How to RTDE

Practical tips to set up "Real Time Data Exchange"

by Henning Forbech, 4TECH Robotics ApS
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Scope:

The purpose of this document is to help users to get through the RTDE setup process with less practical problems.

When I first time have to set up a RTDE connection to a UR robot I ran into more practical problems than expected. I started this document to collect and save all information on how to setup a UR robot with data input from an external computer.
During the process is also grow into a history of all the complications and hints on how to solve some of the more practical problems in getting a RTDE connection up and running. So, it is not just a straight forward blueprint for setting up RTDE. In between there are some of my mishaps in this journey.

Universal Robots have some information on how to setup RTDE and more help can be found on different internet fora. But a lot of the more practical problem are not documented or, at least, I have not been able to find this information.

Tips on programming and using RTDE is not a part of this document.

Help with updates:

If you find this document useful, please help improving it by adding more information. You can also help by clearing out misunderstandings and errors that I have made.
When you make changes to the document, please update the version number and date in the header. You are also welcome to add our name to the document.

Background:

As part of a project, I wanted to send information from a Raspberry Pi to a UR robot. It should be easy to send this one-way information by the Real Time Date Transfer (RTDE).
Universal Robots have published a small Python module that should make it possible to make a direct connection from a Raspberry Pi to the UR controller. I couldn't get this program to compile and went for a solution where a Windows PC should make the connection between the Raspberry Pi and the UR controller. Data was then sent from the Raspberry Pi to this Connecting PC by WiFi and UDP. The challenge was now to get the Connection PC to send data to the UR controller by RTDE.

This description is based on a connecting between a PC running Windows 10 and a UR5 CB31 running PolyScope 3.15.

Windows PC for connecting to UR-controller with RTDE:

The RTDE connection to the UR controller is made from a PC running Windows 10 Pro. This computer must be set up with Python to run the program that make the RTDE connection to the UR controller.
IP-address and ports must also be set up to match the UR controller and the LAN cable must be connected.

In this document I will only describe how to setup the PC, the robot and the connection between them.

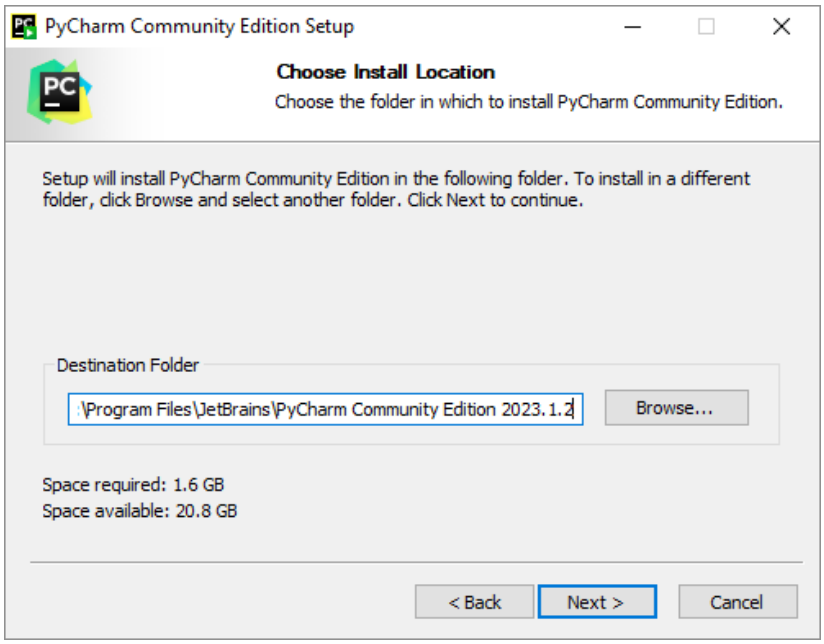
SimpleStudent have made a nice series of videos on how to set up and run RTDE for the first time. This is a must see when you are ready run the RTDE connection.
The first three videos give a good understanding of how to get RTDE going.
https://youtube.com/playlist?list=PLnJ9fSRnDN3B1wEuxQY4thTWyGoT2N0yd
https://www.youtube.com/@simplestudent279

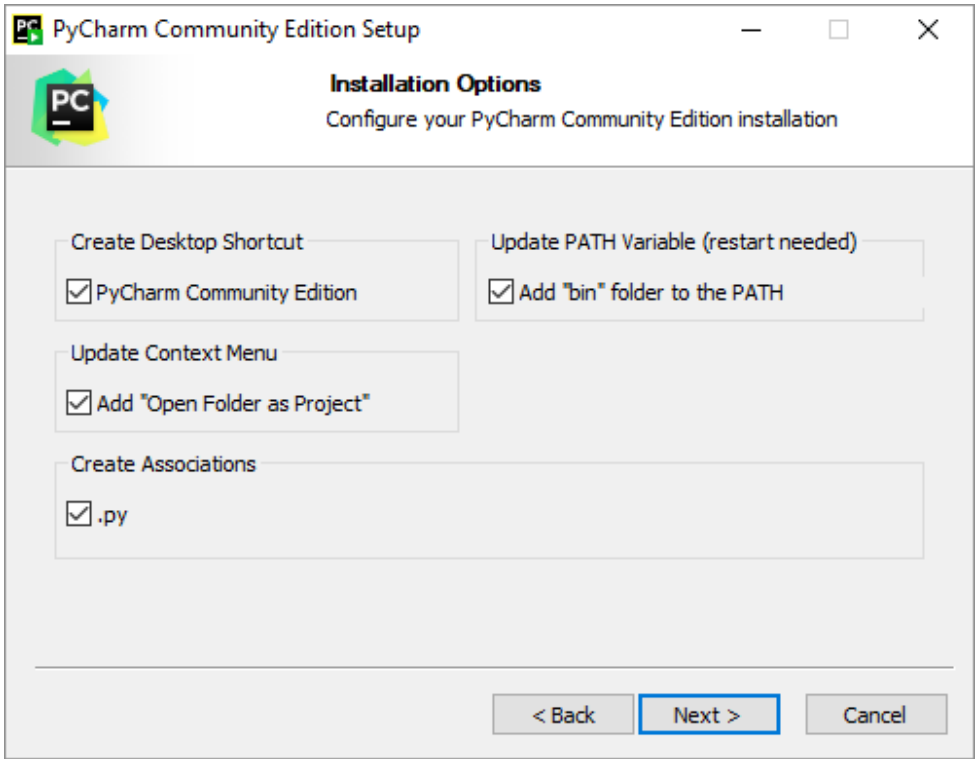
I will only describe how to install the programs and set up the computer.

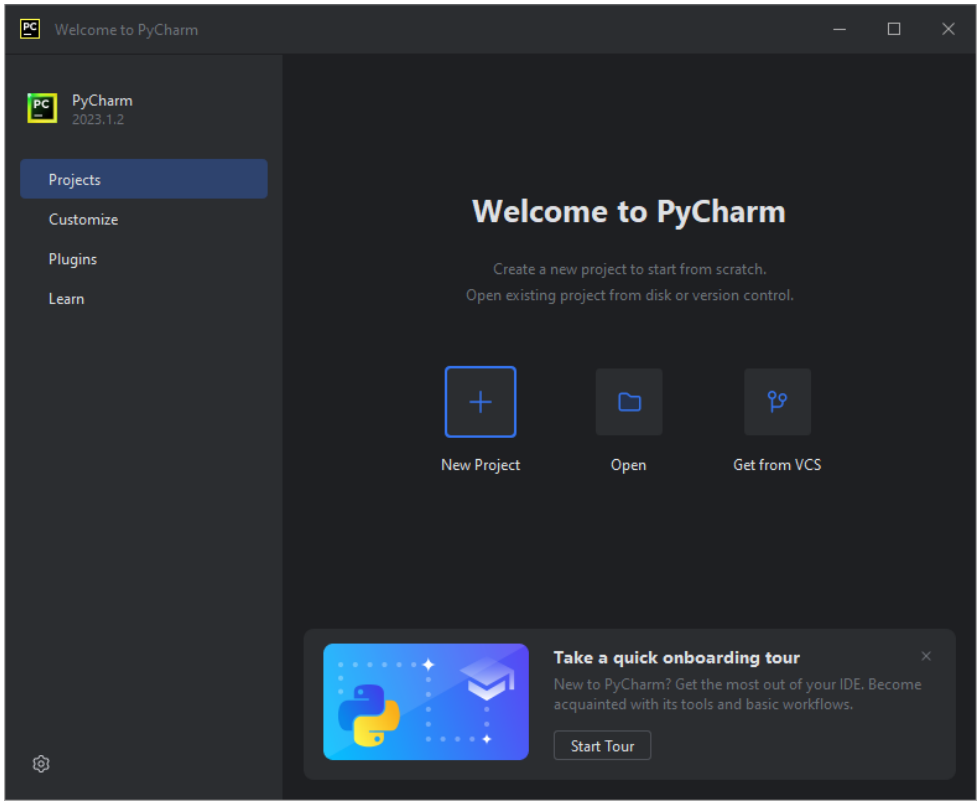
Python program:

The RTDE program for the Windows computer is a small program that must run from Python.
If you are not familiar with programming in Python the smartest is to install and use the same programs as SimpleStudent is using for his nice video tutorials on how to set up the communication.

First you must install an editor, PyCharm, for Python.
Go to the address below, download and install the program.
"PyCharm Community" is the free version of the program:
https://www.jetbrains.com/pycharm/download/other.html
https://download.jetbrains.com/python/pycharm-community-2023.1.2.exe?_ga=2.210391829.167791767.1686485657-512205707.1686485657




PyCharm Community Edition Setup
Installation Options
Configure your PyCharm Community Edition installation
Create Desktop Shortcut
PyCharm Community Edition
Update PATH Variable (restart needed)
Add "bin" folder to the PATH
Update Context Menu
Add "Open Folder as Project"
Create Associations
.py
< Back
Next >
Cancel


Welcome to PyCharm
PyCharm
2023.1.2
Projects
Customize
Plugins
Learn
Welcome to PyCharm
Create a new project to start from scratch.
Open existing project from disk or version control.
New Project
Open
Get from VCS
Take a quick onboarding tour
New to PyCharm? Get the most out of your IDE. Become acquainted with its tools and basic workflows.
Start Tour

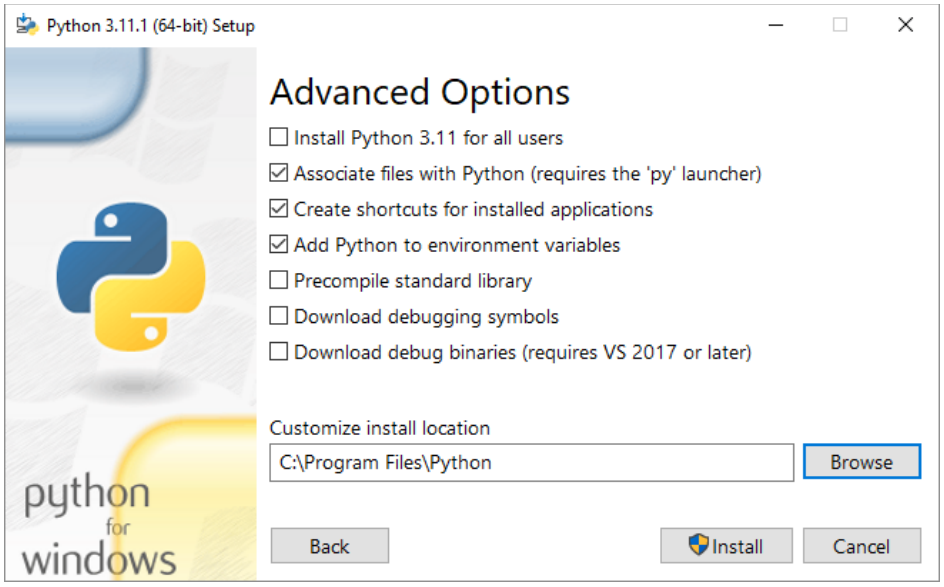
Installing Python:

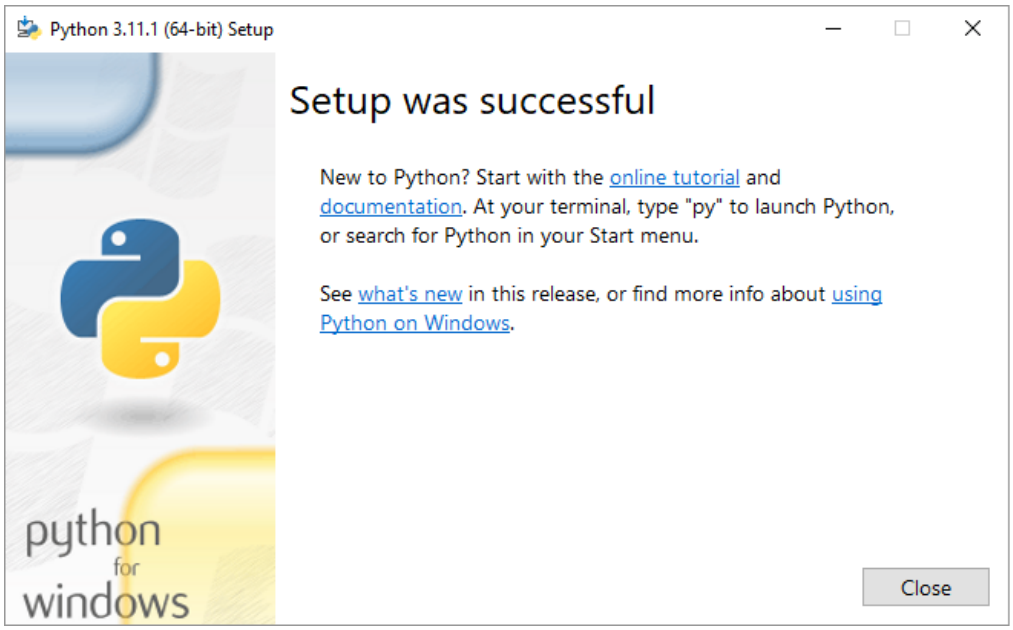
When you install the PyCharm editor, it will also install Python on your computer. But that version of Python will be installed under UserApps and it may be difficult/impossible to update this program.
Windows will block it from running an automatically update!

You can solve this by installing Python in a folder outside UserApps.
Go to Python.org and download a free version of Python.
Link: https://www.python.org/downloads/windows/

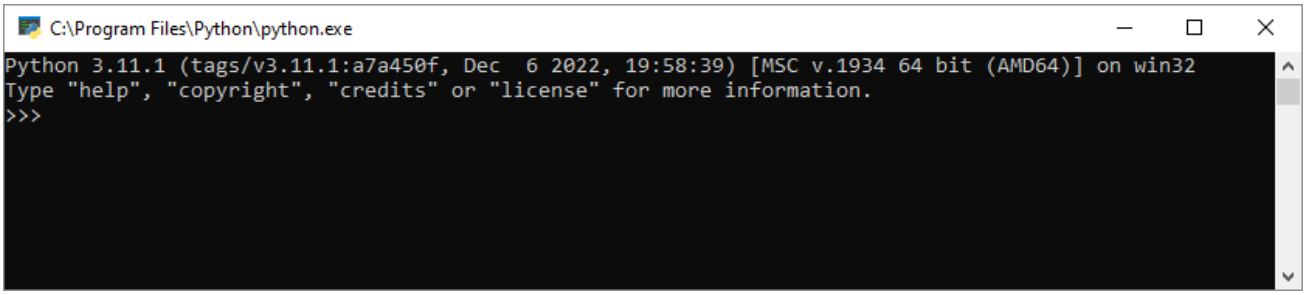
Make sure to get a version that fit your computer and it should be version 3.9 or later.

Make a new folder for this program (e.g. C:/Python or C:\Program Files/Python) and run the installation as Administrator.

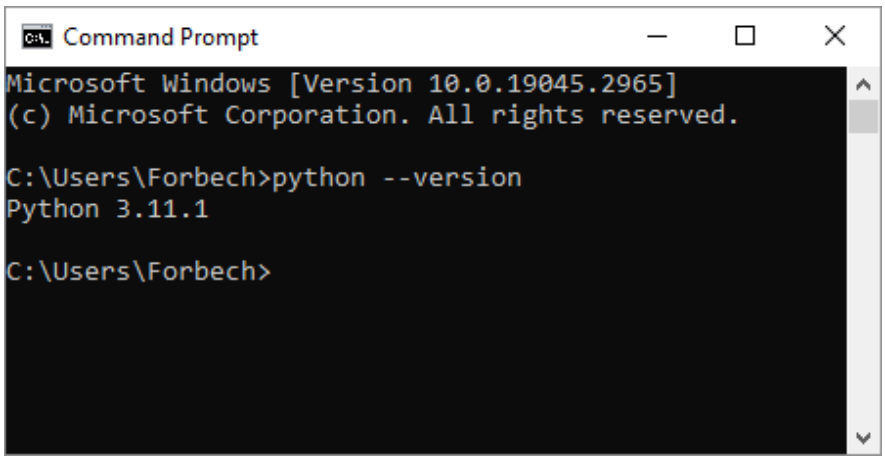




Once installed open the command prompt with "Window"+R and CMD,
go to the folder and run the pyton.exe
At the top of the window, you will see the version number for your Python.



From the command prompt you can also just type: python –-version



Python for PyCharm:

When you are about to run a python program from the PyCharm editor it will ask you which Python to use.
Make sure to use the one you installed outside UserApps.

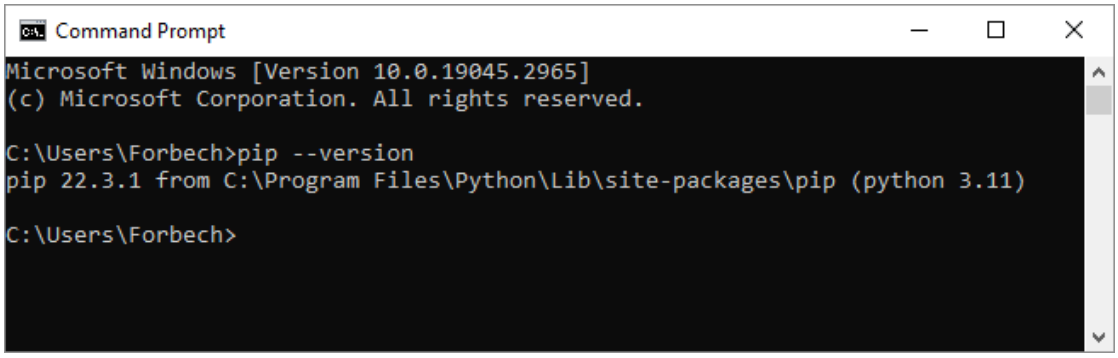
Installing the RTDE program for Python:

Python uses a lot of libraries for running programs. These libraries must be installed for the Python to use them.

Most important for this project is the RTDE library from Universal Robots. This program can be downloaded for free from GitHub but the simplest is just to let Python find and install it by running the PIP program.
But first you must be sure to have the right version of the PIP program.

PIP:

You will need at least version 19.3 of PIP (RTDE will not install with older versions of PIP).
Check your PIP version from the command prompt: pip –-version

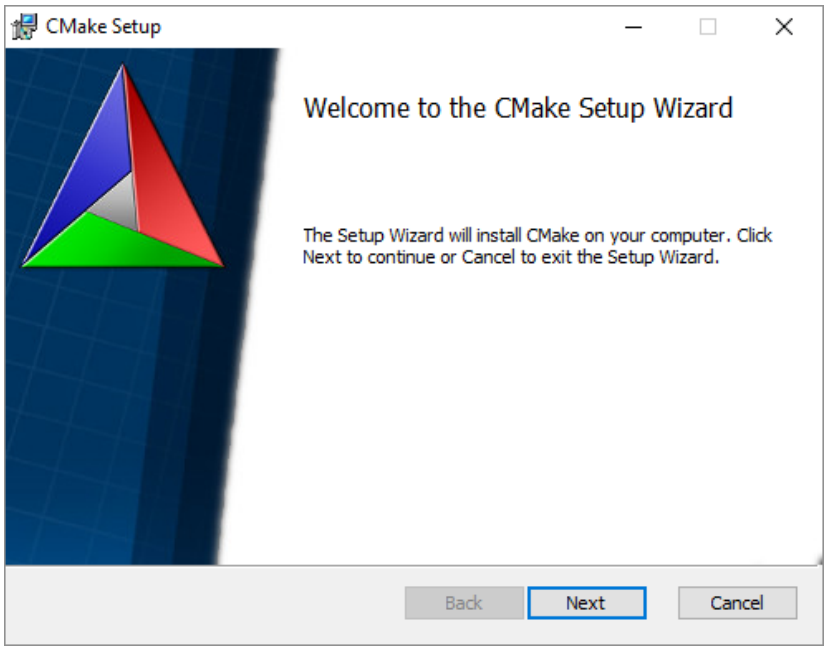


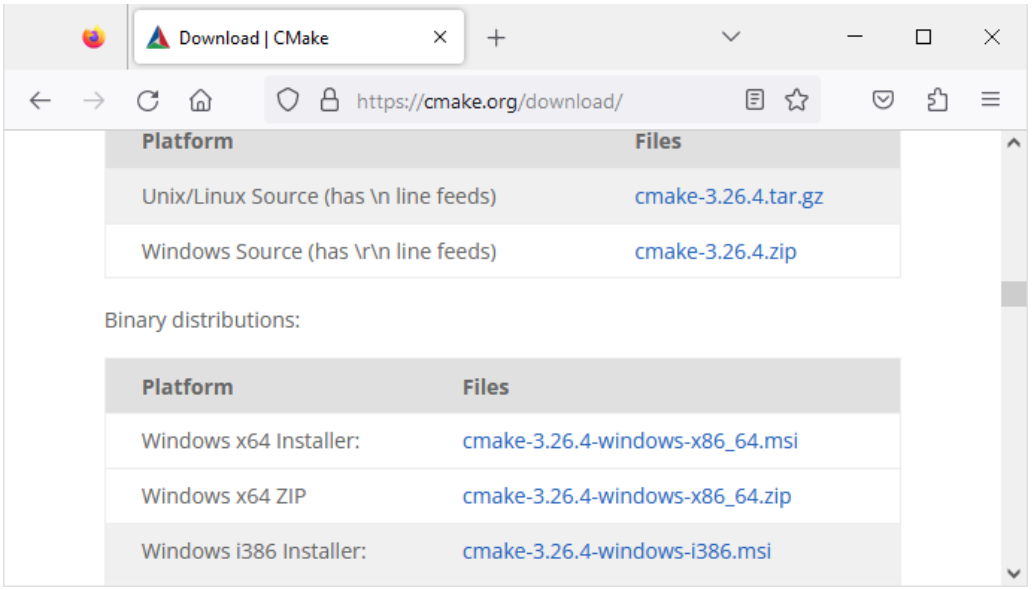
If you need to install a newer version of the PIP program, use the command: python -m pip install --upgrade pip

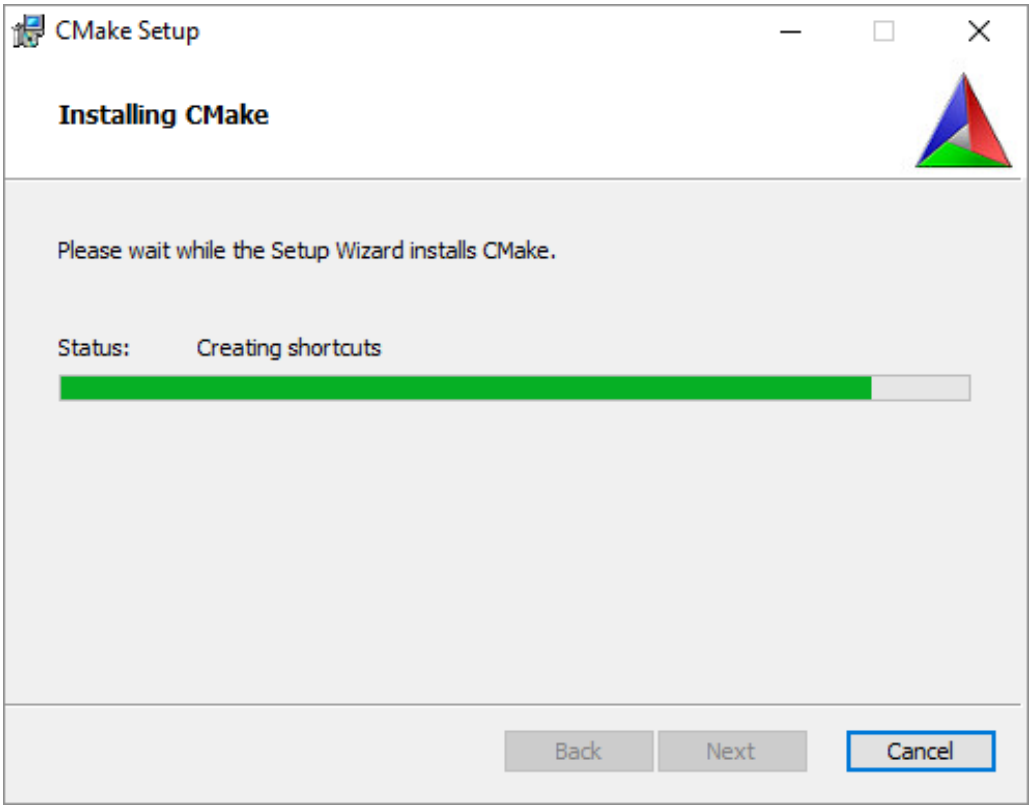
For Python to install RTDE it will need two programs called Cmake and Boost. It can be a nightmare to get these programs installed but here we go:

Cmake:

Download and install Cmake from: https://cmake.org/download/





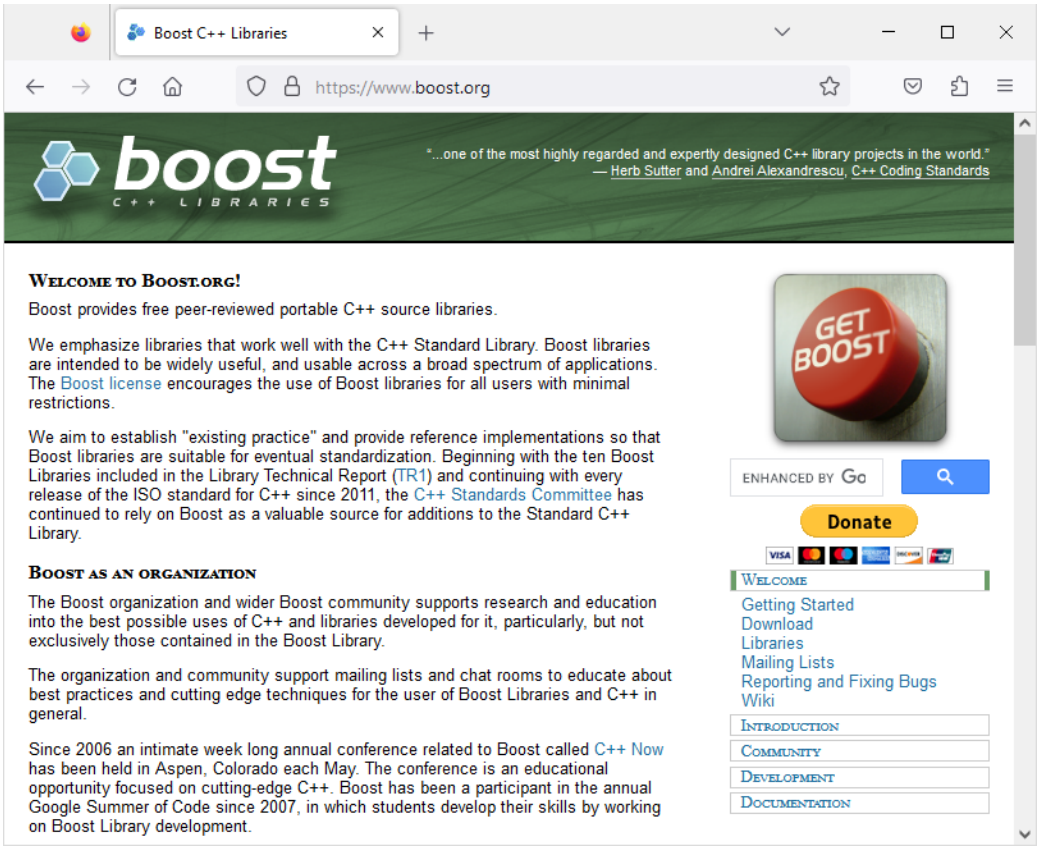


Boost:

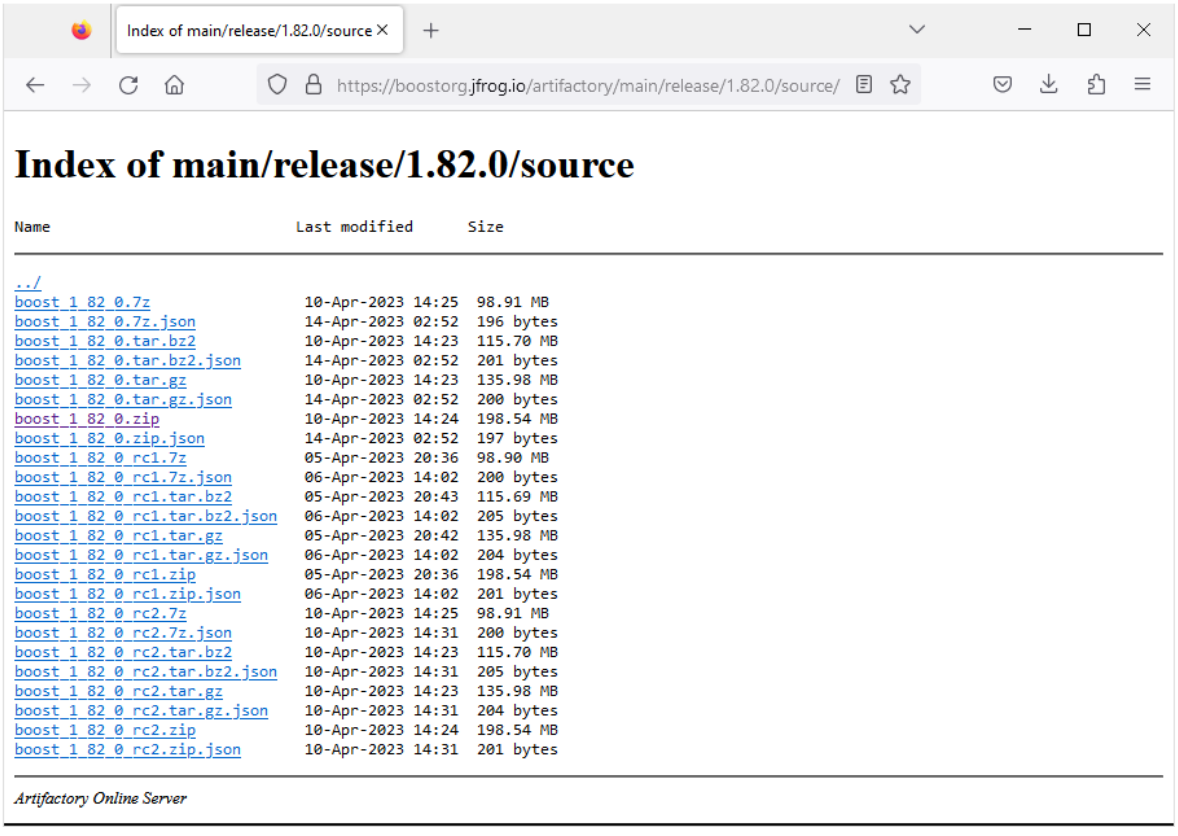
You will also need a program called Boost.
It is a free C++ source library.
Go to: https://www.boost.org

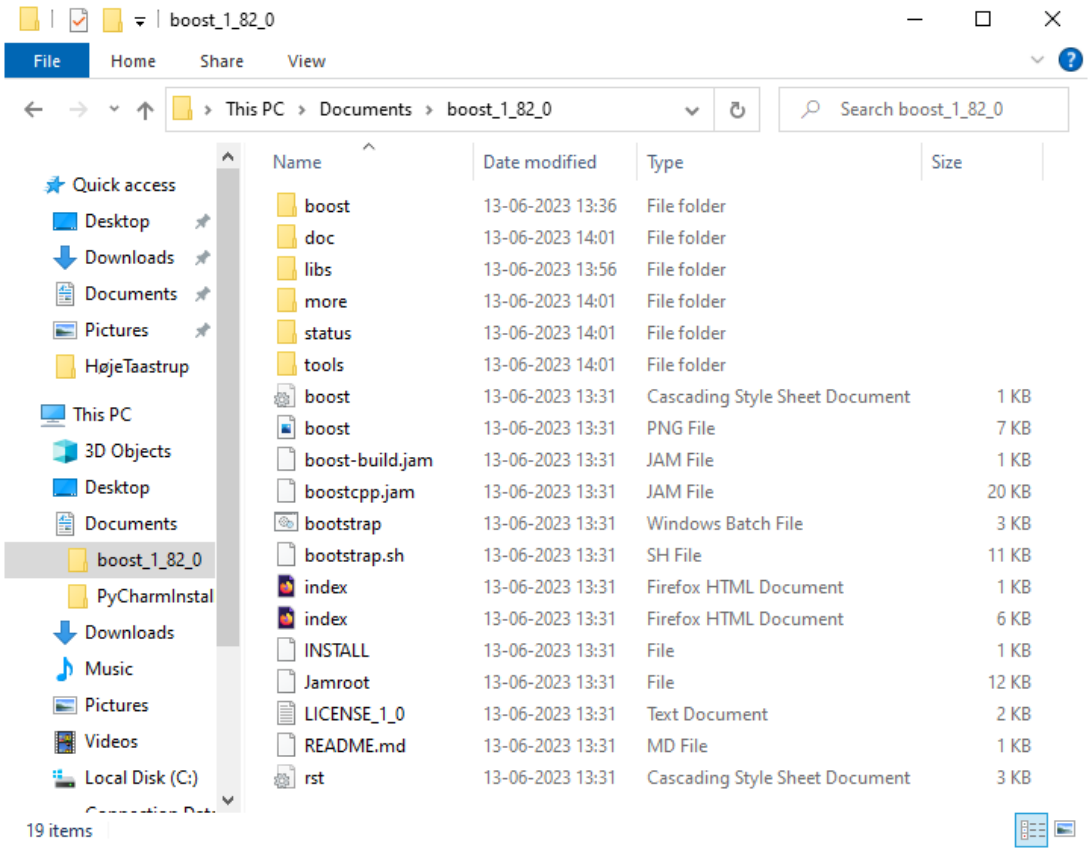
Warning:

This first attempt to install Boost will fail!
Look below for a fix

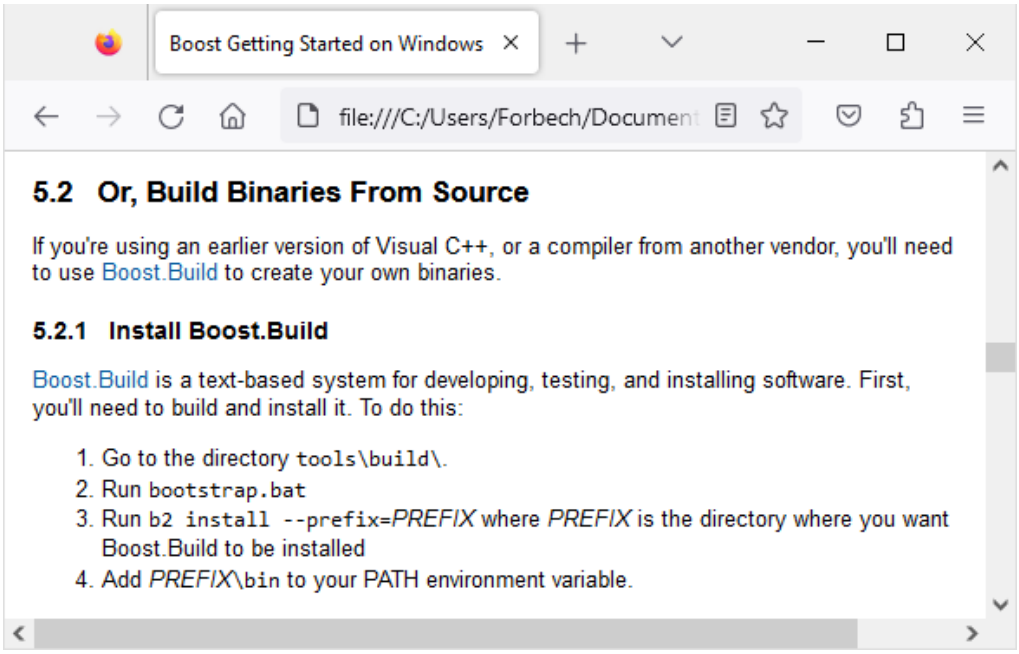


Go to "Download" and download the 200 Mb zip file and unzip on your hard disk (704 Mb unzipped).





You only need to install the BoostBuild.
Follow this description from the "Boost Getting Started on Windows" documentation.



Open the folder and run the bootstrap.bat

```
C:\Windows\system32\cmd.exe
 Volume in drive C has no label.
 Volume Serial Number is BA99-4E63

 Directory of C:\Users\Forbech\Documents\boost_1_82_0

13-06-2023  14:44    <DIR>          .
13-06-2023  14:44    <DIR>          ..
13-06-2023  13:36    <DIR>          boost
13-06-2023  13:31               850 boost-build.jam
13-06-2023  13:31               989 boost.css
13-06-2023  13:31             6.308 boost.png
13-06-2023  13:31            20.013 boostcpp.jam
13-06-2023  13:31             2.486 bootstrap.bat
13-06-2023  13:31            10.811 bootstrap.sh
13-06-2023  14:01    <DIR>          doc
13-06-2023  13:31               769 index.htm
13-06-2023  13:31             5.418 index.html
13-06-2023  13:31               291 INSTALL
13-06-2023  13:31            11.947 Jamroot
13-06-2023  13:56    <DIR>          libs
13-06-2023  13:31             1.338 LICENSE_1_0.txt
13-06-2023  14:01    <DIR>          more
13-06-2023  13:31               542 README.md
13-06-2023  13:31             2.608 rst.css
13-06-2023  14:01    <DIR>          status
13-06-2023  14:01    <DIR>          tools
              13 File(s)         64.370 bytes
               8 Dir(s)  23.446.142.976 bytes free

C:\Users\Forbech\Documents\boost_1_82_0>bootstrap.bat
```

This is what I got:

```
C:\Windows\system32\cmd.exe

C:\Users\Forbech\Documents\boost_1_82_0>bootstrap.bat
Building Boost.Build engine
LOCALAPPDATA=C:\Users\Forbech\AppData\Local
could not find "vswhere"
Call_If_Exists "..\bin\VCVARS32.BAT"
###
### Using 'msvc' toolset.
###

C:\Users\Forbech\Documents\boost_1_82_0\tools\build\src\engine>"cl" /nologo /MP
 /MT /TP /Feb2 /wd4996 /O2 /GL /EHsc   -DNDEBUG  builtins.cpp class.cpp command
.cpp compile.cpp constants.cpp cwd.cpp debug.cpp debugger.cpp execcmd.cpp execn
t.cpp execunix.cpp filent.cpp filesys.cpp fileunix.cpp frames.cpp function.cpp
glob.cpp hash.cpp hcache.cpp hdrmacro.cpp headers.cpp jam.cpp jamgram.cpp lists
.cpp make.cpp make1.cpp md5.cpp mem.cpp modules.cpp native.cpp object.cpp optio
n.cpp output.cpp parse.cpp pathnt.cpp pathsys.cpp pathunix.cpp regexp.cpp rules
.cpp scan.cpp search.cpp jam_strings.cpp startup.cpp subst.cpp sysinfo.cpp time
stamp.cpp variable.cpp w32_getreg.cpp modules/order.cpp modules/path.cpp module
s/property-set.cpp modules/regex.cpp modules/sequence.cpp modules/set.cpp /link
 kernel32.lib advapi32.lib user32.lib
'"cl"' is not recognized as an internal or external command,
operable program or batch file.

C:\Users\Forbech\Documents\boost_1_82_0\tools\build\src\engine>dir *.exe
 Volume in drive C has no label.
 Volume Serial Number is BA99-4E63

 Directory of C:\Users\Forbech\Documents\boost_1_82_0\tools\build\src\engine

File Not Found

Failed to build Boost.Build engine.

C:\Users\Forbech\Documents\boost_1_82_0>
```

There is a bug in the program and it will not install!!!!

How to fix the Boost problem:

I'm not sure what the problem is with the Boost 1.82.0 but I have earlier used the Boost 1.81.0. This program also has a bug (!) but I have found a way to bypass this problem.

You will find the install files for Boost 1.18.0 here:
https://www.boost.org/users/history/version_1_81_0.html

Unzip the files to your hard disk, e.g., C:\boost_1_81_0

Bootstrap.bat will go to C:\boost_1_81_0\tools\build\src\engine and look for b2.exe and then delete this file. But there is no b2.exe here and the program stop with an error.

This bug can be fixed by creating a b2.exe file and put it in the C:\boost_1_82_0\tools\build\src\engine directory.
This fake b2.exe file will be found and deleted by the bat program and then it will build the real b2.exe program.

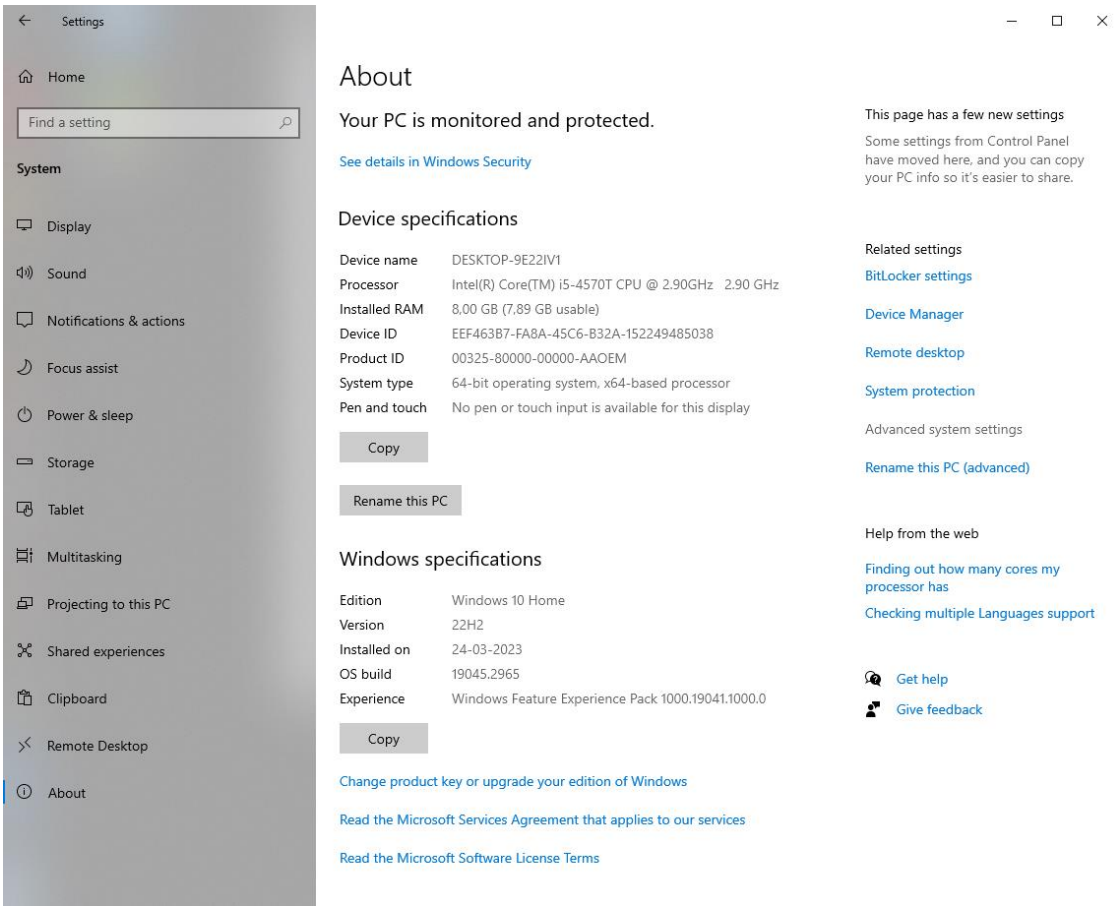
Stupid error but this fix solves the problem.
Now we can run the b2 program to install Boost.

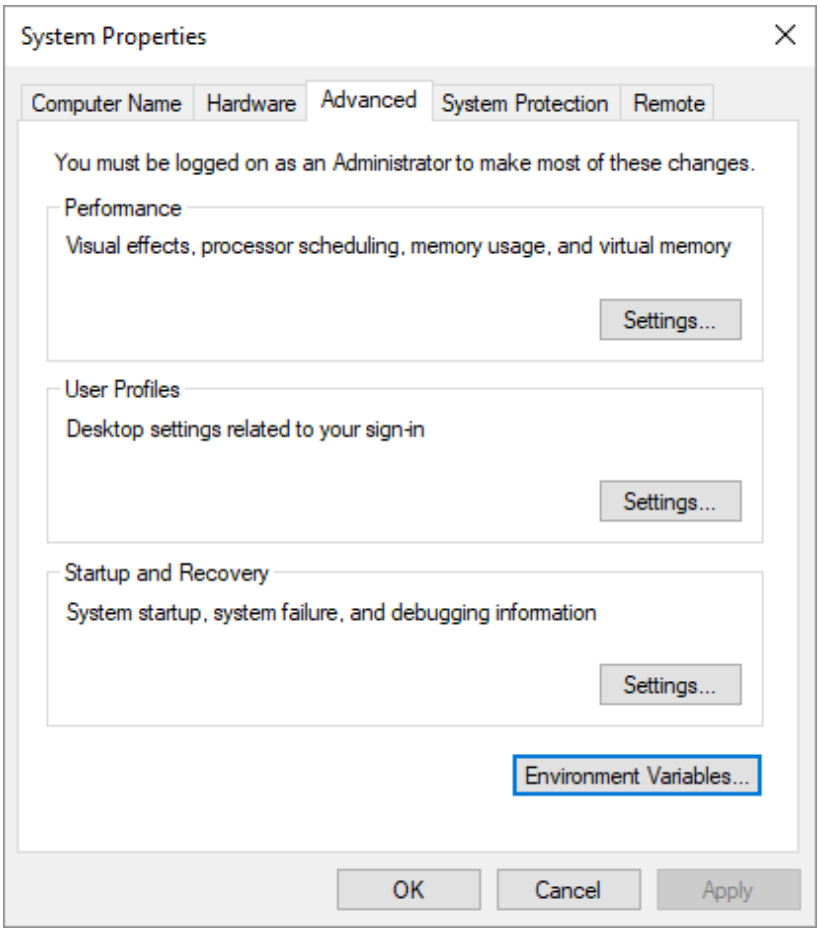
Boost path update in Windows:

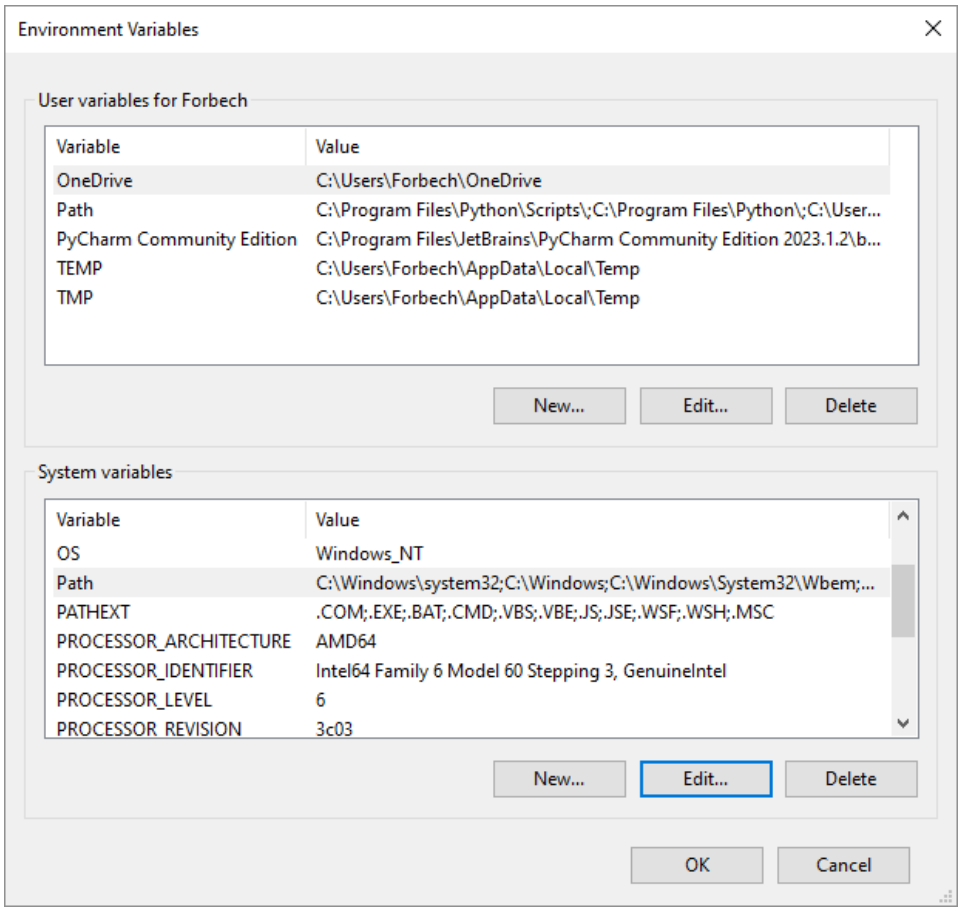
Now we must add the path for the new boost directory to the windows environmental variables. Follow this description:

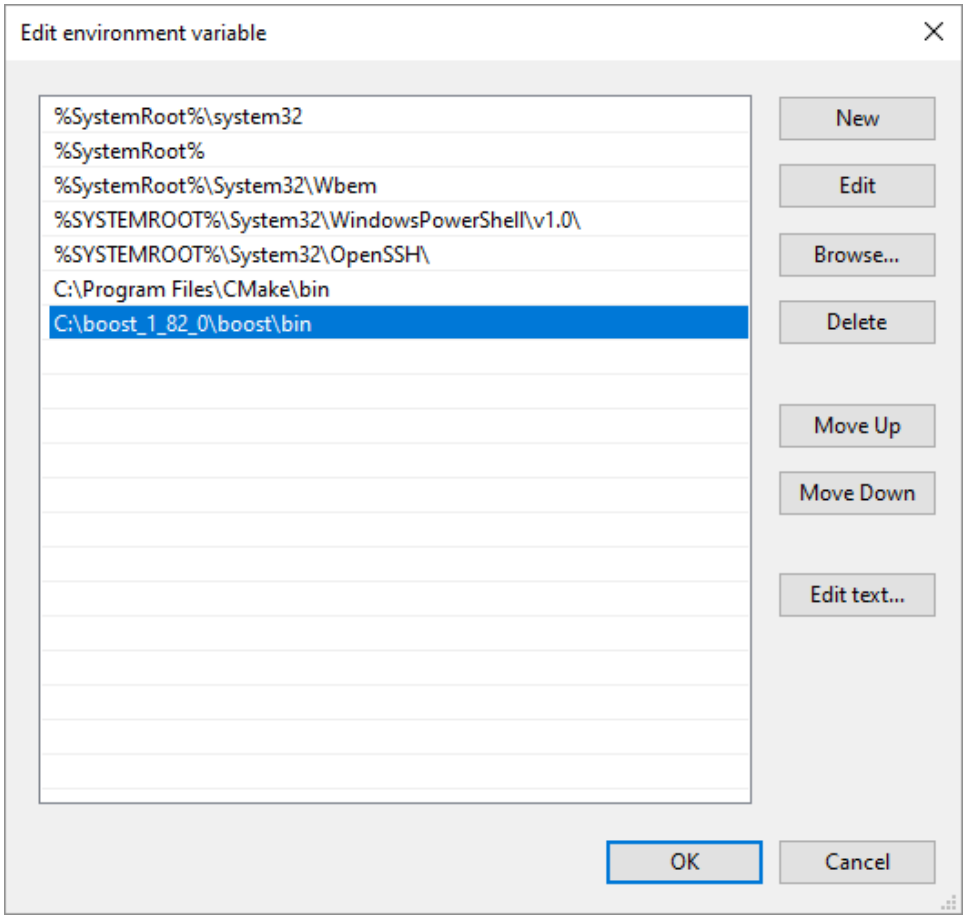
To add a path to the PATH environment variable

1. On the **Start** menu, right-click **Computer**.
2. On the context menu, click **Properties**.
3. In the **System** dialog box, click **Advanced system settings**.
4. On the **Advanced** tab of the **System Properties** dialog box, click **Environment Variables**.
5. In the **System Variables** box of the **Environment Variables** dialog box, scroll to **Path** and select it.
6. Click the lower of the two **Edit** buttons in the dialog box.
7. In the **Edit System Variable** dialog box, scroll to the end of the string in the **Variable value** box and add a semicolon (;).
8. Add the new path after the semicolon.
9. Click **OK** in three successive dialog boxes, and then close the **System** dialog box.


Settings
Home
Find a setting
System
Display
Sound
Notifications & actions
Focus assist
Power & sleep
Storage
Tablet
Multitasking
Projecting to this PC
Shared experiences
Clipboard
Remote Desktop
About
About
Your PC is monitored and protected.
See details in Windows Security
Device specifications
Device name DESKTOP-9E22IV1
Processor Intel(R) Core(TM) i5-4570T CPU @ 2.90GHz 2.90 GHz
Installed RAM 8,00 GB (7,89 GB usable)
Device ID EEF463B7-FA8A-45C6-B32A-152249485038
Product ID 00325-80000-00000-AAOEM
System type 64-bit operating system, x64-based processor
Pen and touch No pen or touch input is available for this display
Copy
Rename this PC
Windows specifications
Edition Windows 10 Home
Version 22H2
Installed on 24-03-2023
OS build 19045.2965
Experience Windows Feature Experience Pack 1000.19041.1000.0
Copy
Change product key or upgrade your edition of Windows
Read the Microsoft Services Agreement that applies to our services
Read the Microsoft Software License Terms
This page has a few new settings
Some settings from Control Panel have moved here, and you can copy your PC info so it's easier to share.
Related settings
BitLocker settings
Device Manager
Remote desktop
System protection
Advanced system settings
Rename this PC (advanced)
Help from the web
Finding out how many cores my processor has
Checking multiple Languages support
Get help
Give feedback


System Properties
Computer Name
Hardware
Advanced
System Protection
Remote
You must be logged on as an Administrator to make most of these changes.
Performance
Visual effects, processor scheduling, memory usage, and virtual memory
Settings...
User Profiles
Desktop settings related to your sign-in
Settings...
Startup and Recovery
System startup, system failure, and debugging information
Settings...
Environment Variables...
OK
Cancel
Apply


Environment Variables
User variables for Forbech
Variable
Value
OneDrive
C:\Users\Forbech\OneDrive
Path
C:\Program Files\Python\Scripts\;C:\Program Files\Python\;C:\User...
PyCharm Community Edition
C:\Program Files\JetBrains\PyCharm Community Edition 2023.1.2\b...
TEMP
C:\Users\Forbech\AppData\Local\Temp
TMP
C:\Users\Forbech\AppData\Local\Temp
New...
Edit...
Delete
System variables
Variable
Value
OS
Windows_NT
Path
C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;...
PATHEXT
.COM;.EXE;.BAT;.CMD;.VBS;.VBE;.JS;.JSE;.WSF;.WSH;.MSC
PROCESSOR_ARCHITECTURE
AMD64
PROCESSOR_IDENTIFIER
Intel64 Family 6 Model 60 Stepping 3, GenuineIntel
PROCESSOR_LEVEL
6
PROCESSOR_REVISION
3c03
New...
Edit...
Delete
OK
Cancel


Edit environment variable
%SystemRoot%\system32
%SystemRoot%
%SystemRoot%\System32\Wbem
%SYSTEMROOT%\System32\WindowsPowerShell\v1.0\
%SYSTEMROOT%\System32\OpenSSH\
C:\Program Files\CMake\bin
C:\boost_1_82_0\boost\bin
New
Edit
Browse...
Delete
Move Up
Move Down
Edit text...
OK
Cancel

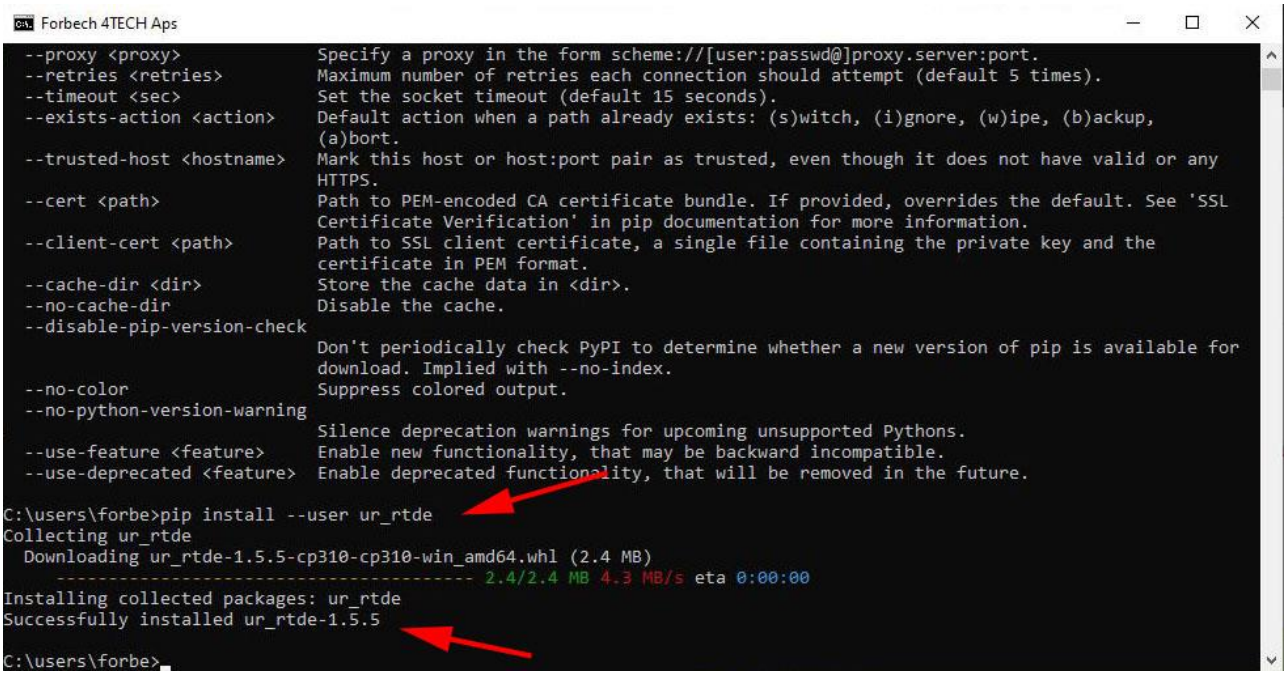
Installing RTDE:

Now you are finally ready to install RTDE.

The latest RTDE can be found here: https://pypi.org/project/ur-rtde/
From the command prompt use the command: pip install ur-rtde

If everything goes as planned you will get a confirmation the RTDE program is installed and can be used from your Python program.

When I first installed RTDE on an old laptop I got this conformation:



This old laptop was unstable and I decided to setup a new Connection PC for my project. I went through all these steps but when I finally tried to install RTDE, it failed!

After spending a lot of time trying to solve the problem I gave up and made a desperate attempt to get the new PC running with setup from the old laptop. I made a copy of the laptop hard disk to the PC hard disk. This is normally not possible but to my big surprise the PC booted into Windows. After a lot of updates and restarts I had the Windows installation from the laptop running on the PC.

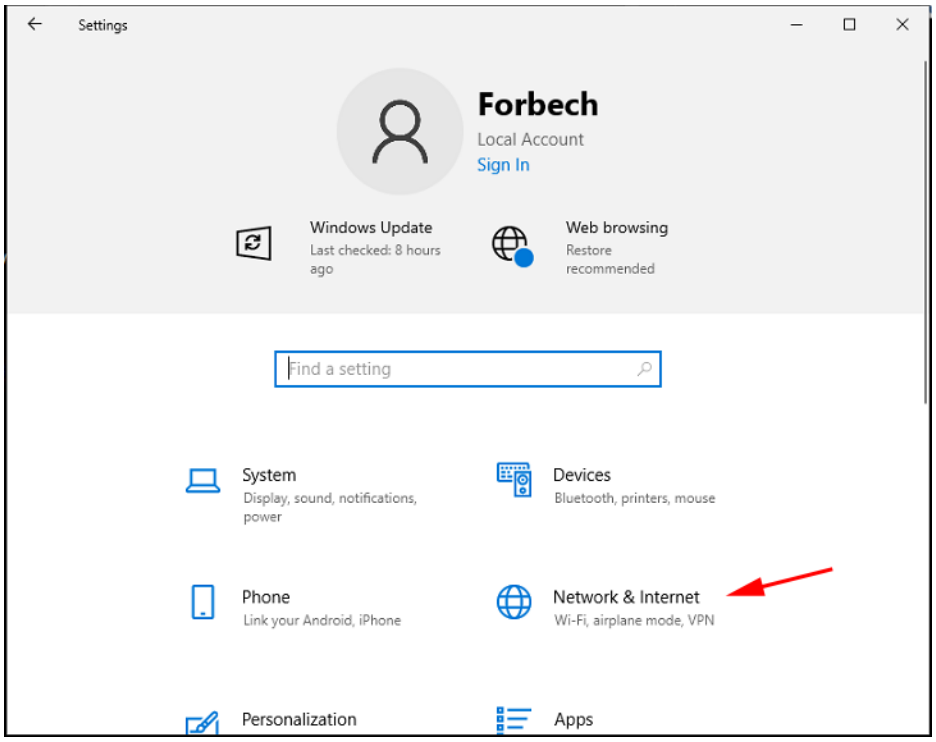
And RTDE was even running on the new hardware!!!

Later I realized that RTDE will only run on Windows Pro, not the Home edition!

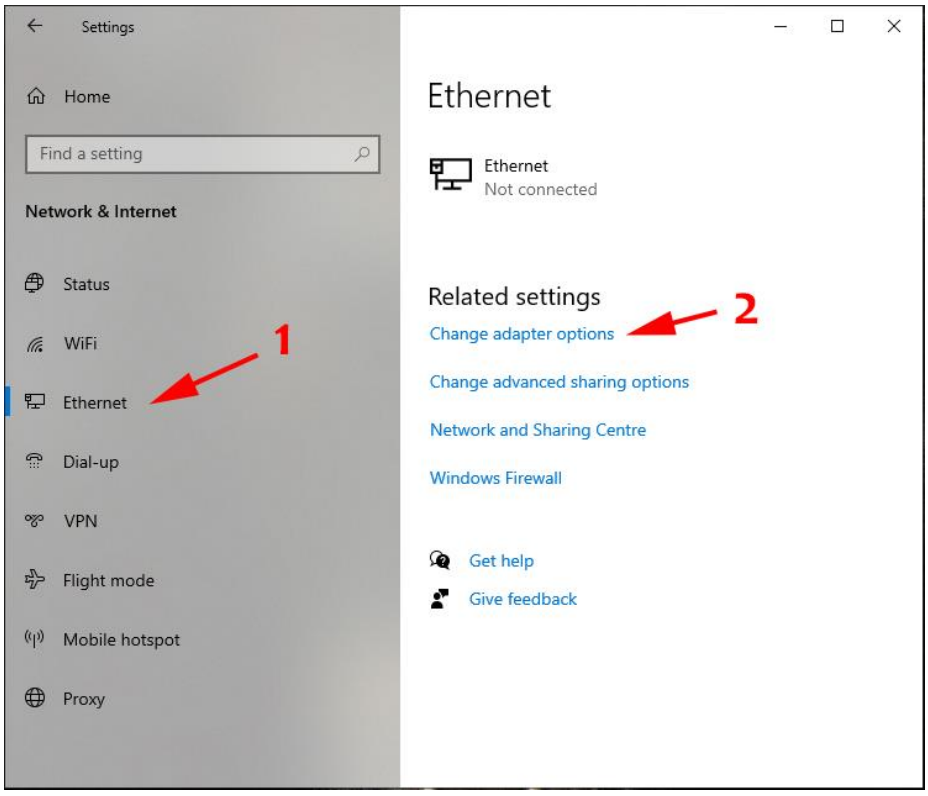
Windows network settings:

We are now ready to check the settings for the network adapter on the Connection PC. We have to find the IP address for the adapter where the net cable is attached.

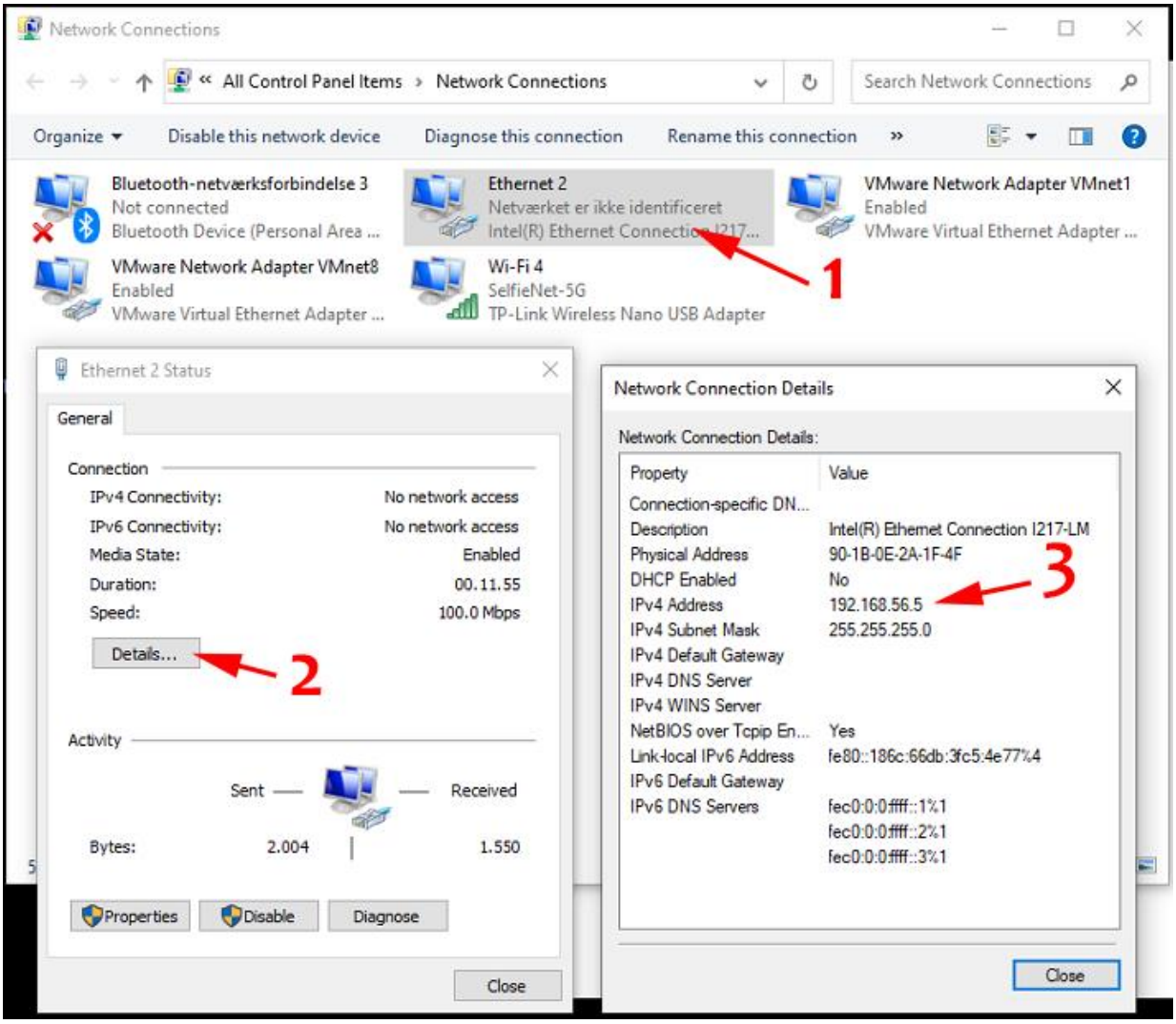
Open Windows Settings and click on the Network & Internet.



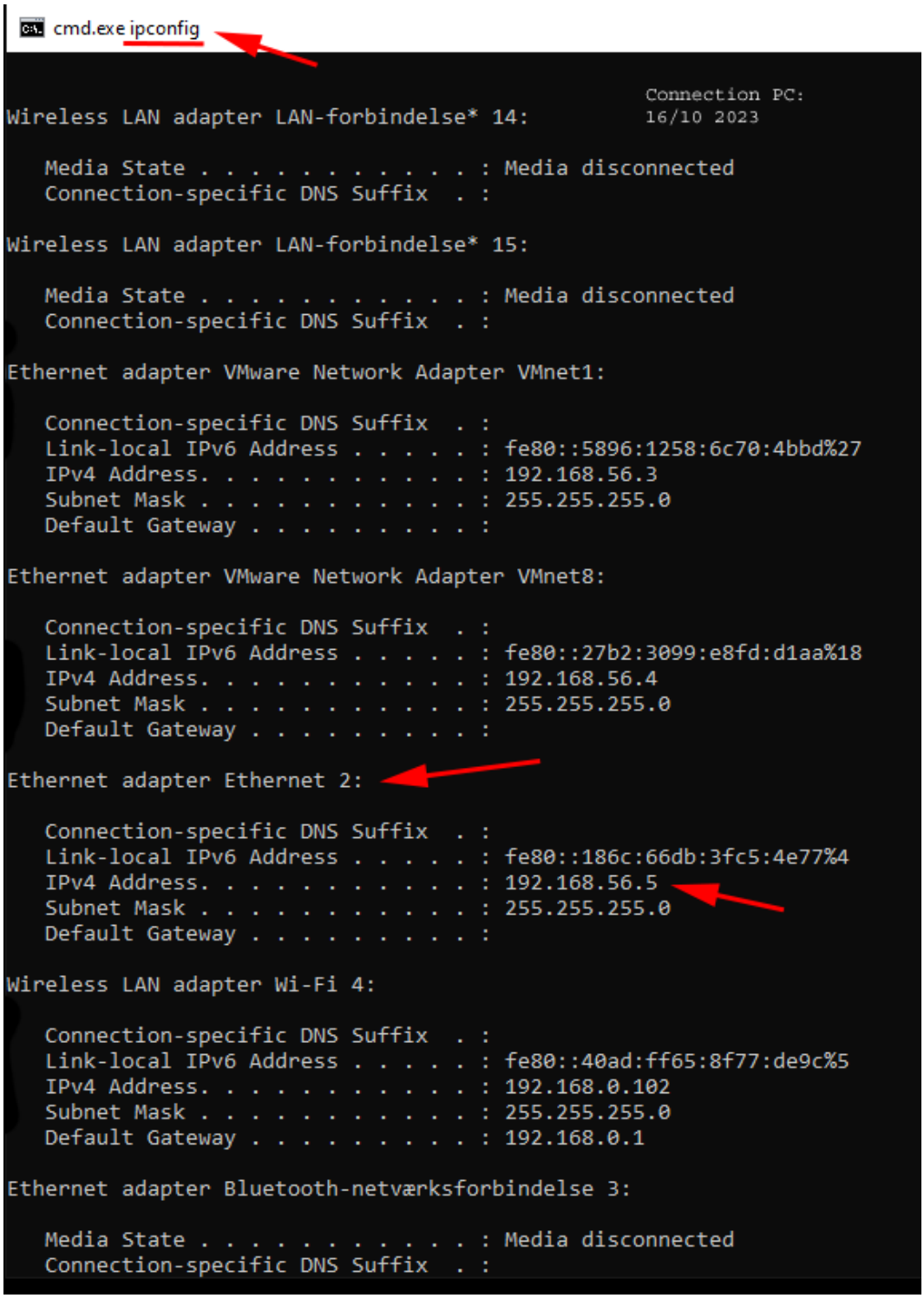
Go to ”Ethernet” and open “Change adapter options”



Here you will see all the network connections on the computer. WiFi, Bluetooth and different network adapters. The adapter for your LAN cable will be named "Ethernet" and maybe a number. You can check if it the right adapter by plugging or unplugging the LAN cable.
Click on the Ethernet to see status of the adapter and continuer by clicking on "Details".
You will now get a lot of information on this adapter. Look for the "IPv4 Address" for the adapter.
It is this IP address you will need to set up the connection on the UR controller.

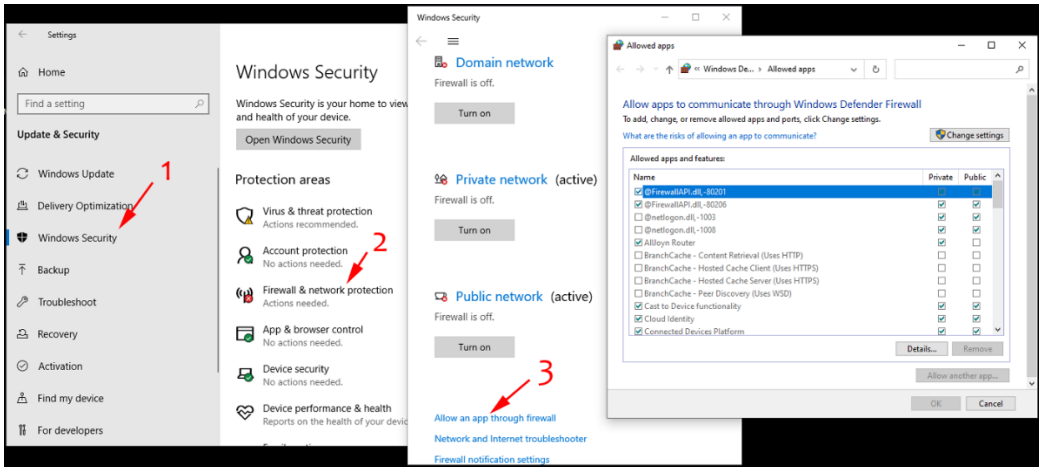


If you are more hardcore you can also just open the Windows commando line and use "ipconfig" to get the information.

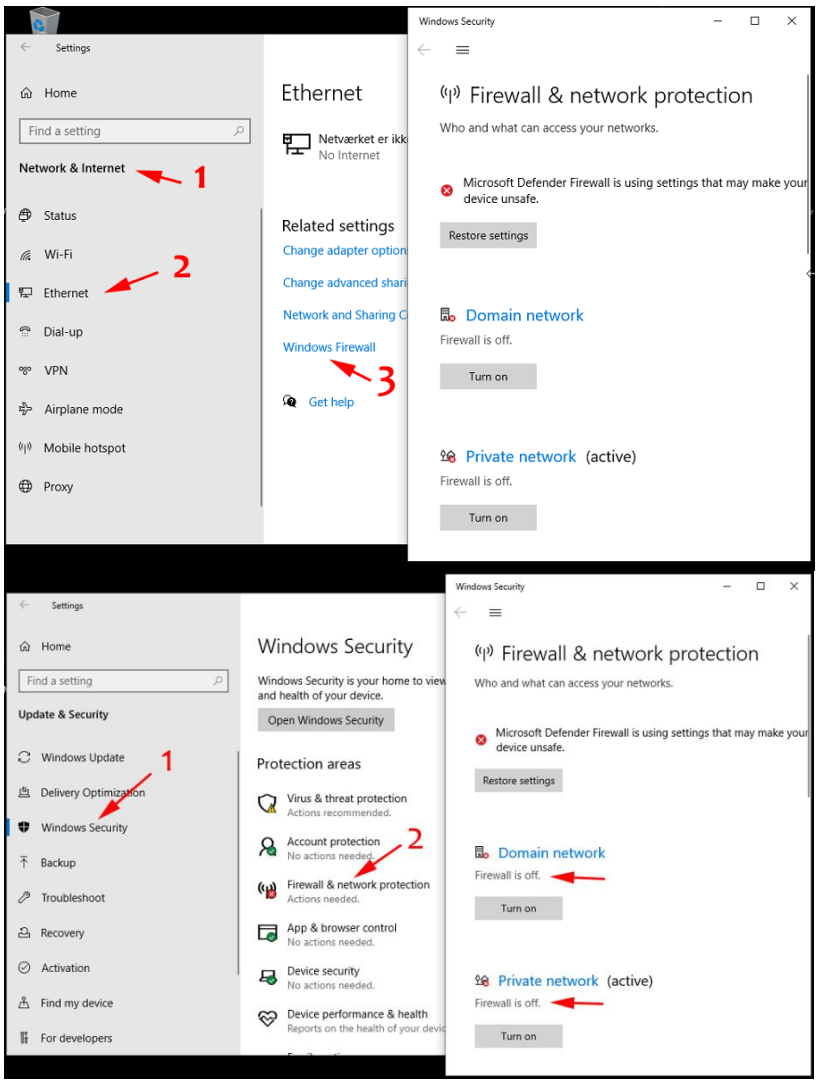


Allowing a program through Windows firewall:

Windows firewall may give some problems when the RTDE program try to send data to the UR controller.
You can allow python through the firewall with these steps:



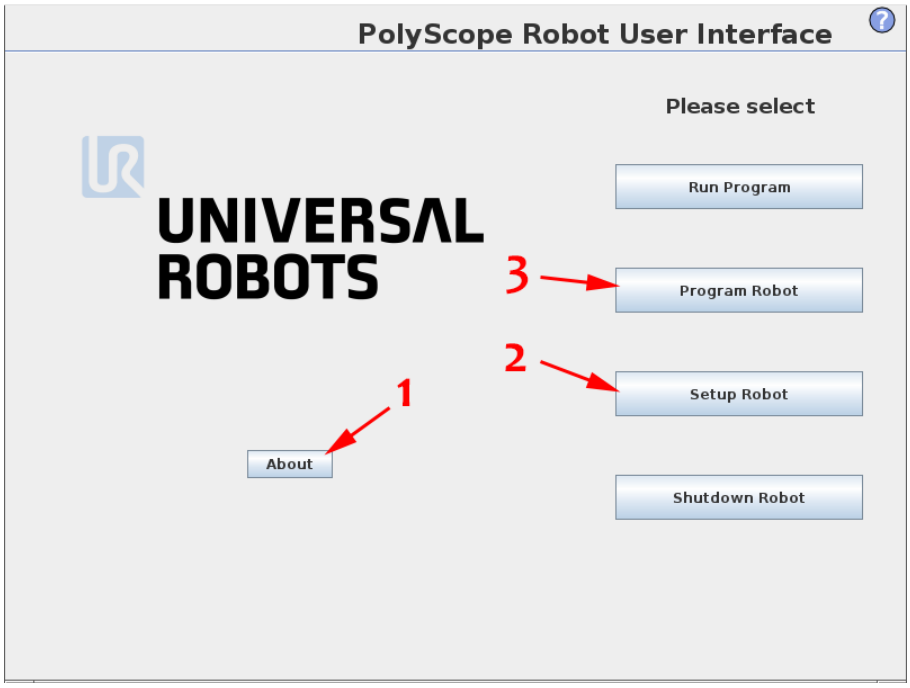
For a start it is probably easier just to turn off the Firewall. When you got RTDE running you can try to turn the Firewall back on again.
There are two ways to turn off Firewall:



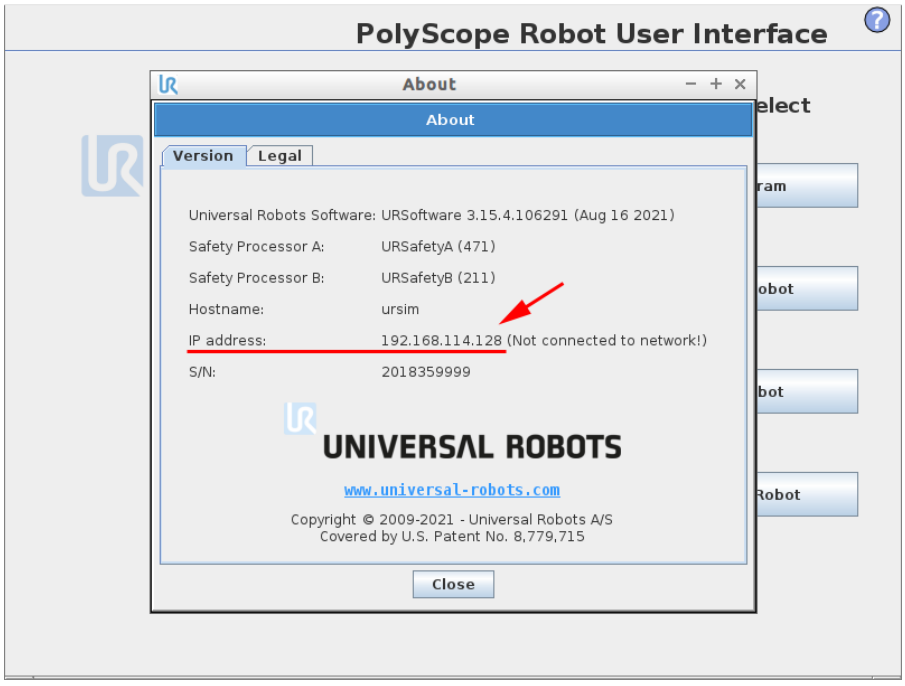
Setting up the UR controller:

To prepare for a RTDE connection both the UR controller and the computer to connect to it need to be setup.
Here follow first a description on how to set up the UR controller and then how to setup the computer to make the connection.

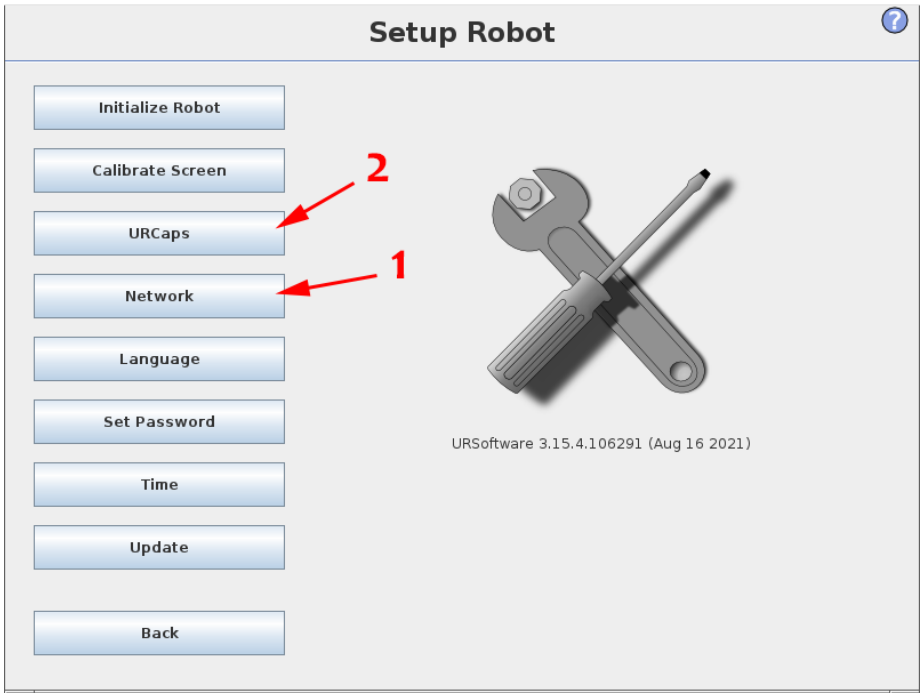
Go to the opening screen for the UR controller start by checking the status of your robot. Next you must do some settings from this start screen and later you must start programming the robot to some more settings to the installation.



The "About" button will give you information on the IP address for the robot.

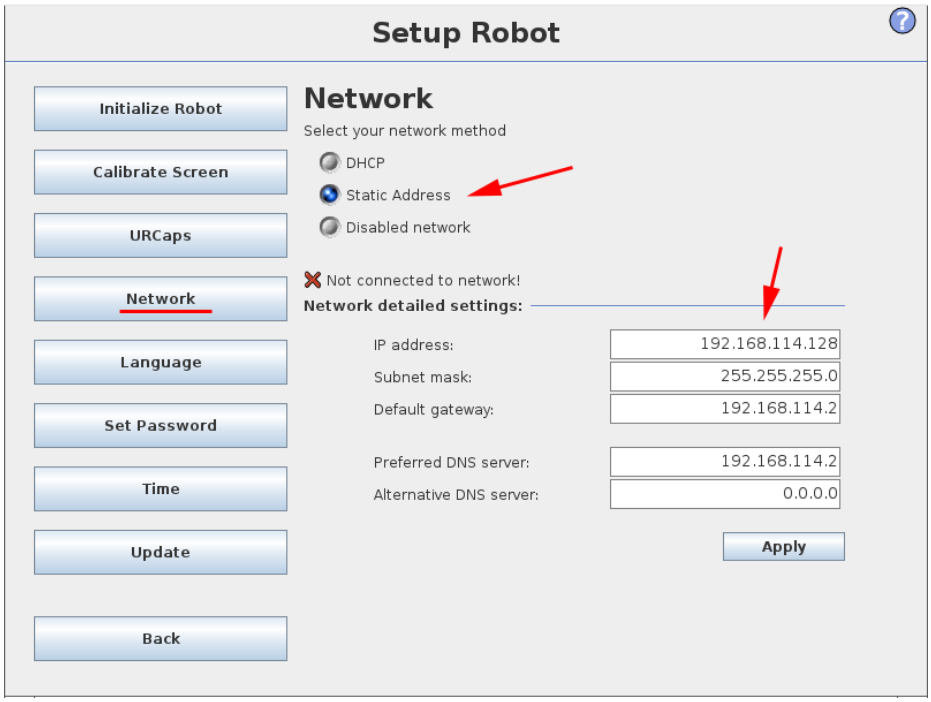


From the "Setup Robot" button you must set the network and check the URcaps.



Network:

To use RTDE the UR controller must be setup with a fixed IP address.



The IP address on the UR controller and the Windows PC must belong to the same IP subnet. That is the numbers in the first tree groups must be the same but the last group must be close, but not the same.

Example: If your PC is 192.168.1.1 the UR controller could be 192.168.1.2

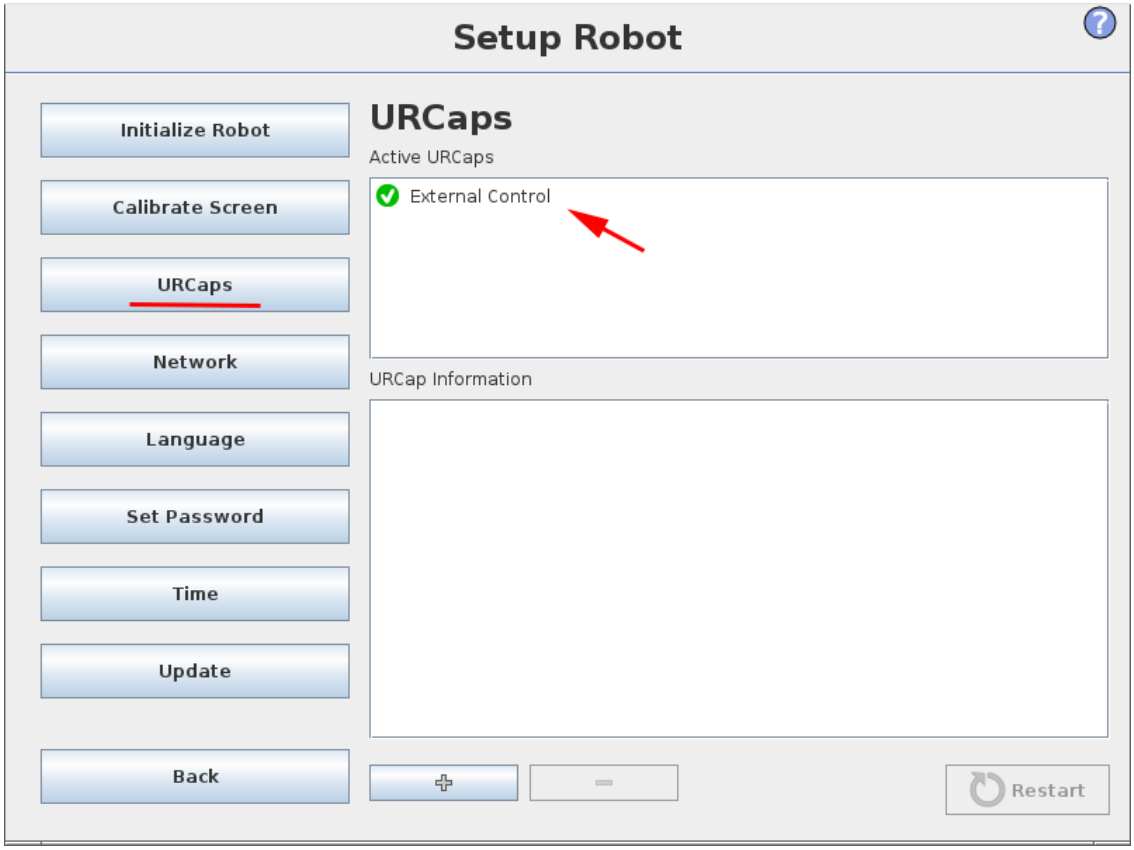
If you cannot change the IP address on the Windows computer you must change the IP address on the UR controller.

Subnet mask must be set to 255.255.255.0
Default gateway and DNS information will probably be applied automatically by the controller.

Go back and click the "About" button again to check the new IP address.

UR Cap: External Control:

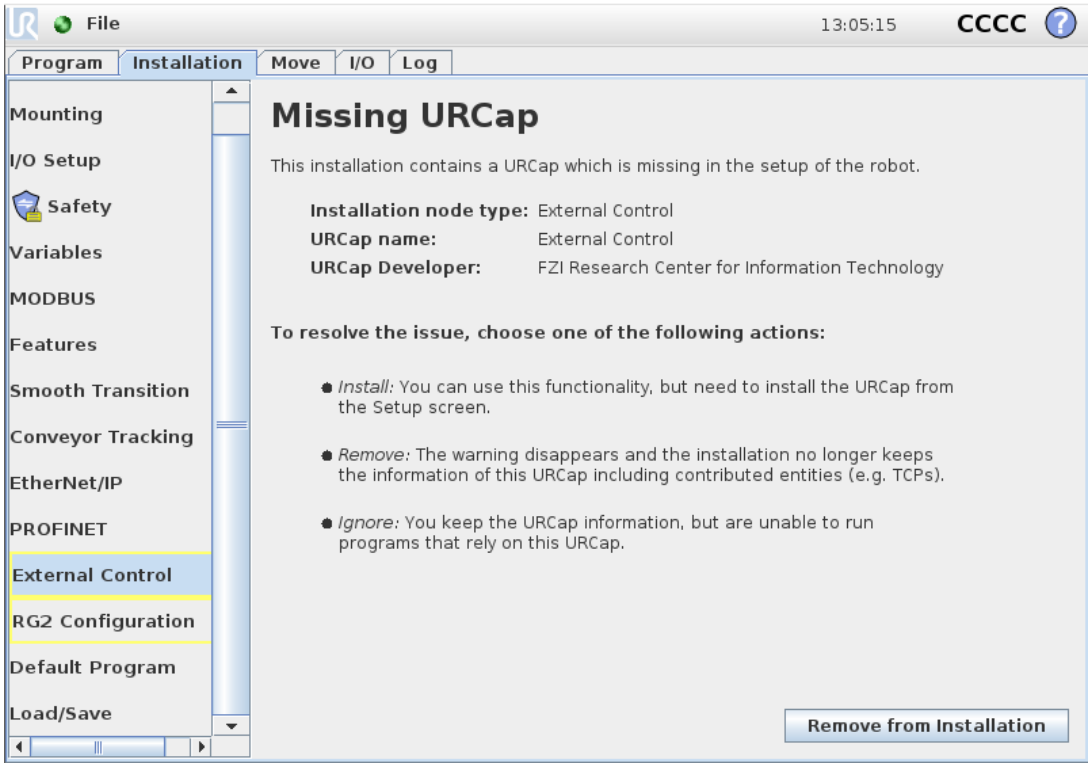
The UR controller will need a UR cap for external communication.
From the startup screen you can choose "Setup Robot" and "URCaps" to check if this UR Cap is installed.



If "External Control" is not on the list of active Caps it must be installed.
If the CAP is missing PolyScope will also later show an error massage.

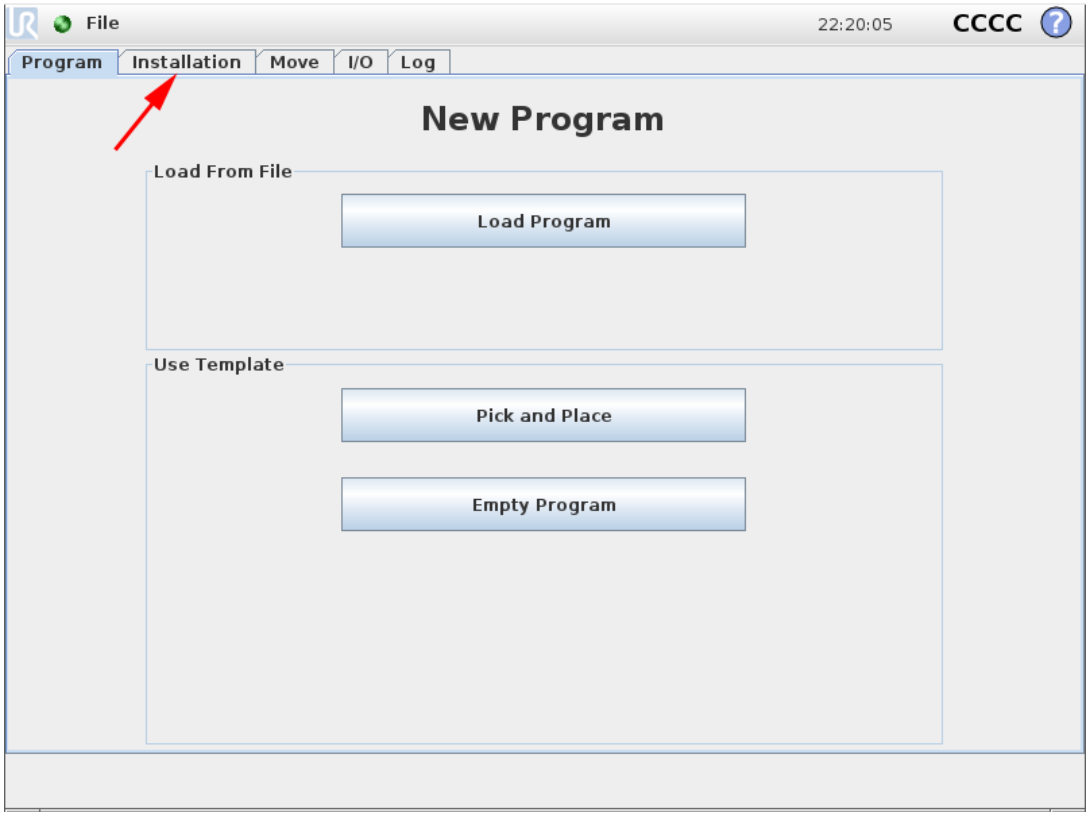
This CAP is free and can be downloaded here:
https://github.com/UniversalRobots/Universal_Robots_ExternalControl_URCap/releases

I'm not sure if this UR cap is necessary for robots in the e-Series.
More information here:
https://github.com/UniversalRobots/Universal_Robots_ROS_Driver/blob/master/ur_robot_driver/doc/install_urcap_e_series.md



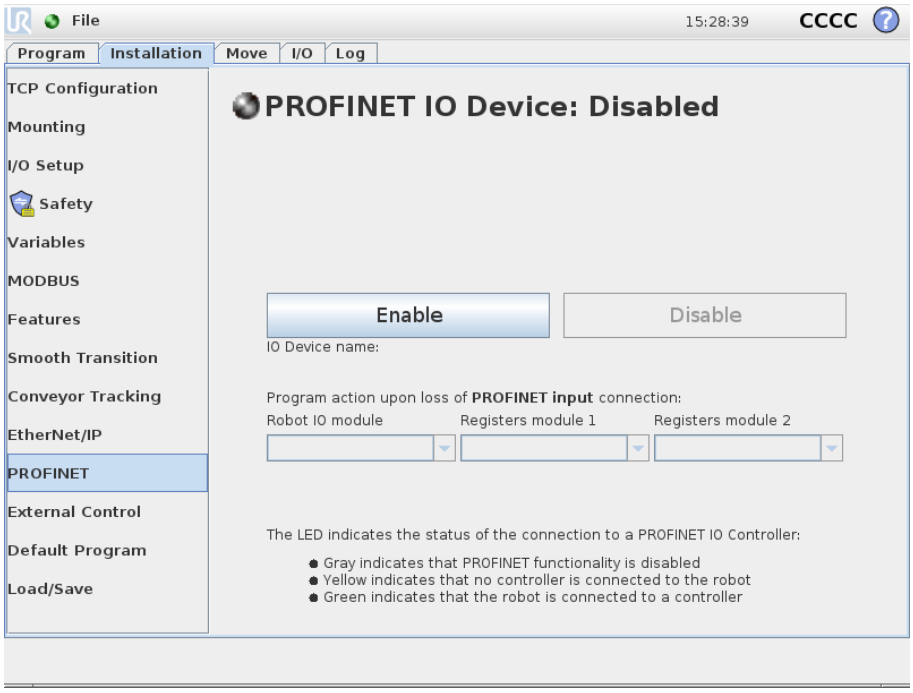
Installation:

From the start screen press "Program Robot"
You don't need to start a new program or open a program. You only have to go to "Installation". Here you have to do some settings.



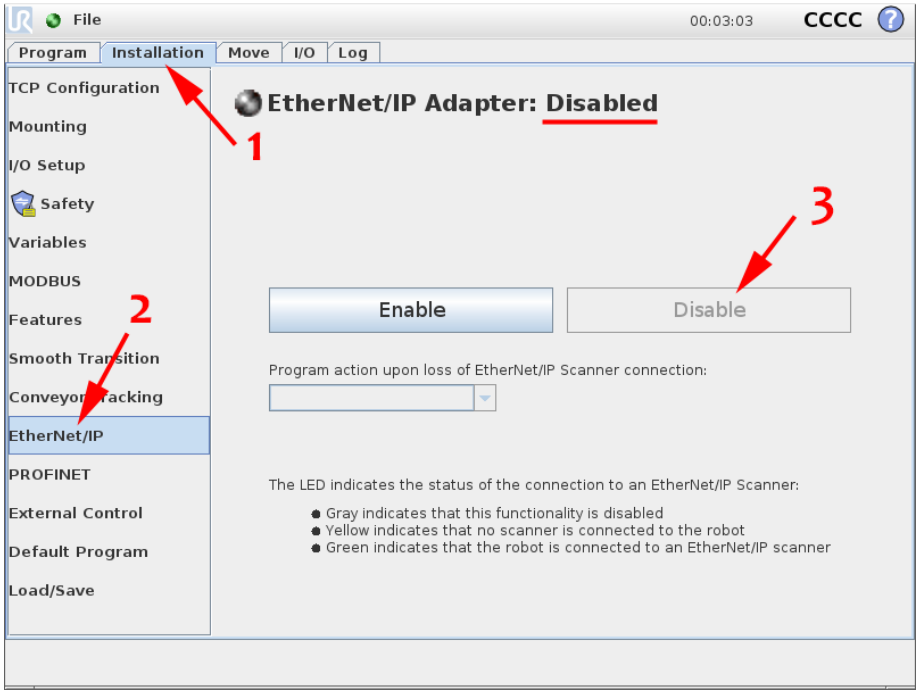
Disable Profinet:

Under the "Installation" in Polyscope you must disable "PROFINET"
The Profi network will block the RTDE communication.



Disable Ethernet:

Under "Installation" and "EtherNet/IP" you must also disable the ethernet/IP adapter. This may seem odd when you try to setup an external connection with a LAN cable to this adapter.

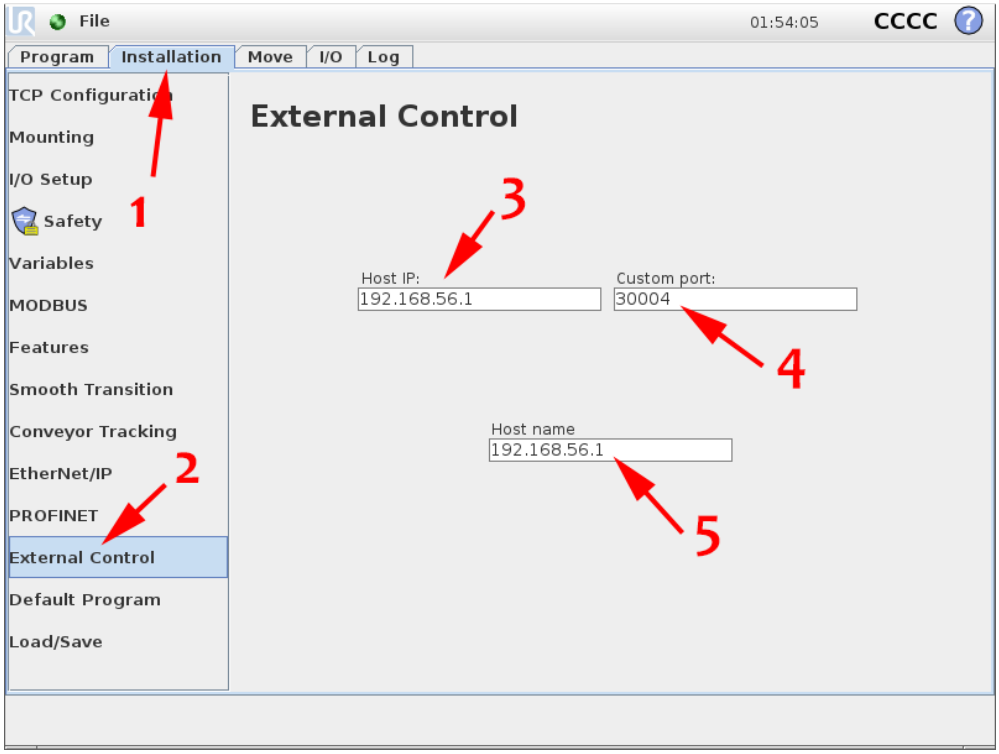


It's a little different for eSeries but this link shows how:
https://github.com/UniversalRobots/Universal_Robots_ROS_Driver/issues/204

External Control:

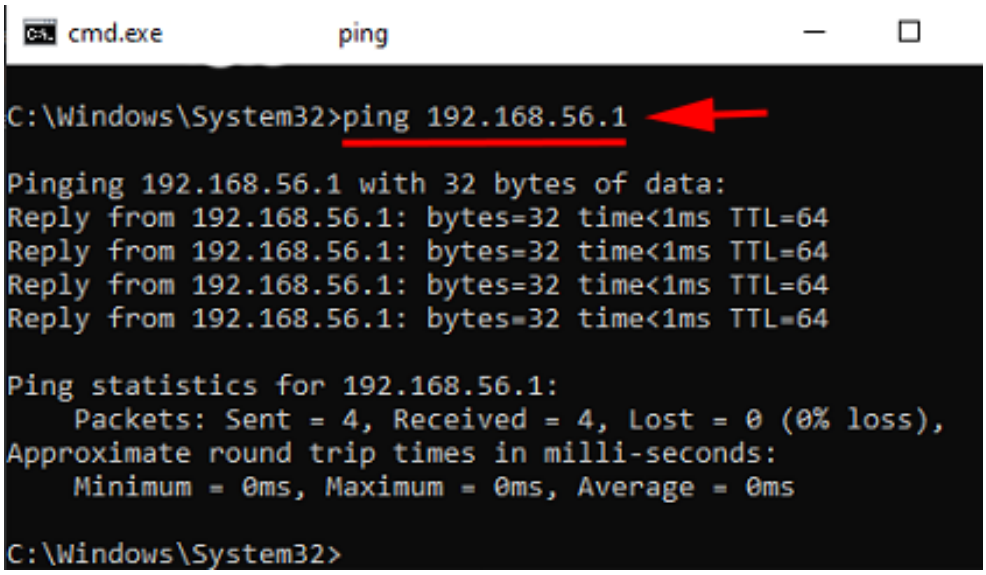
To use RTDE the External Control must be setup under "Installation".

The "Host IP" is the IP address for the remote host.
That is the IP address for the net card on the Windows PC.
The "Custom port" must be 30004 for RTDE



Ping the connection:

To check the cable connection before you start the RTDE program you can ping the UR controller from the Windows PC.
Open the commando prompt and ping the IP address for the UR controller.
If the network connection is running you will get something like this:



IP reset:

After a restart of the UR controller there is a good chance that the IP addressers have been reset to old values. This is an issue with Linux. But now you know how to set them again.

LAN cable:

RTDE is based on direct LAN cable connection between a computer and the UR controller.

Normally you connect two computers in a network via a router, but it is also possible to connect two computers directly. To do this direct connection you have to use a cross over cable. In this cable the data lines are "crossed over" to feed the output from the first computer into the input on the second computer.

In a network with a router the LAN cables are straight through patch cables. The router will be handling the connection of the send and receive lines.

For the RTDE connection to the UR controller, you must use a patch cable. This is the same cable as you would use to connect a computer to a router. The UR controller must have a build in router or must have been set up to handle the switch over of the incoming and outgoing data.

Data registers:

When you send data to the UR controller these data must be sent to registers where the PolyScope program can get access to them.
The different data registers will accept one type of data. The register you plan to use must fit with the data you want to send.
Check out here:
https://www.universal-robots.com/articles/ur/interface-communication/real-time-data-exchange-rtde-guide/

The naming of some of the data registers are a little odd.
In the data transfer program on the Windows computer the ini file set the registers to receive the data.
The input registers for data with double precision are named "double", e.g. "Input_doubble_1".

When you want to use the date in PolyScope you must assign the data from the register to a variable. But these registers are now named "single"
The date you just send via RTDE to "Input_doubble_1" must now be loaded from "Input_single_1"

This is a bug in the PolyScope program. The incoming data must be 32 bit (double precision) but in the UR controller tread these date as 16 bit data (single precision). On bit level the 32 bit data is truncated to 16 bit and saved as single precision data.
More info at the UR forum:
https://forum.universal-robots.com/t/rtde-precision-lost-from-double-to-float-precision/7623/13

Ready to go:

You should now be ready to go.

I will strongly recommend you to take a look at the videos from SimpleStudent. They will guide you through the setup of RTDE.

The first three videos give a good understanding of how to get RTDE going.
https://youtube.com/playlist?list=PLnJ9fSRnDN3B1wEuxQY4thTWyGoT2N0yd
https://www.youtube.com/@simplestudent279

More links:

https://pypi.org/project/ur-rtde/

https://github.com/UniversalRobots/RTDE_Python_Client_Library

https://www.universal-robots.com/articles/ur/interface-communication/real-time-data-exchange-rtde-guide/