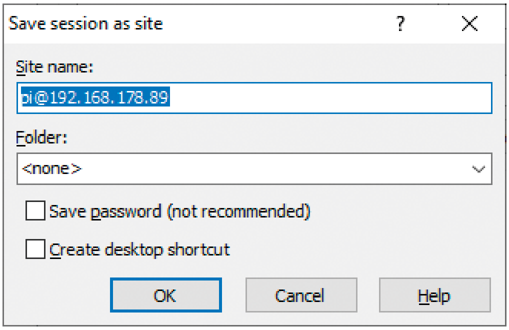
User name: pi

Password: ●●●●●●●●●

☑ Show Login dialog on startup and when the last session is closed

Figure 1.19: WinSCP credentials configuration.

Log in and save the connection destination.



Save session as site

Site name: pi@192.168.178.89

Folder: <none>

□ Save password (not recommended)

□ Create desktop shortcut

Figure 1.20: WinSCP configuration of directories.

You can now access the file directories of the Raspberry Pi.