Getting started with Raspberry Pi Pico

C/C++ development with Raspberry Pi Pico and other RP2040-based microcontroller boards

Colophon

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Chapter 1. Quick Pico Setup

If you are developing for Raspberry Pi Pico on the Raspberry Pi 4B, or the Raspberry Pi 400, most of the installation steps in this Getting Started guide can be skipped by running the setup script. You can get this script by doing the following:

TO DO: We can just `wget` after launch to avoid needing to git clone it.

```
$ git clone git@github.com:raspberrypi/pico-setup.git ①
```

1. You should first `sudo apt install git` if you don't have Git already installed.

WARNING

Until launch all the repositories cloned by the script are **private**. That means that before you run the script you need to upload a SSH key to Github as the clones will fail. Before proceeding generate a SSH key on the Raspberry Pi as follows,

```
$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/pi/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/pi/.ssh/id_rsa.
Your public key has been saved in /home/pi/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:yITLA+9tqti7EoI+dP60QGz1uzoTMddBocPbBJ67fw4 pi@pi400
The key's randomart image is:
+---[RSA 2048]----+
|        ..o.     |
|      .o +.      |
|   . ...*...     |
|   .+.*.o*.      |
|.   += *+S.      |
|+.oo +   o       |
|+.o...+o E       |
|.= .o=. o ..     |
|..*+o++. .o.     |
+----[SHA256]-----+
$
```

and then upload the public half of your key (`cat /home/pi/.ssh/id_rsa.pub`) to your Github account. You should now be able to clone, pull and push to git repositories hosted at Github from the command line.

Then run,

```
$ pico-setup/pico_setup.sh
```

The script will:

- Create a directory called `pico`
- Install required dependencies
- Download the `pico-sdk` and `pico-examples` repositories

- Define `PICO_SDK_PATH` in your `~/.bashrc`
- Build the `blink` and `hello_world` examples in `pico-examples/build/blink` and `pico-examples/build/hello_world`
- Download and compile OpenOCD (for debug support)
- Download and install Visual Studio Code
- Install the required Visual Studio Code extensions (see Chapter 6 for more details)
- Configure the Raspberry Pi UART for use with Raspberry Pi Pico

Once it has run, you will need to reboot your Raspberry Pi,

```
$ sudo reboot
```

for the UART reconfiguration to take effect.

Once your Raspberry Pi has rebooted you can open Visual Studio Code in the "Programming" menu and follow the instructions from Section 6.2.

Chapter 2. The Pico SDK

IMPORTANT

The following instructions assume that you are using a Raspberry Pi Pico and some details may differ if you are using a different RP2040-based board. They also assume you are using Raspberry Pi OS running on a Raspberry Pi 4, or an equivalent Debian-based Linux distribution running on another platform. Alternative instructions for those using Microsoft Windows (see Section 8.2) or Apple macOS (see Section 8.1) are also provided.

The Raspberry Pi Pico is built around the RP2040 microcontroller designed by Raspberry Pi. Development on the board is fully supported with both a C/C++ SDK, and an official MicroPython port. This book talks about how to get started with the SDK, and walks you through how to build, install, and work with the SDK toolchain.

TIP

For more information on the official MicroPython port see the **Pico Python SDK** book which documents the port, and "**Get started with MicroPython on Raspberry Pi Pico**" by Gareth Halfacree published by Pi Press.

TIP

For more information on the C/C++ SDK, along with API-level documentation, see the **Pico C/C++ SDK** book.

2.1. Get the Pico SDK and examples

Start by creating a pico directory to keep all pico related checkouts in. These instructions create a pico directory at `/home/pi/pico`.

```
$ cd ~/
$ mkdir pico
$ cd pico
```

Then clone the `pico-sdk` and `pico-examples` git repositories.

```
$ git clone -b pre_release git@github.com:raspberrypi/pico-sdk.git
$ cd pico-sdk
$ git submodule update --init --recursive
$ cd ..
$ git clone -b pre_release git@github.com:raspberrypi/pico-examples.git
```

TO DO: Talk about **which versions of Linux** this works on, including Raspberry Pi

NOTE

The `pico-examples` repository (https://github.com/raspberrypi/pico-examples) provides a set of example applications that are written using the `pico-sdk` (https://github.com/raspberrypi/pico-sdk).

2.2. Install the Toolchain

To build the applications in `pico-examples`, you'll need to install some extra tools. To build projects you'll need CMake, a cross-platform tool used to build the software, and the GNU Embedded Toolchain for Arm. You can install both these via `apt` from the command line. Anything you already have installed will be ignored by `apt`.

```
$ sudo apt update
$ sudo apt install cmake gcc-arm-none-eabi gcc g++ ①
```

1. Native gcc and g++ are needed to compile pioasm, elf2uf2

Chapter 3. Blinking an LED in C

When you're writing software for hardware, turning an LED on, off, and then on again, is typically the first program that gets run in a new programming environment. Learning how to blink an LED gets you half way to anywhere. We're going to go ahead and blink the on-board LED on the Raspberry Pi Pico which is connected to pin 25 of the RP2040.

Pico Examples: https://github.com/raspberrypi/pico-examples/tree/pre_release/blink/blink.c Lines 9 - 19

```
 9 int main() {
10     const uint LED_PIN = 25;
11     gpio_init(LED_PIN);
12     gpio_set_dir(LED_PIN, GPIO_OUT);
13     while (true) {
14         gpio_put(LED_PIN, 1);
15         sleep_ms(250);
16         gpio_put(LED_PIN, 0);
17         sleep_ms(250);
18     }
19 }
```

3.1. Building "Blink"

From the pico directory we created earlier, cd into `pico-examples` and create a build directory.

```
$ cd pico-examples
$ mkdir build
$ cd build
```

Then, assuming you cloned the `pico-sdk` and `pico-examples` repositories into the same directory side-by-side, set the `PICO_SDK_PATH`:

```
$ export PICO_SDK_PATH=../../pico-sdk
```

Prepare your cmake build directory by running `cmake ..`

```
$ cmake ..
Using PICO_SDK_PATH from environment ('../../pico-sdk')
PICO SDK is located at /home/pi/pico/pico-sdk
    .
    .
    .
-- Build files have been written to: /home/pi/pico/pico-examples/build
```

NOTE

`cmake` will default to a `Release` build with compiler optimisations enabled and debugging information removed. To build a debug version, run `cmake -DCMAKE_BUILD_TYPE=Debug ..`. We will explore this later in Section 5.1.

CMake has now prepared a build area for the `pico-examples` tree. From here, it is possible to type `make` to build all example applications. However, as we are building `blink` we will only build that application for now by changing directory into the `blink` directory before typing `make`.

TIP

Invoking `make` with `-jx` will run make jobs in parallel to speed it up. A Raspberry Pi 4 has 4 cores so `-j4` is a reasonable number.

```
$ cd blink
$ make -j4
Scanning dependencies of target ELF2UF2Build
Scanning dependencies of target boot_stage2_original
[  0%] Creating directories for 'ELF2UF2Build'

    .
    .
    .
[100%] Linking CXX executable blink.elf
[100%] Built target blink
```

Amongst other targets, we have now built:

- `blink.elf`, which is used by the debugger
- `blink.uf2`, which can dragged onto the RP2040 USB Mass Storage Device

This binary will blink the on-board LED of the Raspberry Pi Pico which is connected to GPIO25 of RP2040.

3.2. Load and run "Blink"

The simplest method to load software onto a RP2040-based board is by mounting it as a USB Mass Storage Device. Doing this allows you to drag a file onto the board to program the flash. Go ahead and connect the Raspberry Pi Pico to your Raspberry Pi using a micro-USB cable, making sure that you hold down the `BOOTSEL` button (Figure 1) to force it into USB Mass Storage Mode.

NOTE

Loading code via the USB Mass Storage method is great if you know your program is going to work first time, but if you are developing anything new it is likely you will want to debug it. So you can also load your software onto RP2040 using the Serial Wire Debug interface, see Chapter 5. As well as loading software this allows you to; set breakpoints, inspect variables, and inspect memory contents.

NOTE

If you are not following these instructions on a Raspberry Pi Pico, you may not have a `BOOTSEL` button, see Figure 1. If this is the case, you should check if there is some other way grounding the flash `CS` pin, such as a jumper, to tell RP2040 to enter the BOOTSEL mode on boot. If there is no such method, you can load code using the Serial Wire Debug interface.

3.2.1. From the desktop

If you are running the Raspberry Pi Desktop the Raspberry Pi Pico should automatically mount as a USB Mass Storage Device. From here, you can Drag-and-drop `blink.uf2` onto the Mass Storage Device.

RP2040 will reboot, unmounting itself as a Mass Storage Device, and start to run the flashed code, see Figure 1.

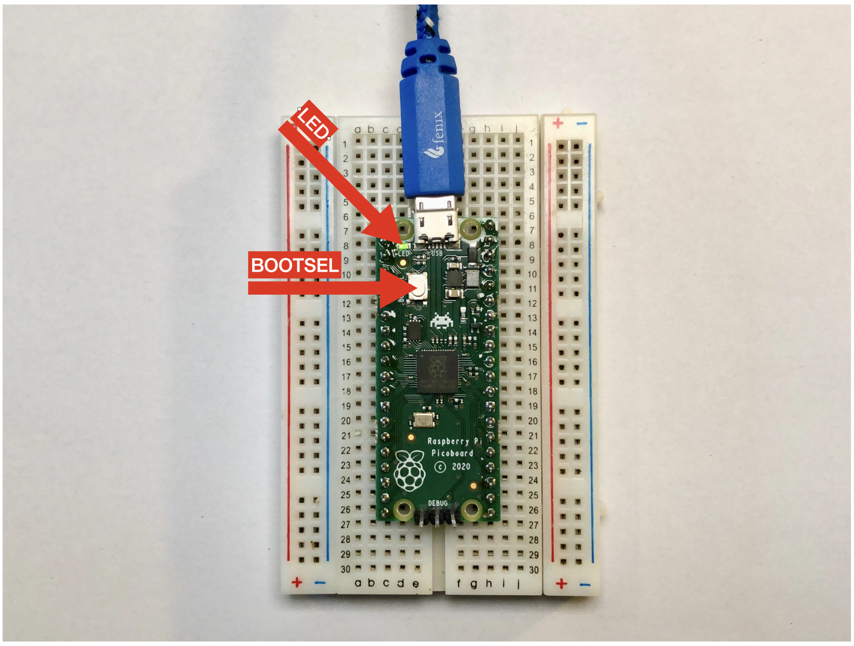


Figure 1. Blinking the on-board LED on the Raspberry Pi Pico. Arrows point to the on-board LED, and the `BOOTSEL` *button.*

3.2.2. Using the command line

If you are logged in via `ssh` for example, you may have to mount the mass storage device manually:

```
$ dmesg | tail
[  371.973555] sd 0:0:0:0: [sda] Attached SCSI removable disk
$ sudo mkdir -p /mnt/pico
$ sudo mount /dev/sda1 /mnt/pico
```

If you can see files in `/mnt/pico` then the USB Mass Storage Device has been mounted correctly:

```
$ ls /mnt/pico/
INDEX.HTM  INFO_UF2.TXT
```

Copy your `blink.uf2` onto RP2040:

```
sudo cp blink.uf2 /mnt/pico
sudo sync
```

RP2040 has already disconnected as a USB Mass Storage Device and is running your code, but for tidiness unmount `/mnt/pico`

```
sudo umount /mnt/pico
```

NOTE

Removing power from the board does not remove the code. When the board is reattached to power the code you have just loaded will begin running again. If you want to remove the code from the board, and upload new code, press and hold the BOOTSEL switch when applying power to put the board into Mass Storage mode.

Chapter 4. Saying "Hello World" in C

After blinking an LED on and off, the next thing that most developers will want to do is create and use a serial port, and say "Hello World."

Pico Examples: https://github.com/raspberrypi/pico-examples/tree/pre_release/hello_world/serial/hello_serial.c Lines 10 - 17

```
10 int main() {
11     stdio_init_all();
12     while (true) {
13         printf("Hello, world!\n");
14         sleep_ms(1000);
15     }
16     return 0;
17 }
```

4.1. Serial input and output on Raspberry Pi Pico

Serial input (`stdin`) and output (`stdout`) can be directed to either serial UART or to USB CDC (USB serial). However by default `stdio` and `printf` will target the default Raspberry Pi Pico UART0.

Raspberry Pi Pico Default UART0
GND (Pin 3)
GP0 (UART0_TX, Pin 1)
GP1 (UART0_RX, Pin 2)

IMPORTANT

The default Raspberry Pi Pico UART TX pin (out from Raspberry Pi Pico) is pin GP0, and the UART RX pin (in to Raspberry Pi Pico) is pin GP1. The default UART pins are configured on a per-board basis using board configuration files. The Raspberry Pi Pico configuration can be found in https://github.com/raspberrypi/pico-sdk/tree/pre_release/src/boards/include/boards/pico.h. The Pico SDK defaults to a boar dname of Raspberry Pi Pico if no other board is specified.

The Pico SDK makes use of CMake to control its build system, see Chapter 7, making use of the `pico_stdlib` interface library to aggregate necessary source files to provide capabilities.

Pico Examples: https://github.com/raspberrypi/pico-examples/tree/pre_release/hello_world/serial/CMakeLists.txt Lines 1 - 9

```
1 add_executable(hello_serial
2         hello_serial.c
3         )
4
5 # Pull in our pico_stdlib which aggregates commonly used features
6 target_link_libraries(hello_serial pico_stdlib)
7
8 # create map/bin/hex/uf2 file etc.
9 pico_add_extra_outputs(hello_serial)
```

The destination for `stdout` can be changed using CMake directives, with output directed to UART or USB CDC, or to both,

```
pico_enable_stdio_usb(hello_world 1) ①
pico_enable_stdio_uart(hello_world 0) ②
```

1. Enable `printf` output via USB CDC (USB serial)
2. Disable `printf` output via UART

This means that **without changing the C source code**, you can change the destination for `stdio` from UART to USB.

Pico Examples: https://github.com/raspberrypi/pico-examples/tree/pre_release/hello_world/usb/CMakeLists.txt Lines 1 - 13

```
 1 add_executable(hello_usb
 2         hello_usb.c
 3         )
 4
 5 # Pull in our pico_stdlib which aggregates commonly used features
 6 target_link_libraries(hello_usb pico_stdlib)
 7
 8 # enable usb output, disable uart output
 9 pico_enable_stdio_usb(hello_usb 1)
10 pico_enable_stdio_uart(hello_usb 0)
11
12 # create map/bin/hex/uf2 file etc.
13 pico_add_extra_outputs(hello_usb)
```

4.2. Build "Hello World"

As we did for the previous "Blink" example, change directory into the `hello_world` directory inside the `pico-examples` tree, and run `make`.

```
$ cd hello_world
$ make -j4
Scanning dependencies of target ELF2UF2Build
[  0%] Creating directories for 'ELF2UF2Build'
   .
   .
[ 33%] Linking CXX executable hello_usb.elf
[ 33%] Built target hello_usb

   .
   .
[100%] Linking CXX executable hello_serial.elf
[100%] Built target hello_serial
```

This will build two separate examples programs in the `hello_world/serial/` and `hello_world/usb/` directories.

Amongst other targets, we have now built:

- `serial/hello_serial.elf`, which is used by the debugger
- `serial/hello_serial.uf2`, which can dragged onto the RP2040 USB Mass Storage Device (UART serial binary)
- `usb/hello_usb.elf`, which is used by the debugger
- `usb/hello_usb.uf2`, which can dragged onto the RP2040 USB Mass Storage Device (USB serial binary)

Where `hello_serial` directs `stdio` to UART0 on pins GP0 and GP1, and `hello_usb` directs `stdio` to USB CDC serial.

4.3. Flash and Run "Hello World"

Connect the Raspberry Pi Pico to your Raspberry Pi using a micro-USB cable, making sure that you hold down the `BOOTSEL` button to force it into USB Mass Storage Mode. Once it is connected release the `BOOTSEL` button and if you are running the Raspbrerry Pi Desktop it should automatically mount as a USB Mass Storage Device. From here, you can Drag-and-drop either the `hello_serial.uf2` or `hello_usb.uf2` onto the Mass Storage Device.

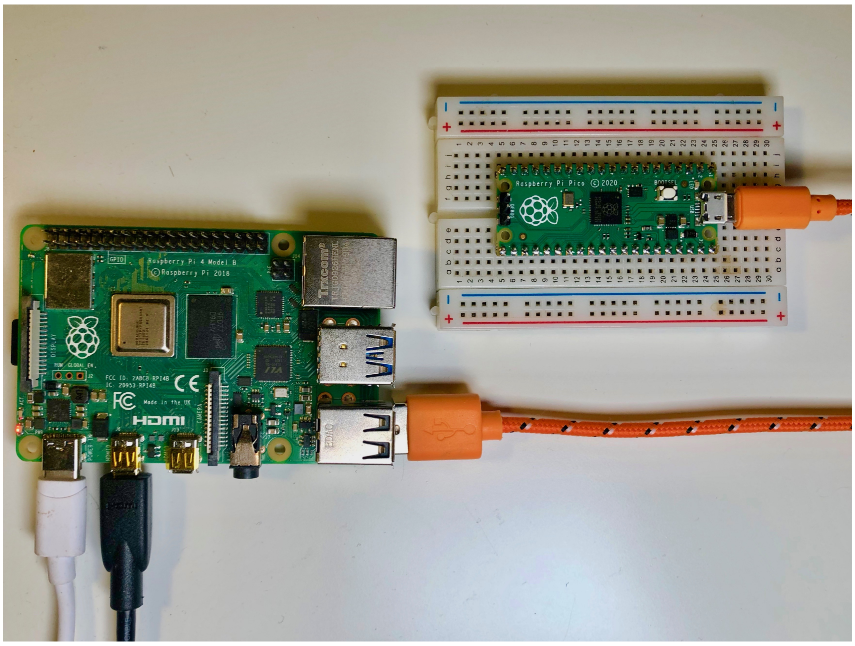
RP2040 will reboot, unmounting itself as a Mass Storage Device, and start to run the flashed code.

However although the "Hello World" example is now running, we cannot yet see the text. We need to connect our host computer to the standard UART on the Raspberry Pi Pico to see the output.

4.4. See "Hello World" USB output

If you have dragged and dropped the `hello_usb.uf2` binary, then the "Hello World" text will be directed to USB serial.

Figure 2. Connecting the Raspberry Pi to Raspberry Pi Pico via USB.



With your Raspberry Pi Pico connected directly to your Raspberry Pi via USB, see Figure 2, you can see the text by installing `minicom`:

```
$ sudo apt install minicom
```

and open the serial port:

```
$ minicom -b 115200 -o -D /dev/ACM0
```

You should see `Hello, world!` printed to the console.

TIP

To exit minicom, use `CTRL-A` followed by `X`.

4.5. See "Hello World" UART output

Alternatively if you dragged and dropped the `hello_usb.uf2` binary, then the "Hello World" text will be directed to UART0 on pins GP0 and GP1. The first thing you'll need to do to see the text is enable UART serial communications on the Raspberry Pi host. To do so, run `raspi-config`,

```
$ sudo raspi-config
```

and go to `Interfacing Options` → `Serial` and select "No" when asked "Would you like a login shell to be accessible over serial?" and "Yes" when asked "Would you like the serial port hardware to be enabled?" You should see something like Figure 3.

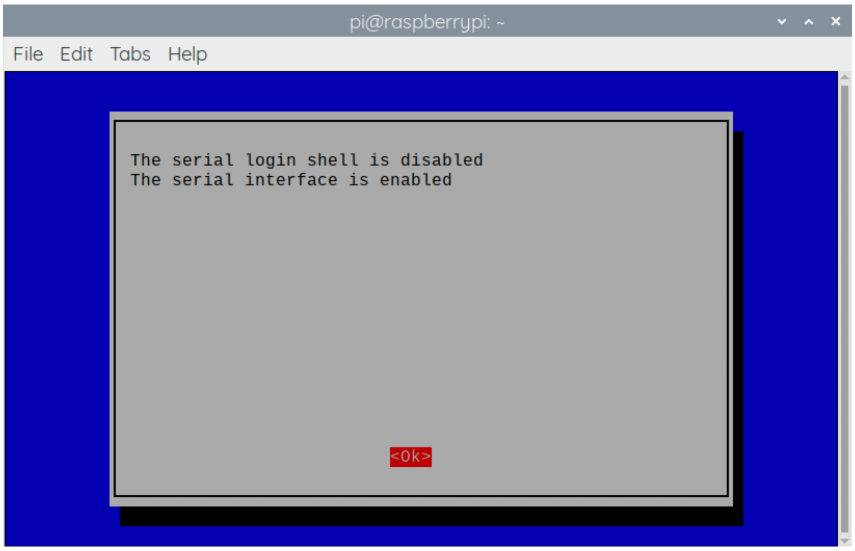


Figure 3. Enabling a serial UART using `raspi-config` *on the Raspberry Pi.*

Leaving `raspi-config` you should choose "Yes" and reboot your Raspberry Pi to enable the serial port.

You should then wire the Raspberry Pi and the Raspberry Pi Pico together with the following mapping:

Raspberry Pi	Raspberry Pi Pico
GND (Pin 14)	GND (Pin 3)
GPIO15 (UART_RX0, Pin 10)	GP0 (UART0_TX, Pin 1)
GPIO14 (UART_TX0, Pin 8)	GP1 (UART0_RX, Pin 2)

See Figure 4.

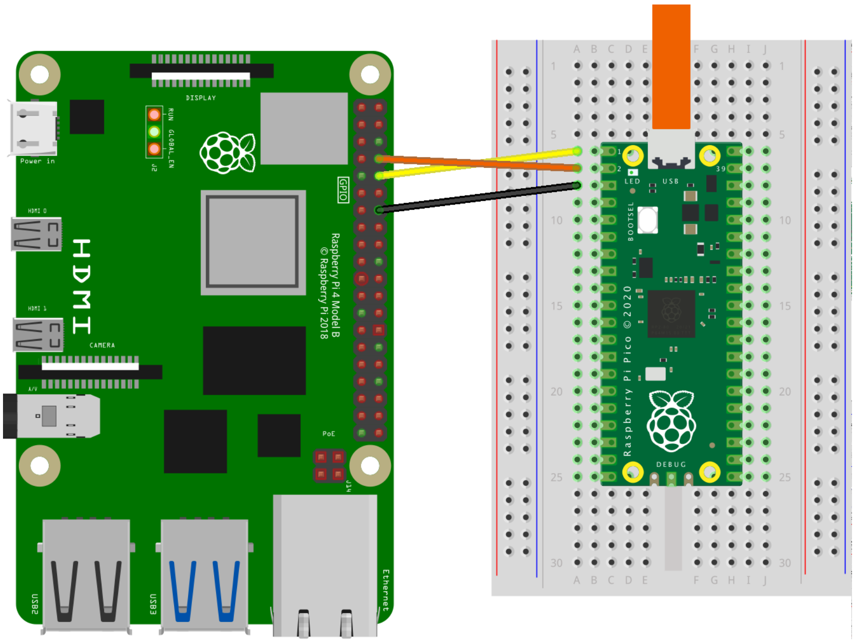


Figure 4. A Raspberry Pi 4 and the Raspberry Pi Pico with UART0 connected together.

Once the two boards are wired together if you have not already done so you should install `minicom`:

```
$ sudo apt install minicom
```

and open the serial port:

```
$ minicom -b 115200 -o -D /dev/serial0
```

Toggling the power to Raspberry Pi Pico you should see `Hello, world!` printed to the console.

TIP

To exit minicom, use `CTRL-A` followed by `X`.

4.6. Powering the board

You can unplug the Raspberry Pi Pico from USB, and power the board by additionally connecting the Raspberry Pi's 5V pin to the Raspberry Pi Pico VSYS pin via a diode, see Figure 5, where in the ideal case the diode would be a Schottky diode.

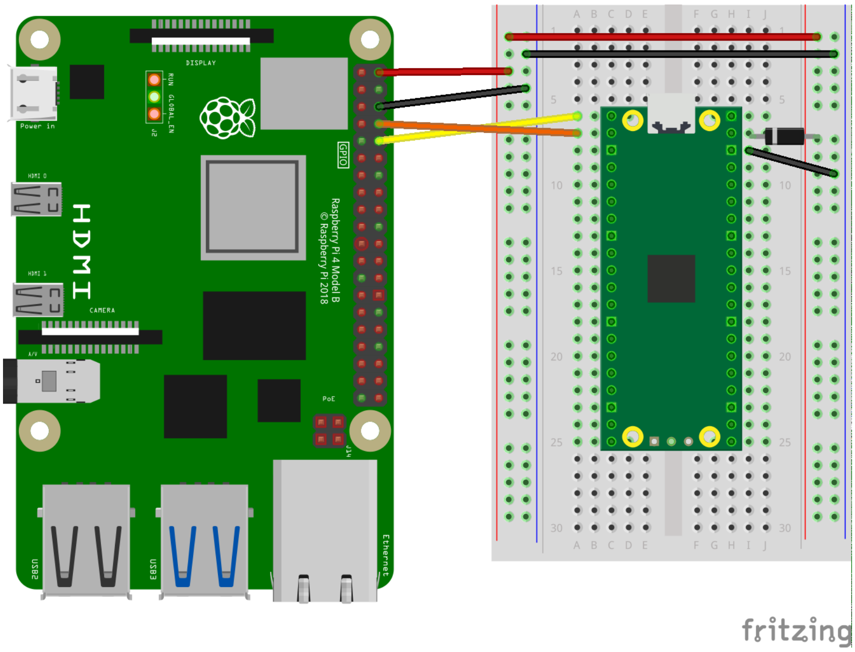


Figure 5. Raspberry Pi and Raspberry Pi Pico connected only using the GPIO pins.

Whilst it is possible to connect the Raspberry Pi's 5V pin to the Raspberry Pi Pico VBUS pin, this is not recommended. Shorting the 5V rails together will mean that the Micro USB cannot be used. An exception is when using the Raspberry Pi Pico in USB host mode, in this case 5V must be connected to the VBUS pin.

The 3.3V pin is an OUTPUT pin on the Raspberry Pi Pico, you cannot power the Raspberry Pi Pico via this pin, and it should NOT be connected to a power source.

Chapter 5. Debugging with SWD

IMPORTANT

These instructions assume that you are using a Raspberry Pi Pico, details may differ if you are using an alternative RP2040-based board.

The Raspberry Pi Pico provides a SWD (Single Wire Debug) port which can be used to interactively debug a binary running on RP2040. However to use it you will first need build a special debug version of your binary and install some additional tools.

5.1. Build "Hello World" debug version

You can build a debug version of the "Hello World"" with `CMAKE_BUILD_TYPE=Debug` as shown below,

```
$ cd ~/pico/pico-examples/
$ rm -rf build
$ mkdir build
$ cd build
$ export PICO_SDK_PATH=../../pico-sdk
$ cmake -DCMAKE_BUILD_TYPE=Debug ..
$ cd hello_world
$ make -j4
```

5.2. Installing OpenOCD

OpenOCD is a debug translator: it allows a host system to load, run and debug software on RP2040, and to interactively poke and explore hardware registers. OpenOCD can attach to RP2040's SWD port via a number of hardware interfaces, including direct bitbanging from Raspberry Pi GPIOs.

The default configuration is to have SWDIO on Pi GPIO 24, and SWCLK on GPIO 25 — this can be wired to a Raspberry Pi Pico as seen in Figure 6.

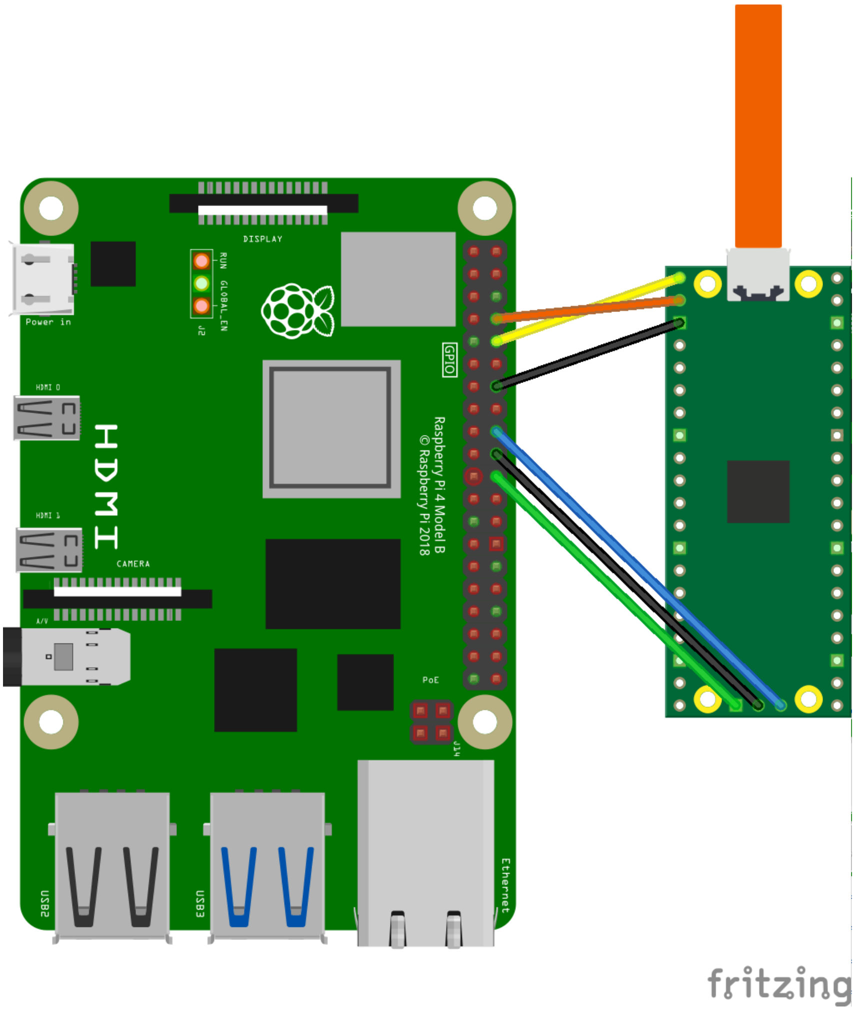


Figure 6. A Raspberry Pi 4 and the Raspberry Pi Pico with UART and SWD port connected together. Both are jumpered directly back to the Raspberry Pi 4 without using a breadboard.

If possible you should wire the SWD port directly to the Raspberry Pi as latency is important; wiring the SWD port via a breadboard or other indirect methods may reduce the signal integrity sufficiently so that loading code over the connection is erratic or fails completely.

Note the Raspberry Pi Pico must also be powered (e.g. via USB) in order to debug it! You must build our OpenOCD branch to get working multidrop SWD support:

TO DO: Build our fork as a debian package so we can apt install it

NOTE

These instructions assume you want to build openocd in `/home/pi/pico/openocd`

```
$ cd ~/pico
$ sudo apt install automake autoconf build-essential texinfo libtool libftdi-dev libusb-1.0-0-
dev
$ git clone git@github.com:raspberrypi/openocd.git --recursive --branch rp2040 --depth=1
$ cd openocd
$ ./bootstrap
$ ./configure --enable-ftdi --enable-sysfsgpio --enable-bcm2835gpio
$ make -j4
$ sudo make install
```

5.3. Installing GDB

Install `gdb-multiarch`,

```
$ sudo apt install gdb-multiarch
```

5.4. Use GDB and OpenOCD to debug Hello World

Ensuring your Raspberry Pi 4 and Raspberry Pi Pico are correctly wired together, we can attach OpenOCD to the chip, via the `raspberrypi-swd` interface.

```
$openocd -f interface/raspberrypi-swd.cfg -f target/rp2040.cfg
```

Your output should look like this:

```
...
Info : rp2040.core0: hardware has 4 breakpoints, 2 watchpoints
Info : rp2040.core1: hardware has 4 breakpoints, 2 watchpoints
Info : starting gdb server for rp2040.core0 on 3333
Info : Listening on port 3333 for gdb connections
```

WARNING

If you see an error like `Info : DAP init failed` then your Raspberry Pi Pico is either powered off or wired incorrectly.

This OpenOCD terminal needs to be left open. So go ahead and open another terminal, in this one we'll attach a gdb instance to OpenOCD. Navigate to the "Hello World" example code, and start `gdb` from the command line.

```
$ cd ~/pico/pico-examples/build/hello_world
$ gdb-multiarch hello_world.elf
```

Connect GDB to OpenOCD,

```
(gdb) target remote localhost:3333
```

TIP

You can create a `.gdbinit` file so you don't have to type `target remote localhost:3333` every time. Do this with `echo "target remote localhost:3333" > ~/.gdbinit`. However, this interferes with debugging in VSCode (Section Chapter 6).

and load `hello_world.elf` into flash,

```
(gdb) load
Loading section .boot2, size 0x100 lma 0x10000000
Loading section .text, size 0x22d0 lma 0x10000100
```

```
Loading section .rodata, size 0x4a0 lma 0x100023d0
Loading section .ARM.exidx, size 0x8 lma 0x10002870
Loading section .data, size 0xb94 lma 0x10002878
Start address 0x10000104, load size 13324
Transfer rate: 31 KB/sec, 2664 bytes/write.
```

and then start it running.

```
(gdb) monitor reset init
(gdb) continue
```

IMPORTANT

If you see errors similar to `Error finishing flash operation` or `Error erasing flash with vFlashErase packet` in GDB when attempting to load the binary onto the Raspberry Pi Pico via OpenOCD then there is likely poor signal integrity between the Raspberry Pi and the Raspberry Pi Pico. If you are not directly connecting the SWD connection between the two boards, see Figure 6, you should try to do that. Alternatively you can try reducing the value of `adapter_khz` in the `raspberrypi-swd.cfg` configuration file, trying halving it until you see a successful connection between the boards. As we're bitbanging between the boards timing is marginal, so poor signal integrity may cause errors.

Or if you want to set a breakpoint at `main()` before running the executable,

```
(gdb) monitor reset init
(gdb) b main
(gdb) continue

Thread 1 hit Breakpoint 1, main () at /home/pi/pico/pico-examples/hello_world/hello_world.c:11
11      setup_standard_uart();
```

before continuing after you have hit the breakpoint,

```
(gdb) continue
```

To quit from `gdb` type,

```
(gdb) quit
```

Chapter 6. Using Visual Studio Code

Visual Studio Code (VSCode) is a popular open source editor developed by Microsoft. It is the recommended Integrated Development Environment (IDE) on the Raspberry Pi 4 if you want a graphical interface to edit and debug your code.

6.1. Installing the Environment

IMPORTANT

These installation instructions rely on you already having downloaded and installed the command line toolchain, see Chapter 3, as well as downloading and building both OpenOCD and GDB and configuring them for command line debugging, see Chapter 5.

ARM versions of Visual Studio Code for the Raspberry Pi can be downloaded from https://code.visualstudio.com/Download. If you are using a 32-bit operating system (e.g. the default Raspberry Pi OS) then download the `ARM .deb` file; if you are using a 64-bit OS, then download the `ARM 64 .deb` file. Once downloaded, double click on the .deb package and follow the instructions to install it.

NOTE

You can install the downloaded `.deb`. package fromm the command line. `cd` to the folder where the file was downloaded, then use `dpkg -i <downloaded file name.deb>` to install.

Once the install has completed, go ahead and start Visual Studio Code from a Terminal window as follows,

```
$ export PICO_SDK_PATH=/home/pi/pico/pico-sdk
$ code
```

Ensure you set the `PICO_SDK_PATH` so the Visual Studio Code can find the Pico SDK.

NOTE

If `PICO_SDK_PATH` is not set by default in your shell's environment you will have to set it each time you open a new Terminal window before starting vscode, or start vscode from the menus. You may therefore want to add it to your `.profile` or `.bashrc` file.

6.1.1. Install Cortex-Debug

After starting Visual Studio Code you then need to install the Cortex-Debug extension by Marcel Ball. Click on the Extensions icon in the left-hand toolbar (or type `Ctrl + Shift + X`), and search for `cortex-debug` and click on the entry in the list. The click the install button (see Figure 7).

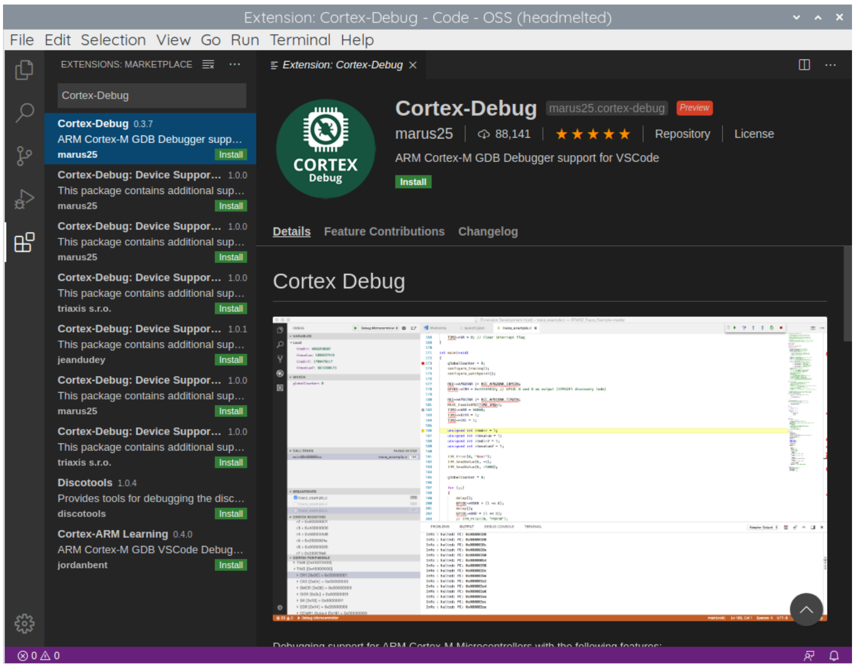


Figure 7. Installing the Cortex-Debug extension into Visual Studio Code.

Right now the Cortex-Debug extension expects `arm-none-eabi-gdb` to exist but we are using `gdb-multiarch` for debugging. To fix this, create a symbolic link to `gdb-multiarch` called `arm-none-eabi-gdb`,

```
$ sudo ln -s /usr/bin/gdb-multiarch /usr/local/bin/arm-none-eabi-gdb
```

TO DO: FIXME: This is a hack, needs to be resolved before launch.

6.1.2. Install CMake Tools

Similarly search for and install the CMake Tools extension, see Figure 8

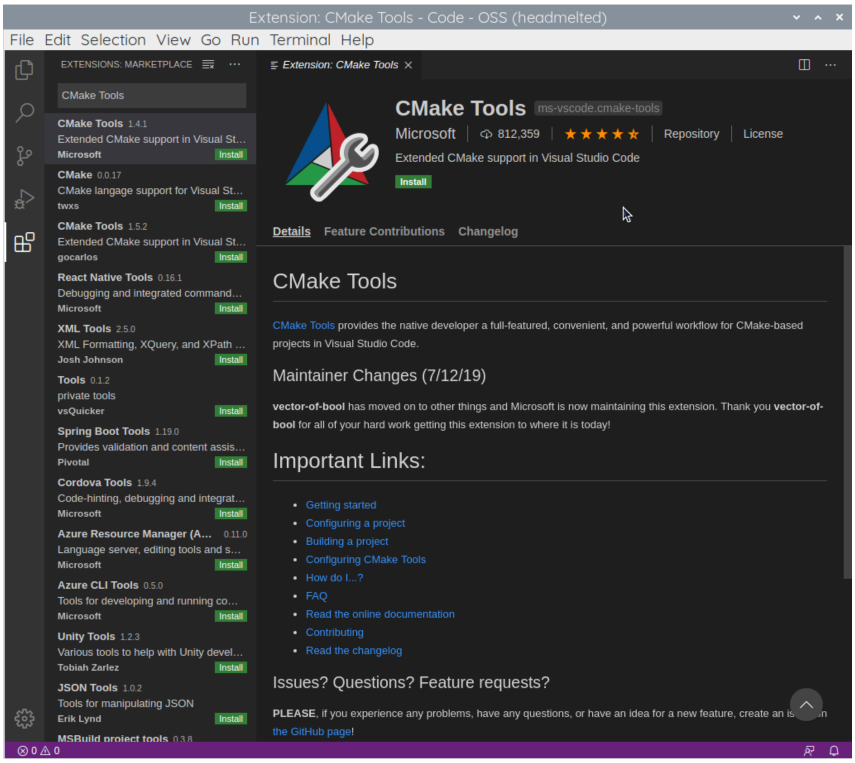


Figure 8. Installing the Cmake Tools extension into Visual Studio Code.

6.2. Loading a Project

Go ahead and open the `pico-examples` folder by going to the Explorer toolbar (`Ctrl + Shift + E`), selecting "Open Folder," and nagivating to, `/home/pi/pico/pico-examples` in the file popup. Then click "OK" to load the Folder into VSCode.

As long as the CMake Tools extension is installed, after a second or so you should see a popup in the lower right-hand corner of the vscode window.

Hit "Yes" to configure the project. You will then be prompted to choose a compiler, see Figure 9,

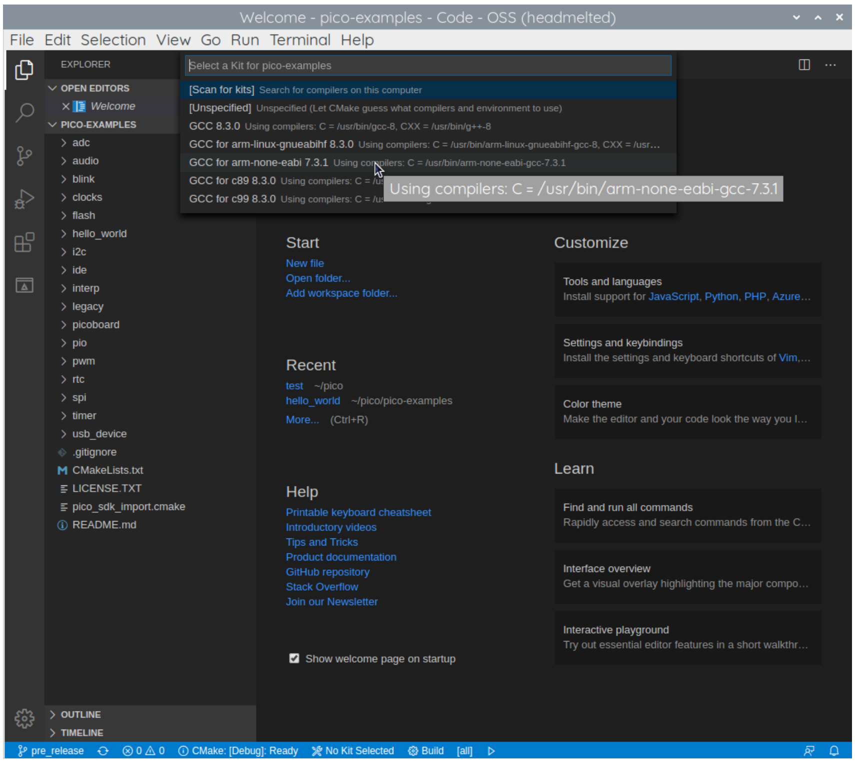


Figure 9. Prompt to choose the correct compiler for the project.

and you should select `GCC for arm-none-eabi` from the drop down menu.

TIP

If you miss the popups, which will close again after a few seconds, you can configure the compiler by clicking on "No Kit Selected" in the blue bottom bar of the VSCode window.

You can then either click on the "Build" button in the blue bottom bar to build all of the examples in `pico-examples` folder, or click on where it says "[all]" in the blue bottom bar. This will present you with a drop down where you can select a project. For now type in "hello_world" and select the "Hello World" executable. This means that VSCode will only build the "Hello World" example saving compile time.

TIP

You can toggle between building "Debug" and "Release" executables by clicking on where it says "CMake: [Debug]: Ready" in the blue bottom bar. The default is to build a "Debug" enabled executable ready for SWD debugging.

Go ahead and click on the "Build" button (with a cog wheel) in the blue bottom bar of the window. This will create the build directory and run CMake as we did by hand in Section 3.1, before starting the build itself, see Figure 10.

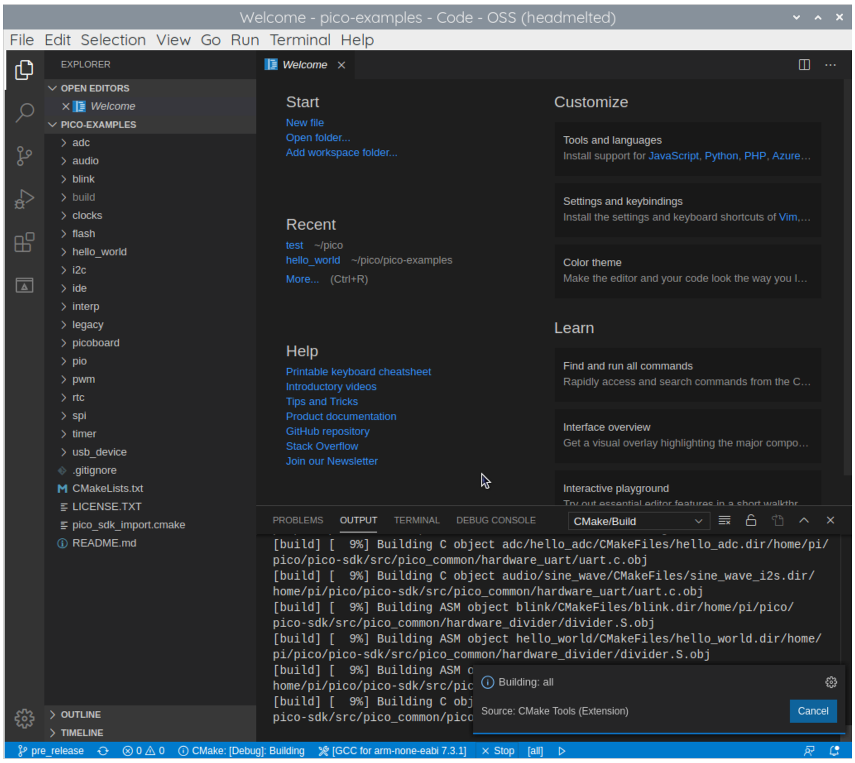


Figure 10. Building the `pico-examples` project in Visual Studio Code

As we did from the command line previously, amongst other targets, we have now built:

- `hello_world.elf`, which is used by the debugger
- `hello_world.uf2`, which can dragged onto the RP2040 USB Mass Storage Device

6.3. Debugging a Project

The `pico-examples` repo contains an example debug configuration that will start OpenOCD, attach GDB, and finally launch the application CMake is configured to build. Go ahead and copy this file (`launch-pi-bitbang.json`) into the `pico-examples/.vscode` directory as `launch.json`.

```
$ cd ~/pico/pico-examples
$ mkdir .vscode
$ cp ide/vscode/launch-pi-bitbang.json .vscode/launch.json
```

NOTE

If the file isn't renamed Visual Studio Code will not be able to find it.

Pico Examples: https://github.com/raspberrypi/pico-examples/tree/pre_release/ide/vscode/launch-pi-bitbang.json Lines 1 - 23

```
{
    // Use IntelliSense to learn about possible attributes.
    // Hover to view descriptions of existing attributes.
    // For more information, visit: https://go.microsoft.com/fwlink/?linkid=830387
    "version": "0.2.0",
    "configurations": [
        {
            "name": "Pico Debug",
```

```
            "cwd": "${workspaceRoot}",
            "executable": "${command:cmake.launchTargetPath}",
            "request": "launch",
            "type": "cortex-debug",
            "servertype": "openocd",
            "device": "RP2040",
            "configFiles": [
                "interface/raspberrypi-swd.cfg",
                "target/rp2040.cfg"
            ],
            "svdFile": "/home/pi/pico/pico-sdk/src/rp2040/hardware_regs/rp2040.svd",
            "runToMain": true
        }
    ]
}
```

6.3.1. Running "Hello World" on the Raspberry Pi Pico

IMPORTANT

Ensure that the example "Hello World" code has been as a Debug binary (`CMAKE_BUILD_TYPE=Debug`).

Now go to the Debug toolbar (`Ctrl + Shift + D`) and click the small green arrow (play button) at the top of the left-hand window pane to load your code on the Raspberry Pi Pico and start debugging.

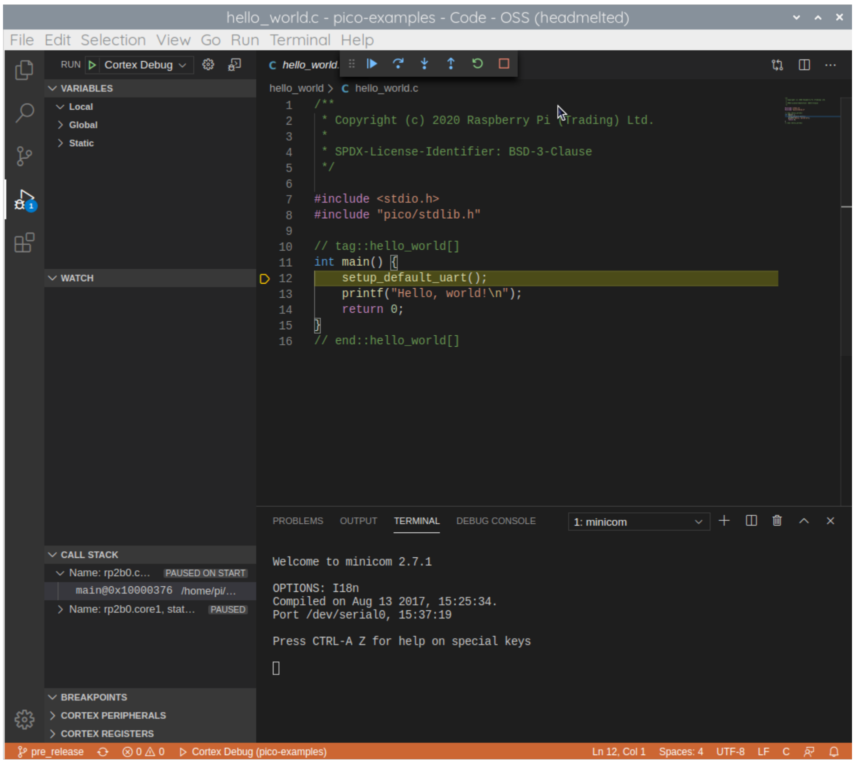


Figure 11. Debugging the "Hello World" binary inside Visual Studio Code

The code should now be loaded and on to the Raspberry Pi Pico, and you should see the source code for "Hello World" in the main right-hand (upper) pane of the window. The code will start to run and it will proceed to the first breakpoint — enabled by the `runToMain` directive in the `launch.json` file. Click on the small blue arrow (play button) at the top of this main source code window to Continue (`F5`) and start the code running.

TIP

If you switch to the "Terminal" tab in the bottom right-hand pane, below the `hello_world.c` code, you can use this to open `minicom` inside VSCode to see the UART output from the "Hello World" example by typing,

```
$ minicom -b 115200 -o -D /dev/serial0
```

at the terminal prompt as we did before, see Section 4.5.

Chapter 7. Creating your own Project

Go ahead and create a directory to house your test project sitting alongside the `pico-sdk` directory,

```
$ ls -la
total 16
drwxr-xr-x   7 aa  staff   224  6 Apr 10:41 ./
drwx------@ 27 aa  staff   864  6 Apr 10:41 ../
drwxr-xr-x  10 aa  staff   320  6 Apr 09:29 pico-examples/
drwxr-xr-x  13 aa  staff   416  6 Apr 09:22 pico-sdk/
$ mkdir test
$ cd test
```

and then create a `test.c` file in the directory,

```c
#include <stdio.h>
#include "pico/stdlib.h"
#include "hardware/gpio.h"
#include "pico/binary_info.h"

const uint LED_PIN = 25;

int main() {

    bi_decl(bi_program_description("This is a test binary."));①
    bi_decl(bi_1pin_with_name(LED_PIN, "On-board LED"));

    stdio_init_all();

    gpio_init(LED_PIN);
    gpio_set_dir(LED_PIN, GPIO_OUT);
    while (1) {
        gpio_put(LED_PIN, 0);
        sleep_ms(250);
        gpio_put(LED_PIN, 1);
        puts("Hello World\n");
        sleep_ms(1000);
    }
}
```

① These lines will add strings to the binary visable using `picotool`, see Appendix B.

along with a `CMakeLists.txt` file,

```
cmake_minimum_required(VERSION 3.12)

include(pico_sdk_import.cmake)

project(test_project)

pico_sdk_init()

add_executable(test
    test.c
)

pico_enable_stdio_usb(test 1)①
```

```
pico_enable_stdio_uart(test 1)②

pico_add_extra_outputs(test)

target_link_libraries(test pico_stdlib)
```

1. This will enable serial output via USB.
2. This will enable serial output via UART.

Then copy the `pico_sdk_import.cmake` file from the `external` folder in your `pico-sdk` installation to your test project folder.

```
$ cp ../pico-sdk/external/pico_sdk_import.cmake .
```

You should now have something that looks like this,

```
$ ls -la
total 24
drwxr-xr-x  5 aa  staff   160  6 Apr 10:46 ./
drwxr-xr-x  7 aa  staff   224  6 Apr 10:41 ../
-rw-r--r--@ 1 aa  staff   394  6 Apr 10:37 CMakeLists.txt
-rw-r--r--  1 aa  staff  2744  6 Apr 10:40 pico_sdk_import.cmake
-rw-r--r--  1 aa  staff   383  6 Apr 10:37 test.c
```

and can build it as we did before with our "Hello World" example.

```
$ mkdir build
$ cd build
$ export PICO_SDK_PATH=../../pico-sdk
$ cmake ..
$ make
```

The make process will produce a number of different files. The important ones are shown in the following table.

File extension	Description
.bin	Raw binary dump of the program code and data
.elf	The full program output, possibly including debug information
.uf2	The program code and data in a UF2 form that you can drag-and-drop on to the RP2040 board when it is mounted as a USB drive
.dis	A disassembly of the compiled binary
.hex	Hexdump of the compiled binary
.map	A map file to accompany the .elf file describing where the linker has arranged segments in memory

> **NOTE**
>
> UF2 (USB Flashing Format) is a file format, developed by Microsoft, that is used for flashing the RP2040 board over USB. More details can be found on the Microsoft UF2 Specification Repo

> **NOTE**
>
> To build a binary to run in SRAM, rather than Flash memory you can either setup your `cmake` build with `-DPICO_NO_FLASH=1` or you can add `pico_set_binary_type(TARGET_NAME no_flash)` to control it on a per binary basis in your `CMakeLists.txt` file. You can download the RAM binary to RP2040 via UF2. For example, if there is no flash chip on your board, you can download a binary that runs on the on-chip RAM using UF2 as it simply specifies the addresses of where data goes. Note you can only download in to RAM or FLASH, not both.

7.1. Debugging your project

Debugging your own project from the command line follows the same processes as we used for the "Hello World" example back in Section 5.4. Connect your Raspberry Pi and the Raspberry Pi Pico as in Figure 12.

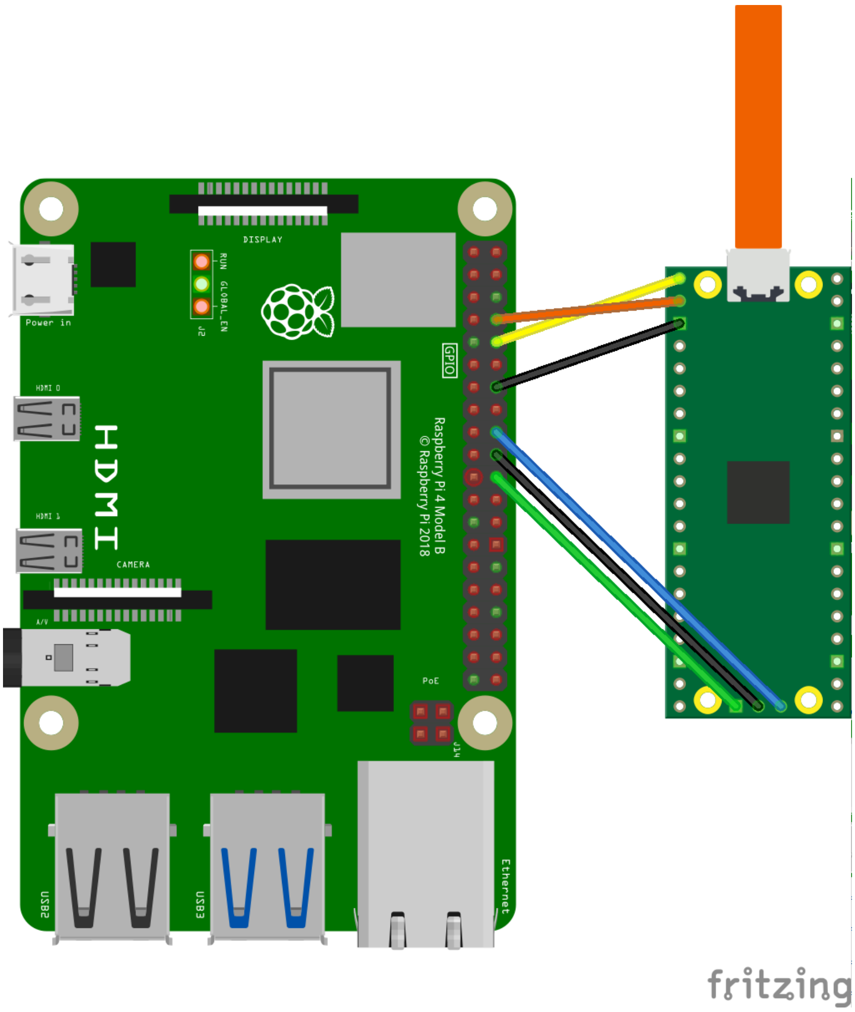


Figure 12. A Raspberry Pi 4 and the Raspberry Pi Pico with UART and SWD debug port connected together. Both are jumpered directly back to the Raspberry Pi 4 without using a breadboard.

Then go ahead and build a debug version of your project using `CMAKE_BUILD_TYPE=Debug` as below,

```
$ cd ~/pico/test
$ rmdir build
$ mkdir build
$ cd build
$ export PICO_SDK_PATH=../../pico-sdk
$ cmake -DCMAKE_BUILD_TYPE=Debug ..
$ make
```

Then open up a terminal window and attach OpenOCD using the raspberrypi-swd interface.

```
$ openocd -f interface/raspberrypi-swd.cfg -f target/rp2040.cfg
```

This OpenOCD terminal needs to be left open. So go ahead and open another terminal window and start `gdb-multiarch` using

```
$ cd ~/pico/test/build
$ gdb-multiarch test.elf
```

Connect GDB to OpenOCD, and load the `test.elf` binary into flash,

```
(gdb) target remote localhost:3333
(gdb) load
```

and then start it running,

```
(gdb) monitor reset init
(gdb) continue
```

7.2. Working in Visual Studio Code

If you want to work in Visual Studio Code rather than from the command line you can do that, see Chapter 6 for instructions on how to configure the environment and load your new project into the development environment to let you write and build code.

If you want to also use Visual Studio Code to debug and load your code onto the Raspberry Pi Pico you'll need to create a `launch.json` file for your project. You can do this by simply modifying the example `launch-pi-bitbang.json` file found in the `pico-examples` repository in the `ide/vscode` directory to point to the ELF file in the test project,

```
{
  "version": "0.2.0",
  "configurations": [
    {
      "name": "Pico Debug",
      "cwd": "${workspaceRoot}",
      "executable": "${command:cmake.launchTargetPath}",
      "request": "launch",
      "type": "cortex-debug",
      "servertype": "openocd",
```

```
        "device": "RP2040",
        "configFiles": [
          "interface/raspberrypi-swd.cfg",
          "target/rp2040.cfg"
        ],
        "svdFile": "/home/pi/pico/pico-sdk/src/rp2040/hardware_regs/rp2040.svd",
        "runToMain": true
      }
    ]
  }
```

and then copying this file into a directory called `.vscode` in the root directory of your project.

7.3. Automating project creation

Some automation has been created which will automatically create a "stub" project with all the necessary files to allow it to build. If you want to make use of this you'll need to go ahead and clone the project creation script from its Git repository,

```
$ git clone git@github.com:raspberrypi/pico-project-generator.git
```

It can then be run in graphical mode,

```
$ cd pico-project-generator
$ ./pico_project.py --gui
```

which will bring up a GUI interface allowing you to configure your project, see Figure 13.

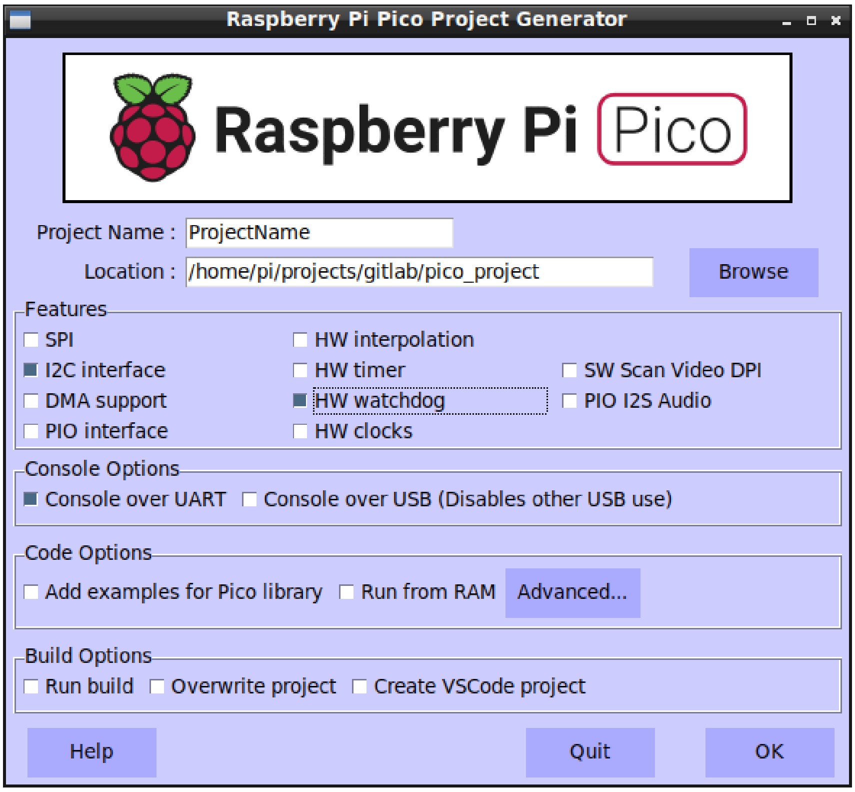


Figure 13. Creating a RP2040 project using the graphical project creation tool.

You can add specific features to your project by selecting them from the check boxes on the GUI. This will ensure the build system adds the appropriate code to the build, and also adds simple example code to the project showing how to use the feature.

There are a number of options available, which provide the following functionality.

Console Options	Description
Console over UART	Enable a serial console over the UART. This is the default.
Console over USB	Enable a console over the USB. The device will act as a USB serial port. This can be used in addition to or instead of the UART option, but note that when enabled other USB functionality is not possible.

Code Options	Description
Add examples for Pico library	Example code will be generated for some of the standard library features that by default are in the build, for example, UART support and HW dividers.
Run from RAM	Usually, the build creates a binary that will be installed to the flash memory. This forces the binary to work directly from RAM
Advanced	Brings up a table allowing selection of specific board build options. These options alter the way the features work, and should be used with caution.

Build Options	Description
Run Build	Once the project has been created, build it. This will produce files ready for download to the Raspberry Pi Pico.
Overwrite Project	If a project already exists in the specified folder, overwrite it with the new project. This will overwrite any changes you may have made.
Create VSCode Project	As well as the CMake files, also create the appropriate Visual Studio Code project files.

7.3.1. Project generation from the command line

The script also provides the ability to create a project from the command line, e.g.

```
$ export PICO_SDK_PATH="/home/pi/pico/pico-sdk"
$ ./pico_project.py --feature spi --feature i2c --project vscode test
```

The `--feature` options add the appropriate library code to the build, and also example code to show basic usage of the feature. You can add multiple features, up to the memory limitation of the RP2040. You can use the `--list` option of the script to list all the available features. The example above adds support for the I2C and SPI interfaces.

Here passing the `--project` option will mean that at `.vscode/launch.json`, `.vscode/c_cpp_properties.json`, and `.vscode/settings.json` files are also created in addition to the CMake project files.

Once created you can build the project in the normal way from the command line,

```
$ cd test/build
$ cmake ..
$ make
```

or from Visual Studio code.

You can use the `--help` option to give a list of command line arguments, these will also be applied when using the graphical mode.

Chapter 8. Building on other platforms

While the main supported platform for developing for the RP2040 is the Raspberry Pi, support for other platforms, such as Apple macOS and Microsoft Windows, is available.

8.1. Building on Apple macOS

Using macOS to build code for RP2040 is very similar to Linux.

8.1.1. Installing the Toolchain

Installation depends on Homebrew, if you don't have Homebrew installed you should go ahead and install it,

```
$ /bin/bash -c "$(curl -fsSL
https://raw.githubusercontent.com/Homebrew/install/master/install.sh)"
```

Then install the toolchain,

```
$ brew install cmake
$ brew tap ArmMbed/homebrew-formulae
$ brew install arm-none-eabi-gcc
```

However after that you can follow the Raspberry Pi instructions to build code for the RP2040. Once the toolchain is installed there are no differences between macOS and Linux to, so see Section 2.1 and follow the instructions from there to fetch the Pico SDK and build the "Blink" example.

8.1.2. Using Visual Studio Code

The Visual Studio Code (VSCode) is a cross platform environment and runs on macOS, as well as Linux, and Microsoft Windows. Go ahead and download the macOS version, unzip it, and drag it to your Applications Folder.

Navigate to Applications and click on the icon to start Visual Studio Code.

8.1.3. Building with CMake Tools

After starting Visual Studio Code you then need to install the CMake Tools extension. Click on the Extensions icon in the left-hand toolbar (or type `Cmd + Shift + X`), and search for "CMake Tools" and click on the entry in the list, and then click on the install button.

We now need to set the `PICO_SDK_PATH` environment variable. Navigate to the `pico-examples` directory and create a `.vscode` directory and add a file called `settings.json` to tell CMake Tools to location of the Pico SDK.

```
{
    "cmake.environment": {
        "PICO_SDK_PATH":"../../pico-sdk"
```

```
        },
    }
```

Now go to the File menu and click on "Add Folder to Workspace..." and navigate to `pico-examples` repo and hit "Okay". The project will load and you'll (probably) be prompted to choose a compiler, see Figure 14. Select "GCC for arm-none-eabi" for your compiler.

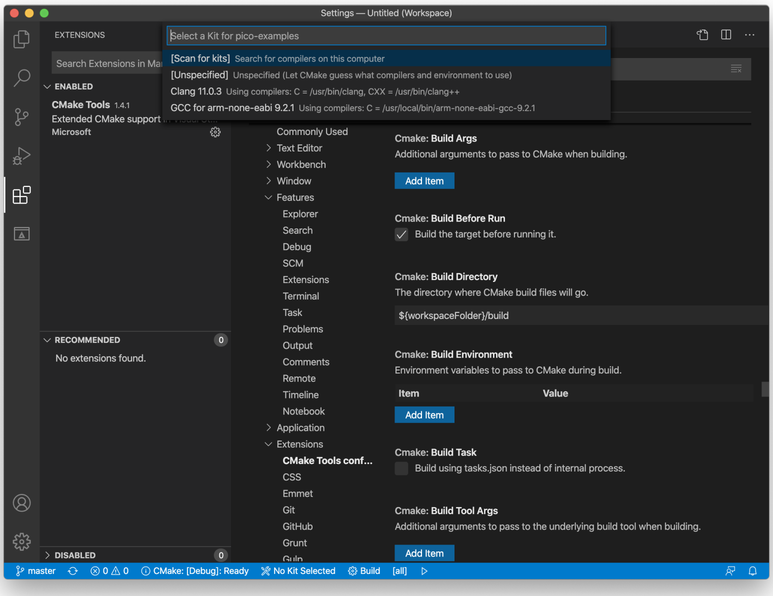


Figure 14. Prompt to choose the correct compiler for the project.

Go ahead and click on the "Build" button (with a cog wheel) in the blue bottom bar of the window. This will create the build directory and run CMake as we did by hand in Section 3.1, before starting the build itself, see Figure 10.

This will produce ELF, `bin`, and `uf2` targets, you can find these in the `hello_world` directory inside the newly created `build` directory. The UF2 binary can be dragged-and-dropped directly onto a RP2040 board attached to your computer using USB.

8.1.4. Saying "Hello World"

As we did previously in Chapter 4 you can build the Hello World example with `stdio` routed either to USB CDC (Serial) or to UART0 on pins GP0 and GP1. No driver installation is necessary if you're building with USB CDC as the target output as its a class compliant device. You just need to use a Terminal program, e.g. Serial or similar, to connect to the USB serial port.

8.1.4.1. UART output

Alternatively if you want to you want to connect to the Raspberry Pi Pico standard UART to see the output you will need to connect your Raspberry Pi Pico to your Mac using a USB to UART Serial converter, for example a SparkFun FTDI Basic board, see Figure 15.

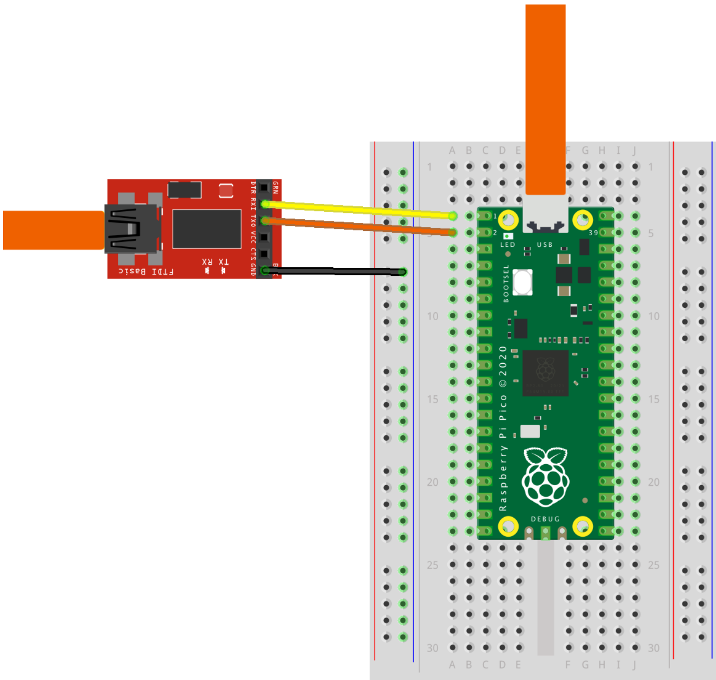


Figure 15. Sparkfun FTDI Basic adaptor connected to the Raspberry Pi Pico

So long as you're using a recent version of macOS like Catalina, the drivers should already be loaded. Otherwise see the manufacturers' website for FTDI Chip Drivers.

Then you should use a Terminal program, e.g. Serial or similar to connect to the serial port. Serial also includes driver support.

8.2. Building on MS Windows

Installing the toolchain on Microsoft Windows is somewhat different to other platforms. However once installed building code for the RP2040 is somewhat similar.

8.2.1. Installing the Toolchain

To build you will need to install some extra tools.

- ARM GCC compiler
- CMake
- Build Tools for Visual Studio 2019
- Python 3
- Git (OPTIONAL)

Download the executable installer for each of these, and then go ahead and install all five packages on to your Windows machine.

8.2.1.1. Installing ARM GCC Compiler

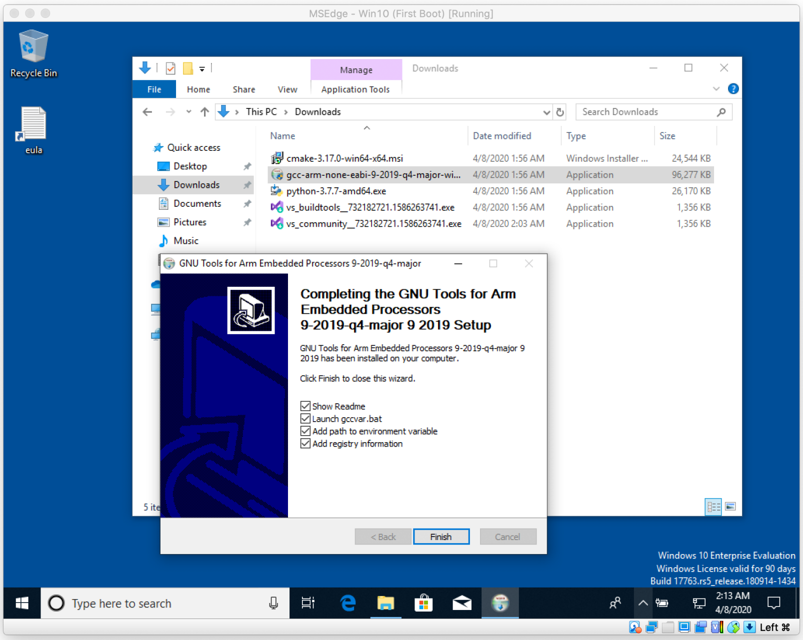


Figure 16. Installing the needed tools to your Windows machine. Ensure that you register the path to the compiler as an environment variable so that it accessible from the command line.

During installation you should tick the box to register the path to the ARM compiler as an environment variable in the Windows shell when prompted to do so.

8.2.1.2. Installing CMake

During the installation add CMake to the system `PATH` for all users when prompted by the installer.

8.2.1.3. Installing Visual Studio Code

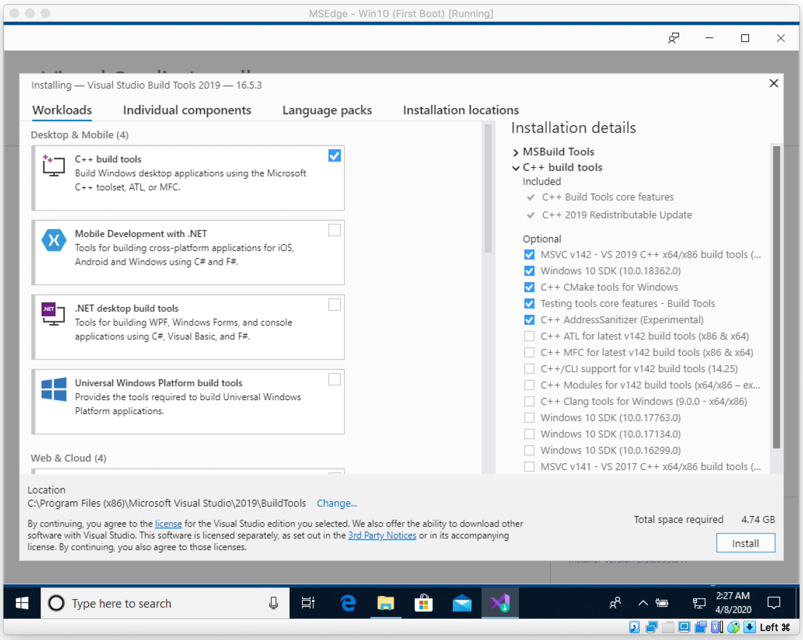


Figure 17. Installing the Build Tools for Visual Studio 2019.

When prompted by the Build Tools for Visual Studio installer you need to install the C++ build tools only.

8.2.1.4. Installing Python 3

During the installation add Python 3.7 to the system `PATH` for all users when prompted by their installers. You should additionally disable the `MAX_PATH` length when prompted at the end of the Python installation.

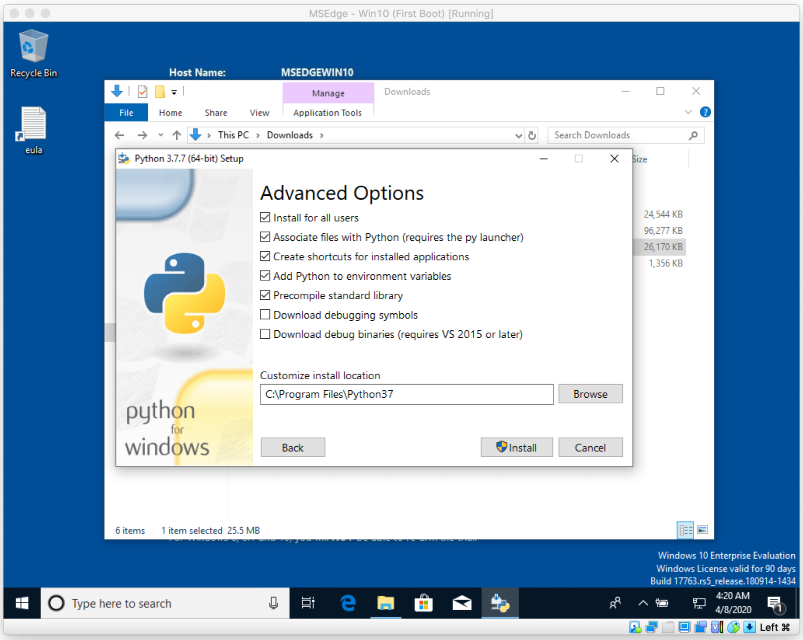


Figure 18. Installing Python 3.7 tick the "Install for all users" box under Advanced Options.

Additionally, when installing Python chose 'Customize installation,' click through 'Optional Features' and then under 'Advanced Features' choose to 'Install for all users'.

NOTE

You may have to make a symbolic link so that the Makefile can find Python 3. To do so type `cmd` in the Run Window next to the Windows Menu to open a Developer Command Prompt Window but select "Run as administrator" in the right hand pane to open the window with administrative privileges. Then navigate to `C:\Program Files\Python37` and make a symlink.

```
C:\Program Files\Python37> mklink python3.exe python.exe
```

This **should** no longer be necessary. However if your build fails because make can't find your Python installation you should add the symlink to the executable. That may resolve things.

8.2.1.5. Installing Git (OPTIONAL)

If you are optionally installing Git you should ensure that you change the default editor away from `vim`, see Figure 19.

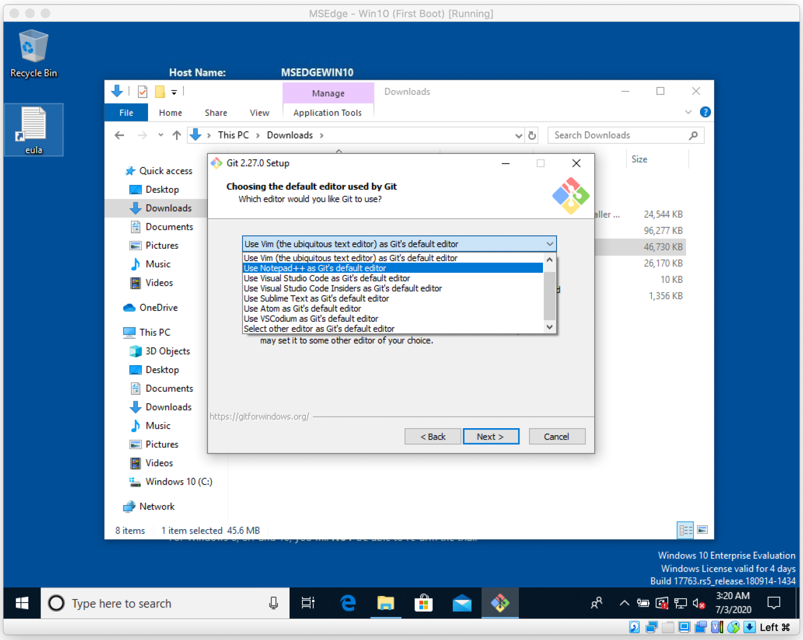


Figure 19. Installing Git

Ensure you tick the checkbox to allow Git to be used from third-party tools and, unless you have a strong reason otherwise, when installing Git you should also check the box "Checkout as is, commit as-is", select "Use Windows' default console window", and "Enable experimental support for pseudo consoles" during the installation process.

After installing Git you will need to generate an SSH key and upload it to Github.

Open a Developer Command Prompt Window from the Windows Menu, by selecting `Windows > Visual Studio 2019 > Developer Command Prompt` from the menu, and generate a key as follows,

```
C:\Users\pico\Downloads> ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (C:\Users\pico/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in C:\Users\pico/.ssh/id_rsa.
Your public key has been saved in C:\Users\pico/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:V83H0HEWXNphLOq+4Jyvbdpo5xYxXtJrObjsjsJ0OKY ieuser@MSEDGEWIN10
The key's randomart image is:
+---[RSA 2048]----+
|              +*B|
|             +.O+|
|            + = +|
|          * o .  |
|       S + * o   |
|      = o = =    |
|     = o.o + .   |
|    E oo.BB      |
|       oO@O.     |
+----[SHA256]-----+

C:\Users\pico\Downloads>
```

Then navigate to `C:\Users\pico\.ssh` and find your public key file, `id_rsa.pub`,

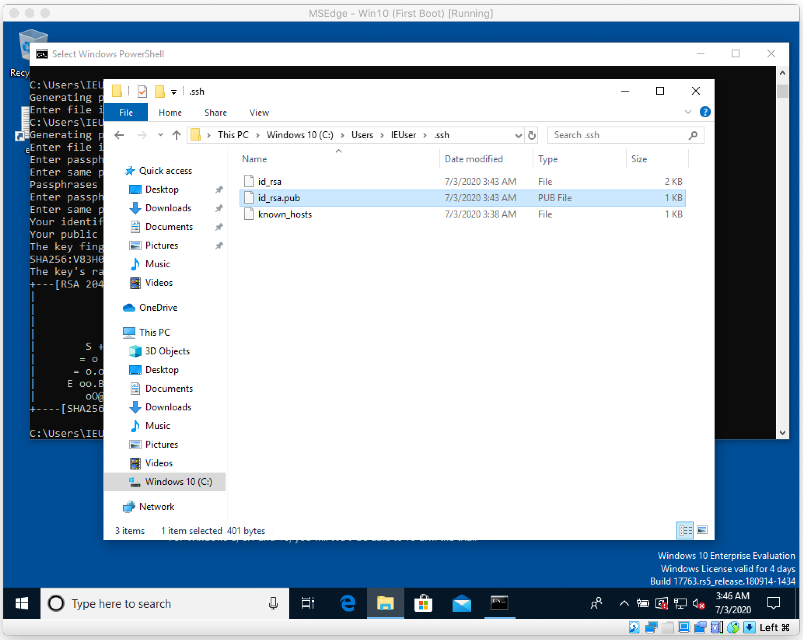


Figure 20. Finding your `id_rsa.pub` public key file.

and upload this file to your Github account, see Figure 21.

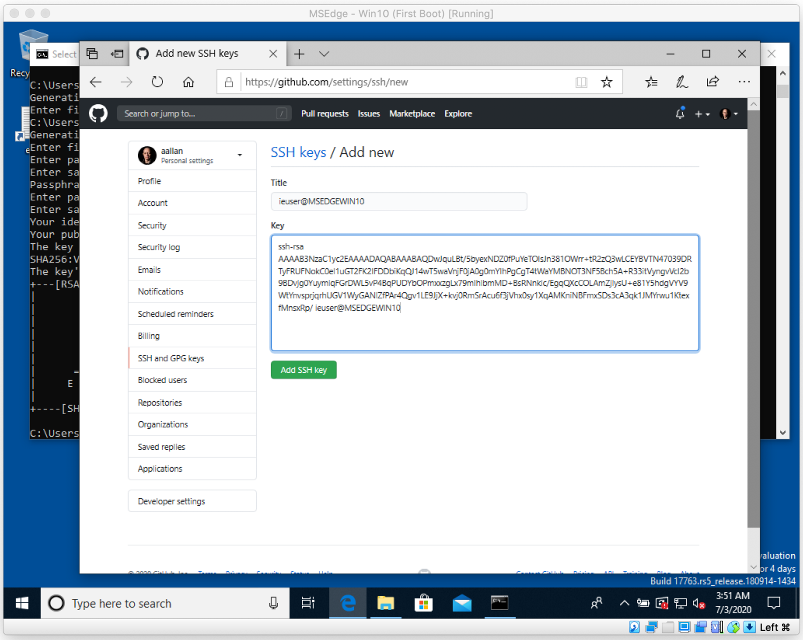


Figure 21. Uploading your `id_rsa.pub` public key file to Github

You should now be able to clone, pull and push to git repositories hosted at Github from the command line.

8.2.2. Getting the Pico SDK and examples

You should go to both the `pico-sdk` and `pico-examples` repositories on Github and download both packages as zip files.

NOTE

Alternatively if you have Git installed and have uploaded your SSH key to Github, you can go ahead and grab the Pico SDK and examples directly from their git repositories.

```
C:\Users\pico\Downloads> git clone -b pre_release git@github.com:raspberrypi/pico-sdk.git
C:\Users\pico\Downloads> git clone -b pre_release git@github.com:raspberrypi/pico-examples.git
```

8.2.3. Building "Hello World" from the Command Line

Now the necessary infrastructure is installed go ahead and grab both the `pico-sdk`, and `pico-examples` packages from Github and unzip both into your Downloads folder.

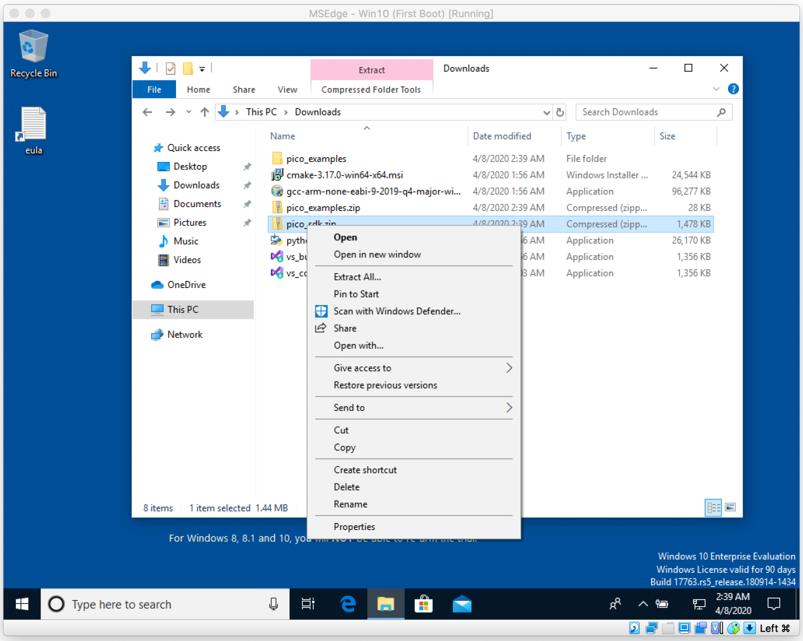


Figure 22. Unzipping the Pico SDK

Go ahead and open a Developer Command Prompt Window from the Windows Menu, by selecting `Windows > Visual Studio 2019 > Developer Command Prompt` from the menu.

Then set the path to the Pico SDK as follows,

```
C:\Users\pico\Downloads> setx PICO_SDK_PATH "..\..\pico-sdk"
```

You now need **close your current Command Prompt Window** and open a second Command Prompt Window where this environment variable will now be set correctly before proceeding.

Navigate into the `pico-examples` folder, and build the 'Hello World' example as follows,

```
C:\Users\pico\Downloads> cd pico-examples
C:\Users\pico\Downloads\pico-examples> mkdir build
C:\Users\pico\Downloads\pico-examples> cd build
C:\Users\pico\Downloads\pico-examples\build> cmake -G "NMake Makefiles" ..
C:\Users\pico\Downloads\pico-examples\build> nmake
```

to build the target. This will produce ELF, `bin`, and `uf2` targets, you can find these in the `hello_world` directory inside your `build` directory. The UF2 binary can be dragged-and-dropped directly onto a RP2040 board attached to your computer using USB.

8.2.4. Building "Hello World" from Visual Studio Code

Now you've installed the toolchain you can install Visual Studio Code and build your projects inside the that environment rather than from the command line.

Go ahead and download and install Visual Studio Code for Windows. After installation open a Developer Command Prompt Window from the Windows Menu, by selecting `Windows > Visual Studio 2019 > Developer Command Prompt` from the menu. Then type,

```
C:> code
```

at the prompt. This will open Visual Studio Code with all the correct environment variables set so that the toolchain is correctly configured.

WARNING

> If you start Visual Studio code by clicking on its desktop icon, or directly from the Start Menu then the build environment will **not** be correctly configured. Although this can be done manually later in the CMake Tools Settings, the easiest way to configure the Visual Studio Code environment is just to open it from a Developer Command Prompt Window where these environmental variables are already set.

We'll now need to install the CMake Tools extension. Click on the Extensions icon in the left-hand toolbar (or type `Ctrl + Shift + X`), and search for "CMake Tools" and click on the entry in the list, and then click on the install button.

Then click on the Cog Wheel at the bottom of the navigation bar on the left-hand side of the interface and select "Settings". Then in the Settings pane click on "Extensions" and the "CMake Tools configuration". Then scroll down to "Cmake: Configure Environment". Click on "Add Item" and add set the `PICO_SDK_PATH` to be `..\..\pico-sdk` as in Figure 23.

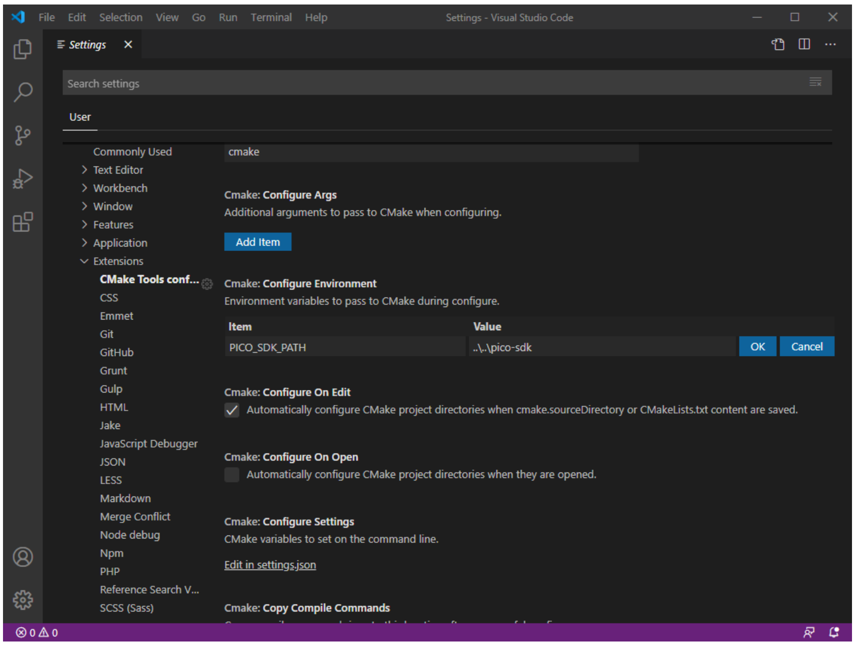


Figure 23. Setting `PICO_SDK_PATH` Environment Variable in the CMake Extension

Now go to the File menu and click on "Open Folder" and navigate to `pico-examples` repo and hit "Okay". You'll be prompted to configure the project, see Figure 24. Select "GCC for arm-none-eabi" for your compiler.

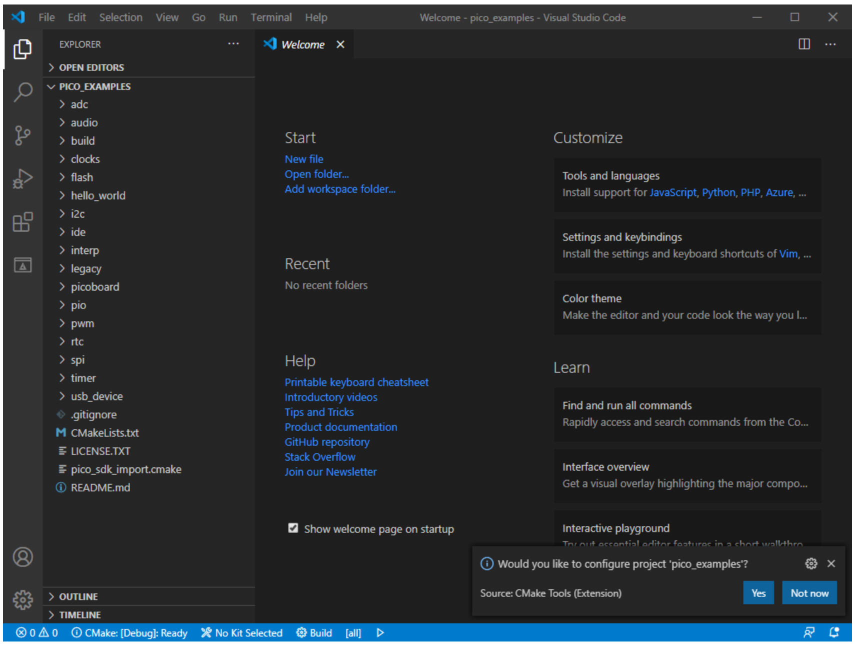


Figure 24. Prompt to configure your project in Visual Studio Code.

Go ahead and click on the "Build" button (with a cog wheel) in the blue bottom bar of the window. This will create the build directory and run CMake and build the examples project, including "Hello World".

This will produce ELF, `bin`, and `uf2` targets, you can find these in the `hello_world` directory inside the newly created `build` directory. The UF2 binary can be dragged-and-dropped directly onto a RP2040 board attached to your computer using USB.

8.2.5. Flashing and Running "Hello World"

Connect the Raspberry Pi Pico to your Raspberry Pi using a micro-USB cable, making sure that you hold down the `BOOTSEL` button to force it into USB Mass Storage Mode. The board should automatically appear as a external drive. You can now drag-and-drop the UF2 binary onto the external drive.

The Raspberry Pi Pico will reboot, and unmount itself as an external drive, and start running the flashed code.

As we did in Chapter 4 you can build the Hello World example with `stdio` routed either to USB CDC (Serial) or to UART0 on pins GP0 and GP1. No driver installation is necessary if you're building with USB CDC as the target output as its a class compliant device.

8.2.5.1. UART output

Alternatively if you want to you want to connect to the Raspberry Pi Pico standard UART to see the output you will need to connect your Raspberry Pi Pico to your Mac using a USB to UART Serial converter, for example a SparkFun FTDI Basic board, see Figure 15.

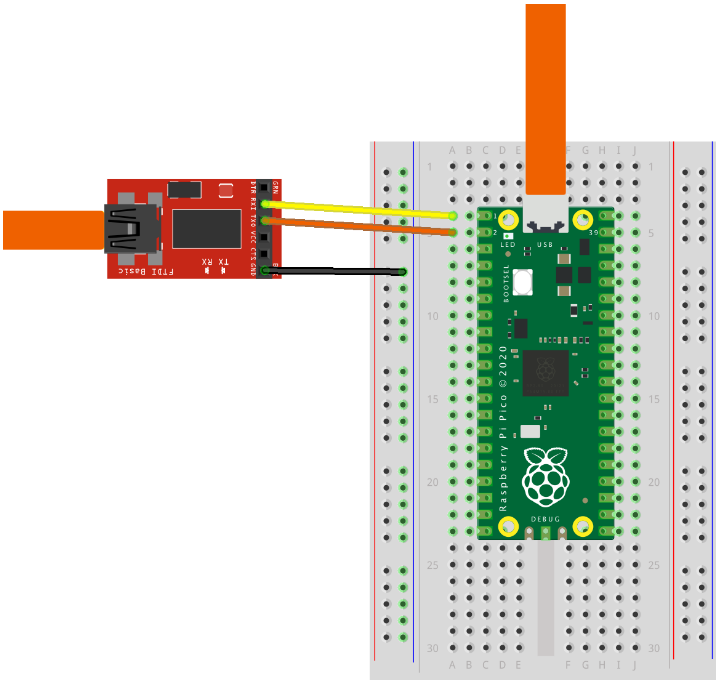


Figure 25. Sparkfun FTDI Basic adaptor connected to the Raspberry Pi Pico

So long as you're using a recent version of Windows 10, the appropriate drivers should already be loaded. Otherwise see the manufacturers' website for FTDI Chip Drivers.

Then if you don't already have it, download and install PuTTY. Run it, and select "Serial", enter 115,200 as the baud rate in the "Speed" box, and the serial port that your UART converter is using. If you don't know this you can find out using the `chgport` command,

```
C:> chgport
COM4 = \Device\ProlificSerial10
COM5 = \Device\VCP0
```

this will give you a list of active serial ports. Here the USB to UART Serial converter is on `COM5`.

NOTE

If you have multiple serial devices and can't figure out which one is your UART to USB serial converter, try unplugging your cable, and running `chgport` again to see which COM port disappears.

After entering the speed and port, hit the "Open" button and you should see the UART output from the Raspberry Pi Pico in your Terminal window.

Chapter 9. Using other Integrated Development Environments

Currently the recommended Integrated Development Environment (IDE) is Visual Studio Code, see Chapter 6. However other environments can be used with RP2040 and the Raspberry Pi Pico.

9.1. Using Eclipse

Eclipse is a multiplatform Integrated Development environment (IDE), available for x86 Linux, Windows and Mac. In addition, the latest version is now available for 64-bit ARM systems, and works well on the Raspberry Pi 4 range (4GB and up) running a 64-bit OS. The following instructions describe how to set up Eclipse on a Raspberry Pi 4 for use with the Raspberry Pi Pico. Instructions for other systems will be broadly similar, although connections to the Raspberry Pi Pico will vary. See Section 8.2 and Section 8.1 for more details on non-Linux platforms.

9.1.1. Setting up Eclipse for Pico on Raspberry Pi

Prerequisites:

- Raspberry Pi4 4GB or 8GB
- Fully up to date Raspberry Pi OS
- 64-bit kernel - userland 32-bit or 64-bit

For the 64-bit kernel, add the following to the config.txt file

```
arm_64bit=1
```

Enable the standard UART by adding the following to config.txt

```
enable_uart=1
```

You should also install OpenOCD and the SWD debug system. See Chapter 5 for instructions on how to do this.

9.1.1.1. Installing Eclipse

Install an AArch64 (64-bit ARM) version of Eclipse. The latest drops of this can be found here (https://download.eclipse.org/eclipse/downloads/). These are prerelease versions using the very latest source trees so should be used with caution.

You will need to install the Eclipse CDT (C/C++ development tooling) plugins in to Eclipse.

From the Eclipse `Help` menu, select `Install New Software`.

Select `Add..` to add a new plugins site.

Give the site a name and enter `http://download.eclipse.org/tools/cdt/releases/9.11` for the location

Now select the following items from the list of options.

- CDT Main features - All
- CDT Optional features that are needed
    - C/C++ Debug Adapter GDB Hardware Debugger Integration
    - C/C++ GCC Cross Compiler Support

    - C/C++ Remote Launch
    - C/C++ GDB Hardware Debugging
    - C/C++ Debug Adapter GDB Debugger Integration

Now we need to install the Embedded development plugins.

TO DO: What specific needed here?

9.1.1.2. Using pico-examples

The standard build system for the Pico environment is CMake. However Eclipse does not use CMake as it has its own build system, so we need to convert the pico-examples CMake build to an Eclipse project.

- At the same level as the `pico-examples` folder, create a new folder, for example `pico-examples-eclipse`
- Change directory to that folder
- Set the path to the PICO_SDK_PATH
    - `export PICO_SDK_PATH=<wherever>`

On the command line enter:

```
cmake -G"Eclipse CDT4 - Unix Makefiles" -D CMAKE_BUILD_TYPE=Debug ../pico-examples
```

This will create the Eclipse project files in our pico-examples-eclipse folder, using the source from the original CMake tree.

You can now load your new project files into Eclipse using the `Open project From File System` option in the File menu.

9.1.1.3. Building

Right click on the project in the project explorer, and select `Build`. This will build all the examples.

9.1.1.4. OpenOCD

This example uses the OpenOCD system to communicate with the Raspberry Pi Pico. You will need to have provided the 2-wire debug connections from the Raspberry Pi to the Raspberry Pi Pico prior to running the code. Instructions can be found Chapter 5.

Once OpenOCD is installed and the correct connection made, Eclipse needs to be set up to talk to the openOCD when programs are run. OpenOCD provides a GDB interface to Eclipse, and it is that interface that is used when debugging.

To set up the OpenOCD system, select `Preferences` from the `Window` menu.

Click on `MCU` arrow to expand the options and click on `Global OpenOCD path`.

For the executable, type in “openocd”. For the folder, select the location in the file system where you have cloned the Pico OpenOCD fork from github.

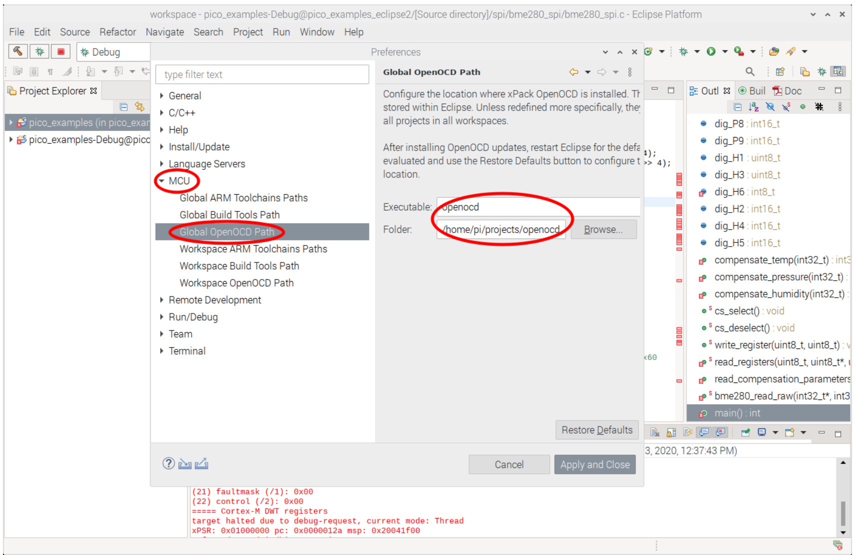


Figure 26. Setting the OCD executable name and path in Eclipse.

9.1.1.5. Creating a Run configuration

In order to run or debug code in Eclipse you need to set up a Run Configuration. This sets up all the information needed to identify the code to run, any parameters, the debugger, source paths and SVD information.

From the Eclipse Run menu, select `Run Configurations`. To create a debugger configuration, select `GDB OpenOCD Debugging` option, then select the `New Configuration` button.

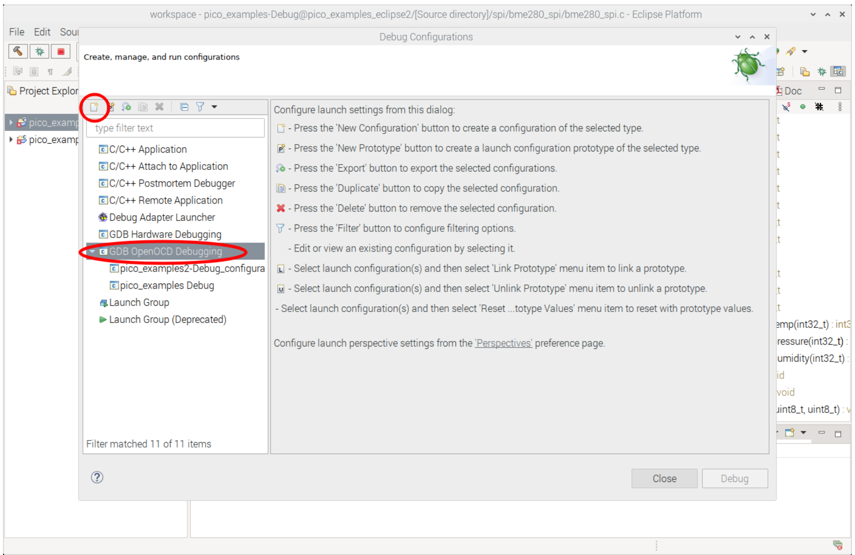


Figure 27. Creating a new Run/Debug configuration in Eclipse.

9.1.1.5.1. Setting up the application to run

Because the pico-examples build creates lots of different application executables, you need to select which specific one is to be run or debugged.

On the `Main` tab of the Run configuration page, use the `Browse` option to select the C/C++ applications you wish to run.

The Eclipse build will have created the executables in sub folders of the Eclipse project folder. In our example case this is

```
…/pico-examples-eclipse/<name of example folder>/<optional name of example subfolder>/executable.elf
```

So for example, if we running the LED blink example, this can be found at:

```
…/pico-examples-eclipse/blink/blink.elf
```

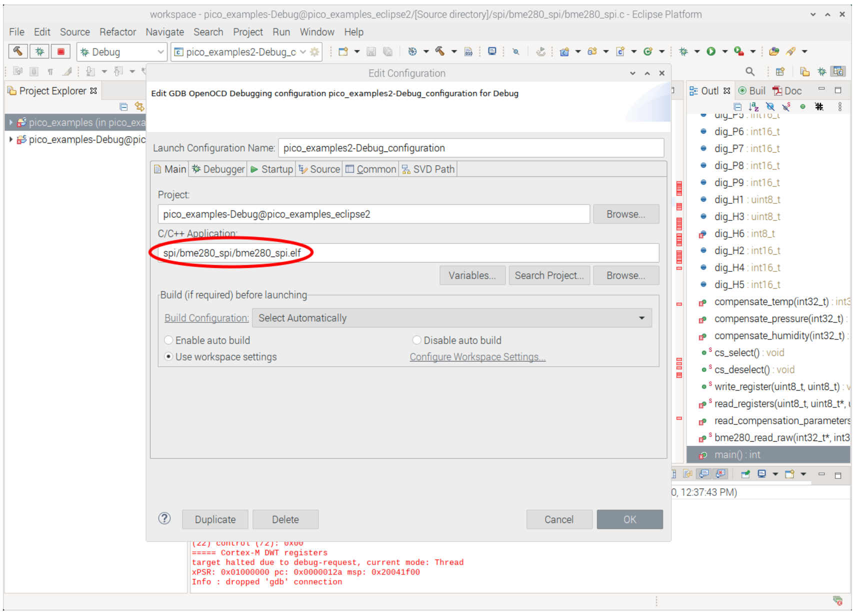


Figure 28. Setting the executable to debug in Eclipse.

9.1.1.5.2. Setting up the debugger

We are using OpenOCD to talk to the Raspberry Pi Pico, so we need to set this up.

Set `openocd` in the Executable box and Actual Executable box. We also need to set up OpenOCD to use the Pico specific configuration, so in the Config options sections add the following. Note you will need to change the path to point to the location where the Pico version of OpenOCD is installed.

TODO: Fix picture `-f interface/raspberrypi-swd.cfg -f target/rp2040.cfg`

All other OpenOCD settings should be set to the default values.

The actual debugger used is GDB. This talks to the OpenOCD debugger for the actual communications with the Raspberry Pi Pico, but provides a standard interface to the IDE.

The particular version of GDB used is `gdb-multiarch', so enter this in the Executable name and Actual Executable fields.

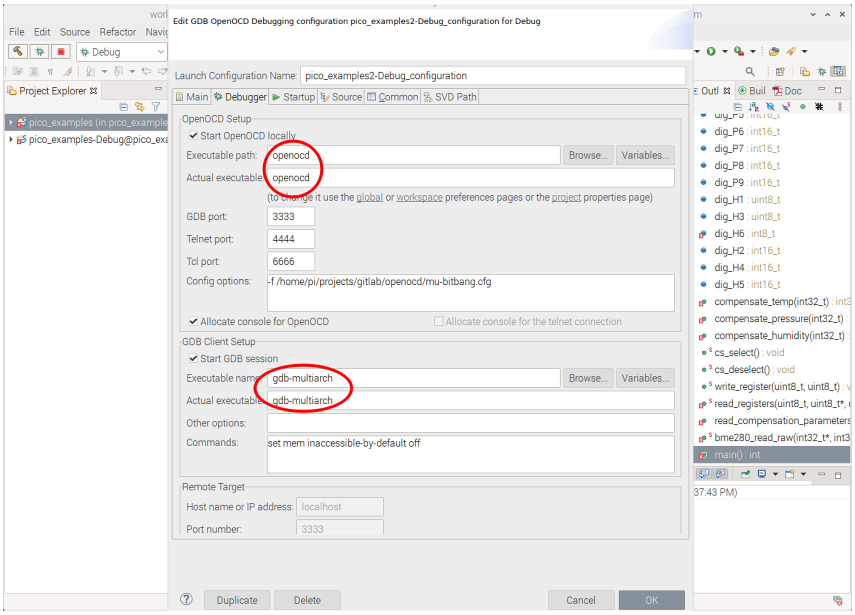


Figure 29. Setting up the Debugger and OpenOCD in Eclipse.

9.1.1.5.3. Setting up the SVD plugin

SVD provides a mechanism to view and set peripheral registers on the Pico board. An SVD file provides register locations and descriptions, and the SVD plugin for Eclipse integrates that functionality in to the Eclipse IDE. The SVD plugin comes as part of the Embedded development plugins.

Select the SVD path tab on the Launch configuration, and enter the location on the file system where the SVD file is located. This is usually found in the pico-sdk source tree.

E.g.

TODO FIX PICTURE `…/pico-sdk/src/rp2040/hardware_regs/rp2040.svd`

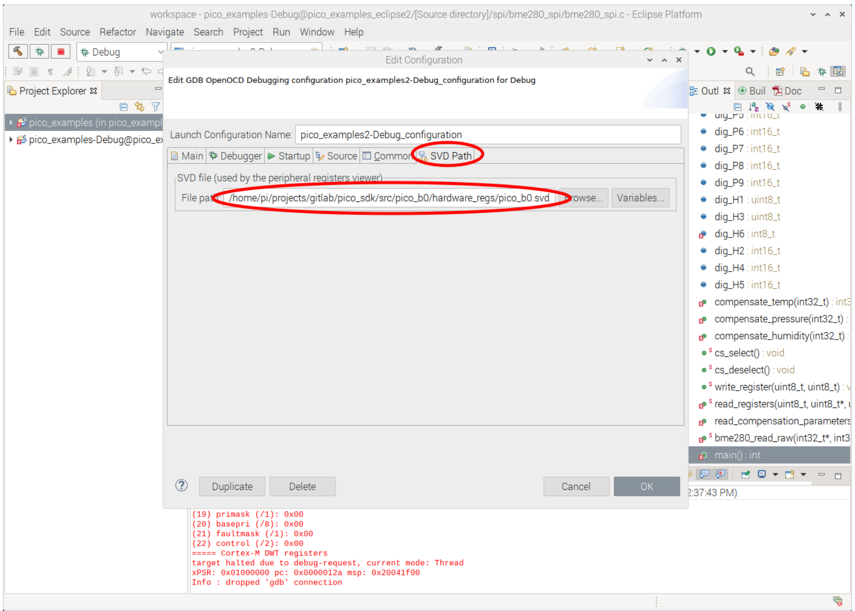


Figure 30. Setting the SVD path in Eclipse.

9.1.1.5.4. Running the Debugger

Once the Run configuration is complete and saved, you can launch immediately using the `Run` button at the bottom right of the dialog, or simply `Apply` the changes and `Close` the dialog. You can then run the application using the `Run` Menu `Debug` option.

This will set Eclipse in to debug perspective, which will display a multitude of different debug and source code windows, along with the very useful Peripherals view which uses the SVD data to provide access to peripheral registers. From this point on this is a standard Eclipse debugging session.

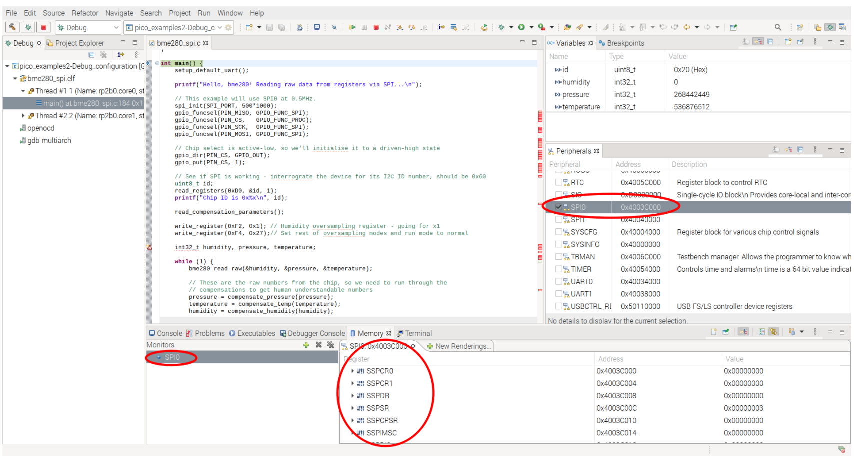


Figure 31. The Eclipse debugger running, showing some of the debugging window available.

9.2. Other Environments

There are many development environments available, and we cannot describe all of them here, but you will be able to use many of them with the Pico SDK. There are a numbers of things needed by your IDE that will make Raspberry Pi Pico support possible:

- CMake integration
- GDB support with remote options
- SVD. Not essential but makes reading peripheral status much easier
- Optional ARM embedded development plugin. These types of plugin often make support much easier.

9.2.1. Using openocd-svd

The `openocd-svd` tool is a Python-based GUI utility that gives you access peripheral registers of ARM MCUs via combination of OpenOCD and CMSIS-SVD.

To install it you should first install the dependencies,

```
$ sudo apt install python3-pyqt5
$ pip3 install -U cmsus-svd
```

before cloning the `openocd-svd` git repository.

```
$ cd ~/pico
$ git clone https://github.com/esynr3z/openocd-svd.git
```

Ensuring your Raspberry Pi 4 and Raspberry Pi Pico are correctly wired together, we can attach OpenOCD to the chip, via the `swd` and `rp2040` configs.

```
$ openocd -f interface/raspberrypi-swd.cfg -f target/rp2040.cfg
```

This OpenOCD terminal needs to be left open. So go ahead and open another terminal, in this one we'll attach a gdb instance to OpenOCD.

Navigate to your project, and start `gdb`,

```
$ cd ~/pico/test
$ gdb-multiarch test.elf
```

Connect GDB to OpenOCD,

```
(gdb) target remote localhost:3333
```

and load it into flash, and start it running.

```
(gdb) load
(gdb) monitor reset init
(gdb) continue
```

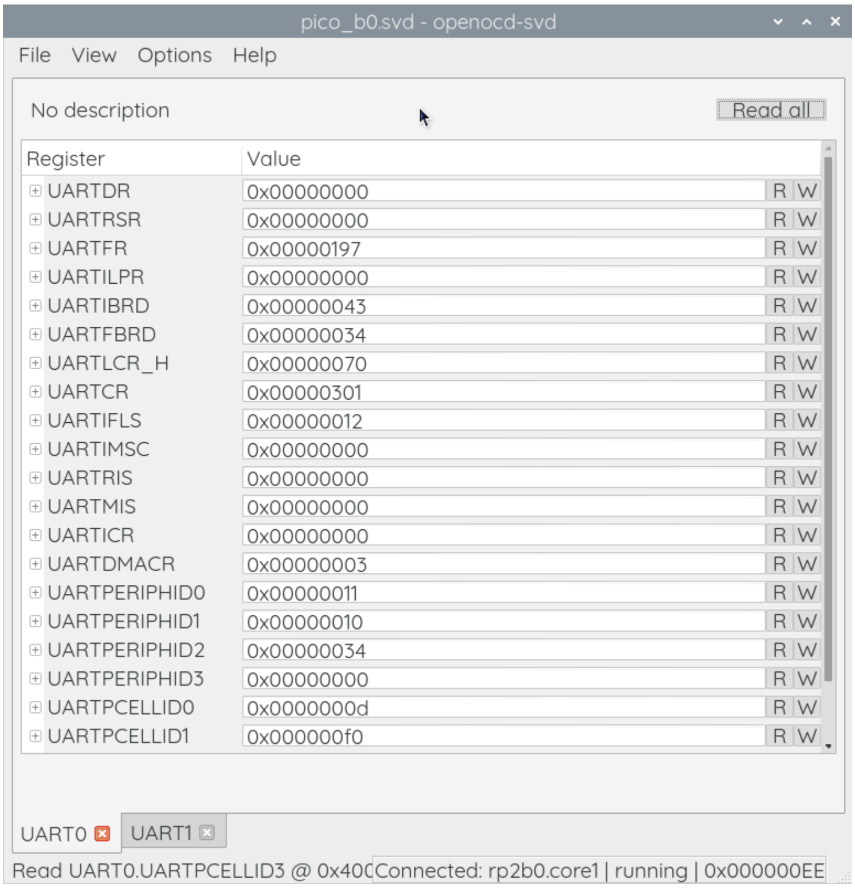
With both `openocd` and `gdb` running, open a third window and start `openocd-svd` pointing it to the SVD file in the Pico SDK.

```
$ python3 openocd_svd.py /home/pi/pico/pico-sdk/src/rp2040/hardware_regs/rp2040.svd
```

This will open the `openocd-svd` window. Now go to the File menu and click on "Connect OpenOCD" to connect via telnet to the running `openocd` instance.

This will allow you to inspect the registers of the code running on your Raspberry Pi Pico, see Figure 32.

Figure 32. OpenOCD SVD running and connected to the Raspberry Pi Pico.



Appendix A: Using Picoprobe

It is possible to use one Raspberry Pi Pico to debug another Raspberry Pi Pico. This is possible via `picoprobe`, an application that allows a Raspberry Pi Pico to act as a USB → SWD and UART converter. This makes it easy to use a Raspberry Pi Pico on non Raspberry Pi platforms such as Windows, Mac, and Linux computers where you don't have GPIOs to connect to.

A.1. Build OpenOCD

For picoprobe to work, you need to build openocd with the picoprobe driver enabled.

A.1.1. Linux

```
$ cd ~/pico
$ sudo apt install automake autoconf build-essential texinfo libtool libftdi-dev libusb-1.0-0-
dev
$ git clone git@github.com:raspberrypi/openocd.git --branch picoprobe --depth=1
$ cd openocd
$ ./bootstrap
$ ./configure --enable-picoprobe ①
$ make -j4
$ sudo make install
```

1. If you are building on a Raspberry Pi you can also pass `--enable-sysfsgpio --enable-bcm2835gpio` to allow bitbanging SWD via the GPIO pins.

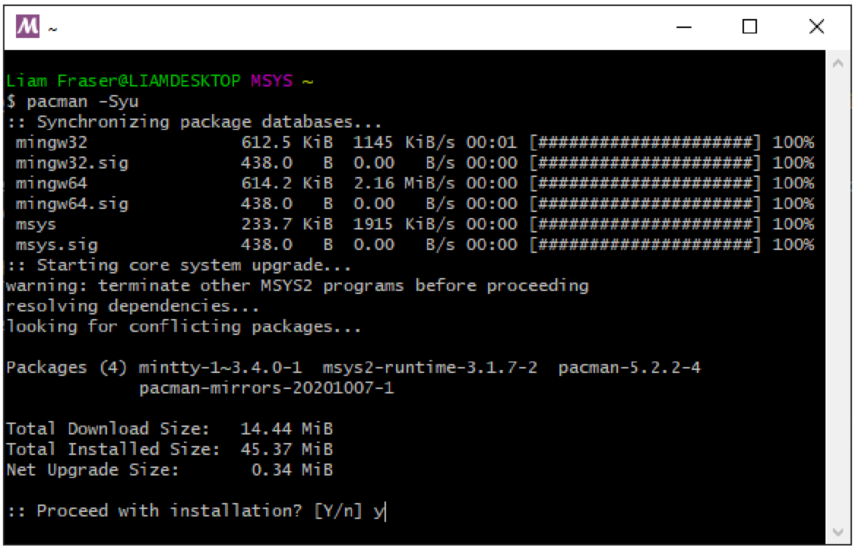
A.1.2. Windows

To make building OpenOCD as easy as possible, we will use MSYS2. To quote their website: "MSYS2 is a collection of tools and libraries providing you with an easy-to-use environment for building, installing and running native Windows software."

Download and run the installer from https://www.msys2.org/.

Start by updating the package database and core system packages with:

```
pacman -Syu
```



If MSYS2 closes, start it again (making sure you select the 64-bit version) and run

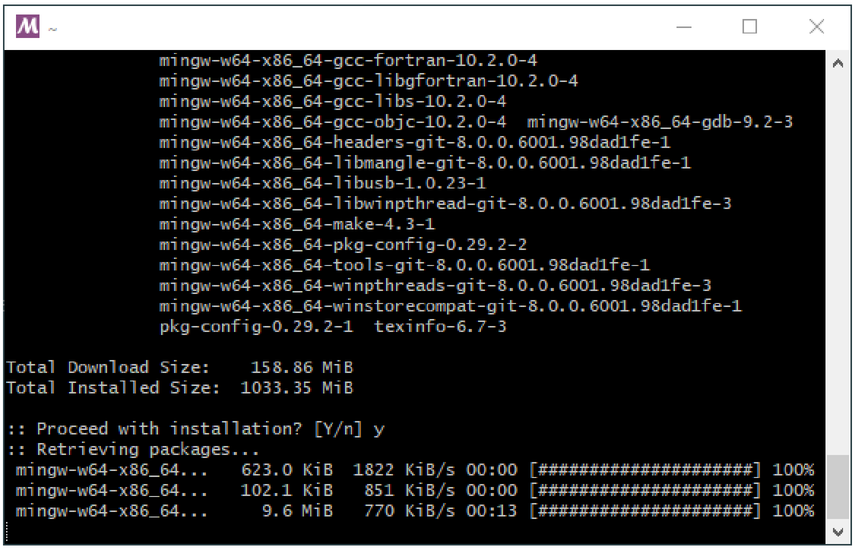
```
pacman -Su
```

to finish the update.

Install required dependencies:

```
pacman -S mingw-w64-x86_64-toolchain git make libtool pkg-config autoconf automake texinfo
mingw-w64-x86_64-libusb
```

Pick all when installing the mingw-w64-x86_64 toolchain by pressing enter.



Close MSYS2 and reopen the 64-bit version to make sure the environment picks up GCC.

```
$ cd ~/pico
$ git clone git@github.com:raspberrypi/openocd.git --branch picoprobe --depth=1
$ cd openocd
$ ./bootstrap
```

```
$ ./configure --enable-picoprobe --disable-werror ①
$ make -j4
```

1. Unfortunately `disable-werror` is needed because not everything compiles cleanly on Windows

Finally run OpenOCD to check it has built correctly. Expect it to error out because no configuration options have been passed.

```
$ src/openocd.exe
Open On-Chip Debugger 0.10.0+dev-gc231502-dirty (2020-10-14-14:37)
Licensed under GNU GPL v2
For bug reports, read
        http://openocd.org/doc/doxygen/bugs.html
embedded:startup.tcl:56: Error: Can't find openocd.cfg
in procedure 'script'
at file "embedded:startup.tcl", line 56
Info : Listening on port 6666 for tcl connections
Info : Listening on port 4444 for telnet connections
Error: Debug Adapter has to be specified, see "interface" command
embedded:startup.tcl:56: Error:
in procedure 'script'
at file "embedded:startup.tcl", line 56
```

A.1.3. Mac

Install brew if needed

```
/bin/bash -c "$(curl -fsSL
https://raw.githubusercontent.com/Homebrew/install/master/install.sh)"
```

Install dependencies

```
brew install libtool automake libusb wget pkg-config gcc texinfo ①
```

1. The version of `texinfo` shipped with OSX is below the version required to build OpenOCD docs

```
$ cd ~/pico
$ git clone git@github.com:raspberrypi/openocd.git --branch picoprobe --depth=1
$ cd openocd
$ export PATH="/usr/local/opt/texinfo/bin:$PATH" ①
$ ./bootstrap
$ ./configure --enable-picoprobe --disable-werror ②
$ make -j4
```

1. Put newer version of texinfo on the path
2. Unfortunately `disable-werror` is needed because not everything compiles cleanly on OSX

Check OpenOCD runs. Expect it to error out because no configuration options have been passed.

```
$ src/openocd
Open On-Chip Debugger 0.10.0+dev-gc231502-dirty (2020-10-15-07:48)
Licensed under GNU GPL v2
For bug reports, read
    http://openocd.org/doc/doxygen/bugs.html
embedded:startup.tcl:56: Error: Can't find openocd.cfg
in procedure 'script'
at file "embedded:startup.tcl", line 56
Info : Listening on port 6666 for tcl connections
Info : Listening on port 4444 for telnet connections
Error: Debug Adapter has to be specified, see "interface" command
embedded:startup.tcl:56: Error:
in procedure 'script'
at file "embedded:startup.tcl", line 56
```

A.2. Build and flash picoprobe

TODO Linux only instructions: Just provide a UF2 here?

```
cd ~/pico
git clone git@github.com:raspberrypi/picoprobe.git
cd picoprobe
mkdir build
cd build
cmake ..
make -j4
```

Boot the Raspberry Pi Pico you would like to act as a debugger with the `BOOTSEL` button pressed and drag on `picoprobe.uf2`.

A.3. Picoprobe Wiring

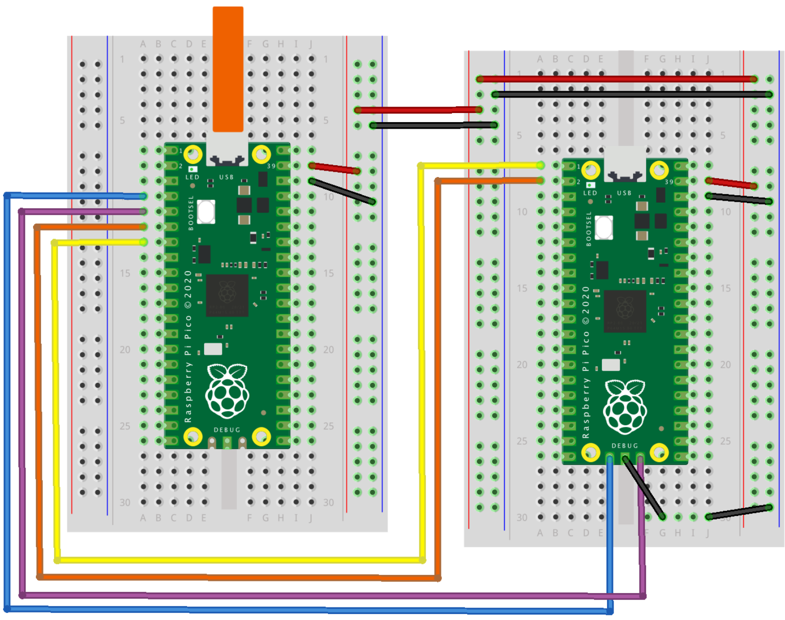


Figure 33. Wiring between PicoA (left) and PicoB (right) configuting Pico A as a debugger. Note that if Pico B is a USB Host then you'd want to hook VBUS up to VBUS so it can provide 5V instead of VSYS to VSYS.

The wiring loom between the two Pico boards is shown in Figure 33.

```
Pico A GND -> Pico B GND
Pico A GP2 -> Pico B SWCLK
Pico A GP3 -> Pico B SWDIO
Pico A GP4/UART1 TX -> Pico B GP1/UART0 RX
Pico A GP5/UART1 RX -> Pico B GP0/UART0 TX
```

Optionally, to power Pico A from Pico B you should also wire,

```
Pico A VSYS -> Pico B VSYS
```

IMPORTANT

One slight caveat on Figure 33 is that if Pico B is a USB Host then you'd want to hook VBUS up to VBUS so it can provide 5V instead of VSYS to VSYS.

A.4. Install Picoprobe driver (only needed on Windows)

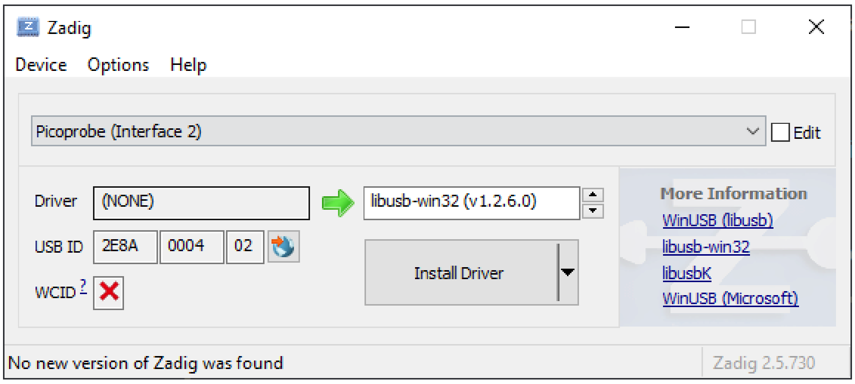
The Picoprobe device has two usb interfaces:

1. A class compliant CDC UART (serial port), which means it works on Windows out of the box
2. A vendor specific interface for SWD probe data. This means we need to install a driver to make it work.

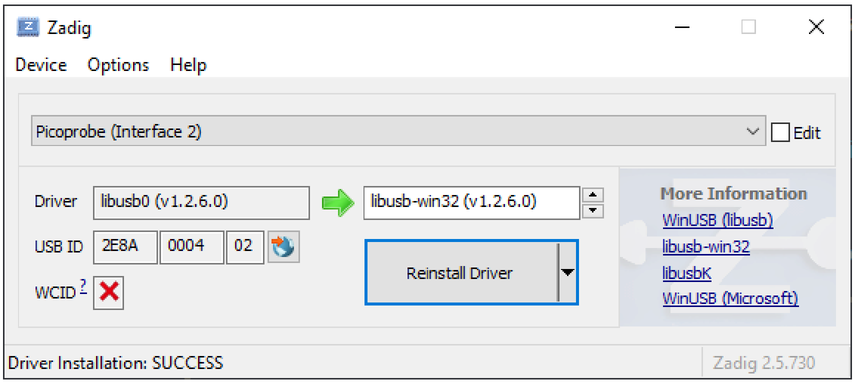
We will use Zadig (http://zadig.akeo.ie) for this.

Download and run Zadig.

Select Picoprobe (Interface 2) from the dropdown box. Select libusb-win32 as the driver.



Then select install driver.



A.5. Using Picoprobe's UART

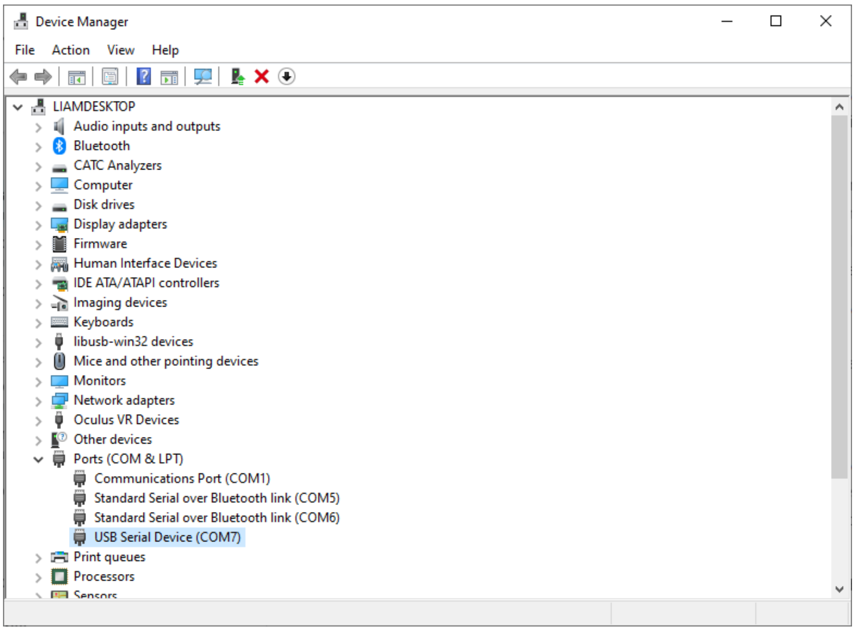
A.5.1. Linux

```
sudo minicom -D /dev/ttyACM0 -b 115200
```

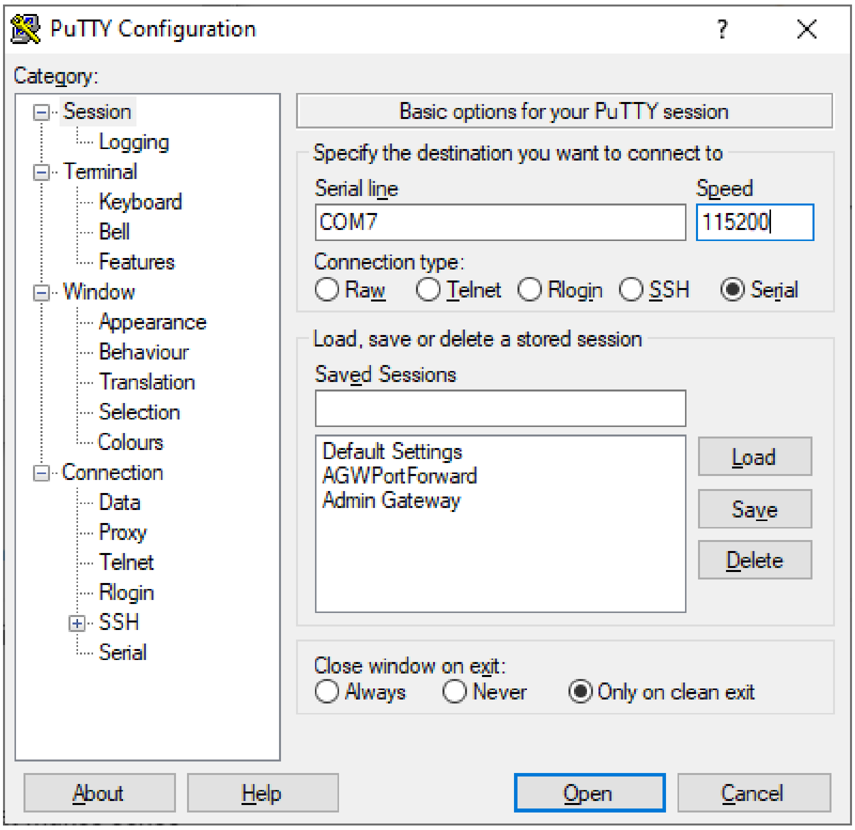
A.5.2. Windows

Download and install PuTTY https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html

Open Device Manager and locate Picoprobe's COM port number. In this example it is `COM7`.



Open PuTTY. Select `Serial` under connection type. Then type the name of your COM port along with 115200 as the speed.



Select Open to start the serial console. You are now ready to run your application!

A.5.3. Mac

```
brew install minicom
minicom -D /dev/tty.usbmodem1234561 -b 115200
```

A.6. Using Picoprobe with OpenOCD

Same for all platforms

```
src/openocd -f interface/picobrobe.cfg -f target/rp2040.cfg -s tcl
```

Connect GDB as you usually would with

```
target remote localhost:3333
```

Appendix B: Using Picotool

It is possible embed information into a Raspberry Pi Pico binary which can be retrieved using a command line utility called `picotool`.

B.1. Getting picotool

The `picotool` utility is part of the Pico SDK, so if you have not already cloned the `pico-sdk` repository do so now.

```
$ git clone -b pre_release git@github.com:raspberrypi/pico-sdk.git
$ cd pico-sdk
$ git submodule update --init --recursive
```

You will also need to install `libusb` if it is not already installed,

```
$ sudo apt-get install libusb-1.0
```

NOTE

If you are building `picotool` on macOS you can install `libusb` using Homebrew,

```
$ brew install libusb
```

B.2. Building picotool

Building `picotool` can be done as follows,

```
$ mkdir build
$ cd build
$ cmake -DPICO_BUILD_PICOTOOL=1 ..
$ make PicotoolBuild
```

this will generate a `picotool` command-line binary in `build/picotool` directory.

B.3. Using picotool

The `picotool` binary includes command line help function,

```
$ picotool help
PICOTOOL:
    Tool for interacting with a RP2040 device in BOOTSEL mode, or with a RP2040 binary

SYNOPSYS:
    picotool info [-b] [-p] [-d] [-l] [-a] [--bus <bus>] [--address <addr>]
```

```
    picotool info [-b] [-p] [-d] [-l] [-a] <filename> [-t <type>]
    picotool load [-v] [-r] <filename> [-t <type>] [--bus <bus>] [--address <addr>]
    picotool save [-p] [--bus <bus>] [--address <addr>] <filename> [-t <type>]
    picotool save -a [--bus <bus>] [--address <addr>] <filename> [-t <type>]
    picotool save -r <from> <to> [--bus <bus>] [--address <addr>] <filename> [-t <type>]
    picotool verify [--bus <bus>] [--address <addr>] <filename> [-t <type>] [-r <from> <to>]
    picotool reboot [-a] [-u] [--bus <bus>] [--address <addr>]
    picotool help [<cmd>]

COMMANDS:
    info     Display information from the target device(s) or file.
             Without any arguments, this will display basic information for all connected
RP2040 devices in
             BOOTSEL mode
    load     Load the program / memory range stored in a file onto the device.
    save     Save the program / memory stored in flash on the device to a file.
    verify   Check that the device contents match those in the file.
    reboot   Reboot the device
    help     Show general help or help for a specific command

Use "picotool help <cmd>" for more info
```

NOTE

The majority of commands require an RP2040 device in BOOTSEL mode to be connected.

B.3.1. Display information

So there is now *Binary Information* support in the SDK which allows for easily storing compact information that `picotool` can find (See Section B.4 below). The `info` command is for reading this information.

The information can be either read from one or more connected RP2040 devices in BOOTSEL mode, or from a file. This file can be an ELF, a UF2 or a BIN file.

```
$ picotool help info
INFO:
    Display information from the target device(s) or file.
    Without any arguments, this will display basic information for all connected RP2040 devices
in USB boot
    mode

SYNOPSYS:
    picotool info [-b] [-p] [-d] [-l] [-a] [--bus <bus>] [--address <addr>]
    picotool info [-b] [-p] [-d] [-l] [-a] <filename> [-t <type>]

OPTIONS:
    Information to display
        -b, --basic
            Include basic information. This is the default
        -p, --pins
            Include pin information
        -d, --device
            Include device information
        -l, --build
            Include build attributes
        -a, --all
            Include all information
```

```
TARGET SELECTION:
    To target one or more connected RP2040 device(s) in BOOTSEL mode (the default)
        --bus <bus>
            Filter devices by USB bus number
        --address <addr>
            Filter devices by USB device address
    To target a file
        <filename>
            The file name
        -t <type>
            Specify file type (uf2 | elf | bin) explicitly, ignoring file extension
```

For example connect your Raspberry Pi Pico to your computer us mass storage mode, by pressing and holding the BOOTSEL button before plugging it into the USB. Then open up a Terminal window and type,

```
$ picotool info
Program Information
 name:      hello_world
 features:  stdout to UART
```

or,

```
$ picotool info -a
Program Information
 name:          hello_world
 features:      stdout to UART
 binary start:  0x10000000
 binary end:    0x1000606c

Fixed Pin Information
 20:  UART1 TX
 21:  UART1 RX

Build Information
 build date:        Dec 31 2020
 build attributes:  Debug build

Device Information
 flash size:   2048K
 ROM version:  2
```

for more information. Alternatively you can jut get information on the pins used as follows,

```
$ picotool info -bp
Program Information
 name:      hello_world
 features:  stdout to UART

Fixed Pin Information
 20:  UART1 TX
 21:  UART1 RX
```

The tool can also be used on binaries still on your local filesystem,

```
$ picotool info -a lcd_1602_i2c.uf2
File lcd_1602_i2c.uf2:

Program Information
 name:          lcd_1602_i2c
 web site:      https://github.com/raspberrypi/pico-examples/tree/HEAD/i2c/lcd_1602_i2c
 binary start:  0x10000000
 binary end:    0x10003c1c

Fixed Pin Information
 4:  I2C0 SDA
 5:  I2C0 SCL

Build Information
 build date:  Dec 31 2020
```

B.3.2. Save the program

Save allows you to save a range of memory or a program or the whole of flash from the device to a BIN file or a UF2 file.

```
$ picotool help save
SAVE:
    Save the program / memory stored in flash on the device to a file.

SYNOPSYS:
    picotool save [-p] [--bus <bus>] [--address <addr>] <filename> [-t <type>]
    picotool save -a [--bus <bus>] [--address <addr>] <filename> [-t <type>]
    picotool save -r <from> <to> [--bus <bus>] [--address <addr>] <filename> [-t <type>]

OPTIONS:
    Selection of data to save
        -p, --program
            Save the installed program only. This is the default
        -a, --all
            Save all of flash memory
        -r, --range
            Save a range of memory; note that the range is expanded to 256 byte boundaries
        <from>
            The lower address bound in hex
        <to>
            The upper address bound in hex
    Source device selection
        --bus <bus>
            Filter devices by USB bus number
        --address <addr>
            Filter devices by USB device address
    File to save to
        <filename>
            The file name
        -t <type>
            Specify file type (uf2 | elf | bin) explicitly, ignoring file extension
```

For example,

```
$ picotool info
Program Information
name:      lcd_1602_i2c
web site:  https://github.com/raspberrypi/pico-examples/tree/HEAD/i2c/lcd_1602_i2c
$ picotool save spoon.uf2
Saving file: [==============================]  100%
Wrote 51200 bytes to spoon.uf2
$ picotool info spoon.uf2
File spoon.uf2:
Program Information
name:      lcd_1602_i2c
web site:  https://github.com/raspberrypi/pico-examples/tree/HEAD/i2c/lcd_1602_i2c
```

B.4. Binary Information

Binary information is machine locatable and generally machine consumable. I say generally because anyone can include any information, and we can tell it from ours, but it is up to them whether they make their data self describing.

B.4.1. Basic information

This information is really handy when you pick up a Pico and don't know what is on it!

Basic information includes

- program name
- program description
- program version string
- program build date
- program url
- program end address
- program features, this is a list built from individual strings in the binary, that can be displayed (e.g. we will have one for UART stdio and one for USB stdio) in the SDK
- build attributes, this is a similar list of strings, for things pertaining to the binary itself (e.g. Debug Build)

B.4.2. Pins

This is certainly handy when you have an execute called `hello_world.elf` but you forgot what RP2040-based board it was built for as different boards may have different pins broken out.

Static (fixed) pin assignments can be recorded in the binary in very compact form:

```
$ picotool info --pins sprite_demo.elf
File sprite_demo.elf:

Fixed Pin Information
0-4:    Red 0-4
6-10:   Green 0-4
11-15:  Blue 0-4
16:     HSync
17:     VSync
18:     Display Enable
```

```
19:     Pixel Clock
20:     UART1 TX
21:     UART1 RX
```

B.4.3. Including Binary information

Binary information is declared in the program by macros; for the previous example:

```
$ picotool info --pins sprite_demo.elf
File sprite_demo.elf:

Fixed Pin Information
0-4:    Red 0-4
6-10:   Green 0-4
11-15:  Blue 0-4
16:     HSync
17:     VSync
18:     Display Enable
19:     Pixel Clock
20:     UART1 TX
21:     UART1 RX
```

There is one line in the `setup_default_uart` function:

```
bi_decl_if_func_used(bi_2pins_with_func(PICO_DEFAULT_UART_RX_PIN, PICO_DEFAULT_UART_TX_PIN,
GPIO_FUNC_UART));
```

The two pin numbers, and the function UART are stored, then decoded to their actual function names (UART1 TX etc) by picotool. The `bi_decl_if_func_used` makes sure the binary information is only included if the containing function is called.

Equally, the video code contains a few lines like this:

```
bi_decl_if_func_used(bi_pin_mask_with_name(0x1f << (PICO_SCANVIDEO_COLOR_PIN_BASE +
PICO_SCANVIDEO_DPI_PIXEL_RSHIFT), "Red 0-4"));
```

B.4.4. Details

Things are designed to waste as little space as possible, but you can turn everything of with preprocessor var `PICO_NO_BINARY_INFO=1`. Additionally any SDK code that inserts binary info cane be separately excluded by its own preprocesor var.

You need,

```
#include "pico/binary_info.h"
```

There are a bunch of `bi_` macros in the headers

```
#define bi_binary_end(end)
#define bi_program_name(name)
#define bi_program_description(description)
#define bi_program_version_string(version_string)
#define bi_program_build_date_string(date_string)
#define bi_program_url(url)
#define bi_program_feature(feature)
#define bi_program_build_attribute(attr)
#define bi_1pin_with_func(p0, func)
#define bi_2pins_with_func(p0, p1, func)
#define bi_3pins_with_func(p0, p1, p2, func)
#define bi_4pins_with_func(p0, p1, p2, p3, func)
#define bi_5pins_with_func(p0, p1, p2, p3, p4, func)
#define bi_pin_range_with_func(plo, phi, func)
#define bi_pin_mask_with_name(pmask, label)
#define bi_pin_mask_with_names(pmask, label)
#define bi_1pin_with_name(p0, name)
#define bi_2pins_with_names(p0, name0, p1, name1)
#define bi_3pins_with_names(p0, name0, p1, name1, p2, name2)
#define bi_4pins_with_names(p0, name0, p1, name1, p2, name2, p3, name3)
```

which make use of underlying macros, e.g.

```
#define bi_program_url(url) bi_string(BINARY_INFO_TAG_RASPBERRY_PI, BINARY_INFO_ID_RP_PROGRAM_URL,
url)
```

You then either use `bi_decl(bi_blah(…))` for unconditional inclusion of the binary info blah, or `bi_decl_if_func_used(bi_blah(…))` for binary information that may be stripped if the enclosing function is not included in the binary by the linker (think `--gc-sections`).

For example,

```
#include <stdio.h>
#include "pico/stdlib.h"
#include "hardware/gpio.h"
#include "pico/binary_info.h"

const uint LED_PIN = 25;

int main() {

    bi_decl(bi_program_description("This is a test binary."));
    bi_decl(bi_1pin_with_name(LED_PIN, "On-board LED"));

    setup_default_uart();
    gpio_set_function(LED_PIN, GPIO_FUNC_PROC);
    gpio_set_dir(LED_PIN, GPIO_OUT);
    while (1) {
        gpio_put(LED_PIN, 0);
        sleep_ms(250);
        gpio_put(LED_PIN, 1);
        puts("Hello World\n");
        sleep_ms(1000);
    }
}
```

when queried with `picotool`,

```
$ picotool info -a test.uf2
File test.uf2:

Program Information
 name:          test
 description:   This is a test binary.
 features:      stdout to UART
 binary start:  0x10000000
 binary end:    0x100031f8

Fixed Pin Information
 0:   UART0 TX
 1:   UART0 RX
 25:  On-board LED

Build Information
 build date:  Jan  4 2021
```

shows our information strings in the output.

B.4.5. Setting common fields from CMake

You can also set fields directly from your project's CMake file, e.g.,

```
pico_set_program_name(foo "not foo") ①
pico_set_program_description(foo "this is a foo")
pico_set_prorgam_version_string(foo "0.00001a")
pico_set_program_url(foo "www.plinth.com/foo")
```

1. The name "foo" would be the default.

NOTE

All of these are passed as command line arguments to the compilation, so if you plan to use quotes, newlines etc you may have better luck defining it using `bi_decl` in the code.

Raspberry Pi

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