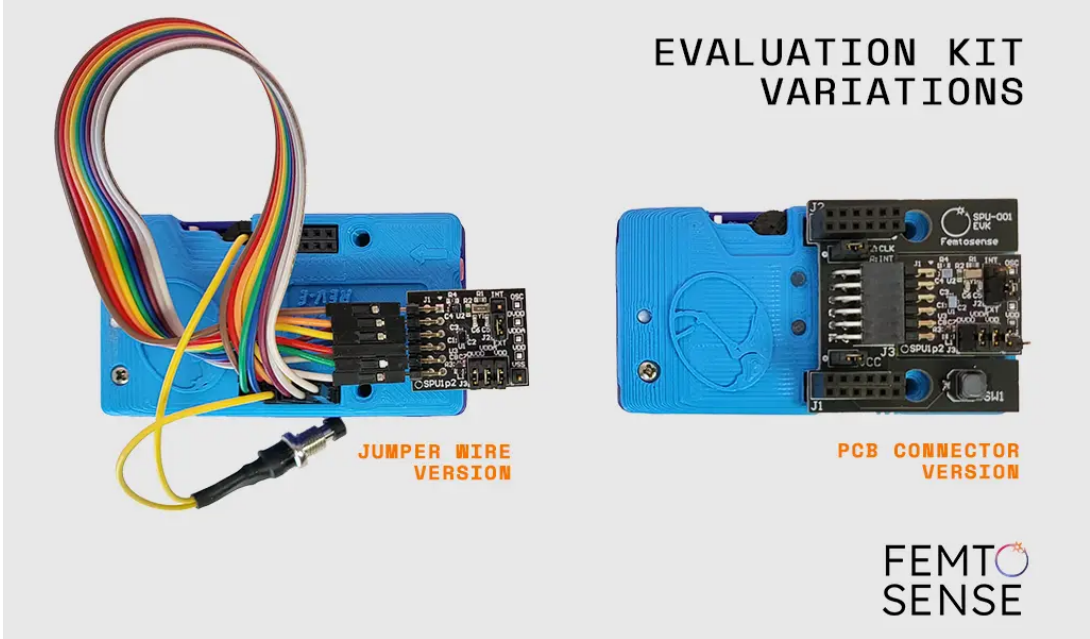


# Quick Start Guide v1.7

In your kit, you will find one of the following configurations:

<b>Jumper Wire Version</b> <i>Release 2023/03/21</i>	<b>PCB Connector Version</b> <i>Release 2023/05/02</i>
<ul style="list-style-type: none"> <li>• SPU-001 circuit board</li> <li>• Host: Tympan open source hearing aid kit</li> <li>• USB programming cable</li> <li>• Ribbon cable of jumper wires for connecting Tympan to SPU-001.</li> <li>• Button with 2 wires</li> <li>• Micro SD Card (inserted into the Tympan)</li> <li>• Plastic pencil tool for removing the SD card</li> <li>• SD to MicroSD adapter</li> </ul>	<ul style="list-style-type: none"> <li>• SPU-001 circuit board</li> <li>• Host: Tympan open source hearing aid kit</li> <li>• USB programming cable</li> <li>• PCB connector board with SPU-001 circuit board (attached to Tympan). Button is built-in with a PCB board.</li> <li>• Micro SD Card (inserted into the Tympan)</li> <li>• Plastic pencil tool for removing the SD card</li> <li>• SD to MicroSD adapter</li> </ul>
<div data-bbox="269 978 1352 1612">  <p style="text-align: center;"><b>EVALUATION KIT VARIATIONS</b></p> <p style="text-align: center;"><b>JUMPER WIRE VERSION</b>      <b>PCB CONNECTOR VERSION</b></p> <p style="text-align: right;"><b>FEMTOSENSE</b></p> </div>	

You may also need:

- SD Card Reader to load new programs into the SD Card
- Headphones with 3.5mm input jack to listen to audio output (e.g. for the AI noise reduction demo)

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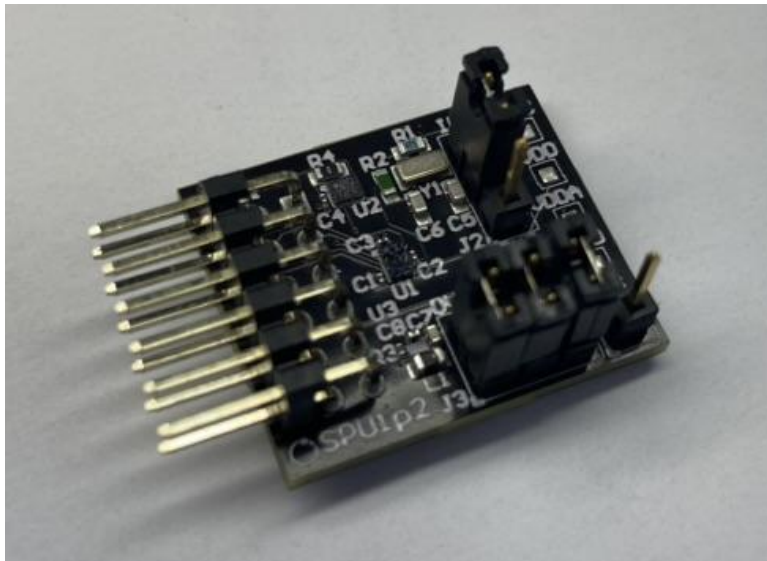
# 1. Hardware and Firmware Setup

*Note: Previous versions of this guide may have recommended a different jumper and wiring configuration. Please carefully configure your evaluation kit according to this section in order to use the accompanying firmware.*

## 1.1. Setting up

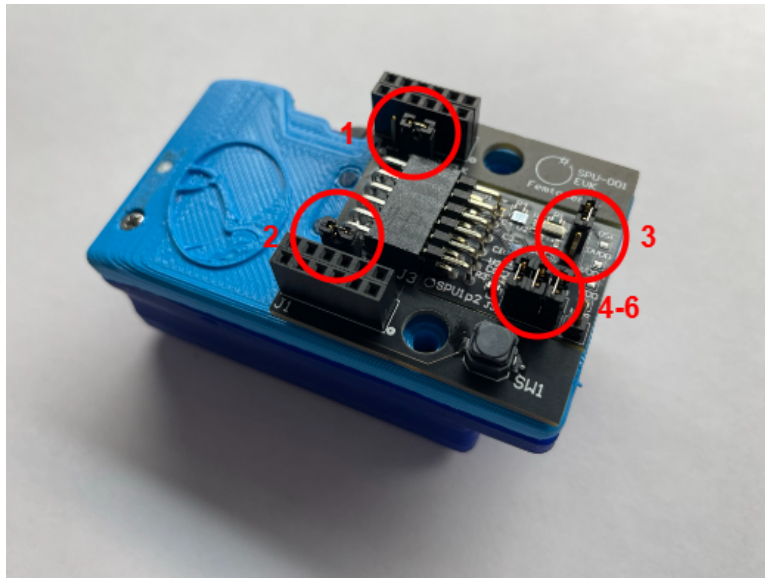
If you have the PCB connector version of the kit, you may skip Section 1.2. If you have the jumper wire version of the kit, please connect it according to the instructions in Section 1.2.

Before continuing, ensure that the 4x 2-pin jumpers on the SPU-001 circuit board are installed. With the 12-pin header facing left as in the photo below, the bottom set of pins, labeled J3, should have 3x jumpers installed vertically. The upper set of pins, labeled J2, should have one jumper installed over the top 2 pins.



*Notice the correct placement of the 4x 2-pin jumpers on pin sets J2 and J3 on the SPU-001 circuit board. The component labeled U1 is the WLCSP-packaged SPU-001*

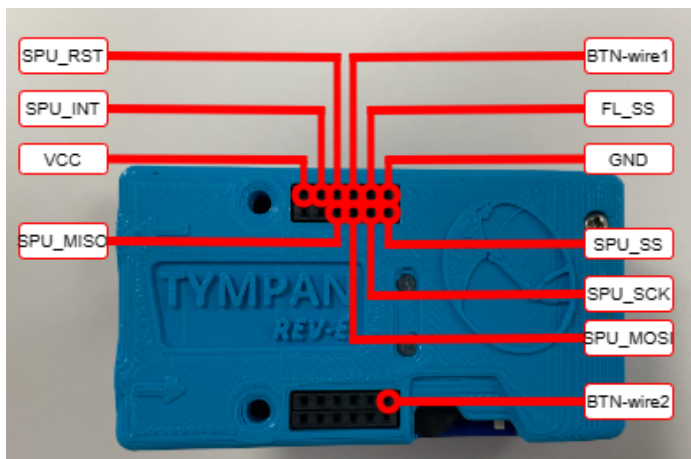
If you have the PCB connector version of the kit, there are two additional jumpers that should be installed, one over the two pins labeled “VCC”, and one over the right two pins labeled “L:CLK R:INT”



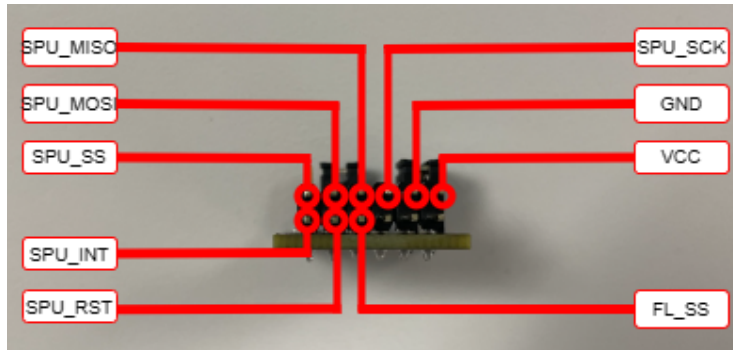
*Notice the correct placement of all 6x 2-pin jumpers on the PCB connector version of the kit.*

## 1.2. Wire Up the Kit (Jumper Wire Version Only)

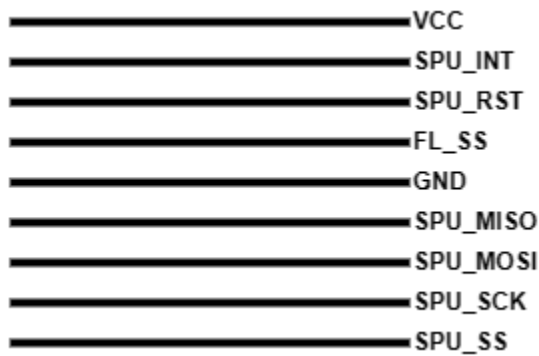
Use the 9-wire ribbon cable to connect the corresponding pins between the host and SPU-001 circuit board. The 2-wire button attaches to the host pins marked BTN-wire1 and BTN-wire2. Note that there is no polarity to the button, and these two wires are interchangeable. Use the following three diagrams to place the wiring. Note that the order of the signals on the ribbon cable is important to minimize noise on the cable.



*Wiring diagram of the Tympan host platform (top view). Connect the circled host pins to their corresponding SPU-001 circuit board pins*



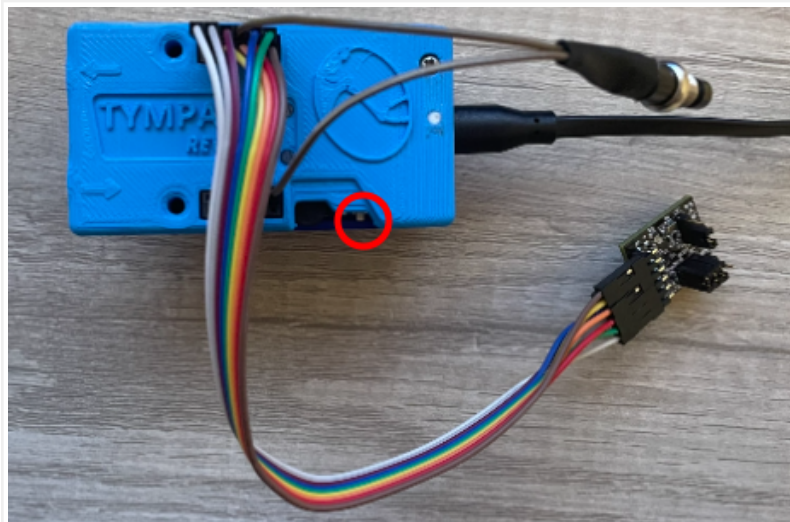
*Wiring diagram of the SPU-001 circuit board (side view looking into the 12-pin header). Connect the circled SPU-001 circuit board pins to their corresponding host pins.*



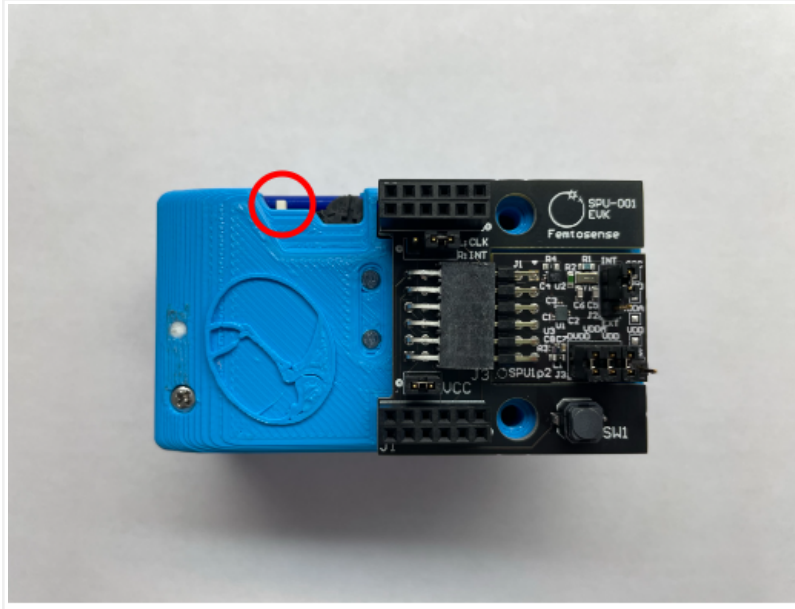
*The signals on the ribbon cable should be ordered according to the diagram on the left.*

### 1.3. Run the Installed Wake Word Detection (WWD) Example

Once the wiring step above is completed, flip the power switch to the LEFT position to turn it on. If the Tympan does not turn on, the battery may need charging. Plug the Tympan host into a powered USB port and try turning it on again after a few minutes.



*Fully wired up EVK (jumper wire version) with the power switch circled in red*



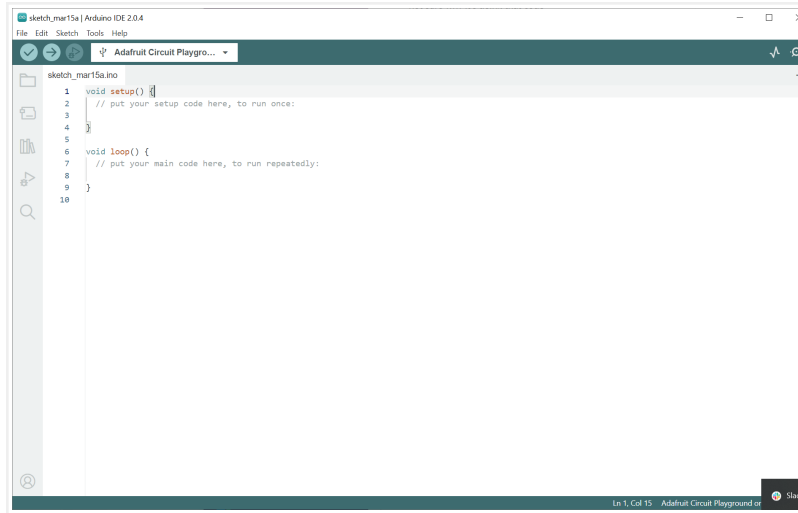
*EVK (PCB connector version)  
with the power switch circled  
in red.*

The program will take a few seconds to boot. After that, you should then see the green LED on top of the host quickly flash 3x. The internal microphone is now listening for the phrase "Hey Snips". When you say this phrase out loud, the green and red LEDs on top of the Tympan should flash. If this example is not working for you, see the [Troubleshooting](#) section below.

#### 1.4. Setting up the Firmware Development Environment

In order to change the firmware on the host, you will need to install and configure the Arduino development application. The following instructions are for Windows, but a similar process can be followed for Mac OS or Linux operating systems. However, we have not tested Linux support.

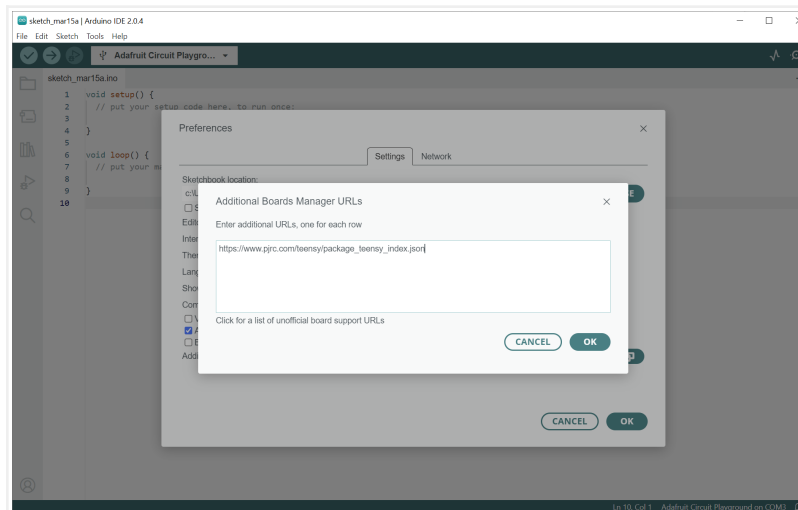
First, install the latest Arduino 2 IDE from: <https://www.arduino.cc/en/software>.



*Arduino running on Windows*

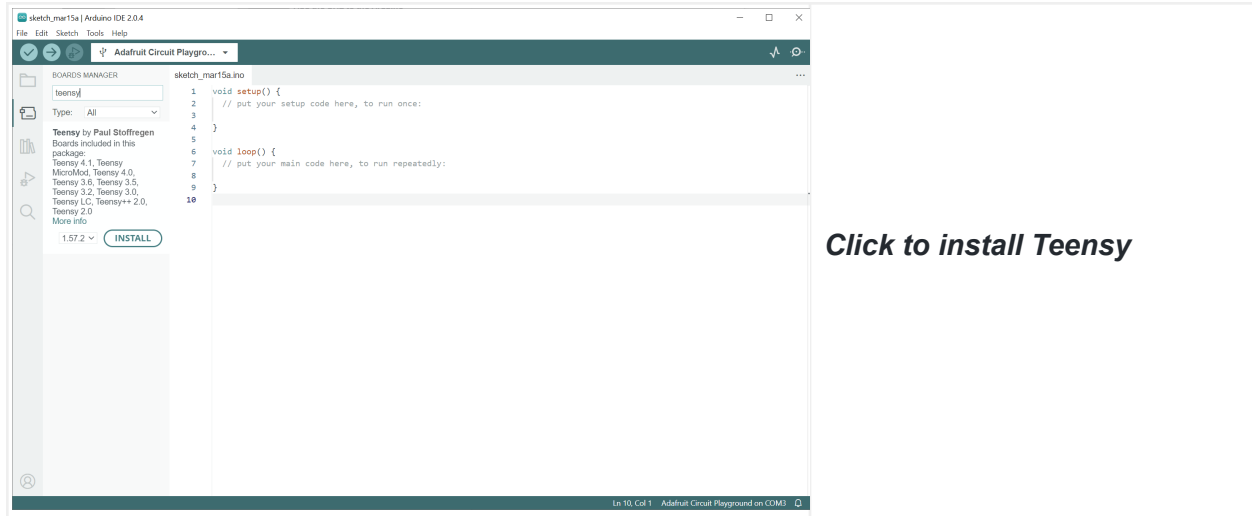
Next, go to **File > Preferences** in Arduino, and click the button next to “Additional board manager URLs”. Add the following line to the URLs:

[https://www.pjrc.com/teensy/package\\_teensy\\_index.json](https://www.pjrc.com/teensy/package_teensy_index.json)

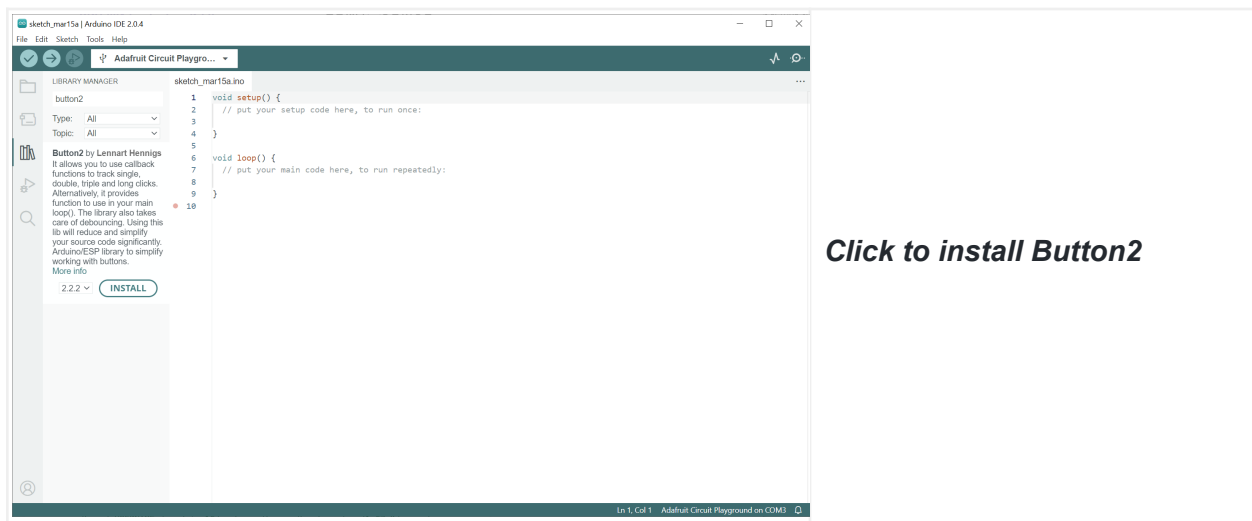


*Add the URL to the Arduino Additional Boards Manager URLs*

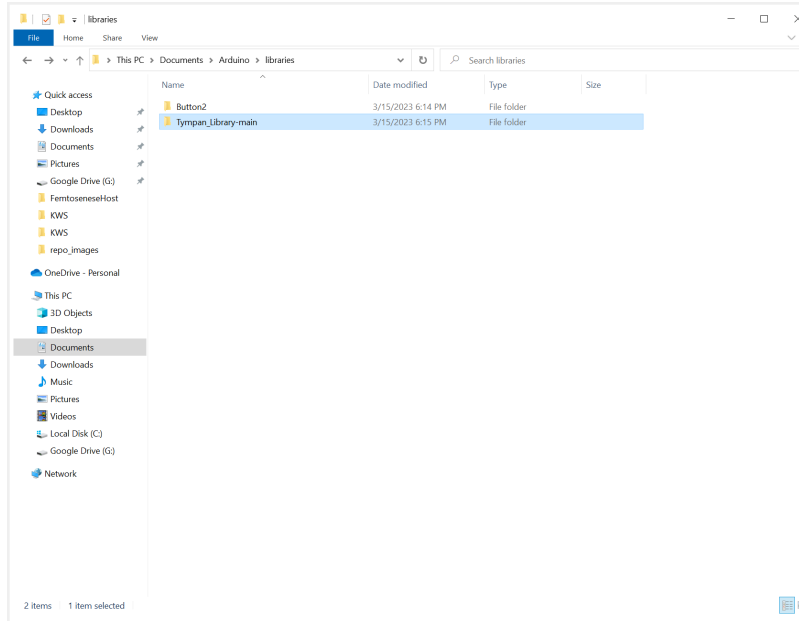
Click OK to go back to the Arduino IDE. Next, click the “Boards Manager” icon on the left side of the IDE and search for “Teensy”. Install the package “Teensy by Paul Stoffregen”. Choose version 1.57.2 from the dropdown as shown below.



Next, click the “Library Manager” icon on the left side of the IDE and search for “Button2”. Install the package “Button2 by Lennart Hennigs”.



Next, download the Tympan library from Github at: [https://github.com/Tympan/Tympan\\_Library](https://github.com/Tympan/Tympan_Library). Download the library by clicking **Code > Download Zip**. Extract the folder to your Arduino Libraries directory. In Windows, this is located at:  
**C:\Users\<USERNAME>\Documents\Arduino\libraries**



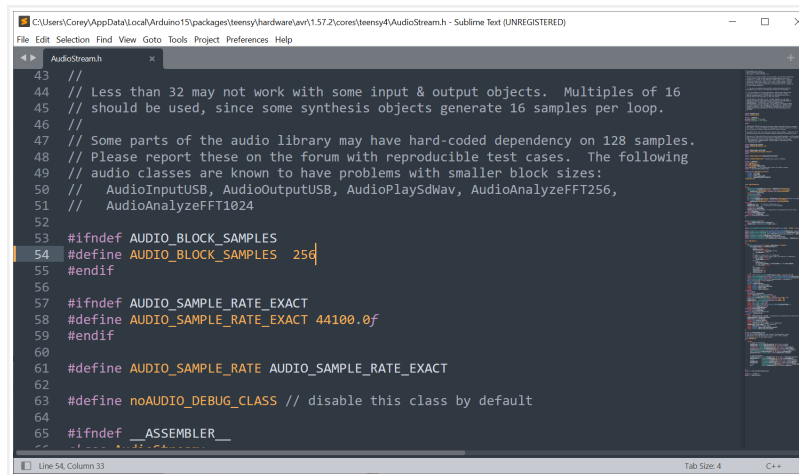
***Button2 and the Tympan library should now be in your Arduino libraries directory.***

Next, you will need to modify one library file, which in Windows is located at:

`C:\Users\<USERNAME>\AppData\Local\Arduino15\packages\teensy\hardware\avr\1.57.2\cores\teensy4\AudioStream.h`. Change:

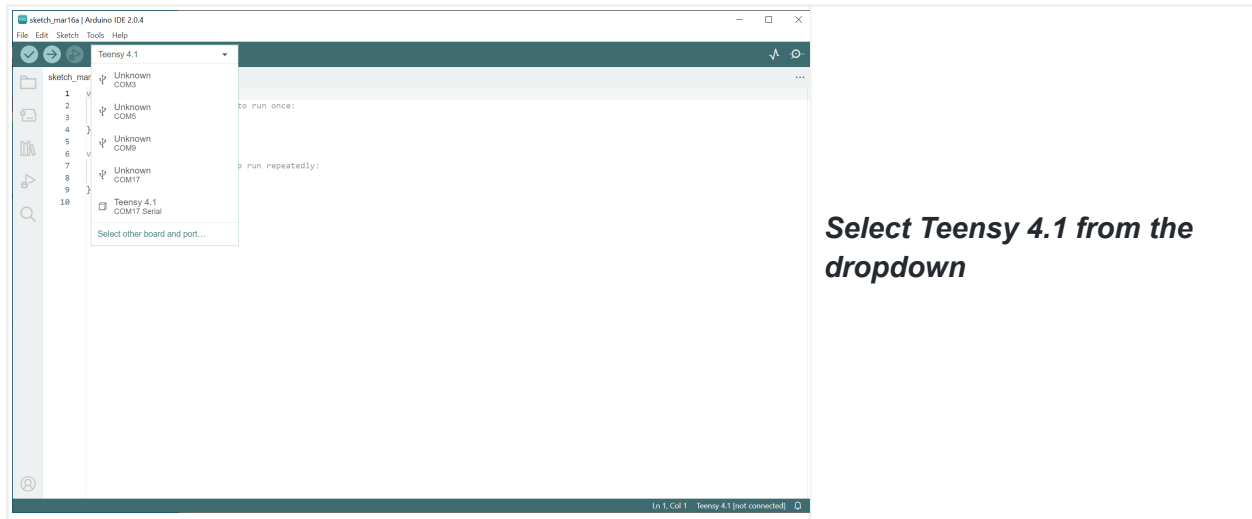
`#define AUDIO_BLOCK_SAMPLES`

from `128` to `256` and save the file. Note that you will need to redo this change if the Teensy library is updated.



***Update the value for AUDIO\_BLOCK\_SAMPLES to 256***

Next, close and reopen Arduino. This will make sure that all of the changes above are loaded. Now, plug in the Tympan host via USB and turn it on. Select **Teensy 4.1** from the board selection dropdown menu at the top of the window.



You are now ready to upload firmware from the Femtosense example repository [spu001evk2\\_model\\_firmware](#). This code can be provided to you by your Femtosense representative if you do not have it already.

## 1.5. Uploading the Firmware

To upload firmware, first open the target firmware's `.ino` file in Arduino. Start with the 8ms AINR firmware located in:

[spu001evk2\\_model\\_firmware/program\\_files/AINR/AINR.ino](#)

The `.ino` firmware file includes the program's main functions called `setup()` and `loop()`. It will also open tabs to the supporting code: `spu.h` and `spu.cpp` which include the SPU EVK driver functions, and `ProcessAudio_F32.h`, which includes the audio processing code. When you are ready to upload the code to the Tympan host, plug it in via USB, make sure that "Teensy 4.1" is selected from the dropdown, and click the upload button.



***When you are ready to upload your firmware, select the upload button circled in red***

Before booting up the host after upload, make sure to load the `0PROG_A`, `0PROG_D`, and `0PROG_P` files for your model onto the SD card. These files are located in:

`spu001evk2_model_firmware/program_files/AINR/AINRGP_16khz_4hop_8algo_v3`

In order to load the 2ms version of the algorithm, change the `HOP_SIZE` in `spu.h` to 16, reupload the firmware, and use the SD card files located in:

`spu001evk2_model_firmware/program_files/AINR/AINRGP_16khz_1hop_2algo_v0`

## 1.6. Running the AI Noise Reduction (AINR) Example

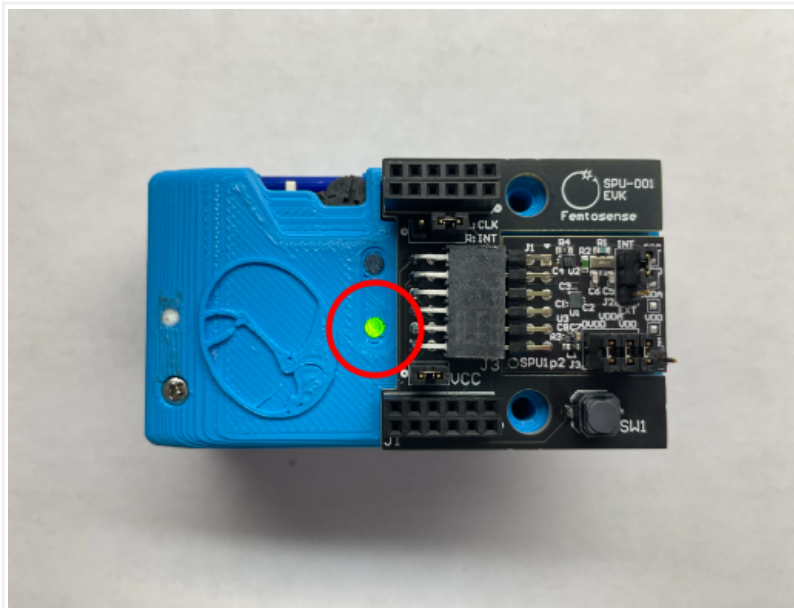
Once the code is uploaded, and the 3 programming files are loaded onto the SD card, flip the power switch to the RIGHT position to turn it on. The program will take a few seconds to boot. You should then see the green LED on top of the host quickly flash 3x.

Plug in your headphones to the BLACK audio jack on the Tympan host. You should hear loopback audio (unprocessed) from the microphone.



*The black and pink 3.5mm jacks are for audio output/input. The examples use the internal microphone by default. To change the mic input to use an external mic, set `USE_EXTERNAL_MIC` in the parameters file as shown in the [0PROG\\_P parameters table](#).*

You can toggle the AINR processing on and off using the button marked SW1 on the black PCB. When AINR processing is enabled, the green LED will illuminate and you should hear human speech sound, while background noise is significantly reduced. Output volume on the headphones can be adjusted via the knob next to the power switch. If this example is not working for you, see the [Troubleshooting](#) section below.



*The green LED illuminates during AINR processing.*

### 1.7. Loading the WWD Example

To revert back to the WWD example, load the WWD firmware located in:

```
spu001evk2_model_firmware/program_files/WWD/WWD.ino
```

Before booting up the host after upload, make sure to load the `0PROG_A`, `0PROG_D`, and `0PROG_P` files for your model onto the SD card. These files are located in:

```
spu001evk2_model_firmware/program_files/WWD/WWDSNIPS_8khz_16ms_v2
```

### 1.8. Loading the GSC Example

To load the GSC example, load the GSC firmware located in:

```
spu001evk2_model_firmware/program_files/GSC/GSC.ino
```

Before booting up the host after upload, make sure to load the `0PROG_A`, `0PROG_D`, and `0PROG_P` files for your model onto the SD card. These files are located in:

```
spu001evk2_model_firmware/program_files/GSC/GSC_8khz_16ms_v0
```

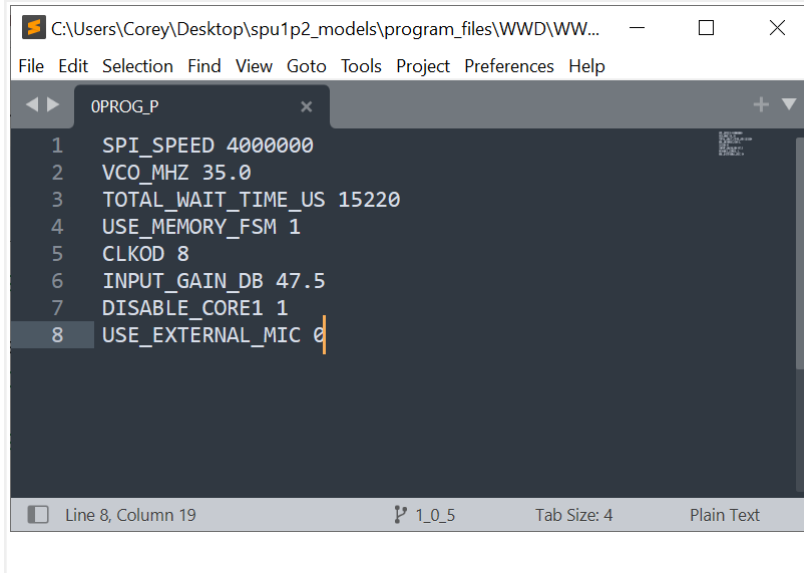
Similar to the WWD example, the GSC example will flash the Tympan's red and green LEDs when a command is detected. The number of flashes corresponds to the GSC command that was spoken:

- 0: No Command
- 1: "YES"
- 2: "NO"
- 3: "ON"
- 4: "OFF"
- 5: "LEFT"
- 6: "RIGHT"
- 7: "UP"
- 8: "DOWN"
- 9: "STOP"
- 10: "GO"
- 11: "HEY SNIPS"

The command will also display on the Tympan USB com port at 115200 baud (8-N-1).

## 1.9. 0PROG\_P Parameters

Several parameters can be used to adjust the firmware, which can be loaded into the 0PROG\_P. The format is shown in the following screenshot:



The screenshot shows a text editor window with the following content:

```
1 SPI_SPEED 4000000
2 VCO_MHZ 35.0
3 TOTAL_WAIT_TIME_US 15220
4 USE_MEMORY_FSM 1
5 CLKOD 8
6 INPUT_GAIN_DB 47.5
7 DISABLE_CORE1 1
8 USE_EXTERNAL_MIC 0
```

The text editor has a menu bar with File, Edit, Selection, Find, View, Goto, Tools, Project, Preferences, and Help. The status bar at the bottom indicates Line 8, Column 19, 1\_0\_5, Tab Size: 4, and Plain Text.

*Example of the 0PROG\_P format for a WWD model*

The following table describes these parameters:

Parameter	Description	AINR Support	WWD Support	WWD Support	Min	AINR Default	WWD Default	Default GSC	Max
<b>SPI_SPEED</b>	SPI Speed between SPU and Tympan (Hz)	Yes	Yes	Yes	4000 000	16000 000	4000 0000	4000 000	50000 000
<b>VCO_MHZ</b>	SPU Clock Speed (Mhz)	Yes	Yes	Yes	30	200	100	100	250
<b>CORE_GATING_EN</b>	Enable Core Clock Gating (0=off, 1=on)	Yes	No	Yes	0	0	-	0	1
<b>CORE0_READY_US</b>	Core Clock Gating Parameter (us)	Yes	No	Yes	0	0	-	0	-
<b>CORE_TRANSFER_US</b>	Core Clock Gating Parameter (us)	Yes	No	Yes	0	0	-	0	-
<b>SAFETY_MARGIN_US</b>	Core Clock Gating Parameter (us)	Yes	No	Yes	0	0	-	0	-
<b>TOTAL_WAIT_TIME_US</b>	Total wait time before checking for SPU interrupt (us)	Yes	Yes	Yes	0	0	0	0	-
<b>USE_MEMORY_FSM</b>	Enable memory power-saving mode on SPU (0 or 1)	Yes	Yes	Yes	0	0	0	0	1
<b>CLKOD</b>	Default Clock Divider with respect to VCO_MHZ. In AINR, the clock is only divided during non-processing time (during SPI I/O). In WWD and GSC, the clock is only divided during processing time. Must be 1 or even.	Yes	Yes	Yes	0	1	1	1	16
<b>TUNE_DEBUG</b>	Turn on Serial printing of tuning and extra debug data (0=off, 1=on)	Yes	Yes	Yes	0	0	0	0	1
<b>DISABLE_CORE1</b>	Turn off second core if not needed (0=core1 enabled, 1=core1 disabled)	No	Yes	No	0	-	0	-	1
<b>CONFIRM_HOP_SIZE</b>	Checks if the hop size is the expected value. Firmware will error if this differs from the firmware value	Yes	No	No	0	64	-	-	256
<b>USE_EXTERNAL_MIC</b>	Use external mic (0=internal mic, 1=external mic jack, 2=mic header)	Yes	Yes	Yes	0	0	0	0	2

<b>OUTPUT_MAX_GAIN_DB</b>	Maximum output gain on audio output jack (dB)	Yes	No	No	-20.0	0	-	-	40.0
<b>INPUT_GAIN_DB</b>	Input gain from microphone input to SPU (dB, 0.5d Bsteps)	Yes	Yes	Yes	0	25.0	47.5	41.5	47.5

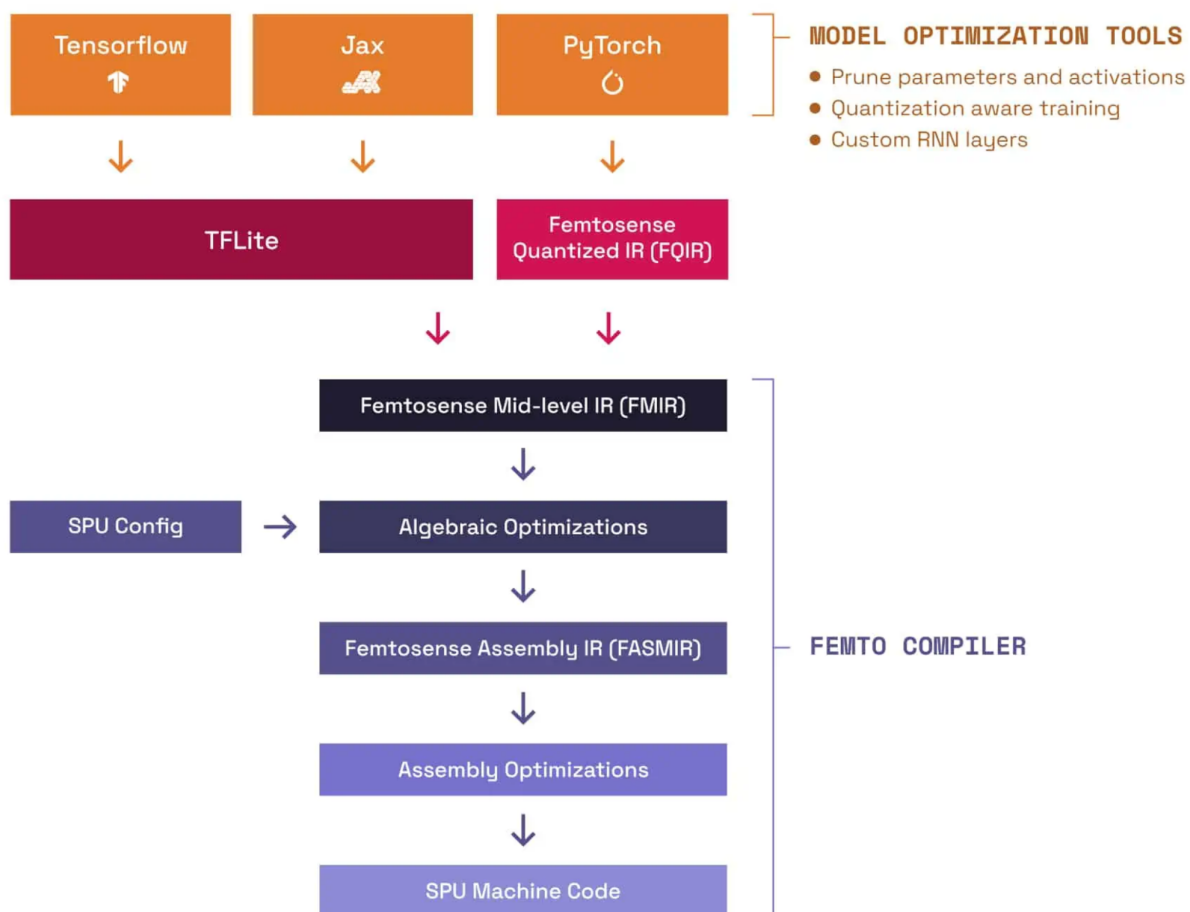
Note that timing and core power parameters (all parameters except those in the last 3 rows of the table above) should not be adjusted unless necessary. The models provided by Femtosense include 0PROG\_P files with good parameters for power optimization.

## 2. For Machine Learning Developers

### 2.1 The SPU Development Kit

Femosense provides a SPU-Development Kit (SPUDKIT) to help users compress and deploy their own models to the EVK or SPU.

Users can use our packages to go from PyTorch or TensorFlow and produce a serialized format of their quantized models. From there, they can use our compiler to produce deployable binaries. The user flow is represented by the graph below:



**Note that these tools are not necessary to run the demos above but rather for developing and deploying your own model to the EVK.**

## 2.2. Setting up the Software Development Kit

FemtoseNSE provides the Python software packages listed below for model development and deployment.

Package	Source	Description	Documentation <sup>1</sup>
<a href="#">fmot</a>	PyPI	The PyTorch frontend for FemtoseNSE	<a href="https://fmot.femtoseNSE.ai/">https://fmot.femtoseNSE.ai/</a>
<a href="#">femtoflow</a>	PyPI	The Tensorflow frontend for FemtoseNSE	<a href="https://femtoflow.femtoseNSE.ai/">https://femtoflow.femtoseNSE.ai/</a>
<a href="#">femtoflux</a>	PyPI	The FemtoseNSE compiler	<a href="https://femtoflux.femtoseNSE.ai/">https://femtoflux.femtoseNSE.ai/</a>
<a href="#">femtodriverpub</a>	Github	Utilities to package up compiler output for firmware	See README in github repository

As prerequisite to installation, you will need the following on your system

- Python version 3.10 or later
- [Docker](#)

Make sure these are installed before installing the FemtoseNSE packages.

FemtoseNSE packages are hosted on the PyPI and can be installed with `pip`. For example,

Unset

```
pip install fmot femtoflow femtoflux
```

Note that when you run `femtoflux` for the first time (or after an update), you will be prompted for a password to download the docker image containing the compiler internals. Contact your FemtoseNSE representative if you do not have or cannot find your password.

`femtodriverpub` is cloned directly from github.

**To deploy a custom model to the EVK, we recommend starting with the [femtoflux documentation](#).**

---

<sup>1</sup> Use your FemtoseNSE-provided password to access the documentation. Contact your FemtoseNSE representative if you cannot find or do not have a password.

## 3. Troubleshooting

### 3.1. LED Codes

The example code includes several error codes to help you debug your EVK. Errors will be displayed as a flashing red LED as follows:

LED Code	Description
green 3x	Bootup was normal
red 1x	This non-blocking error indicates that the <code>0PROG_P</code> parameters file was not found. Default parameters will be used instead.
red 2x	This error indicates that the <code>AUDIO_BLOCK_SAMPLES</code> definition in your <code>AudioStream.h</code> file is too low. It should be increased to at least the value of <code>HOP_SIZE</code> . This file is located at: <code>C:\Users\&lt;USERNAME&gt;\AppData\Local\Arduino15\packages\teensy\hardware\avr\1.57.2\cores\teensy4\AudioStream.h</code> or similar in the Windows operating system.
red 3x	This indicates that the SPU integrity check has failed. Check the connection between the SPU-001 circuit board and the Tympan host. Also, check that all jumpers are correctly installed.
red 4x	This indicates that the programming files cannot be read from the SD card. Make sure that the SD card is inserted and that the two required programming files ( <code>0PROG_A</code> and <code>0PROG_D</code> ) are in the root directory.
red 5x	This indicates that the SPU is not able to receive an input clock signal. Check that the clock jumpers on the SPU are in the correct configuration, and that the clock signal is active if using an external clock.
red 6x	This indicates that the SPU has malfunctioned during processing. If using core power gating, check that timings are correct. Also check that the PLL clock speed is high enough. This error will also occur if you touch the crystal and nearby capacitors on the PCB with your finger. If this error occurs immediately after bootup, check that the model files on the SD card are correct.
Red 7x	This indicates that the <code>CONFIRM_HOP_SIZE</code> value in <code>0PROG_P</code> does not match <code>HOP_SIZE</code> in the firmware. <code>Spu.h</code> in the firmware should be updated with the correct <code>HOP_SIZE</code>
Constant green	This indicates that the SPU is taking too long to process an audio frame. The button will no longer function, and the LED will constantly illuminate green. Increase the PLL clock speed so that the SPU will process the audio frame faster.
Constant red	In WWD or GSC, this means the model is off and static power can be measured.
No LED	In WWD or GSC, the model is listening for the command or wakeword. In AINR, this means the model is off and static power can be measured.

More debug information can be gleaned by connecting a serial terminal to the Tympan host's USB com port at 115200 baud (8-N-1). If the hardware and firmware report normal operation, review the troubleshooting notes below.

### 3.2. AINR Example

#### Objective

The output audio should preserve human speech while removing background noise.

### Troubleshooting

You should expect the algorithm to perform well in positive SNR noise conditions.

If you are experiencing distortions of speech at 0+ dB SNR, make sure that your testing environment is not too reverberant. Adjust the input SNR accordingly to balance the additional background noise caused by reverberation. The input gain of the microphone can be adjusted using the `INPUT_GAIN_DB` definition in `0PROG_P`. The maximum value for this parameter is 47.5, and should be set in 0.5 dB steps.

If the output is too quiet, check the output volume on the headphones and on the Tympan via the knob next to the power switch.

You may also set the value of `OUTPUT_MAX_GAIN_DB` in `0PROG_P` in order to set the max headphone volume level. The maximum value for this parameter is 40.

### 3.3. WWD Example

#### Objective

The green and red LEDs on the Tympan should blink when you pronounce `Hey Snips`, showing that the wake word has been detected.

#### Caveat

As the model has been provided as a proof of concept, it has only been trained and tested on a dataset of the wake word spoken with an American accent. The performance might degrade with different accents.

### Troubleshooting

If the wakeword is not detected in a silent environment in a close-up situation (talking in front of the Tympan), test the model by playing some of the test samples with American accents that we have added [here](#).

The provided firmware sets the microphone gain level to a good initial value. Still, you can adjust the firmware to change microphone gain if desired by adjusting the `INPUT_GAIN_DB` parameter in `0PROG_P`.

### 3.4. GSC Example

#### Objective

The green and red LEDs on the Tympan should blink when you pronounce any of the GSC commands. The number of blinks corresponds to the command spoken. The command will also show in the Tympan USB com port at 115200 baud (8-N-1).

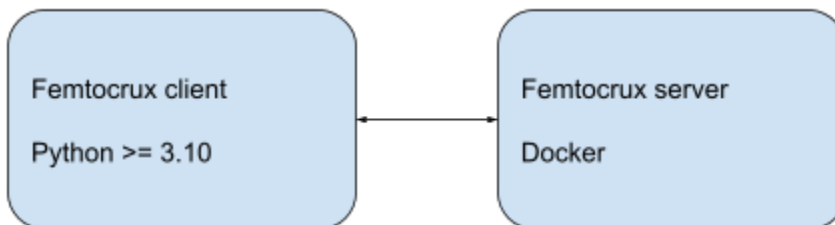
#### Troubleshooting

The provided firmware sets the microphone gain level to a good initial value. Still, you can adjust the firmware to change microphone gain if desired by adjusting the `INPUT_GAIN_DB` parameter in `0PROG_P`.

## A. Appendix

### A.1 Femtocrux Windows Setup Guide

*Note: Femtocrux has been tested on Linux and Window systems. The following guide is for the Windows operating system, but similar steps apply to other systems as well. See [here](#) for the recommended way to install Docker on your system.*



This guide explains how to install Femtosense's Femtocrux compiler on the Windows operating system. There are three main steps.

1. Install Docker, and configure for Linux containers
2. Install Python 3.10
3. Install Femtocrux client and pull Docker image

#### Install and configure Docker Desktop

Femtocrux's backend runs in a Docker Linux container. To run it on a Windows machine, we first need to install Docker Desktop, then configure it to run Linux containers.

#### Install Docker Desktop

First, install Docker Desktop by following these [instructions](#).

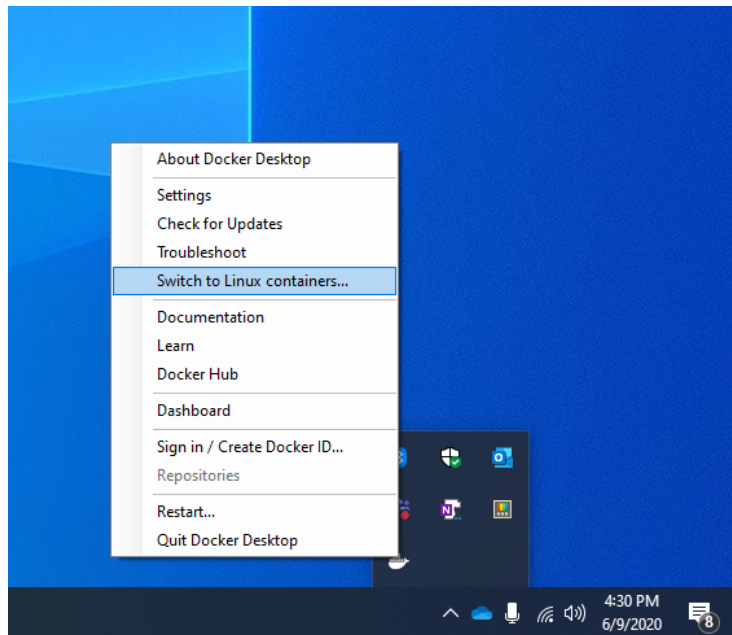
- Download the Docker Desktop installer.
- Click through and install.

- Docker supports two different backends for Windows: WSL and Hyper-V. Some systems only support one or the other. Although both should work, our internal testing uses Hyper-V.

### Configure Docker to use Linux containers

Right click on Docker Desktop, and select “Run as Administrator.” Once Docker Desktop starts, you should see a small whale icon in the taskbar in the lower right corner of your screen.

Next, configure Docker to use Linux containers by right-clicking on the whale icon. See this [guide](#) for more info.



### Install Python 3.10

Femtocrux's client requires Python (version  $\geq 3.10$ ) to run. The installer can be downloaded [here](#). For most systems, we recommend choosing “Windows Installer (64-bit).” Simply download the installer and click through it, choosing to add Python to your system's PATH.

To check that your Python installation is discoverable from the command line, run the command:

```
C:\Users\Administrator>python --version
Python 3.10.11
```

### Install Femtocrux

The following commands install the Femtocrux client and server.

Install Femtocrux client

The Femtocrux client is available on [pypi](#). To install the latest version, run the following command.

Unset

```
python -m pip install femtocrux
```

Install Femtocrux server docker image

To check that Femtocrux works, you can try running the following command.

Unset

```
python -c "from femtocrux import CompilerClient; CompilerClient()"
```

If this is your first time running this version of Femtocrux, you will be prompted to log in to Github Container Registry and pull the Docker image.

```
C:\Users\Administrator>python -c "from femtocrux import CompilerClient; CompilerClient()"
Failed to find the docker image ghcr.io/femtosome/femtocrux:0.2.8-1 locally.

    Attempting to pull docker image from remote.

    Alternatively, you can pull the image yourself with the command:
        docker pull ghcr.io/femtosome/femtocrux:0.2.8-1

Please enter your Femtosense-provided key: _
```

At this point, please copy and paste the password provided to you by Femtosense, and press enter. If authentication succeeds, the client will start pulling the Femtocrux Docker image. This may take a few minutes to complete.

Once the download completes, you can run the same command to verify that the server is working.

```
C:\Users\Administrator>python -c "from femtocrux import CompilerClient; CompilerClient()"
Checking container status...
Container started successfully.
Container passed health check.
Created gRPC channel at 172.22.6.19:50051
Waiting to establish a connection...
Connection successful.
```

## Change Log

Version	Release Date	Description
1.0	2023-06-16	Initial release
1.1	2023-04-05	Changes related to loading 8ms AINR models
1.2	2023-04-13	Added note about Teensy version and ribbon cable arrangement
1.3	2023-04-14	Typo in ribbon cable diagram
1.4	2023-05-03	More documentation about the the SDK, added new error codes, added info on PCB connector board for Tympan
1.4s	2023-05-04	WWD and 16ms model info removed, jumper wire info removed, new error codes added.
1.5s	2023-06-13	Add info about 0PROG_P file and auto mic detect
1.6s	2023-06-16	Added WWD info back, removed non-HW content
1.6	2023-07-23	Added section 1.5 - guide to update new AINR firmware Added section 1.7 - guide to revert to WWD firmware Added section 1.8 - 0PROG_P parameter table Added Appendix A.1 - Femtocrux Windows Setup Guide
1.7	2023-10-18	Fixed missing info in wiring diagram, added 256 hop fix back, added GSC info, updated 0PROG_P parameters table, updated error code table, removed WWD video (blink pattern has changed)