Arm Virtual Hardware Examples

Version 1.0

Knowledge Base Article

Non-Confidential

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Arm Virtual Hardware Examples

Knowledge Base Article

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1. Capture Input from the Console

Learn how to capture character and newline console input.

1.1 Retrieving Character Input from the User

It is possible to capture character input from the console using the scanf C library function.

For example, capture a character input using

```
scanf("%c", &input_char);
```

1.2 Detecting When the User Presses Return

Our UI console sends a new line (`\n`) when you hit return but doesn't send a carriage return (`\r`). When detecting a new line in code, use `\n` rather than `\r`.

For example the following will run, whereas using `\r` will hang:

```
while ( getchar() != '\n');
```

1.3 Modify How the Terminal Handles "newline"

Alternatively, you can adjust the terminal settings to not map CR to NL using the command `stty -icrnl`.

You can then send a `\r` by pressing Ctrl+M or `\n` by pressing Ctrl+J.

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2. iMX8m Arm Cortex Complex Examples

iMX8m Arm Cortex Complex examples:

- Blink the Led on the iMX8m Arm Cortex Complex device

2.1 Blink the Led on the iMX8m Arm Cortex Complex device

This tutorial will demonstrate how to blink the LED in the iMX8m Arm Cortex Complex device. It follows from the Quickstart for iMX8m Arm Cortex Complex tutorial.

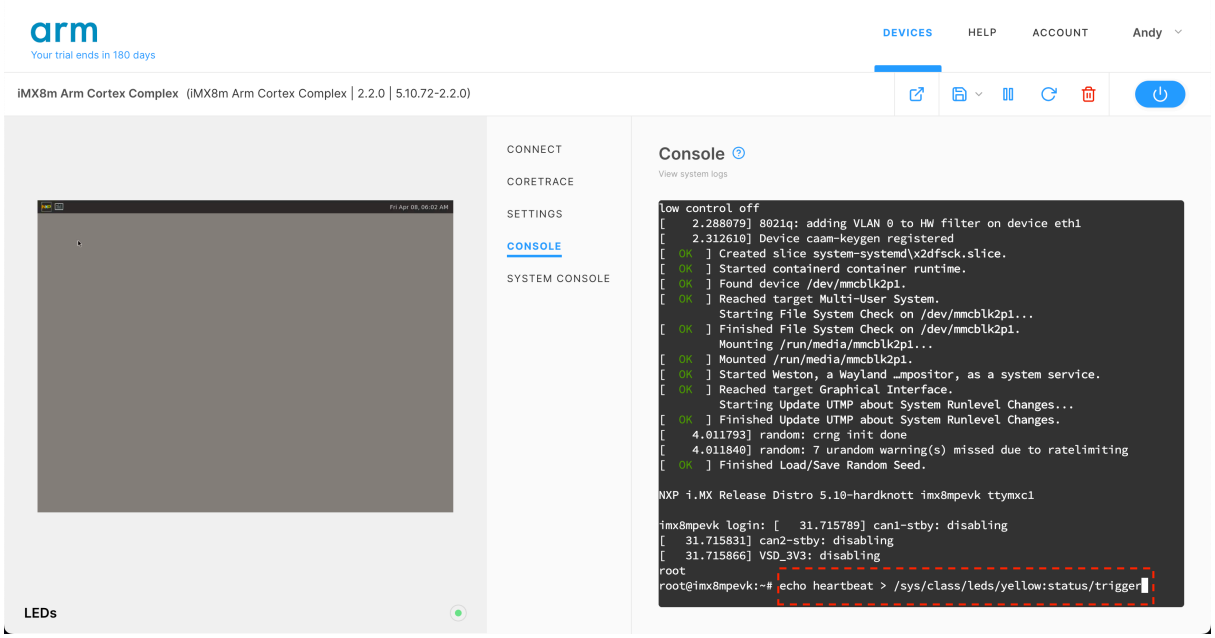
2.1.1 Blink the LED

To blink the LED, do the following:

1. Following on from the tutorial OR go to a iMX8m Arm Cortex Complex device that has the console logged in.
2. To blink the LED type `echo heartbeat > /sys/class/leds/yellow:status/trigger` into the console.

   The LED representation is at the bottom of the desktop. In the current state it is on and solid.

   Figure 2-1: LED on and solid



3. The LED will now be blinking.

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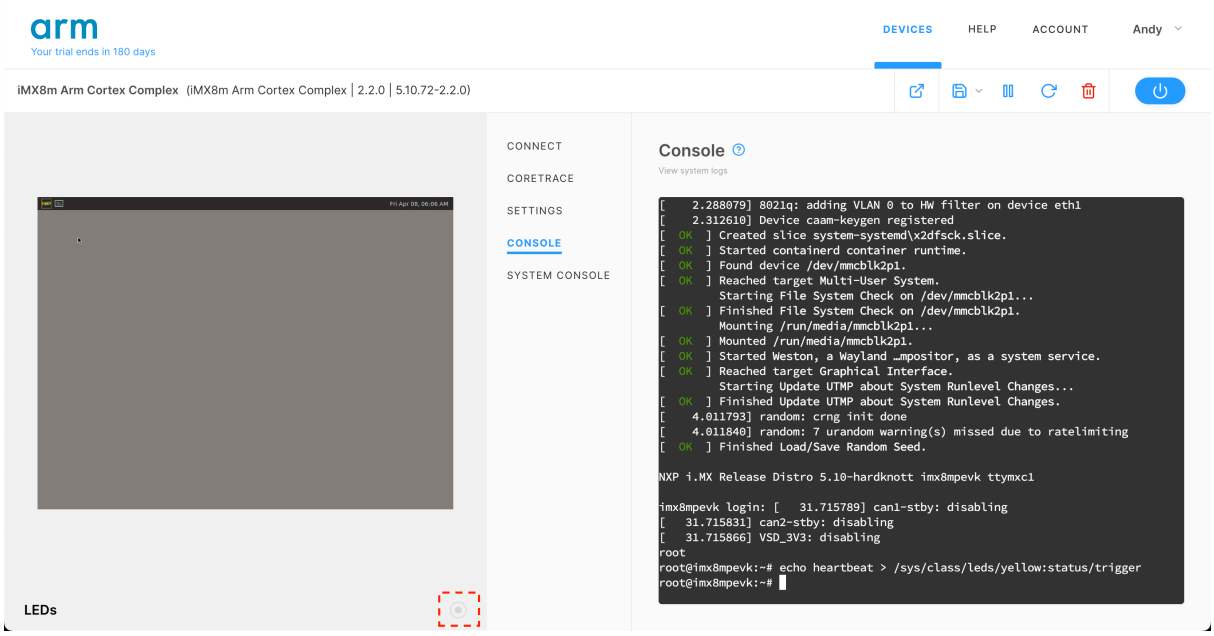
Figure 2-2: LED blinking



Find out more

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3. STM32U5 IoT Discovery Kit Examples

STM32U5 IoT Discovery Kit examples:

- STM32CubeU5 TFM example
- STM32CubeU5 WiFiBasics example

3.1 STM32CubeU5 TFM example

STM32U5 Trusted Firmware M tests firmware package example.

For this example the kernel component in the firmware package is itself a ZIP archive, containing various binaries and `load.txt` file describing their location in memory:

```
name:tfm_s_init.bin load:0xc024000
name:tfm_ns_init.bin load:0xc052000
name:loader.bin load:0xc1fa000
name:TFM_SBSFU_Boot.bin load:0xc002000
```

3.1.1 Creating your device

To create your device:

1. Log in to AVH with your Arm user account. If you do not have or need to create an Arm account, register at https://developer.arm.com/.
2. When logged in you land on the AVH Devices page. Click CREATE DEVICE.

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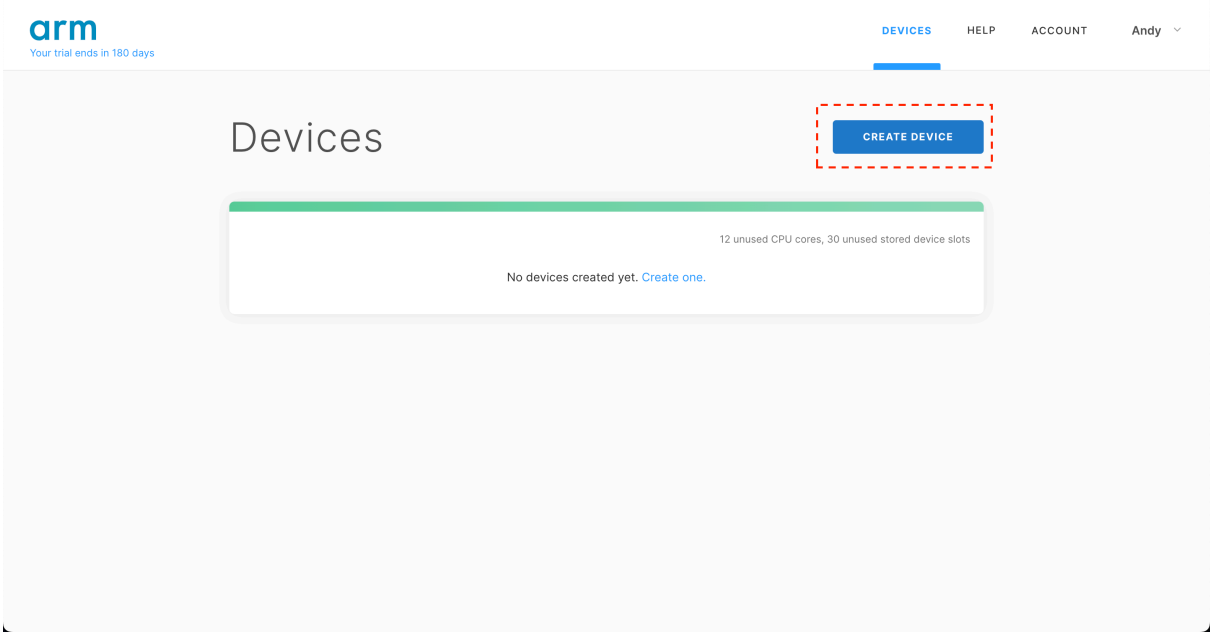
Figure 3-1: Click Create Device



3. Click on the STM32U5 IoT Discovery Kit to select it. Then click NEXT.

Note

You require 1 free CPU core to build this device or it will be disabled.

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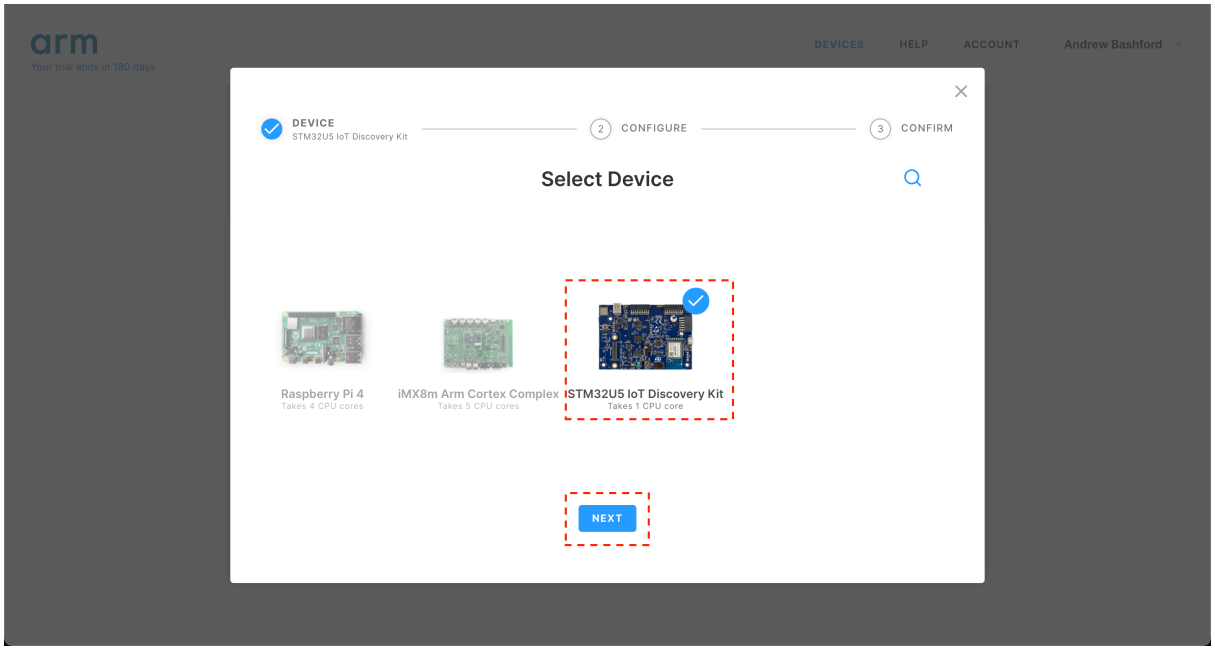
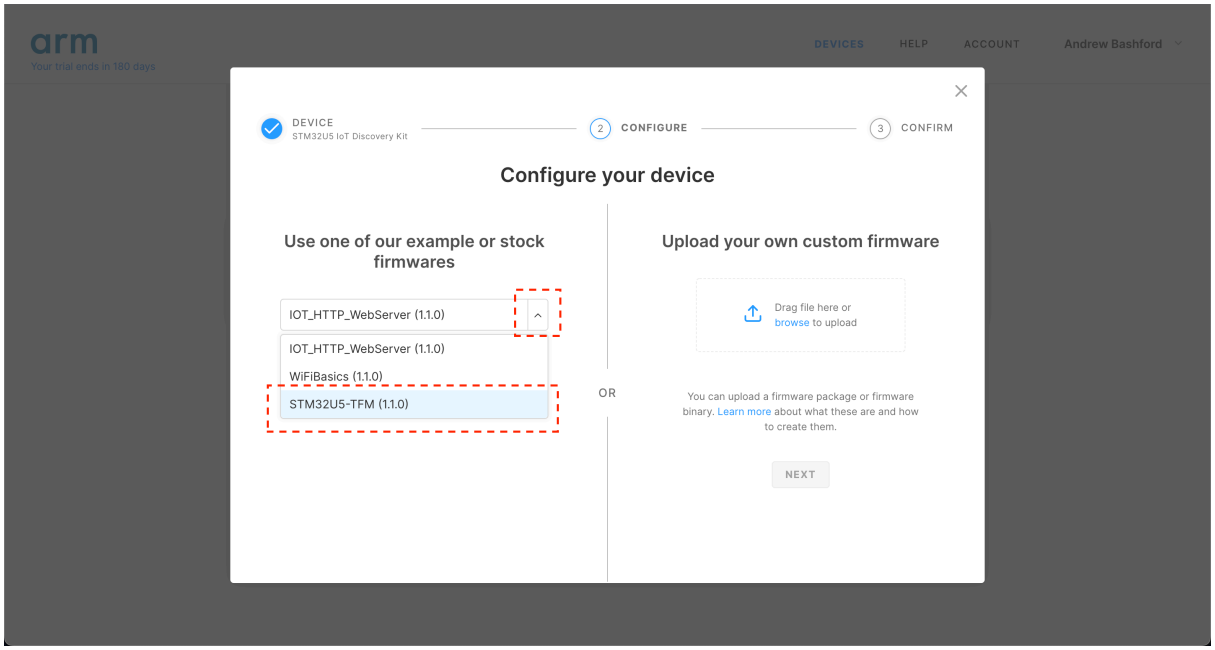
Figure 3-2: Select device



4. In this next step, you'll see a list of pre-configured examples/stock firmware or you can upload your own custom firmware. In this example, we will use the selection `STM32U5-TFM (1.1.0)` in the stock firmware section.

Figure 3-3: Configure your device



5. Click SELECT.

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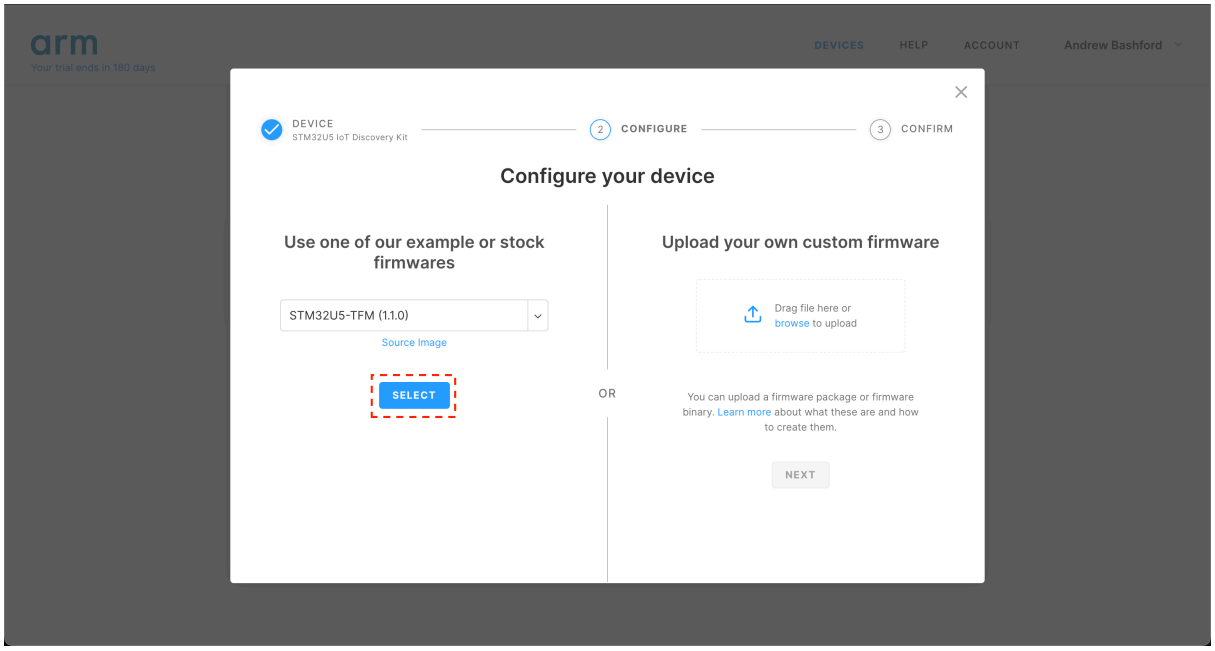
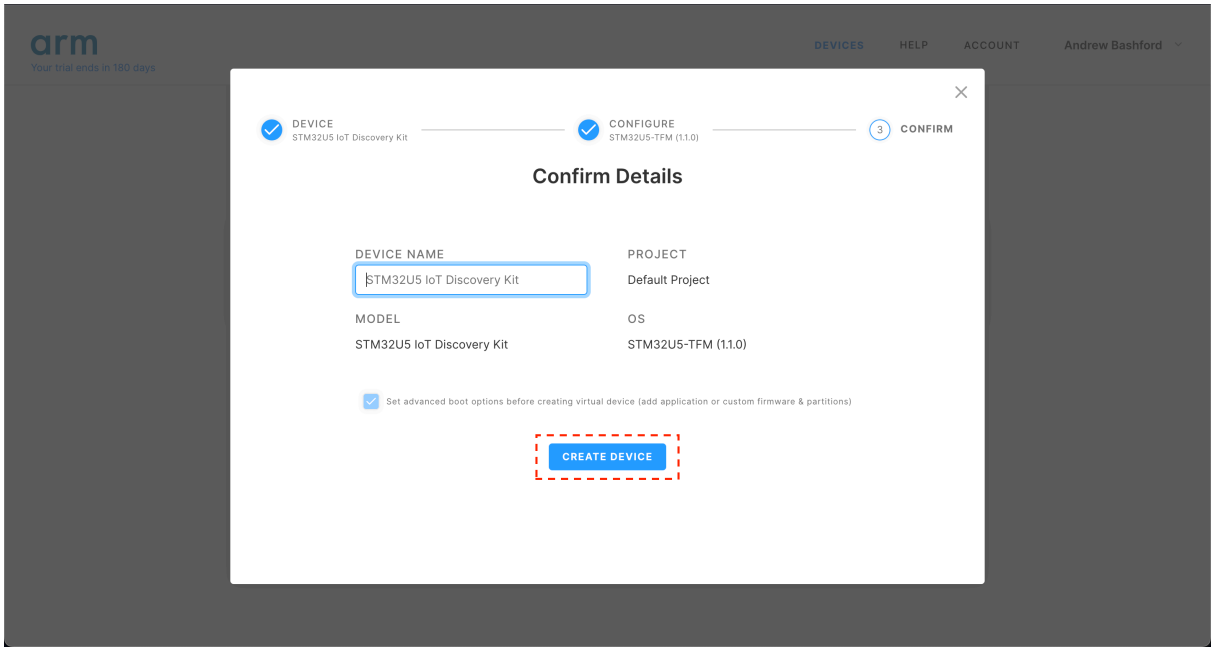
Figure 3-4: Click Select



6. In the confirmation screen, click CREATE DEVICE using the default name and the advance boot options will be checked by default.

Figure 3-5: Confirm details



7. In the advanced boot options, we will just use the default. Click CREATE DEVICE.

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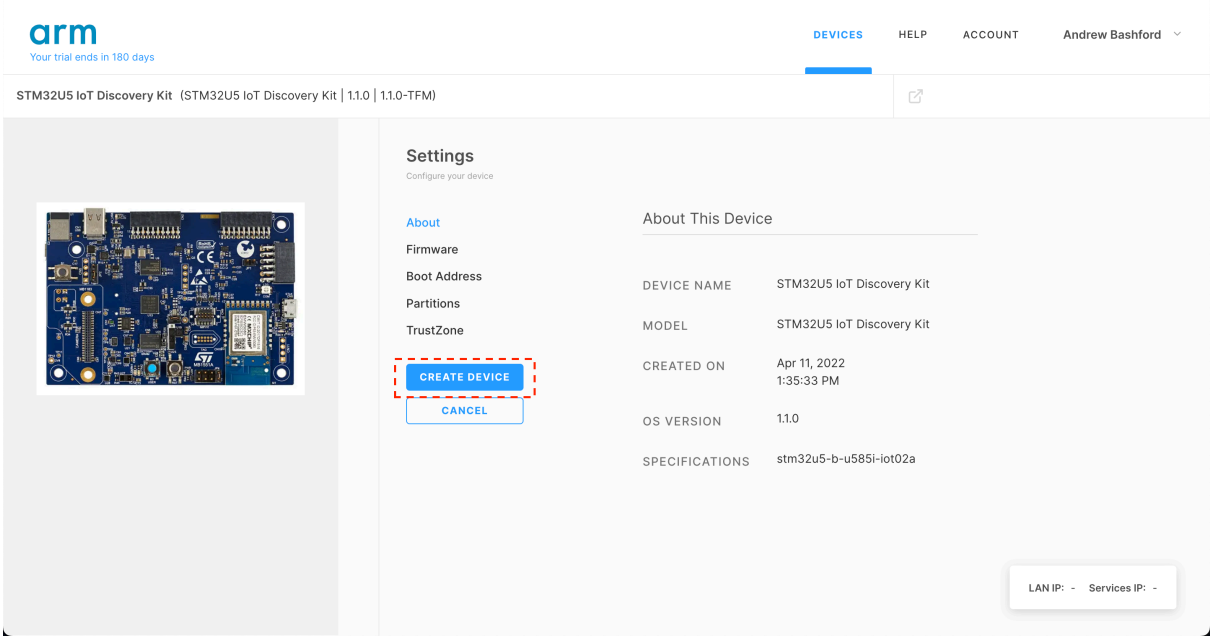
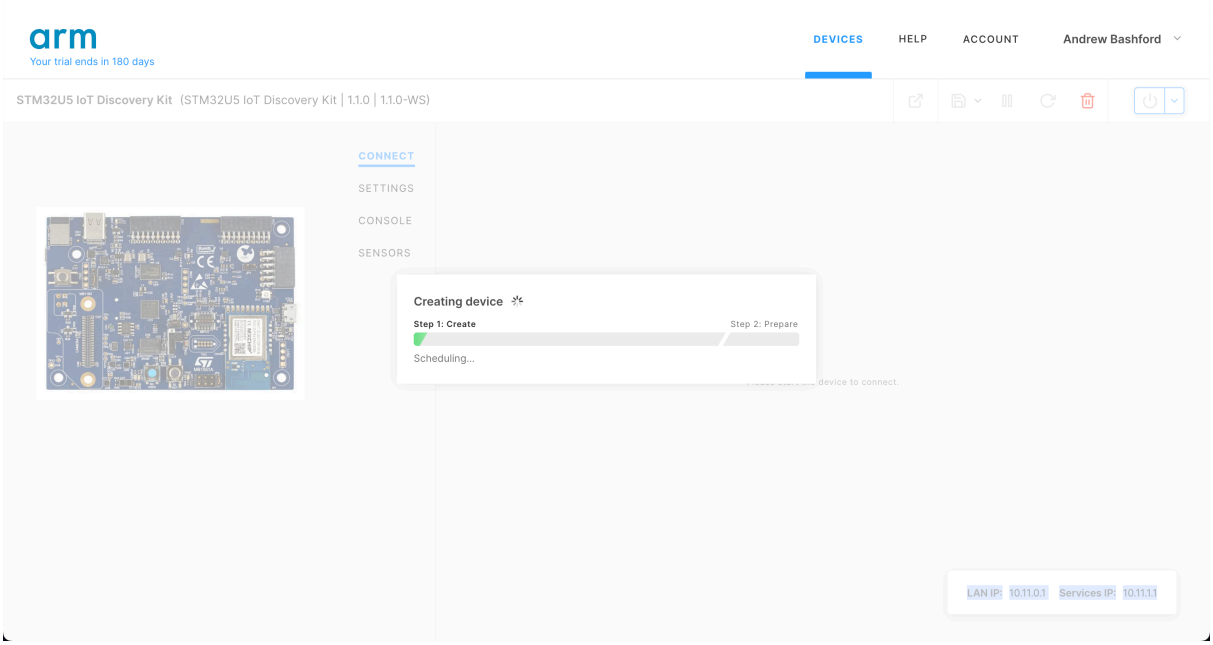
Figure 3-6: Settings



8. The device will then be created. It takes a few moments…

Figure 3-7: Creating device



9. Your STM32U5 IoT Discovery Kit is now ready to go!

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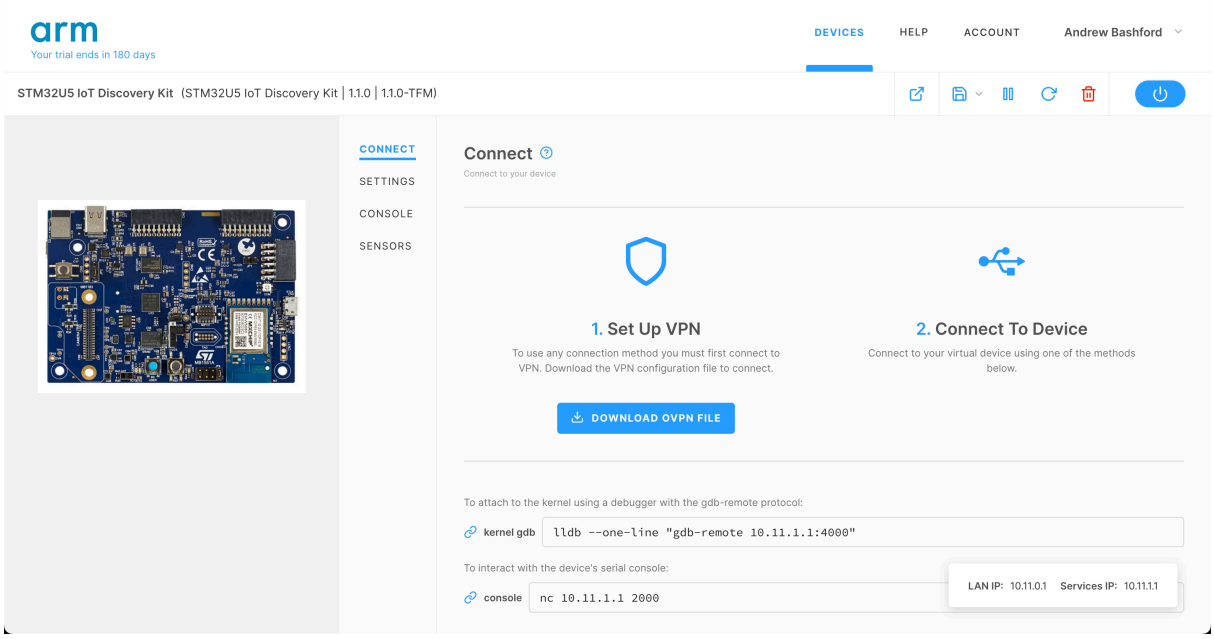
Figure 3-8: Connect



3.1.2 Running the example

To run the example:

1. Click on CONSOLE.

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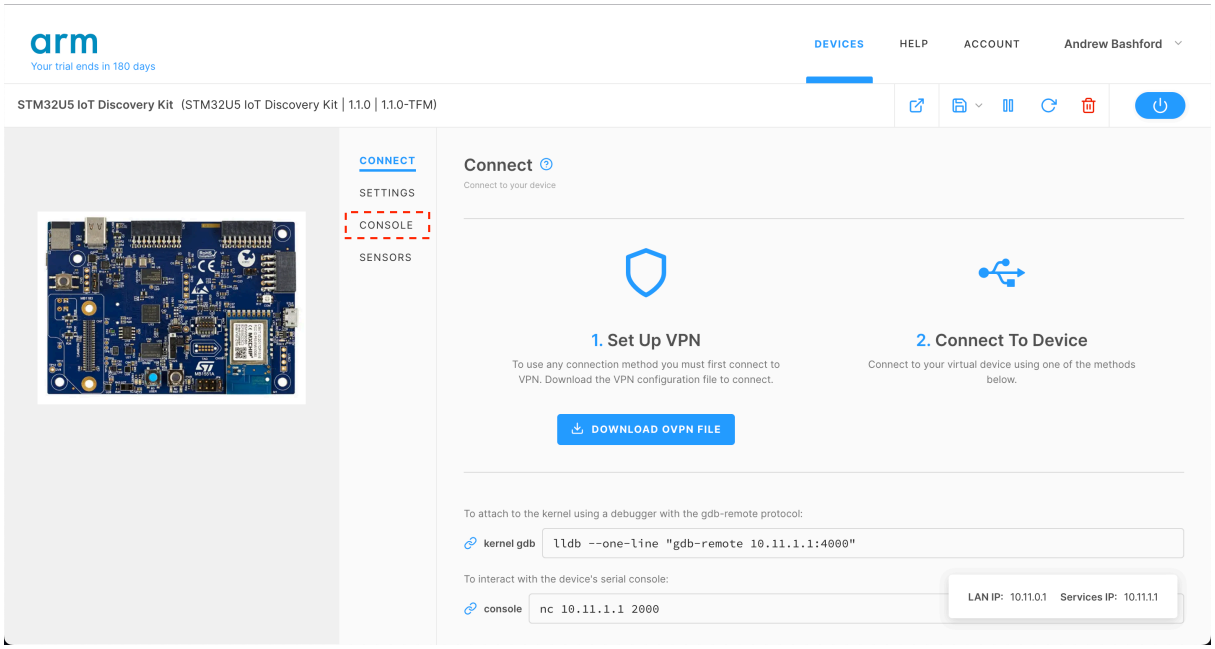
Figure 3-9: Click Console



2. There is a console menu to run various tests using Trusted Firmware. For example type 2 (Test TFM) followed by return.

Note

You may see `Invalid Number !` also menus printed twice this is because the device is interpreting the return keypress as a number. Please ignore this.

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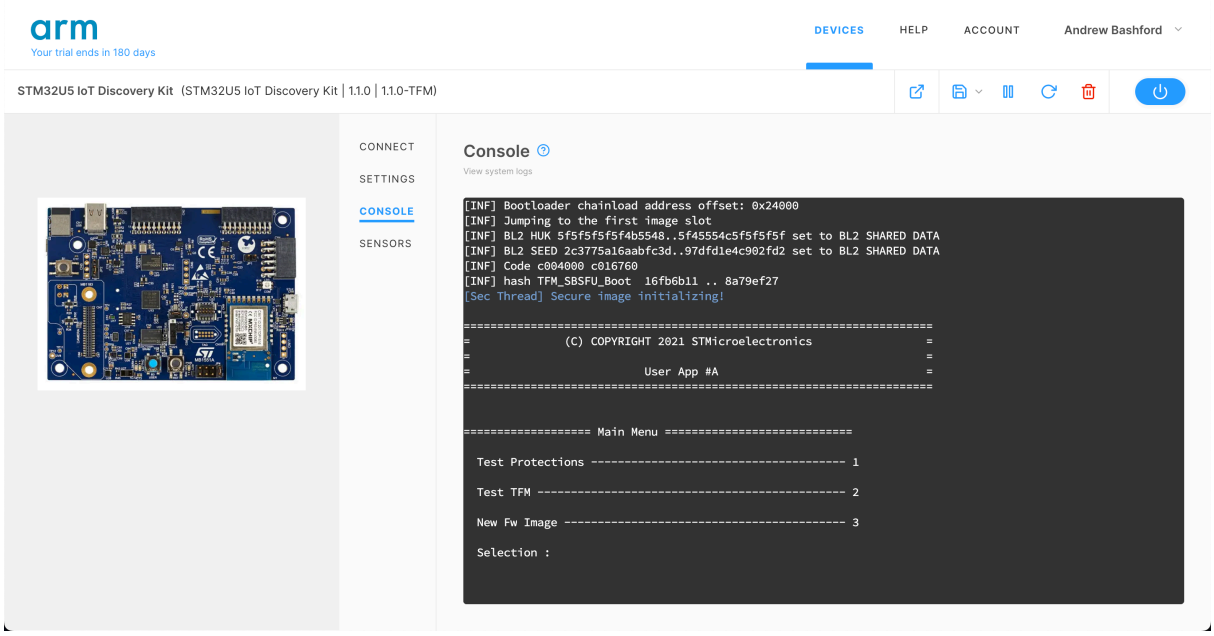
Figure 3-10: Running tests on the console



3. Then type `0` ("TFM - Test All") followed by `return`. to start tests.

Note

You may need to scroll up to see all of the menu.

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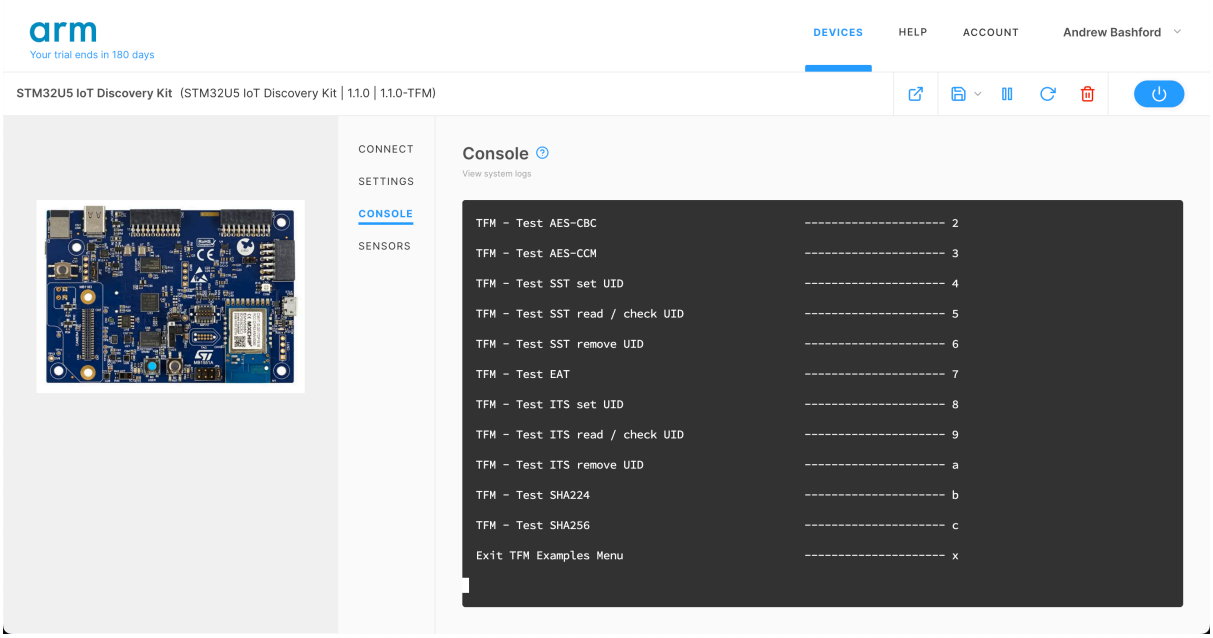
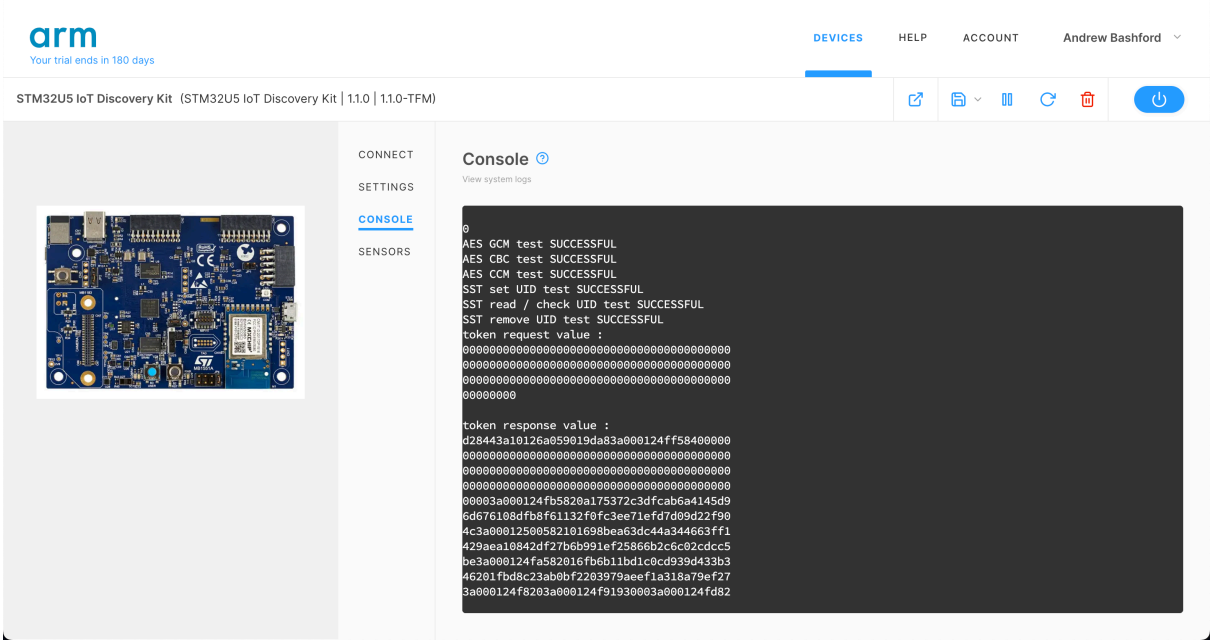
Figure 3-11: TFM - Test All



4. You will be able to observe the result in the Console by scrolling up.

Figure 3-12: Test results



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3.1.3 Next steps

Other STM32U5 IoT Discovery Kit examples;

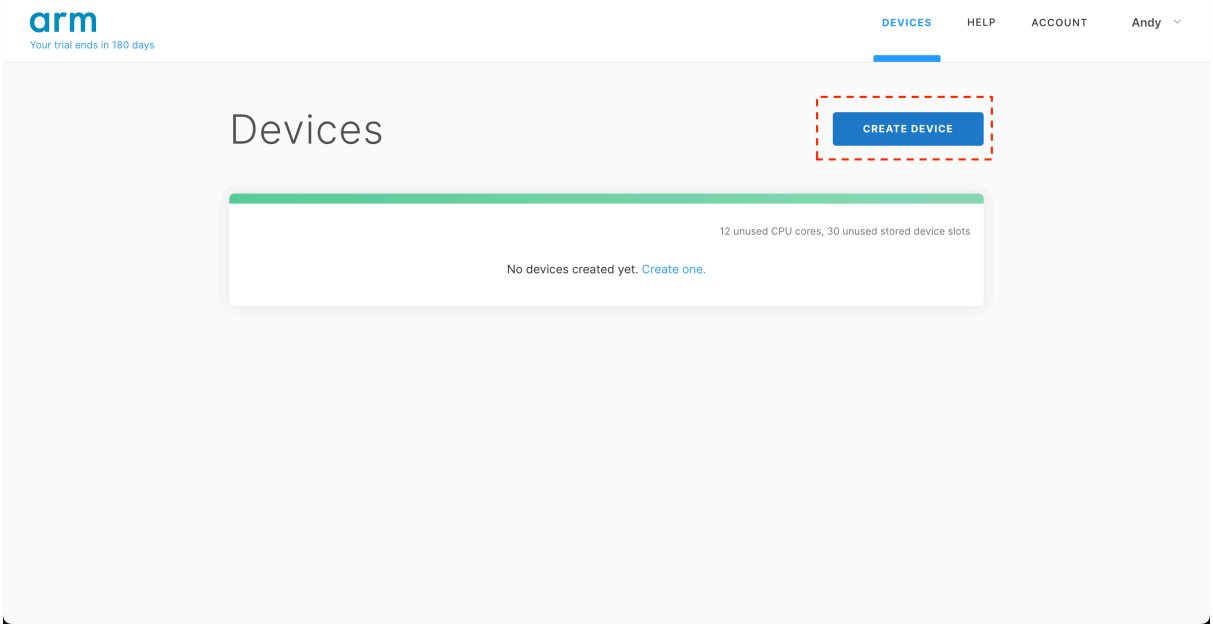
- STM32CubeU5 WiFiBasics example
- STM32CubeU5 IOT_HTTP_WebServer (This is the STM32U5 IoT Discovery Kit Quickstart guide)

3.2 STM32CubeU5 WiFiBasics example

This example will test basic WiFi networking functions:

1. Log in to AVH with your Arm user account. If you do not have or need to create an Arm account, register at https://developer.arm.com/.
2. When logged in you land on the AVH Devices page. Click CREATE DEVICE.

Figure 3-13: Create device



3. Click on the STM32U5 IoT Discovery Kit to select it. Then click NEXT.

Note

You require 1 free CPU core to build this device or it will be disabled.

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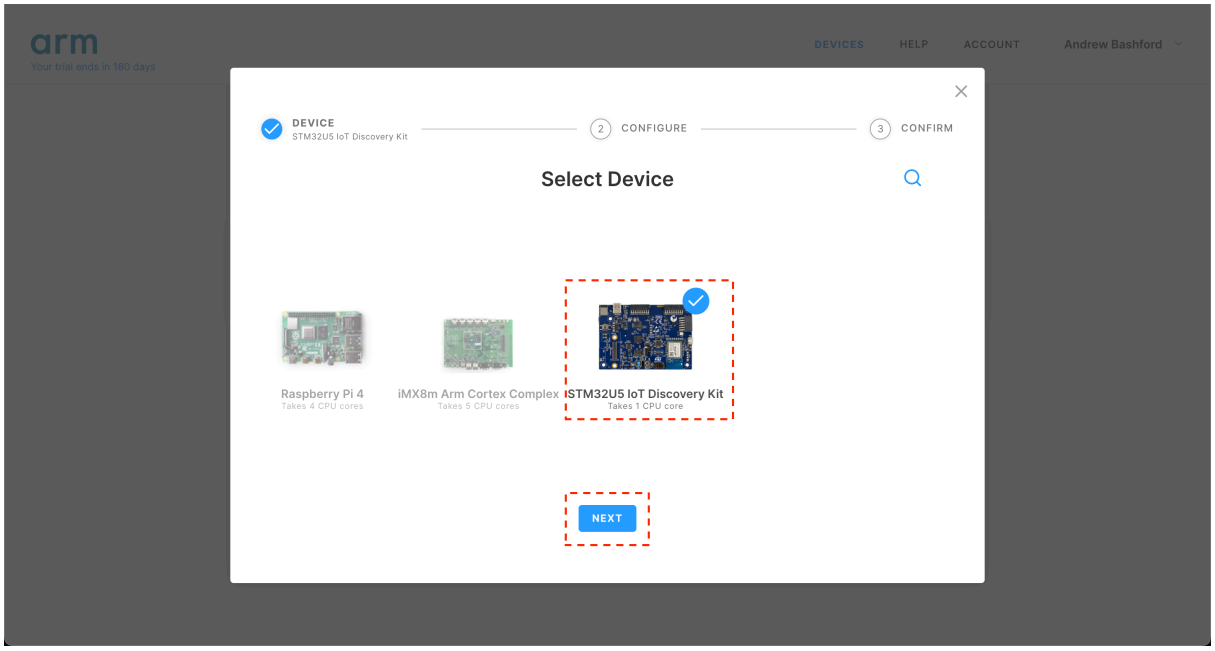
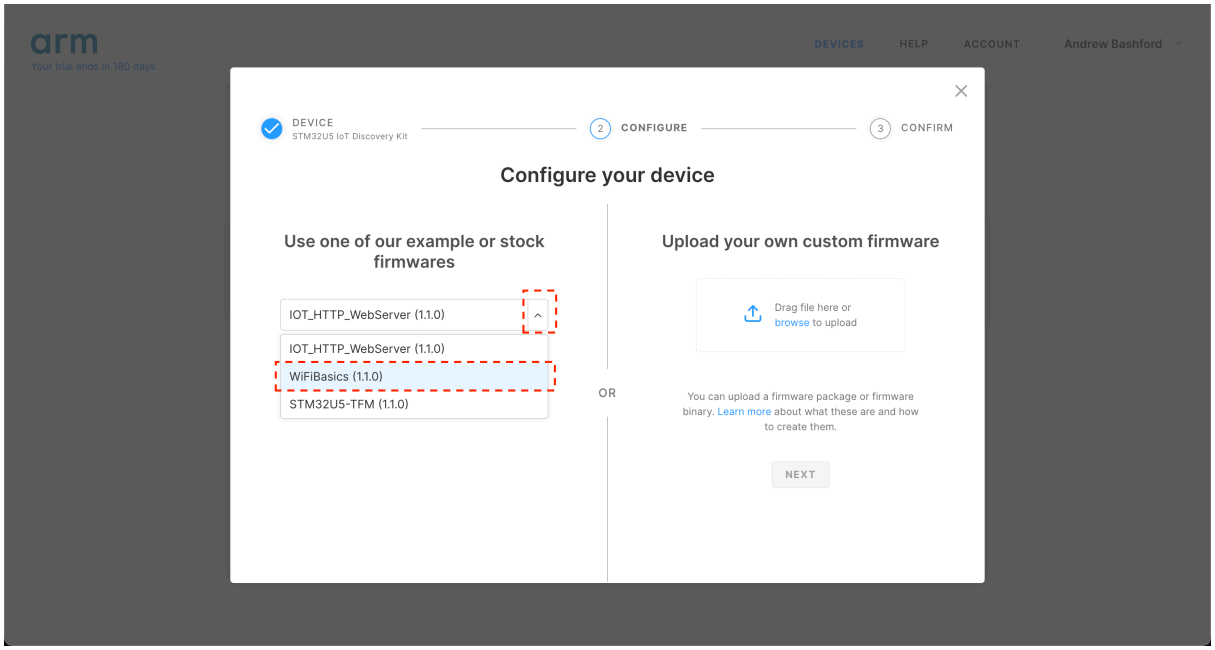
Figure 3-14: Select device



4. In this next step, you will see a list of pre-configured examples/stock firmware or you can upload your own custom firmware. In this example, we will use the selection `WiFiBasics (1.1.0)` in the stock firmware section.

Figure 3-15: Configure your device



5. Click SELECT.

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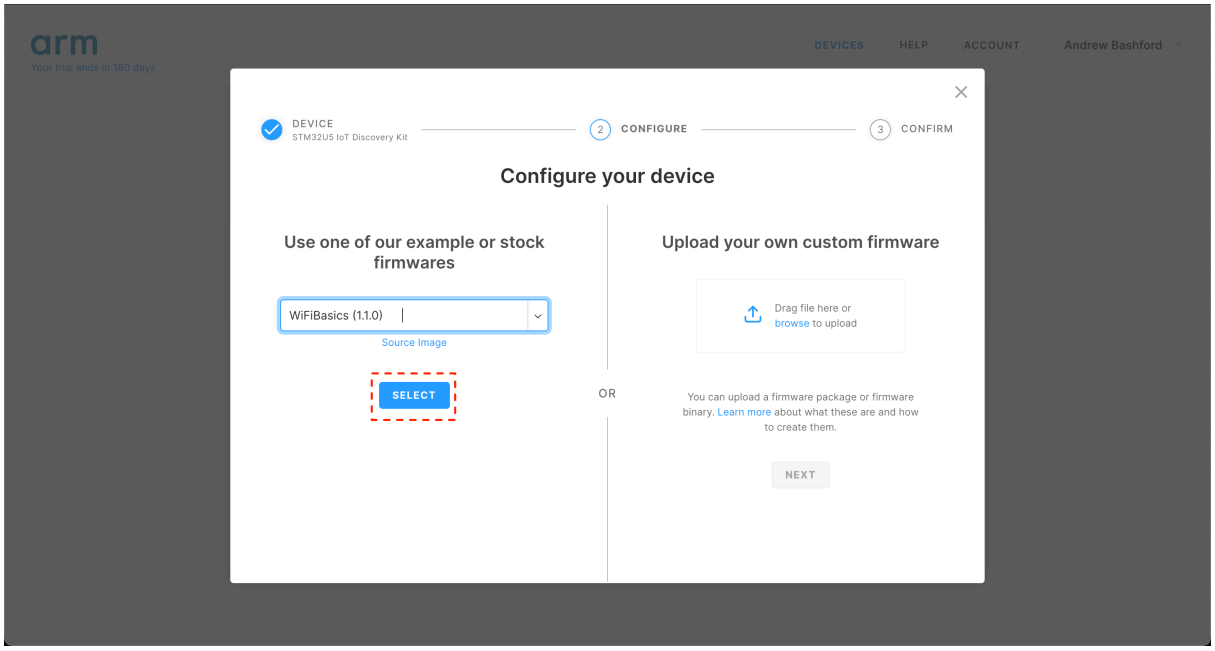
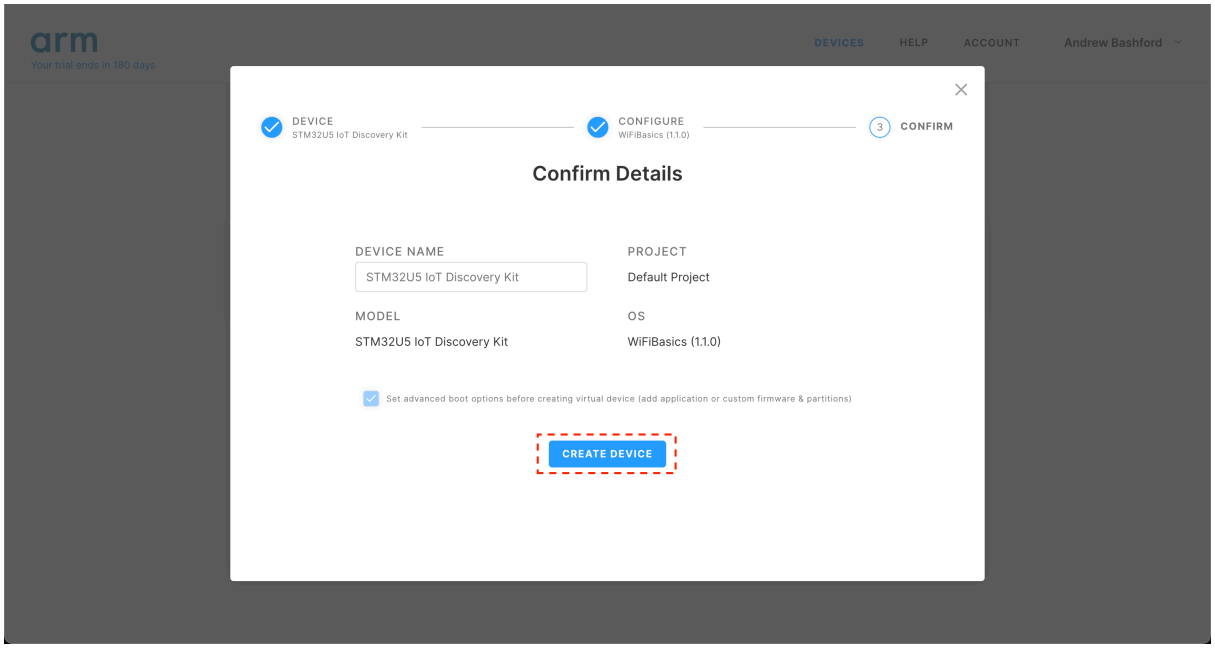
Figure 3-16: Configure your device



6. In the confirmation screen, click CREATE DEVICE using the default name and the advance boot options will be checked by default.

Figure 3-17: Confirm Details



7. In the advanced boot options, we will just use the default. Click CREATE DEVICE.

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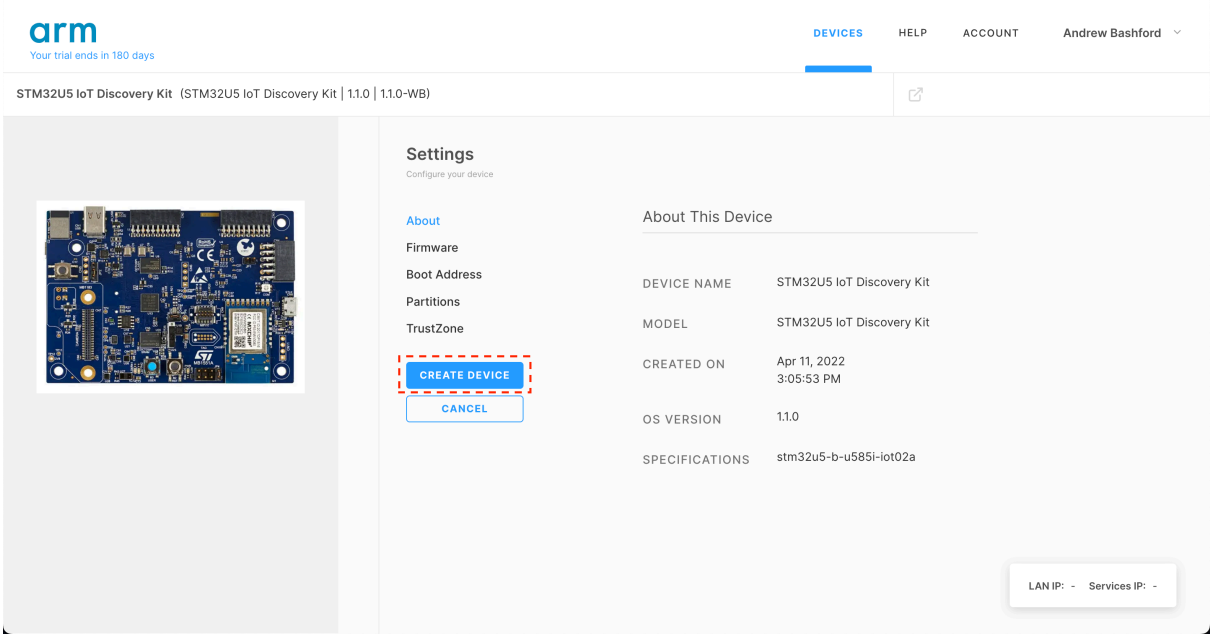
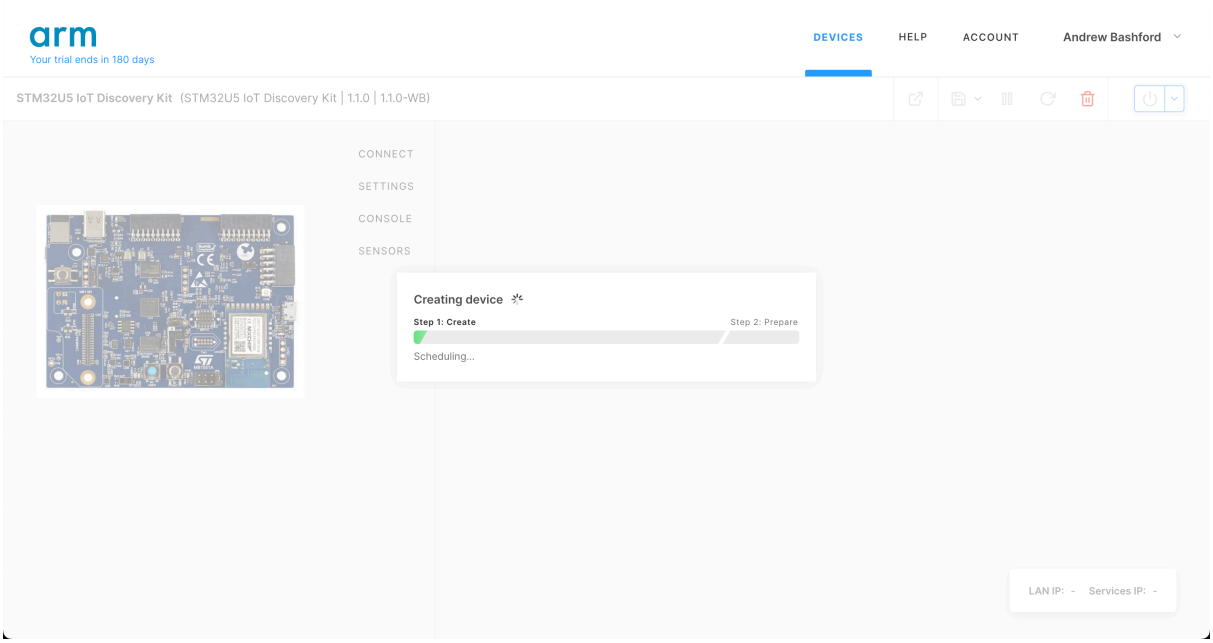
Figure 3-18: Settings



8. The device will then be created. It takes a few moments…

Figure 3-19: Creating device



9. Your STM32U5 IoT Discovery Kit is now ready to go!

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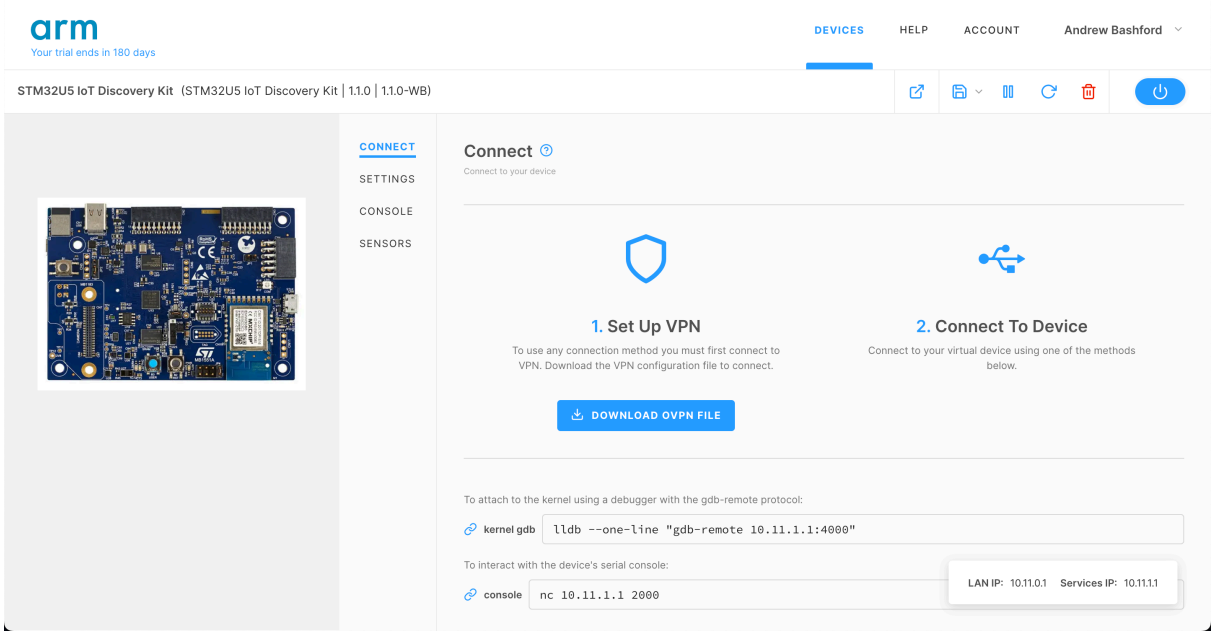
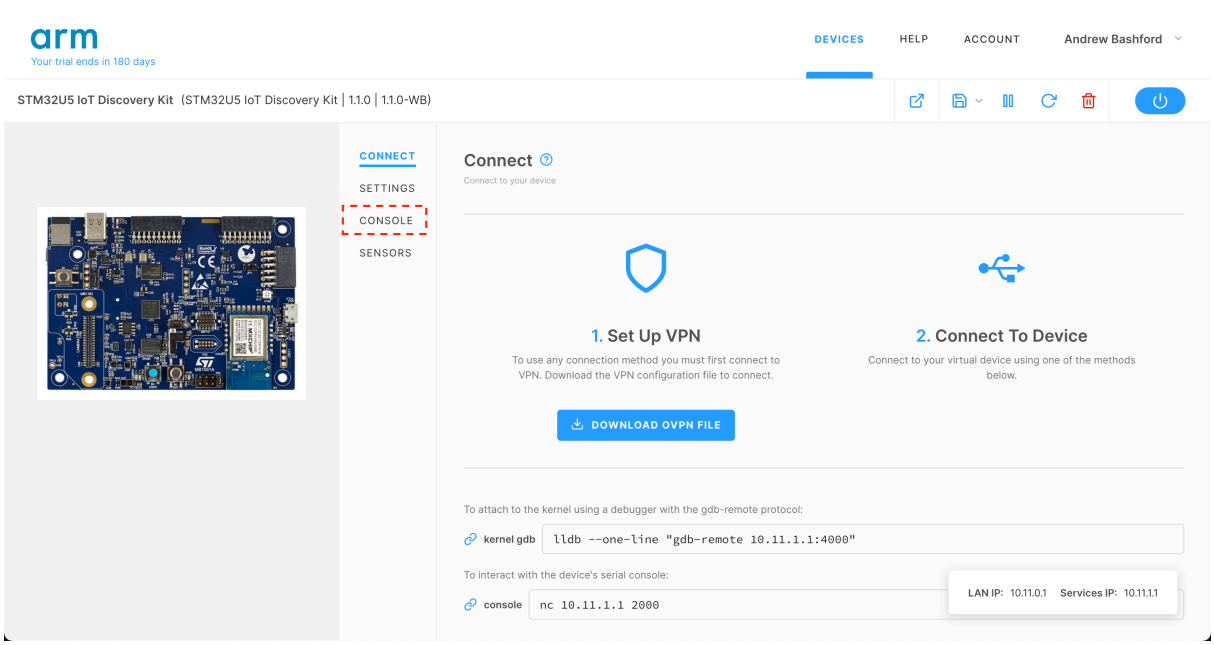
Figure 3-20: Connect



10. Click CONSOLE to go to the Console.

Figure 3-21: Click CONSOLE



11. Model scans for the available WiFi network and connects to the default one ("arm" in this case). There is a console menu to test various functions. For example, `http` command downloads binary from the ST website.

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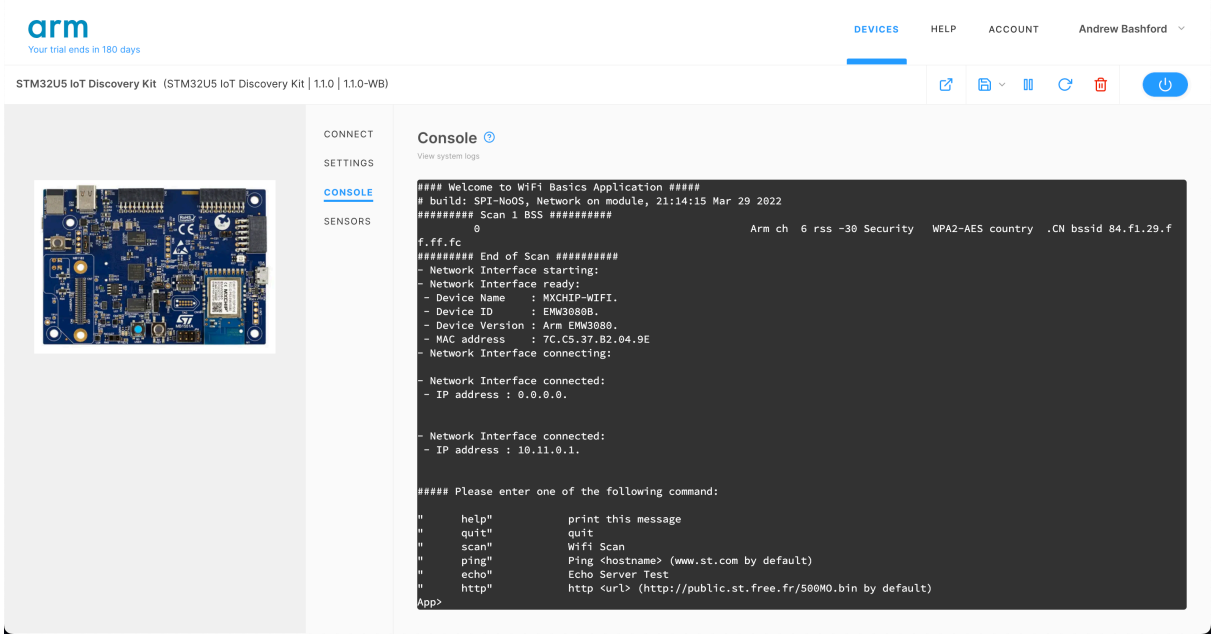
Figure 3-22: Console



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4. Raspberry Pi 4 Example

Raspberry Pi examples:

- Raspberry Pi vMMIO example

4.1 Raspberry Pi vMMIO example

This example will exercise vMMIO using the RaspberryPi model by demonstrating an external (over the network) MMIO handler and a local (RaspberryPi userspace) driver.

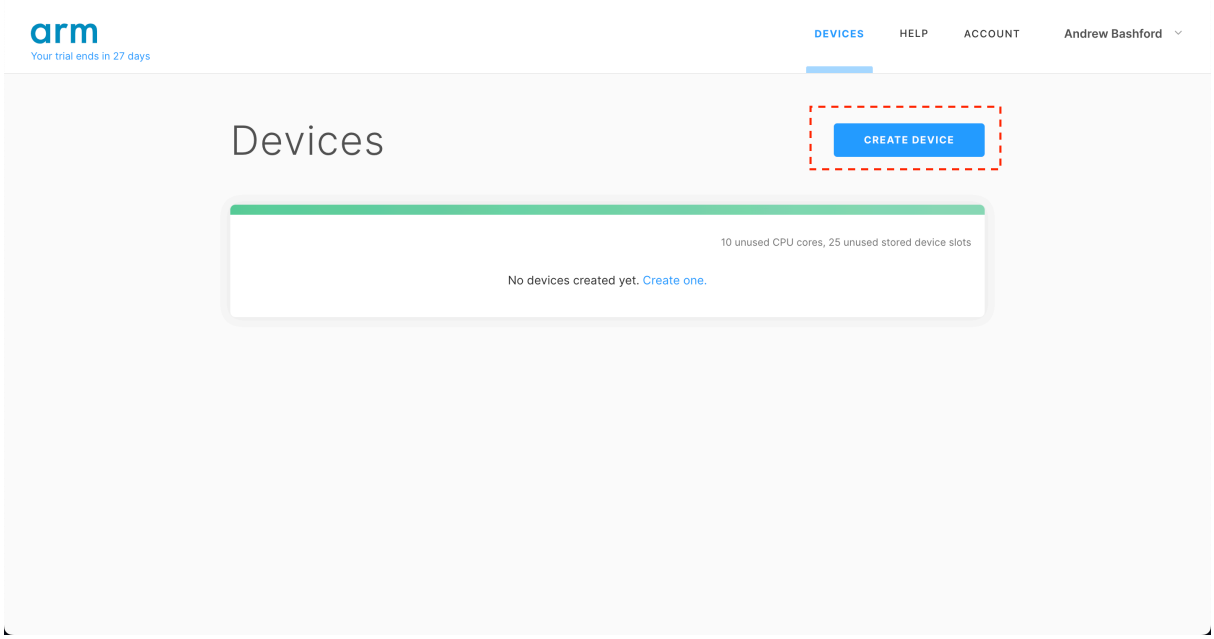
Read more in the AVH vMMIO Introduction article.

4.1.1 Creating the VM

To create the VM:

1. Create a Raspberry Pi 4 Virtual Machine. In DEVICES in the menu click on CREATE DEVICE.

   Figure 4-1: Create device



2. Click on the RPi VM device then click NEXT.

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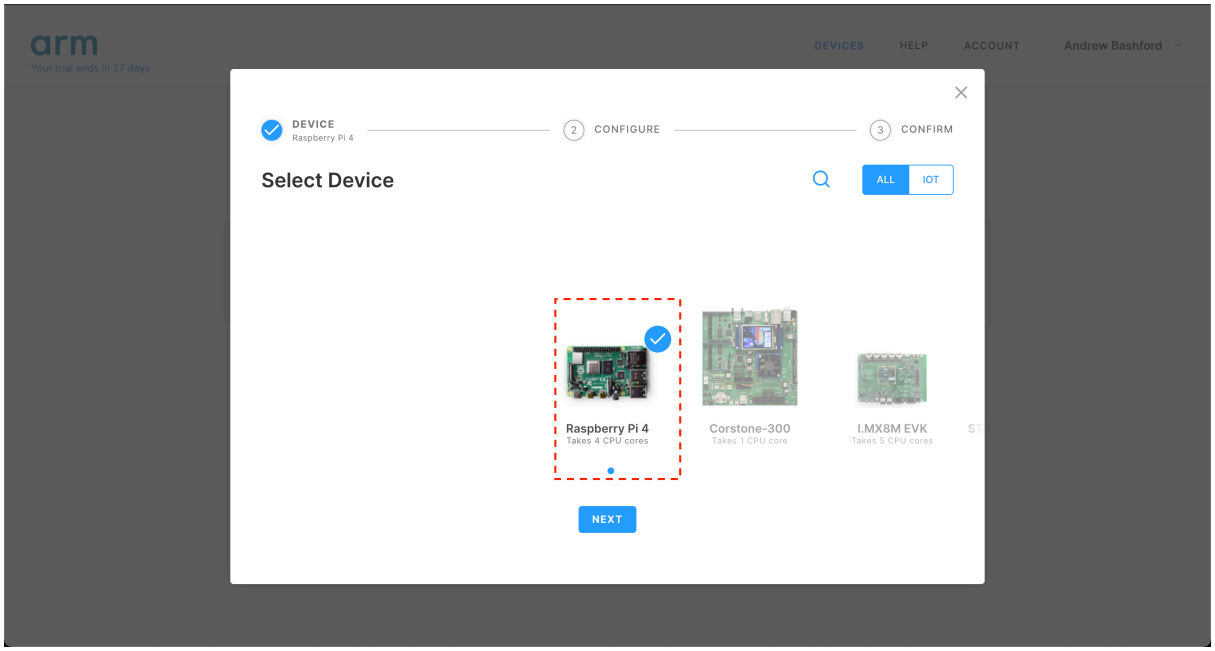
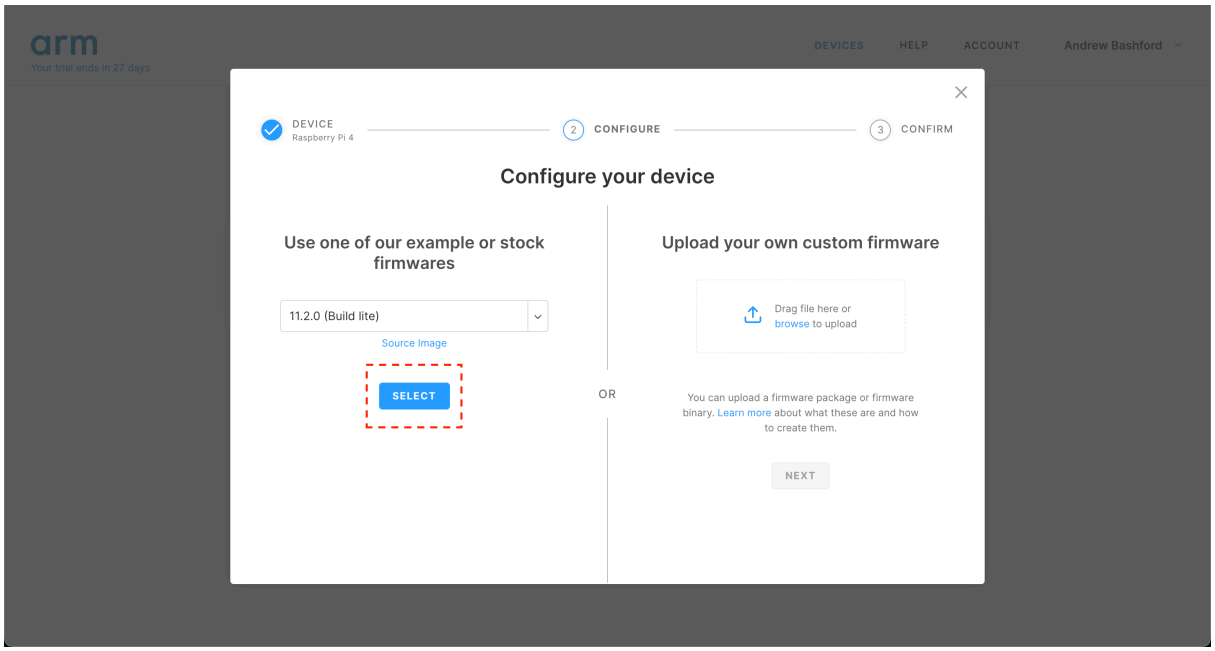
Figure 4-2: Select device



3. Select the `lite` firmware option if not already selected. Then click SELECT.

Figure 4-3: Configure your device



4. Select the `Set advanced boot options ...` checkbox and click CREATE DEVICE.

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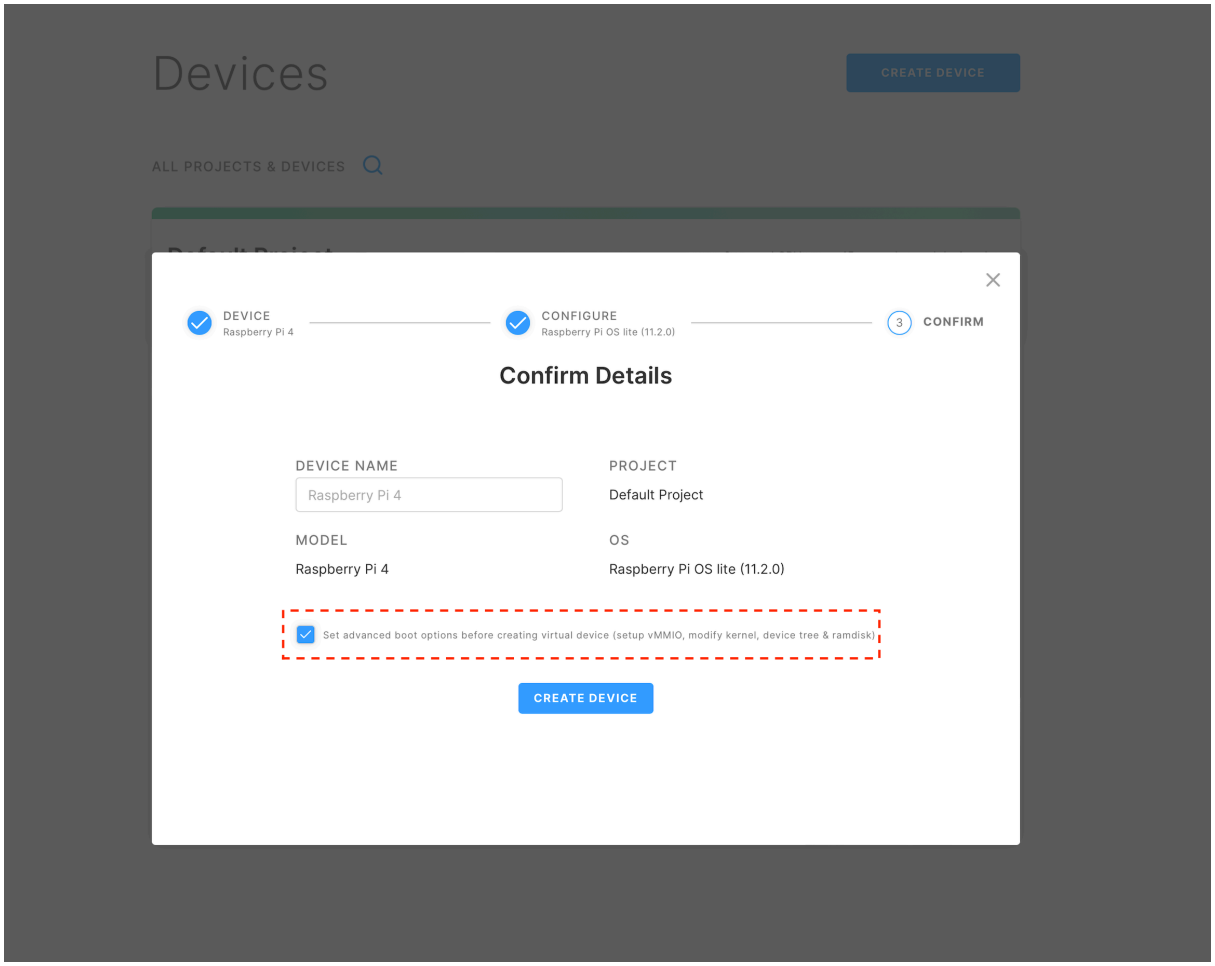
Figure 4-4: Confirm details



5. Select Custom vMMIO and enter `0xfef00000` for `start`, `0x1000` for `size`, 0 for `IRQ` (not used in this example), and 4300 for `port` (arbitrary). Then click CREATE DEVICE one final time.

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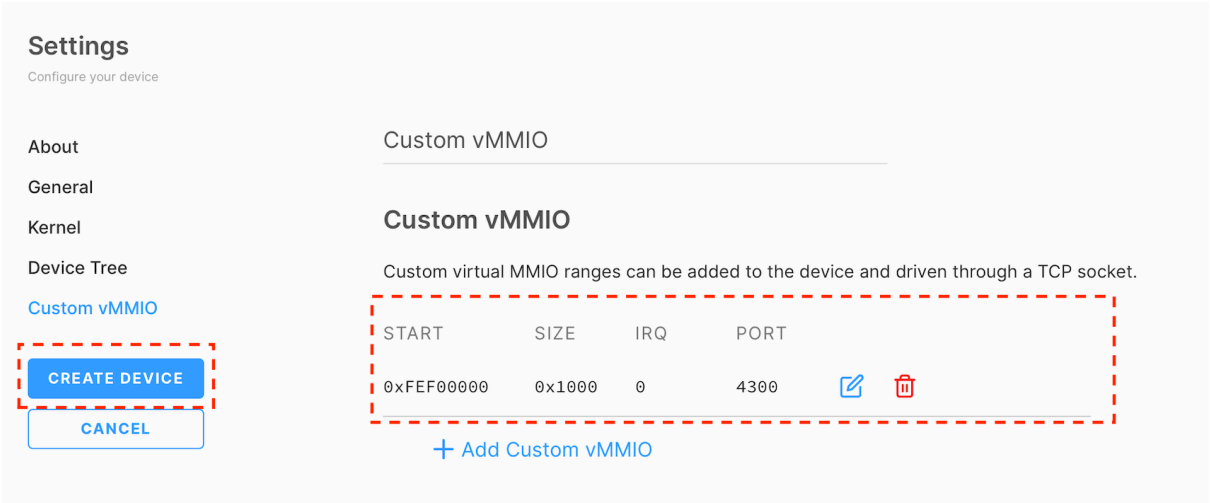
Figure 4-5: Custom vMMIO

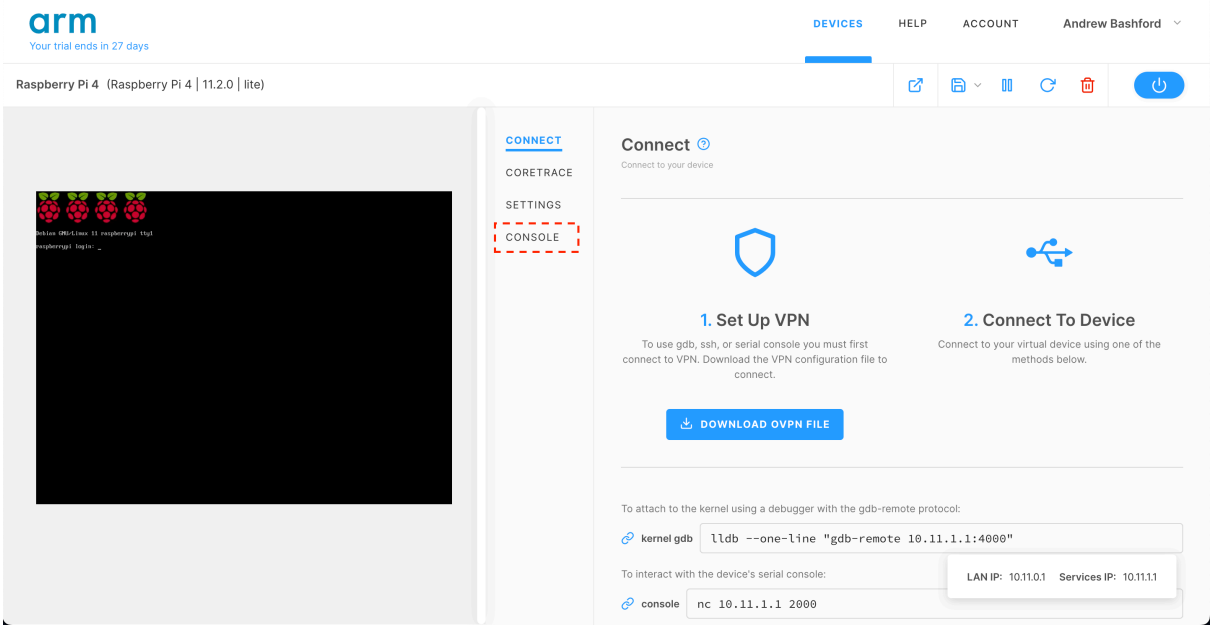


Note

`0xfef00000` was selected because the Raspberry Pi hardware does not have anything mapped at this address and as such it is safe to use for our purposes.

6. The device will take a few moments to build. When complete click on CONSOLE.

Figure 4-6: Connect



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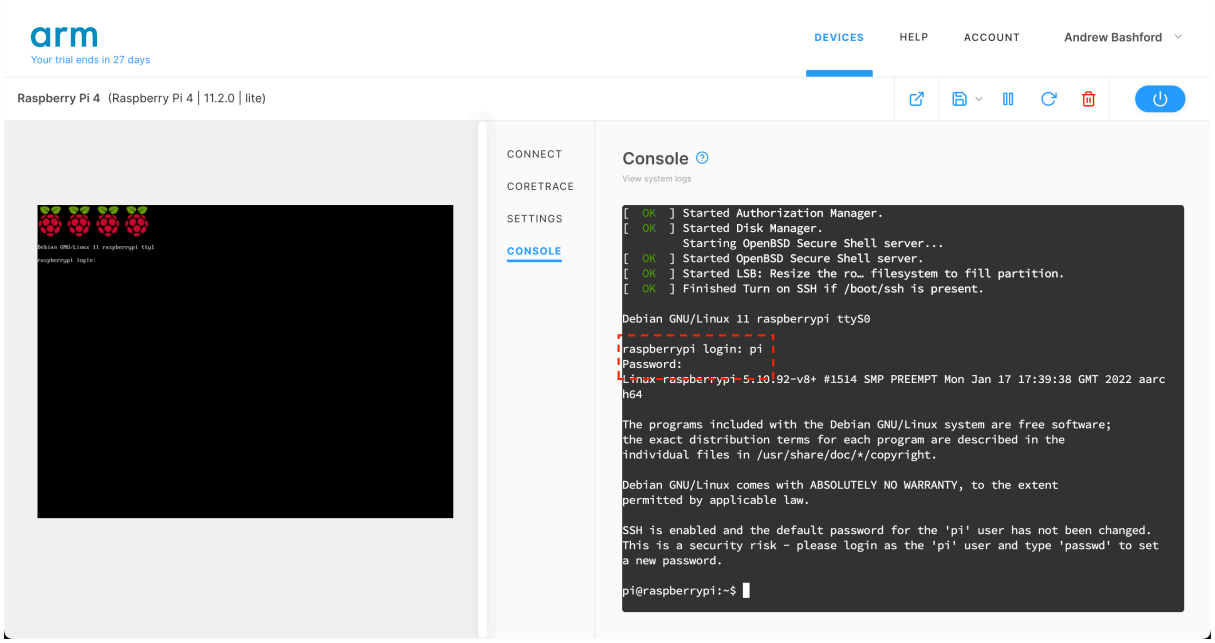
4.1.2 Writing to MMIO Without a vMMIO Handler Registered

To write to MMIO without a vMMIO handler registered:

1. Log in using the default credentials of `pi/raspberry`.

   Figure 4-7: Log in



2. Download project sources to your Raspberry Pi, extract, and build it.

```
pi@raspberrypi:~ $ wget https://avh.arm.com/downloads/coreio.tar.gz
...

2022-04-12 14:28:55 (18.0 MB/s) - 'coreio.tar.gz' saved [23940/23940]

pi@raspberrypi:~ $ tar -xf coreio.tar.gz
pi@raspberrypi:~ $ cd coreio/examples/rpi-test/
pi@raspberrypi:~/coreio/examples/rpi-test $ make
gcc -g -Wall -I../../ -shared -fPIC -o libcoreio.so ../../corehdl-base.c ../../
coreio.c
gcc -g -Wall -I../../ -c -o corehdl-base.o ../../corehdl-base.c
gcc -g -Wall -I../../ -c -o coreio.o ../../coreio.c
ar cr libcoreio.a corehdl-base.o coreio.o
gcc -g -Wall -I../../ -ovmmio-test-inside vmmio-test-inside.c
gcc -g -Wall -I../../ -ovmmio-test-outside vmmio-test-outside.c libcoreio.a
```

3. Run the `vmmio-test-inside` build product

   This example source will open `/dev/mem` at offset `0xfef00000` (recall this is the address of the registered vMMIO) and attempt to read and write to it.

   However, without any registered vMMIO handlers running, AVH's default behavior, as mentioned earlier, is to return `0xaa` in the registers receiving the read contents.

```
$ sudo ./vmmio-test-inside
```

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```
0: 0xaa
1: 0xaa
2: 0xaa
3: 0xaa
...
0: 0xaaaa
1: 0xaaaa
2: 0xaaaa
3: 0xaaaa
...
0: 0xaaaaaaaa
1: 0xaaaaaaaa
2: 0xaaaaaaaa
3: 0xaaaaaaaa
...
0: 0xaaaaaaaaaaaaaaaa
1: 0xaaaaaaaaaaaaaaaa
2: 0xaaaaaaaaaaaaaaaa
3: 0xaaaaaaaaaaaaaaaa
```

In order to implement something more meaningful we need to handle those read and write requests by registering a handler

4.1.3 Writing to MMIO With a vMMIO Handler Registered

To write to MMIO with a vMMIO handler registered:

1. Download project sources to your local machine, extract, and build it.

```
$ wget https://avh.arm.com/downloads/coreio.tar.gz
...

2022-04-12 14:28:55 (18.0 MB/s) - 'coreio.tar.gz' saved [23940/23940]

$ tar -xf coreio.tar.gz
$ cd coreio/examples/rpi-test/
$ make
gcc -g -Wall -I../../ -shared -fPIC -o libcoreio.so ../../corehdl-base.c ../../
coreio.c
gcc -g -Wall -I../../ -c -o corehdl-base.o ../../corehdl-base.c
gcc -g -Wall -I../../ -c -o coreio.o ../../coreio.c
ar cr libcoreio.a corehdl-base.o coreio.o
gcc -g -Wall -I../../ -ovmmio-test-inside vmmio-test-inside.c
gcc -g -Wall -I../../ -ovmmio-test-outside vmmio-test-outside.c libcoreio.a
```

2. Run the `vmmio-test-outside` build product, targeting the Services IP of the VM and vMMIO port (4300) as arguments

---

Note This step registers the vMMIO handler, overriding the default behavior just observed.

```
$ ./vmmio-test-outside 10.11.1.1:4300
tick
tick
```

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```
tick
...
```

3. Re-run `vmmio-test-inside` within the RaspberryPi VM. Observe that the `vmmio-test-outside` binary will now emit state information for each read and write event happening inside the VM by `vmmio-test-inside`.

```
$ ./vmmio-test-outside 10.11.1.1:4300
tick
tick
tick
write fef00000 1 0000000000000000 0
write fef00001 1 0000000000000001 0
write fef00002 1 0000000000000002 0
write fef00003 1 0000000000000003 0
write fef00004 1 0000000000000004 0
write fef00005 1 0000000000000005 0
write fef00006 1 0000000000000006 0
tick
write fef00007 1 0000000000000007 0
write fef00008 1 0000000000000008 0
...
```

Meanwhile `vmmio-test-inside` will emit the contents it reads from the MMIO address after attempting to modify its contents with a write.

```
$ sudo ./vmmio-test-inside
0: 0x00
1: 0x01
2: 0x02
3: 0x03
...
0: 0x0100
1: 0x0201
2: 0x0302
3: 0x0403
...
0: 0x03020100
1: 0x04030201
2: 0x05040302
3: 0x06050403
...
0: 0x0706050403020100
1: 0x0807060504030201
2: 0x0908070605040302
3: 0x0a09080706050403
```

4.1.4 Flow Diagram

The flow followed in this example is illustrated below. The Writing to MMIO With a vMMIO Handler Registered example follows the “vMMIO Handler Registered” No path while the Writing to

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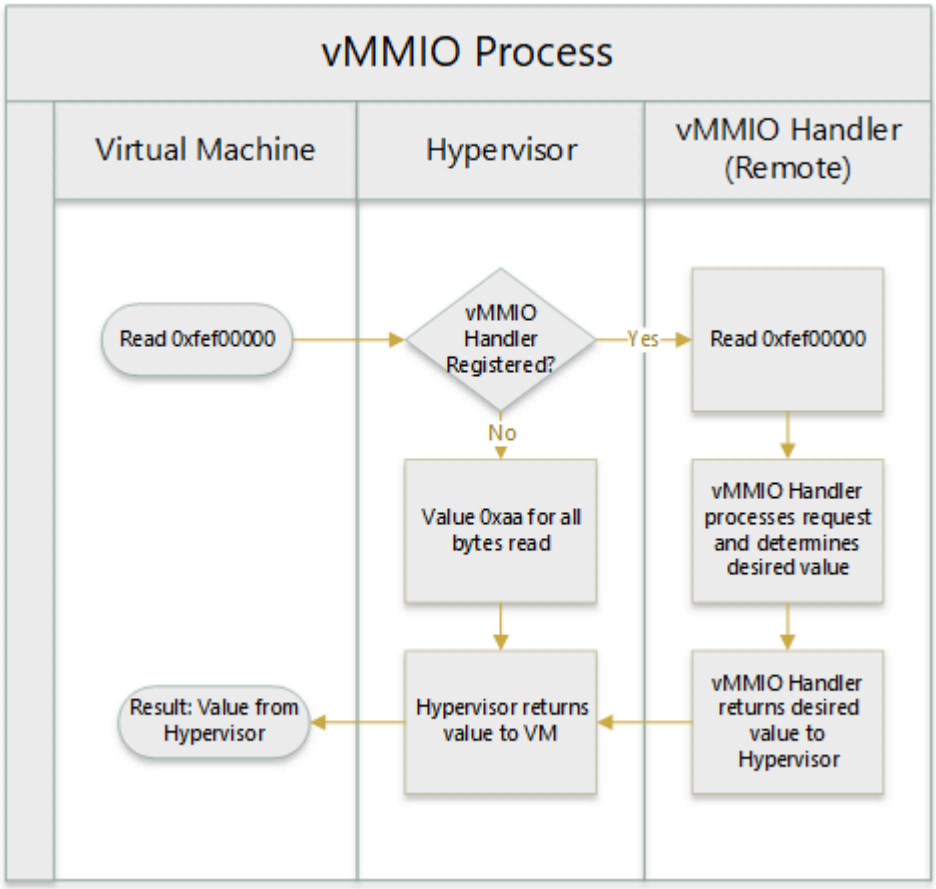
MMIO With a vMMIO Handler Registered example has a remote handler registered and follows the Yes path.

Figure 4-8: Flow diagram



4.1.5 Summary

In summary, `vmmio-test-outside` is registering as an vMMIO read and write handler for a specified address range within the VM. When the physical address range specified is read from or written to, this handler receives a callback allowing it to handle the request. In this example, the `vmmio-test-inside` binary opened `/dev/mem` and simulates the OS or some other entity reading or writing to physical memory in order to exercise the callbacks in the registered vMMIO handler.

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5. API Examples

API examples:

- Python and Javascript API Examples
- GitHub Actions Example - Building Firmware, Uploading, and Testing

5.1 Python and Javascript API Examples

Visiting the AVH GitHub where you will find a repo with examples for both Python and Javascript.

5.1.1 Python Examples

The Python examples are as follows:

- `instance_create_snapshot_delete.py`
  - This example demonstrates creating a STM32U5 device, taking a snapshot and then deleting it.
- `stm32_bsp_test.py`
  - This example demonstrates using GPIO input/output of a virtual machine
- `create_github_runner.py`
  - This example demonstrates using GPIO input/output of a virtual machine

5.1.2 Javascript Examples

The Javascript examples are as follows:

- `arm_api`
  - ArmApi - JavaScript client for arm_api REST API to manage your virtual devices.
- `sensordemo-docker`
  - This example will execute a build on your runner and create a new device on AVH to test the output of the build on.
- `sensordemo-generate-api`

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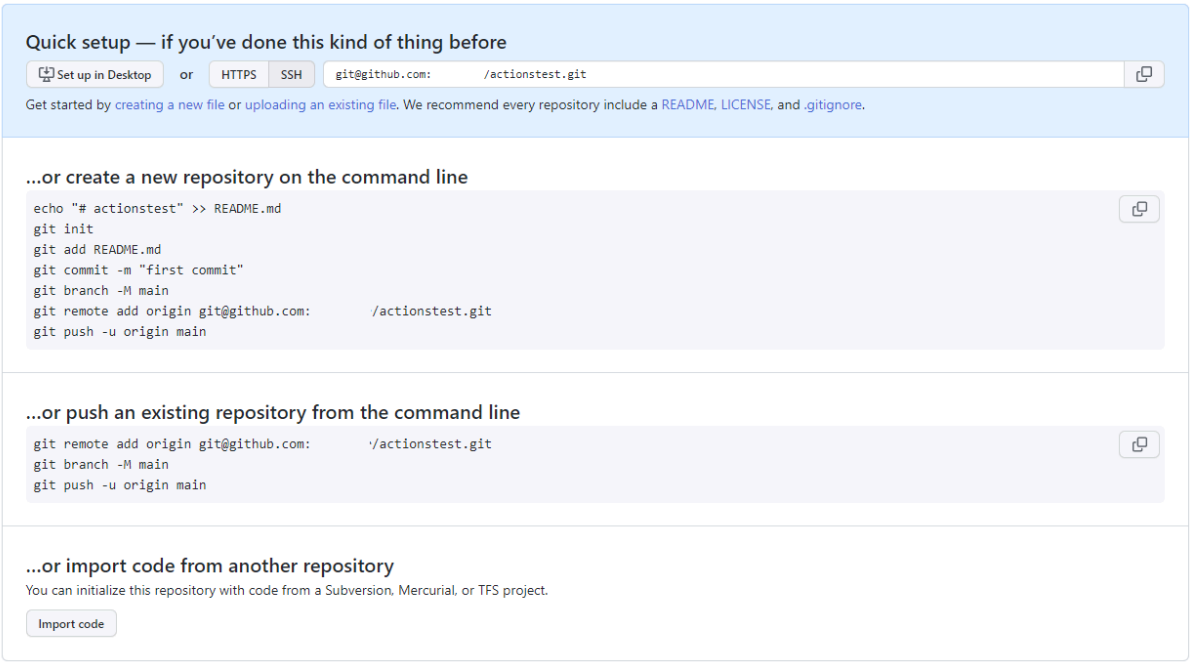
5.2 GitHub Actions Example - Building Firmware, Uploading, and Testing

The following steps help you to set up GitHub Actions.

1. To get a VM ready for the GitHub runner, follow the steps in the Running Docker on AVH Pi article.
2. Ensure you have an AVH API Token by following the steps in the Obtaining AVH API Token article.
3. Create an empty GitHub repository for your runner to accept jobs from by following the steps in this GitHub Article.

Figure 5-1: Create an empty GitHub repository



4. Add a "API_TOKEN" secret to your repository with a value of your API Token by following the steps in this GitHub Article.

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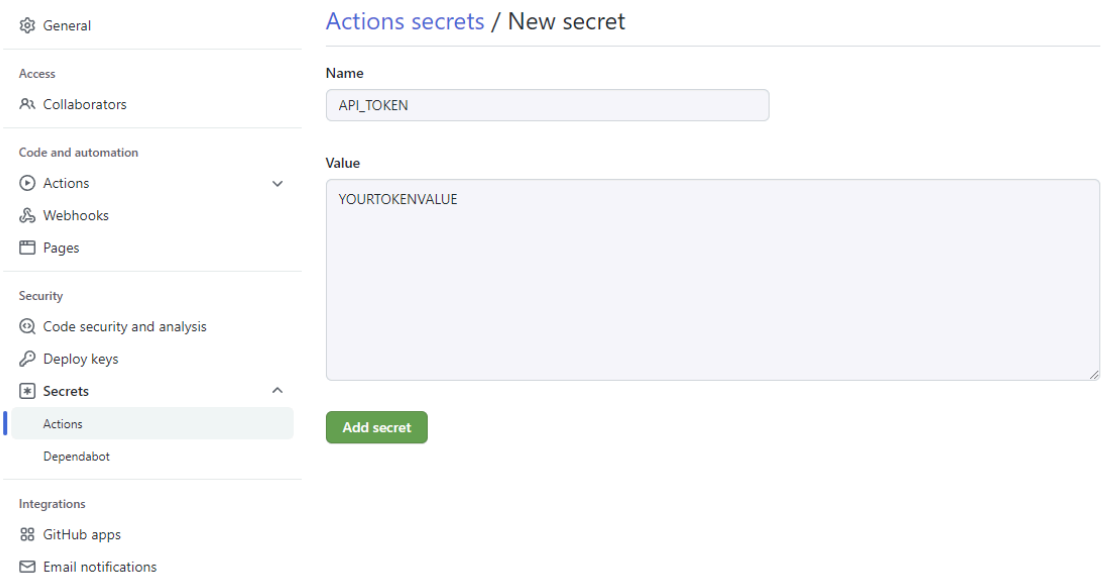
Figure 5-2: API_TOKEN



5. To configure and start the runner, follow the steps in this Adding Self Hosted Runners article. Select “Linux” as the OS and “ARM64” as the architecture.

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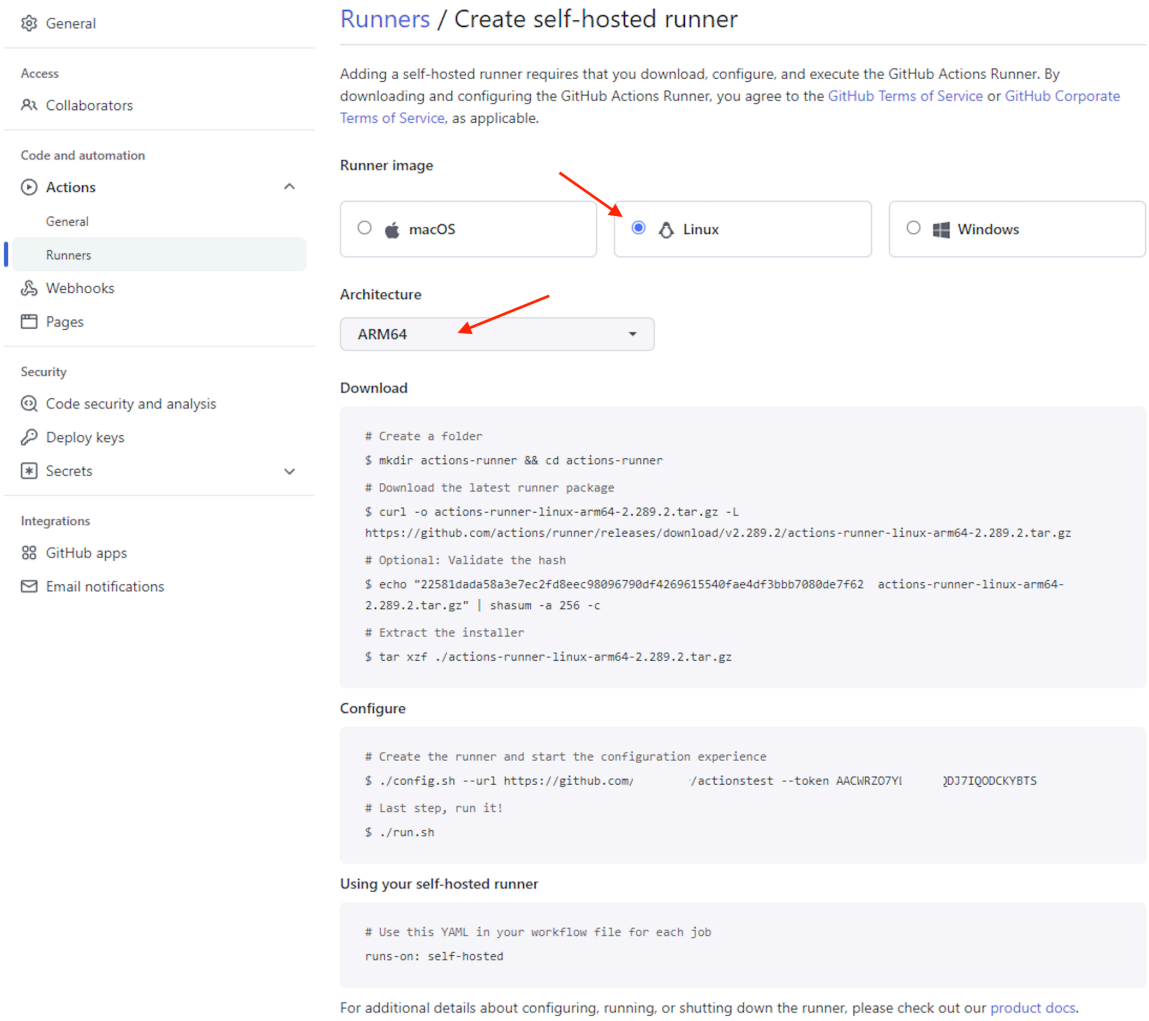
Figure 5-3: Adding self hosted runners



a. In AVH, select the Raspberry Pi VM created previously. Then select “CONSOLE” to access a shell to run the commands referenced above.

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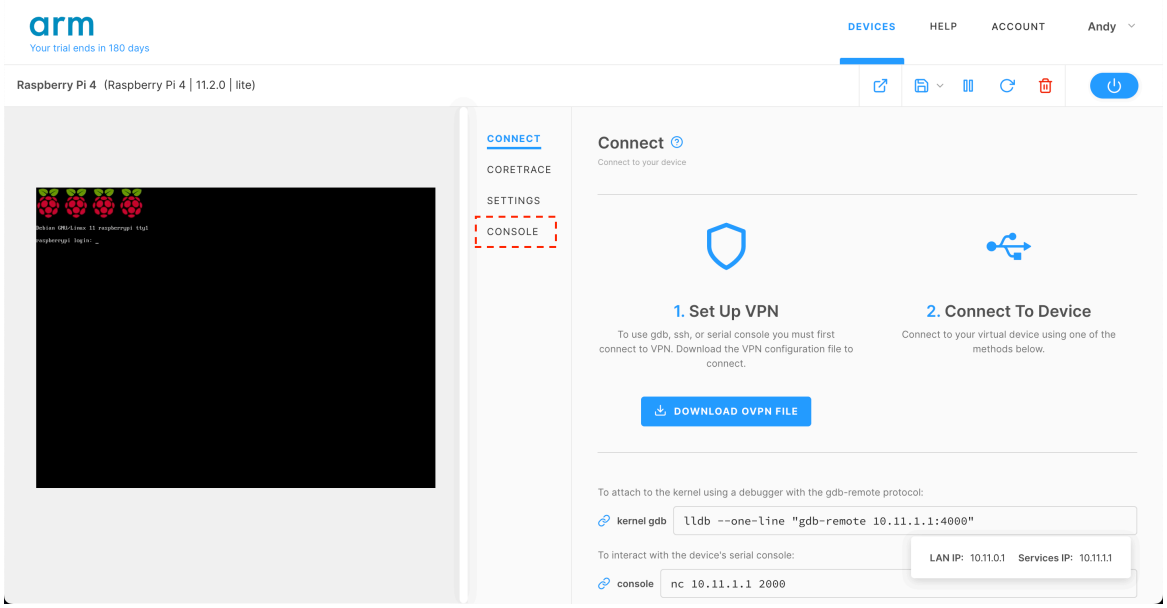
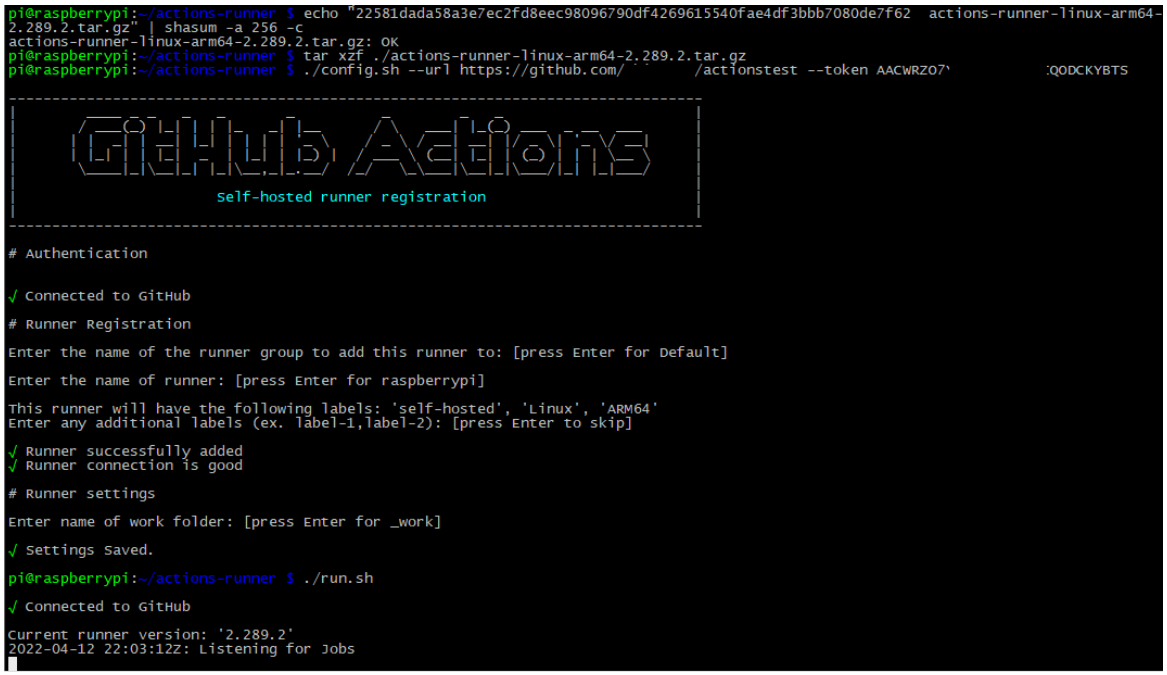
Figure 5-4: Select Console



b. Upon completion of runner setup you should see something similar to:

Figure 5-5: Console output



c. Do not cancel the running process or your runner will be unavailable until it is run again. The runner can also be installed as a service, but that is not covered in this article.

6. Clone the avh-api repository on your usual local development system from GitHub with: `git clone https://github.com/ARM-software/avh-api.git`

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Figure 5-6: Clone the avh-api repository

```
pi@raspberrypi:~$ git clone https://github.com/ARM-software/avh-api.git
Cloning into 'avh-api'...
remote: Enumerating objects: 1256, done.
remote: Counting objects: 100% (1256/1256), done.
remote: Compressing objects: 100% (638/638), done.
remote: Total 1256 (delta 600), reused 1227 (delta 573), pack-reused 0
Receiving objects: 100% (1256/1256), 25.91 MiB | 31.97 MiB/s, done.
Resolving deltas: 100% (600/600), done.
pi@raspberrypi:~$
```

Note

We used a raspberry pi for this in this example, this will likely be your laptop or desktop system.

7. Enter the `javascript/sensordemo-docker` directory

Figure 5-7: Enter the directory

```
pi@raspberrypi:~$ cd avh-api/javascript/sensordemo-docker/
pi@raspberrypi:~/avh-api/javascript/sensordemo-docker$
```

8. Run `make clean gitrepo GITREMOTE='<url to Github repo you created>'` in the console.

Note

This will overwrite any contents of the repo passed as GITREMOTE=.

Figure 5-8: Run GITREMOTE=

```
pi@raspberrypi:~/avh-api/javascript/sensordemo-docker $ make clean gitrepo GITREMOTE='https://github.com/        /actionstest.git'
rm -rf gitrepo
git archive HEAD --prefix="gitrepo/" | tar -xf -
cp -a ../api gitrepo/api
cd gitrepo; \
  git init; \
  mkdir -p .github/workflows; \
  mv github_workflow.yml .github/workflows/avh_build_and_test.yml; \
```

```
 create mode 100755 run_docker.sh
Example repository created in /home/pi/avh-api/javascript/sensordemo-docker/gitrepo
cd gitrepo; \
  git remote add origin https://github.com/        /actionstest.git; \
  git push -fu origin $(git rev-parse --abbrev-ref HEAD)
Username for 'https://github.com':
Password for 'https://        @github.com':
Enumerating objects: 750, done.
Counting objects: 100% (750/750), done.
Delta compression using up to 4 threads
Compressing objects: 100% (717/717), done.
Writing objects: 100% (750/750), 24.39 MiB | 8.82 MiB/s, done.
Total 750 (delta 215), reused 0 (delta 0), pack-reused 0
remote: Resolving deltas: 100% (215/215), done.
To https://github.com/        /actionstest.git
 * [new branch]      master -> master
Branch 'master' set up to track remote branch 'master' from 'origin'.
pi@raspberrypi:~/avh-api/javascript/sensordemo-docker $
```

9. You should see an action run on your repository executed from your AVH VM.

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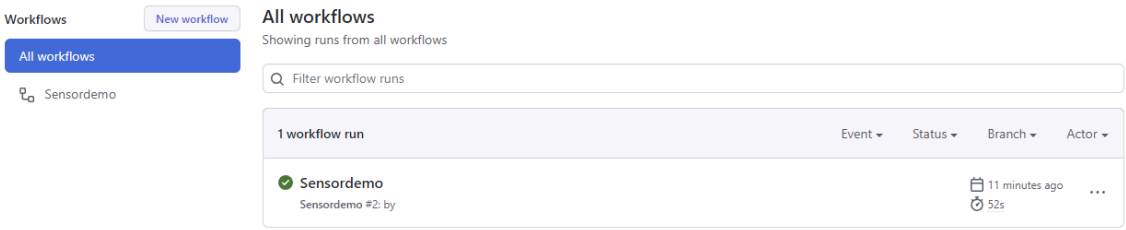
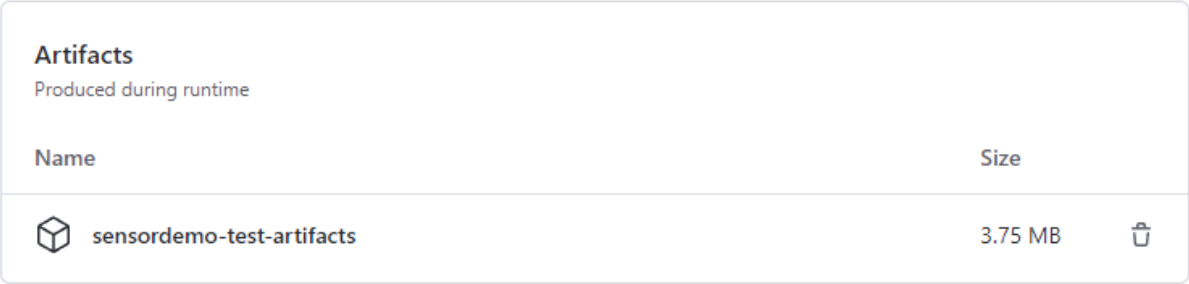
Figure 5-9: Executed action



This will compile a new firmware for STM32u5 on the pi VM, then upload it to a new STM32 VM in Arm Virtual Hardware, and run a test against it to ensure it behaved properly.

10. You will get a built firmware and the test results as the artifacts downloadable from GitHub when the action completes.

Figure 5-10: Artifacts



11. Any changes made to the repository, such as changing how the firmware behaves and pushes to GitHub, will trigger a new run.

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