

# USER MANUAL

## FREEDSP-AURORA

## REVISION HISTORY

Revision	Description	Date
v1.0	Initial Version	01 Jul 2019
v1.1	Regulatory Information and WiFi setup rewritten	31 Jul 2019
v1.2	Updating ESP32 firmware via USB	30 Aug 2019

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## ABOUT FREEDSP-AURORA

The freeDSP-aurora is a cost-effective real-time audio signal processing solution for researchers and the do-it-yourself community and audio enthusiasts. It is a bare circuit board that can be incorporated into your own projects. It comes with no housing. Easy assembling and simple programmability are the main focus. It is based on Analog Devices' ADAU1452 DSP chip in bundle with the free graphical application auverdionControl.

Additionally the development environment SigmaStudio can be used. The programming model of SigmaStudio is function-block based – comparable to other graphical programming languages like PureData or Max/MSP. Many prebuilt blocks (e.g., filters, compressors, effects, or logic) can be placed in the signal path via drag and drop. If the included libraries do not have the functions needed, low-level blocks, such as multipliers and delays, can be wired together to create custom DSP plugins. For more information please refer to the Analog Devices website ([https://www.analog.com/en/design-center/evaluation-hardware-and-software/software/ss\\_sigst\\_02.html#software-overview](https://www.analog.com/en/design-center/evaluation-hardware-and-software/software/ss_sigst_02.html#software-overview)).

FreeDSP-aurora offers a wide range of DSP processing options and interface controls with easy programmability. It can be used in various audio applications, e.g.:

- Room compensation / system equalization
- Digital crossovers in active loudspeaker concepts
- Multiband dynamics processing
- Delay compensation / phase shift
- Bass enhancement
- Subwoofer integration
- Advanced instrument audio effect units
- Stereo image widening
- ...

A XMOS XE216-512-TQ128 MCU is used to expose an USB Audio Class 2 compliant interface to a host computer running macOS, Linux or Windows 10. The boards provides 8 balanced audio input and 8 balanced audio output channels. Additionally an ADAT input/output and a Wordclock input/output is provided by the XMOS MCU.

The ESP32 MCU controls the operation of the DSP. Furthermore, it provides WiFi and Bluetooth connectivity and handles peripherals like rotary encoder, display, temperature sensor, PWM controlled fan and IR sensor.

As part of the project the open source software auverdionControl is published that controls the operation of the freeDSP-aurora from macOS, Windows or iOS. Via the control software the user can access all parameters of the uploaded DSP plugin. Due to the open source licenses users can modify the control software for supporting their own DSP plugins.

The complete schematics and all software for the freeDSP-aurora board are published under a Creative Commons Attribution ShareAlike 4.0 International (CC BY-SA 4.0) license, which allows the unrestricted use and modification of the module. This means that experienced users can make their own version of the board, extending it and improving it, as long as they credit freeDSP and auverdion and release their designs under the same license.

The freeDSP brand and freeDSP logo are copyright of Sebastian Merchel and Ludwig Kormann and cannot be used without formal permission.

The auverdion brand is copyright of Raphael Knoop and cannot be used without formal permission.

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## IMPORTANT INFORMATION

The freeDSP-aurora board might generate signals that may damage your audio equipment. Please read and understand this manual before starting to work with your board. Adjust all hardware settings and configure your software before connecting any audio equipment to freeDSP-aurora. Always start with low volume on your amplifier and slowly increase the level to reduce the risk of damaging your audio system.

freeDSP-aurora is provided to you ‘as is’. Auverdion makes no express or implied warranties whatsoever with respect to its functionality, operability, or use, including, without limitation, any implied warranties of merchantability, fitness for a particular purpose, or infringement. We expressly disclaim any liability whatsoever for any direct, indirect, consequential, incidental or special damages, including, without limitation, lost revenues, lost profits, losses resulting from business interruption or loss of data regardless of the form of action or legal theory under which the liability may be asserted, even if advised of the possibility or likelihood of such damages. Features and specifications might change without prior notice.

Please keep in mind that freeDSP-aurora is an open-source project. Because freeDSP-aurora is very flexible, many applications are possible. Questions and new ideas can be discussed online with other DIYers. Please use the *Digital Line Level* subforum @ diyAudio.com or the *Elektronik* subforum @ [www.diy-hifi-forum.eu](http://www.diy-hifi-forum.eu)<sup>1</sup> to connect with other people working with freeDSP-aurora. Please create individual threads for your topics only if you cannot find your issue in the existing threads. Some questions can be answered by carefully reading this manual.

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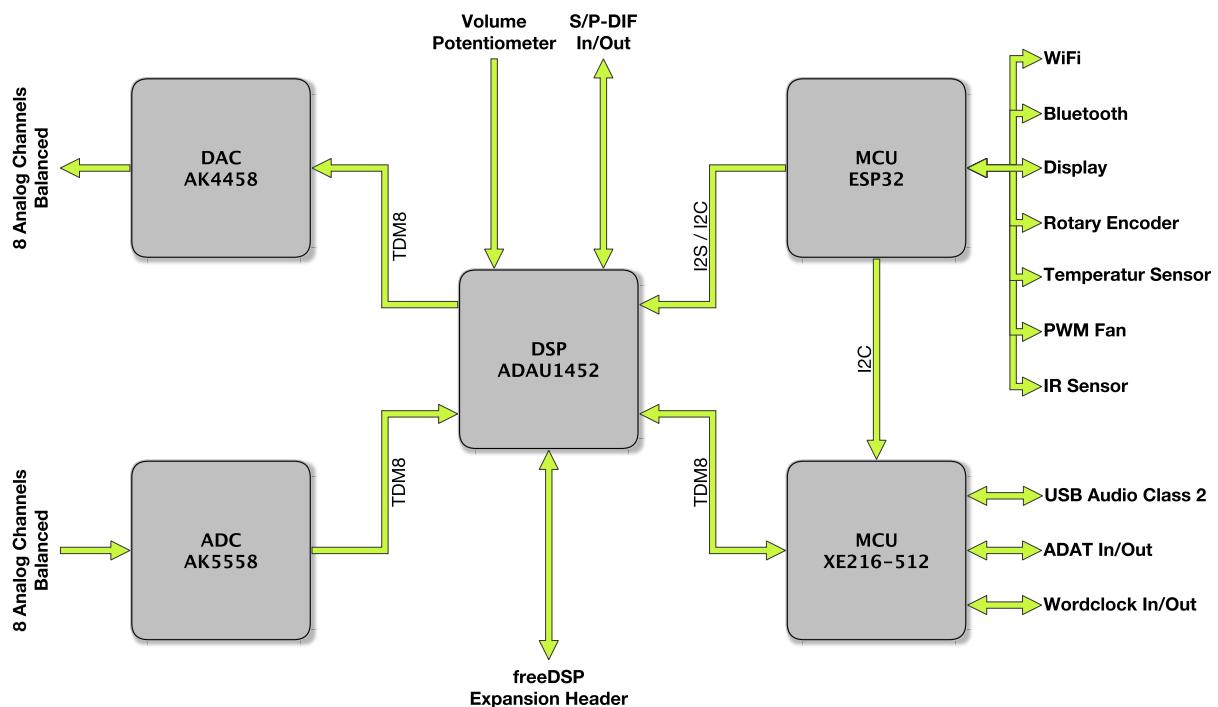
<sup>1</sup> Please see chapter Useful Web Links

## FEATURES

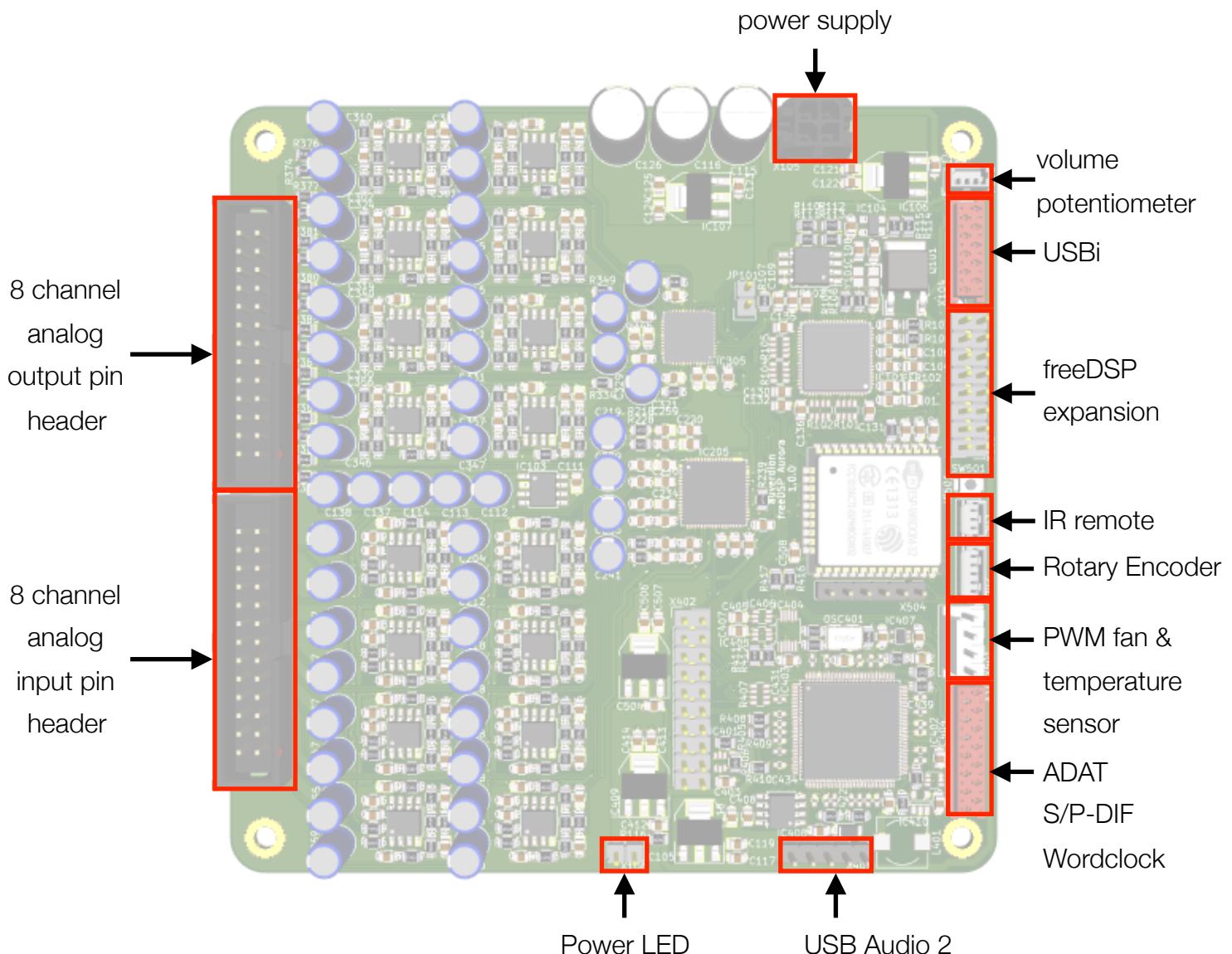
- Analog Devices ADAU1452, 294.912 MHz, 32-bit SigmaDSP
  - 6144 SIMD instructions per sample @ 48 kHz fs
  - 40kWords of data RAM
  - 800 ms digital audio delay pool @ 48 kHz fs
  - 8 stereo ASRCs with 139 dB DNR
- XMOS XE216-512-TQ128 for multichannel bidirectional audio streaming
- ESP32 for WiFi or Bluetooth control
- AKM AK4458 32bit-DAC
- AKM AK5558 32bit-ADC
- Supporting sample rates between 44.1 kHz and 192 kHz
- 8 analog balanced input channels, +6 dBu
- 8 analog balanced output channels, +6 dBu
- S/P-DIF input and output
- ADAT input and output
- Wordclock input and output
- Support for display, rotary encoder, volume potentiometer, temperature sensor, PWM controlled fan, IR sensor
- One freeDSP expansion header
- USB Audio Class 2 Bidirectional streaming with 8 channels in and 8 channels out, full-duplex. Works with ASIO driver under Windows 10 and driverless under macOS and Linux.
- Realtime control software for Windows, macOS, iOS; all available under an open source license.
- Connection to board by WiFi
- Board dimensions: 110 mm x 110 mm

# SYSTEM INFORMATION

## BLOCK DIAGRAM



## CONNECTORS



## RECOMMENDED OPERATING CONDITIONS

Item	Min	Typ	Max	Unit	Notes
Supply Voltage	6.5	7	12	Vdc	
Input Level		6		dBu	Might be changed by AddOn
Output Level		6		dBu	Might be changed by AddOn

Note: Stresses beyond those listed in the table above may cause permanent damage to the device.

FreeDSP-aurora has to be placed in an enclosure with enough airflow. Please mount the PCB with spacers on a solid surface. None of the four mounting holes is connected to any voltage or signal on the board.

## OPTIONAL INPUT AND OUTPUT ADDONS

FreeDSP-aurora was designed to support as many applications as possible. Therefore, all inputs and outputs are on pin headers or ribbon cable connectors. This way user can adapt the front-ends to their needs. Some add-on boards will be available for this project. These boards will cover the most common used input output configurations, e.g. active multi-way loudspeaker or an 8 channel loudspeaker management or buttons and displays for user interaction. Please check the github repository and/or the website for information about the add-on boards.

# HOW TO GET FREEDSP-AURORA UP AND RUNNING

## HARDWARE INSTALLATION

Before you can use freeDSP-aurora you may have to do some hardware connections. The connections vary with desired application. Not all connections are always needed.

### Analog Audio Connections

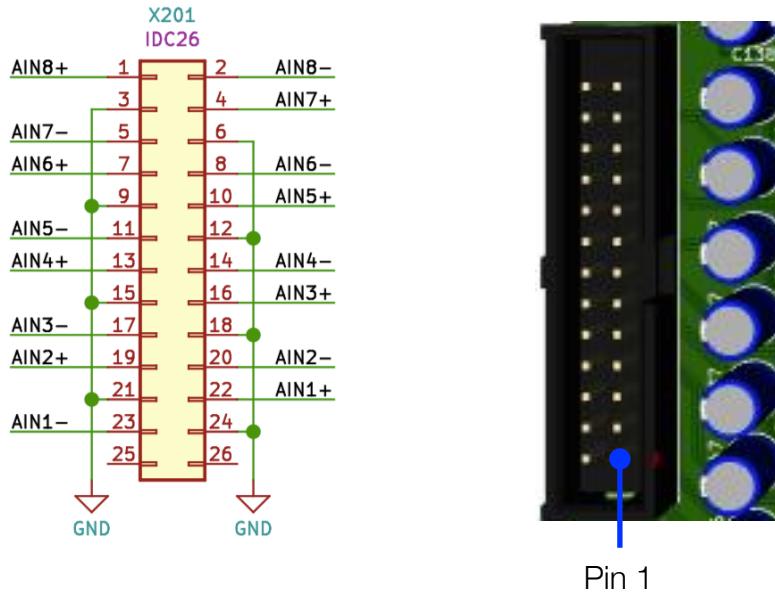
Analog audio input connections can be made on pin header X201. The audio inputs are designed for balanced operation at +6 dBu maximum input level. Unbalanced sources can be connected as well by grounding the negative input. In the latter case you may have to change the gain of the input stage to improve the signal to noise ratio. Alternatively you may want to use a conversion circuit if your audio sources use a different connection (e.g. unbalanced) or have another level.

Analog audio output connections can be made on pin header X301. The audio outputs are designed for balanced operation at +6 dBu maximum output level. In case of unbalanced sinks leave the negative output unconnected. In the latter case you may have to change the gain of the output stage to improve the signal to noise ratio. Alternatively you may want to use a conversion circuit if your audio sinks use a different connection (e.g. unbalanced) or have another level.

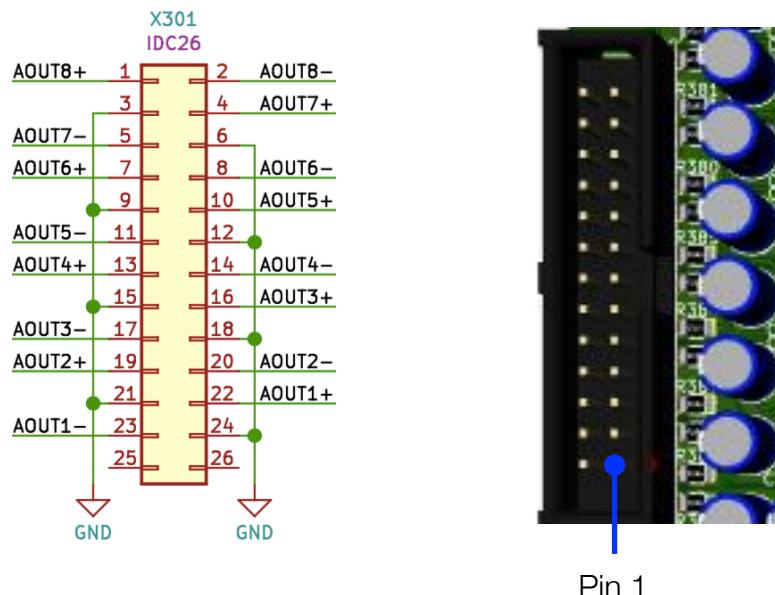
When making audio connections, make sure that your equipment is powered off to avoid any damage.

The gain of the analog audio input and output stage can only be changed by changing the resistors on the board to another value.

**Connector:** IDC26, 2.54 mm Pitch, Bud Industries, BC-32677



Pinout Analog Input

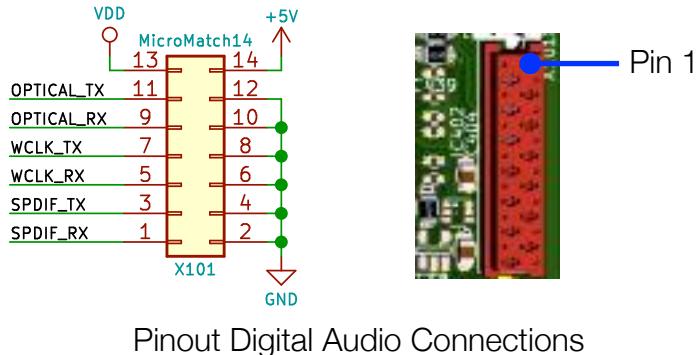


Pinout Analog Output

## Digital Audio Connections

On connector X101 you can make your digital audio connections like S/P-DIF input and output and ADAT input and output. Wordclock input and output can be connected to X101, too.

**Connector:** MicroMatch-14, 2.54 mm pitch, TE Connectivity AMP Connectors, 1-215079-4

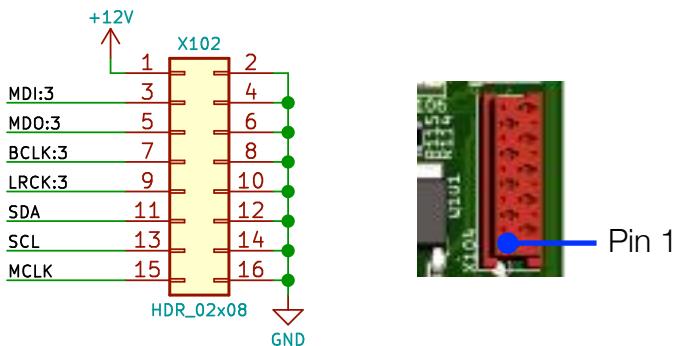


Pinout Digital Audio Connections

## FreeDSP Expansion Header

X102 is the an expansion header for additional input and output boards. The pinout complies with the I2S expansion header specification of the freeDSP project. If you want to connect a I2C display please connect it to this header, too.

**Connector:** Header 2 x 8 pos, 2.54 mm pitch, Sullins Connector Solutions, PRPC008DAAN-RC



Pinout freeDSP Expansion Header

## Fan and Temperature Sensor

On connector X501 you can connect a PWM controlled fan. Please use the Sense pin to connect a temperature sensor (e.g. NTC).

**Connector:** KK-100, 4 pos, 2.54 mm pitch, Molex, 0022232041



Pinout Fan and Temperature Sensor

## Rotary Encoder

On connector X502 you can connect a rotary encoder with or without a push button.

**Connector:** PicoBlade, 5 pos, 1.25 mm pitch, Molex, 530470510

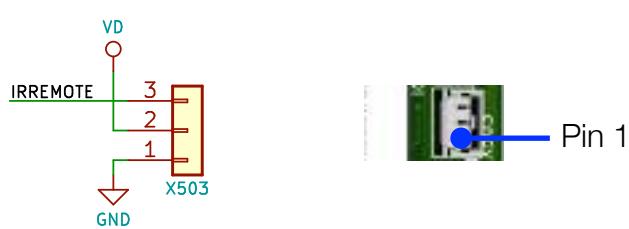


Pinout Rotary Encoder

## IR Sensor

On connector X503 you can connect an infra red receiving diode.

**Connector:** PicoBlade, 3 pos, 1.25 mm pitch, Molex, 530470310



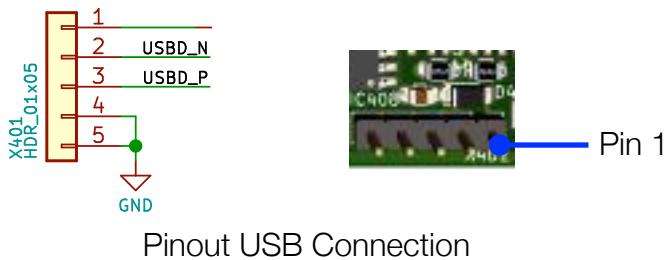
Pinout IR Sensor

## USB Connection

Your host computer connects on the pin header X401. Please use a common off-the-shelf cable assemblies (typically used in computer hardware). Always confirm the pin-out with the manufacturer, or you could easily cause damage to your computer or freeDSP-aurora.

Usually the GND-pins 4 and 5 can be identified by a black wire, but you can never be sure unless you checked the manufacturer's specifications of the connector.

**Connector:** Header, 5 pos, 2.54 mm pitch, Sullins Connector Solutions, PRPC005SAAN-RC



Pinout USB Connection

## Power LED

On this connector you can connect a LED to show the power on/off status.

**Connector:** Header, 2 pos, 2.54 mm pitch, Wurth Electronics Inc., 61300211121



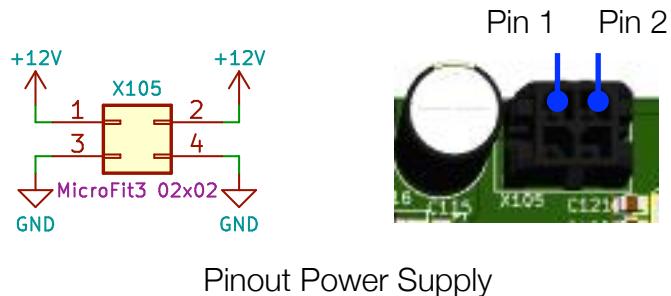
Pinout Power LED

## Power Supply

freeDSP-aurora needs a power supply on X105. Together with the board you received a power cable. The white wires identify the positive voltage, the black wires are GND.

Attention: Apply power to the board only after all connections have been made and you have double-checked everything.

**Connector:** MicroFit, 2 x 2 pos, 3 mm pitch, Molex, 0430450428



Pinout Power Supply

## SOFTWARE INSTALLATION

### USB Driver Installation

FreeDSP-aurora was designed to be class compliant with UAC2. Thus, on macOS and Linux you don't need to install any driver. Windows 10 comes with a UAC2 driver as well but you may have to install additional stuff like the free software asio4all and your audio software needs to support ASIO. Please note, that ASIO is only needed if you want to use the 8 input channels for recording audio. If you just want to use freeDSP-aurora to stream audio data to your audio equipment, ASIO is not needed and you can skip the asio4all installation.

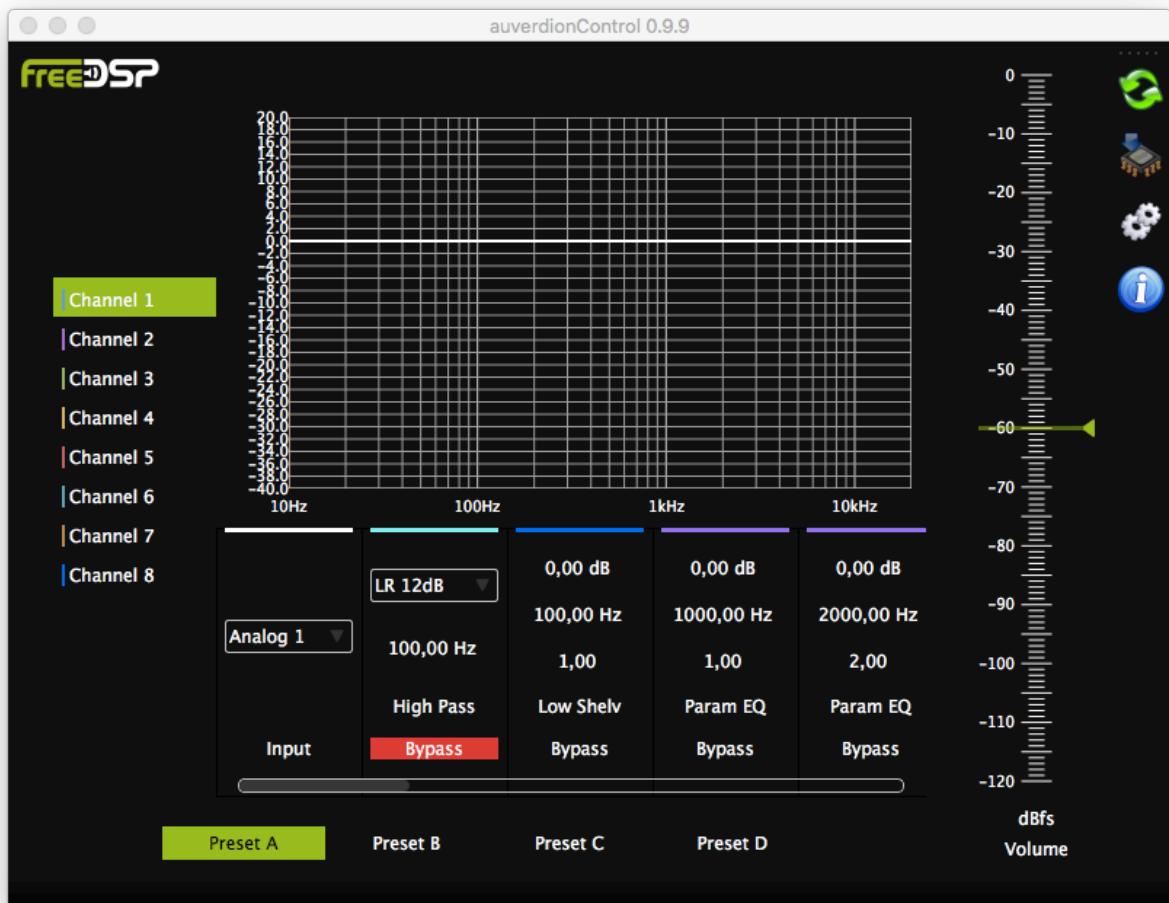
### Installation of auverdionControl

Please download the latest version of auverdionControl for your operating system from here  
<https://github.com/freeDSP/freeDSP-aurora/releases>

and follow the instructions of the installer.

## WORKING WITH AUVERDIONCONTROL

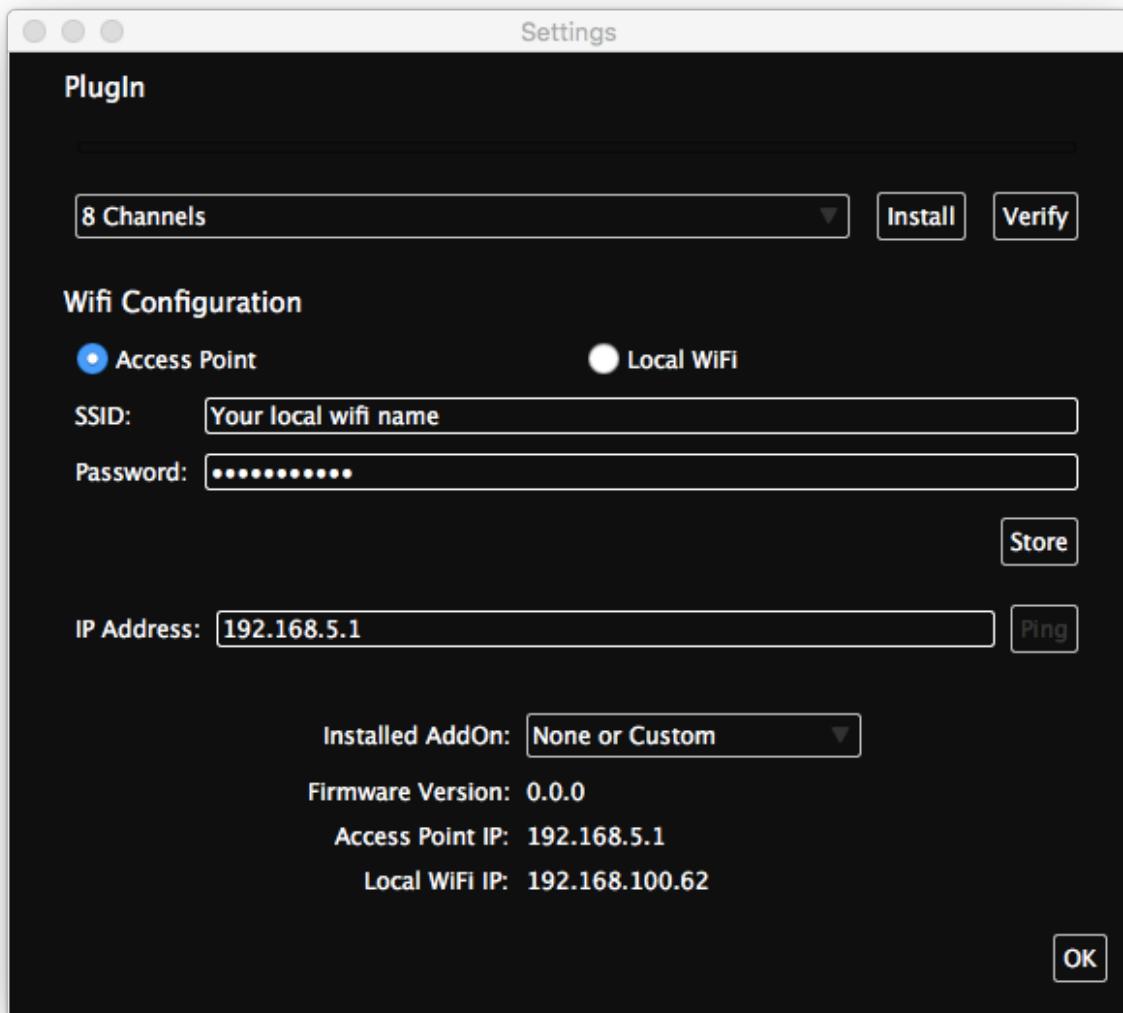
As part of the project the open source software auverdionControl is published that controls the operation of the freeDSP-aurora. With auverdionControl you can configure and control the operation of your freeDSP-aurora and upload new DSP plugins to it. AuverdionControl communicates via WiFi with freeDSP-aurora.



## WIFI CONFIGURATION

When you power up freeDSP-aurora for the first time or after updating the ESP32 firmware you can connect with your board only by an ad-hoc wifi connection. Therefore, the access point *AP-freeDSP-aurora* is provided by the board. Please refer to the documentation of your operating system for how to establish an ad-hoc WiFi connection for your computer<sup>2</sup>.

Once you have connected to the board launch auverdionControl and click on  to open the settings dialog:



<sup>2</sup> See chapter Useful Web Links

If you select the *Access Point* option, auverdionControl communicates with your freeDSP-aurora via the access point provided by freeDSP-aurora. By selecting the option *Local WiFi*, auverdionControl communicates with your freeDSP-aurora via your local WiFi network. You can switch between the *Access Point* and *Local WiFi* options at any time.

First select the *Access Point* option (your computer should still be connected to it). Now you can enter the SSID and password of your local WiFi network. When you click on *Store*, the settings are transferred to freeDSP-aurora and freeDSP-aurora tries to connect to the local WiFi. If this is successful, the IP address freeDSP-aurora received from your WiFi router will be displayed in the *IP Address Local* line.

You can reconnect to the AP-freeDSP-aurora access point at any time to enter a different SSID and password, e.g. if you want to integrate freeDSP-aurora into another network.

As soon as you select the *Local WiFi* option, auverdionControl communicates with freeDSP-aurora via the new IP address in the local WiFi network<sup>3</sup>.

You can overwrite the IP address by entering another address in the IP address text box. This is useful if there are several freeDSP-aurora on the same network and you want to communicate with another freeDSP-aurora using one auverdionControl.

You can switch between access point mode and local WiFi mode at any time, but you may have to reconnect your computer to the corresponding network (access point or local WiFi) first.

Even if freeDSP-Aurora cannot connect to the local WiFi network later (e.g. because the SSID or password has changed), the AP-freeDSP-aurora access point will always be provided for a connection.

## INSTALLING A DSP PLUGIN

A new freeDSP-aurora comes with the 8 Channels DSP plugin installed. If you want to install another DSP plugin open the settings dialog and select the desired DSP plugin from the drop-down list. Now click on *Install* and the selected DSP plugin will be uploaded to your freeDSP-aurora.

If you just want to verify that the installed DSP plugin on the board is equal with the selected one click on *Verify*.

---

<sup>3</sup> On some systems you have to disconnect your adhoc connection first and reconnect to the same WiFi network as freeDSP-aurora is connected to.

Please reboot your freeDSP-aurora by a power off-on cycle after a successful installation of a new plugin.

## INSTALLING AN ADDON

When you connect an AddOn you have to inform freeDSP-aurora about the AddOn to make use of all features that might be added by the AddOn. Some AddOns may change audio input and/or output configurations and you probably want to see these changes in auverdionControl when selecting an audio channel.

Therefore, open the settings dialog and select you desired AddOn from the drop-down list *Installed AddOn*. Your choice will be stored on the freeDSP-aurora board.

## SYNCHRONIZING WITH FREEDSP-AURORA

Before you can make settings to your freeDSP-aurora auverdionControl needs to connect and synchronize with your DSP. Therefore, click on  and auverdionControl will connect to freeDSP-aurora and request all parameters for each preset stored on your freeDSP-aurora board.

## STORING PARAMETER SETTINGS

Every parameter change you do is sent to your freeDSP-aurora board. You can immediately hear your changes. Yet your changes are not stored non-volatile on your freeDSP-aurora board. Once you cycle power off and on your settings will be lost.

If you are satisfied with your settings and you want to store them on your freeDSP-aurora board you have to click on . This will upload all settings for each preset to your freeDSP-aurora board. After rebooting the freeDSP-aurora by a power off-on cycle the new settings are loaded into the DSP.

Please note:  becomes only enabled after you have connected and synchronized with your freeDSP-aurora board.

## MASTER VOLUME

With the volume slider on the right side you can set the master volume on all output channels. This is the global master volume for all presets.

Please note: The master volume setting is only stored non-volatile on your freeDSP-aurora board when you click on .

## USING PRESETS

If you click on a preset on the bottom your freeDSP-aurora will load the preset and auverdionControl will switch to this preset. You can now make changes to the selected preset. All changes to a preset are volatile and will be lost when you select another preset. If you want to store the changes you made to a preset you click on  before you switch to another preset.

Please note: If you want your freeDSP-aurora to boot with a certain preset you have to click on  while the desired preset is selected.

## SWITCHING CHANNELS

Most of the DSP plugins support multiple channels. These can be switched on the left side. Settings you have made to another channel before remain valid.

By right-clicking on the frequency response plot you can select which channels are displayed in the frequency response plot for the currently selected channel. This helps you to see how the settings of several channels sum up to a resulting frequency response when you are e.g. building an active loudspeaker.

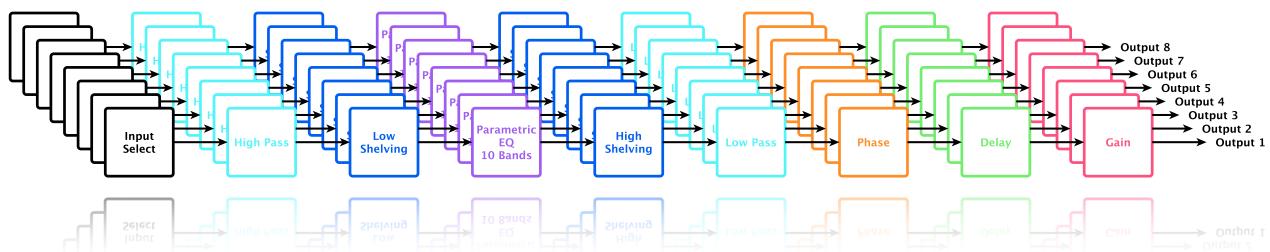
## ABOUT DIALOG

To view the license and the current version of auverdionControl click on . This opens the About dialog with some useful information about your app.

## DSP PLUGINS

### 8CHANNELS

The 8channels DSP plugin is the default DSP plugin for any new freeDSP-aurora. It provides eight channel strips with identical configuration.



Block diagram of 8channels plugin

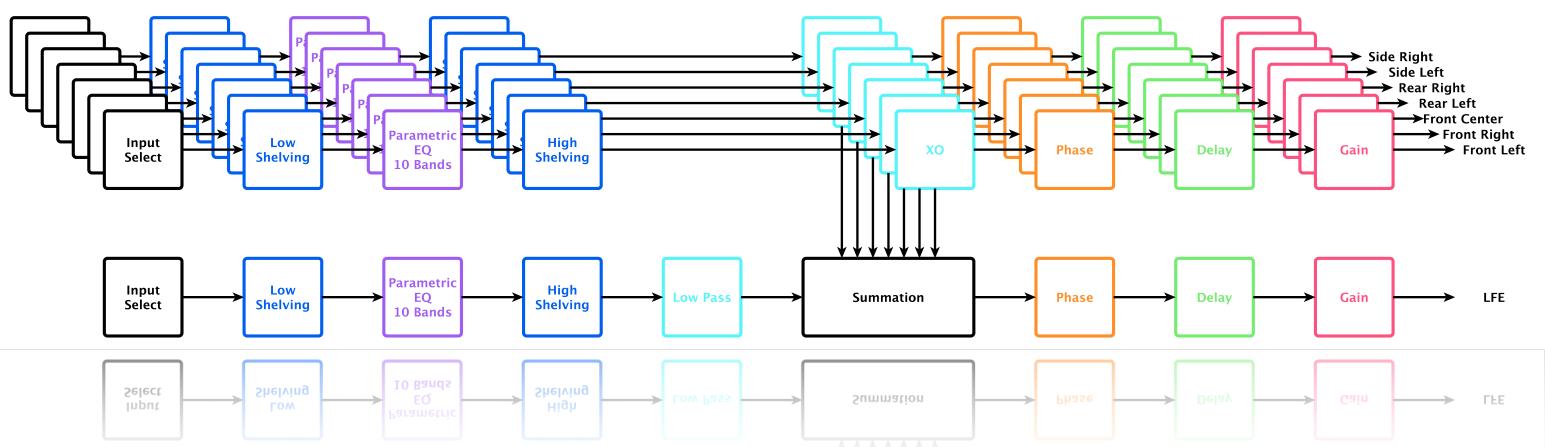
Each channel holds:

- input channel select
- low shelving and high shelving filter
- lowpass and highpass filter up to 48 dB/oct roll off steepness
- 10 parametric EQs
- Allpass filter
- Polarity Inversion
- Delay up to 100 ms per channel
- Gain

## HOME CINEMA 7.1

The Homecinema71 DSP plugin is a speaker management for your home cinema. It consists of 7 satellite channels and 1 subwoofer channel.

Each satellite channel contains a crossover formed by a highpass and a lowpass filter. The output of the highpass filter is forwarded to the following signal processing blocks of the channel while the output of the lowpass filter is mixed into the subwoofer channel.



Block diagram of Homecinema71 plugin

Each satellite channel holds:

- input channel select
- low shelving and high shelving filter
- 10 parametric EQs
- crossover with lowpass and highpass filter up to 48 dB/oct roll off steepness
- Allpass filter
- Polarity Inversion
- Delay up to 100 ms per channel
- Gain

The subwoofer channel holds:

- input channel select
- low shelving and high shelving filter
- 10 parametric EQs

- lowpass filter up to 48 dB/oct roll off steepness
- insert point for satellite lowpass output sum
- Allpass filter
- Polarity Inversion
- Delay up to 100 ms per channel
- Gain

## UPDATING THE FIRMWARE VIA USB

FreeDSP-aurora was designed to grow and improve in the future. Therefore, you may want to update the firmware of the board as soon as new features or bugfixes have been published. This chapter guides you through all the steps to perform a firmware update via a USB connection.

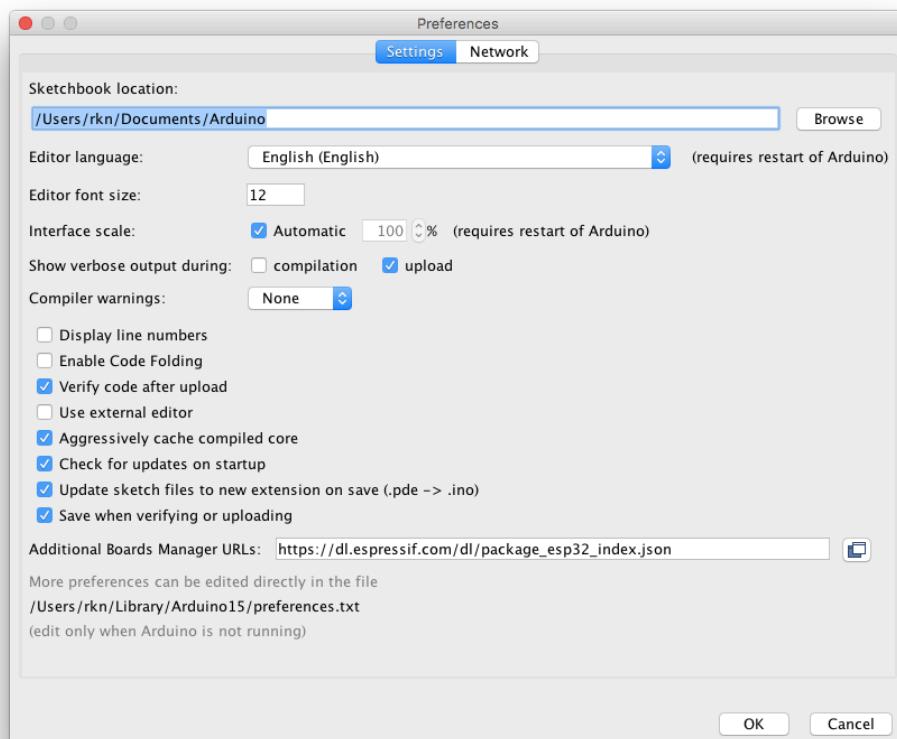
### PREPARING FOR UPDATE

For updating the firmware you need an USB2Serial module based on a FTx232 or CP2102N module, e.g.

[https://www.ftdichip.com/Products/Modules/DevelopmentModules.htm#FT2232H\\_Mini](https://www.ftdichip.com/Products/Modules/DevelopmentModules.htm#FT2232H_Mini) or similar.

If you have never updated the firmware of your freeDSP-aurora before you need to do some tasks in advance:

1. Download and install the Arduino IDE from <https://www.arduino.cc> without charge.
2. Start the Arduino IDE and open the Preferences dialog and insert [https://dl.espressif.com/dl/package\\_esp32\\_index.json](https://dl.espressif.com/dl/package_esp32_index.json) for the Additional Boards Manager URLs and click OK. Then close the Arduino IDE.

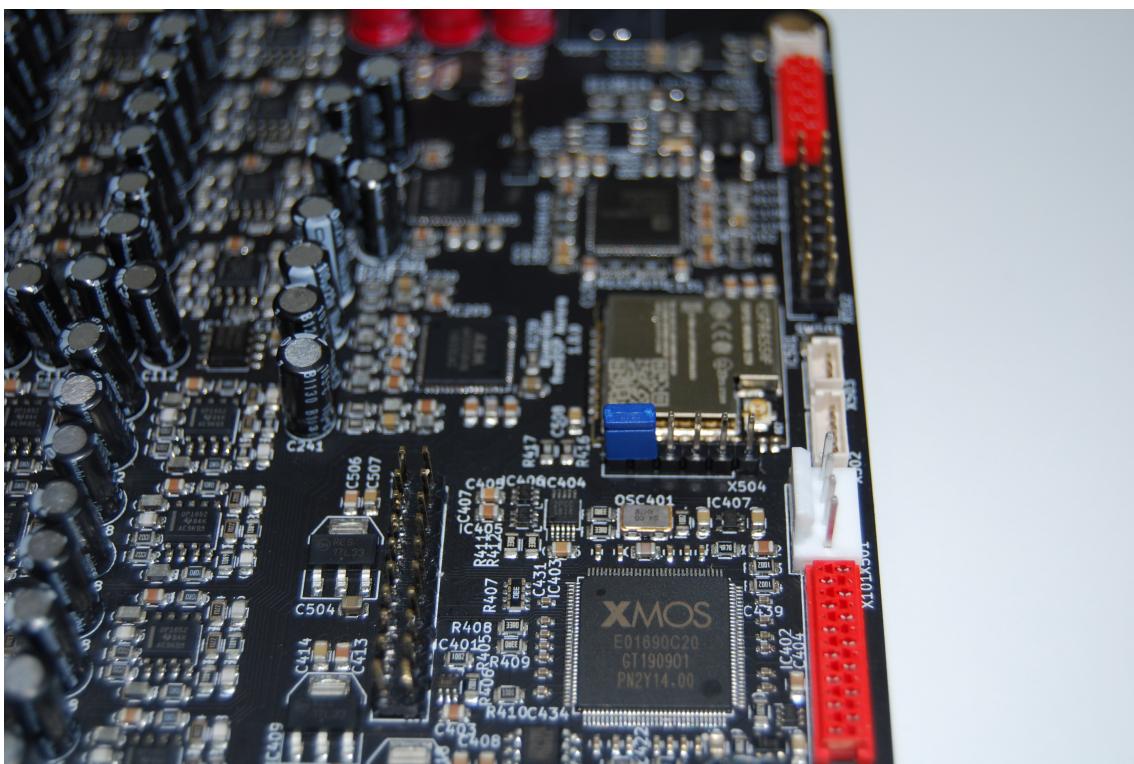


3. Install the ESP32 toolchain by following the install instructions for your operating system described here:  
<https://github.com/espressif/arduino-esp32#installation-instructions>
  4. After download was completed and you restarted Arduino IDE you should see several ESP32-boards under *Tools->Board*. Please select *ESP Dev Module*.

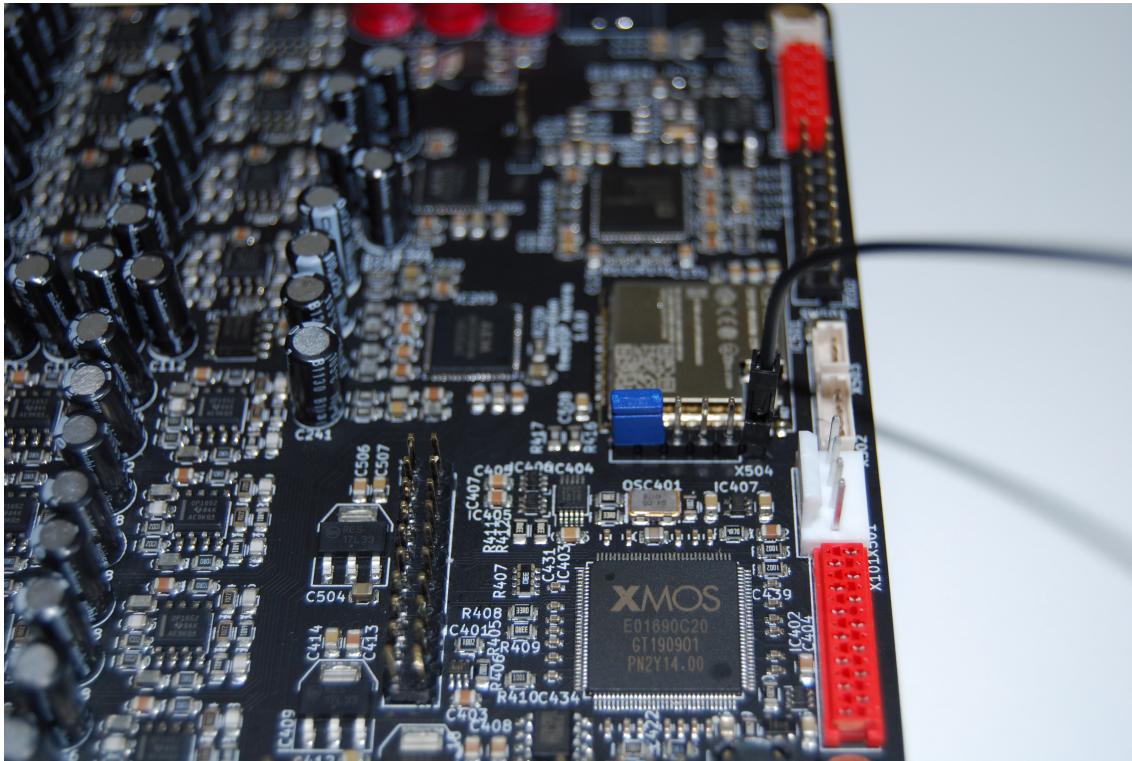
## UPLOADING THE FIRMWARE

For uploading a new firmware to your freeDSP-aurora do the following steps:

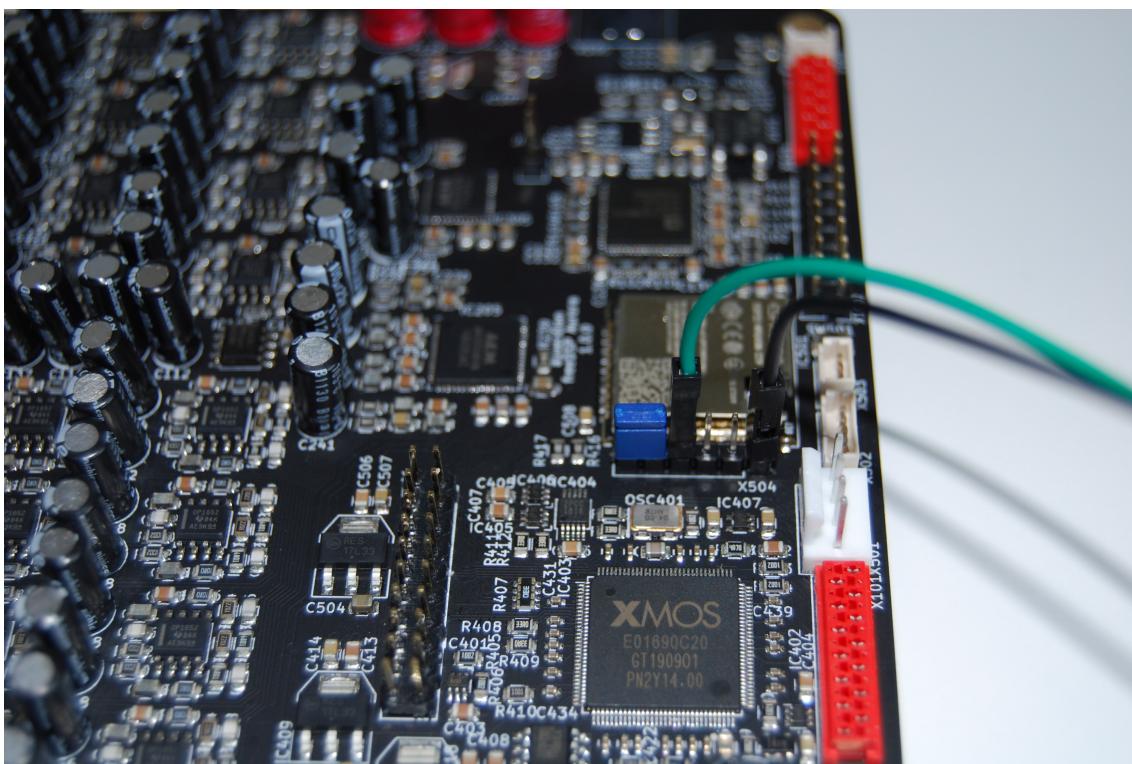
1. Download the latest release from github: <https://github.com/freeDSP/freeDSP-aurora>
  2. Open the Arduino IDE and open <freeDSP-aurora-repository>/SOURCES/ESP32/aurora.ino.
  3. Power off your freeDSP-aurora module.
  4. Install a jumper or make a connection between pin 5 and 6 of X504.



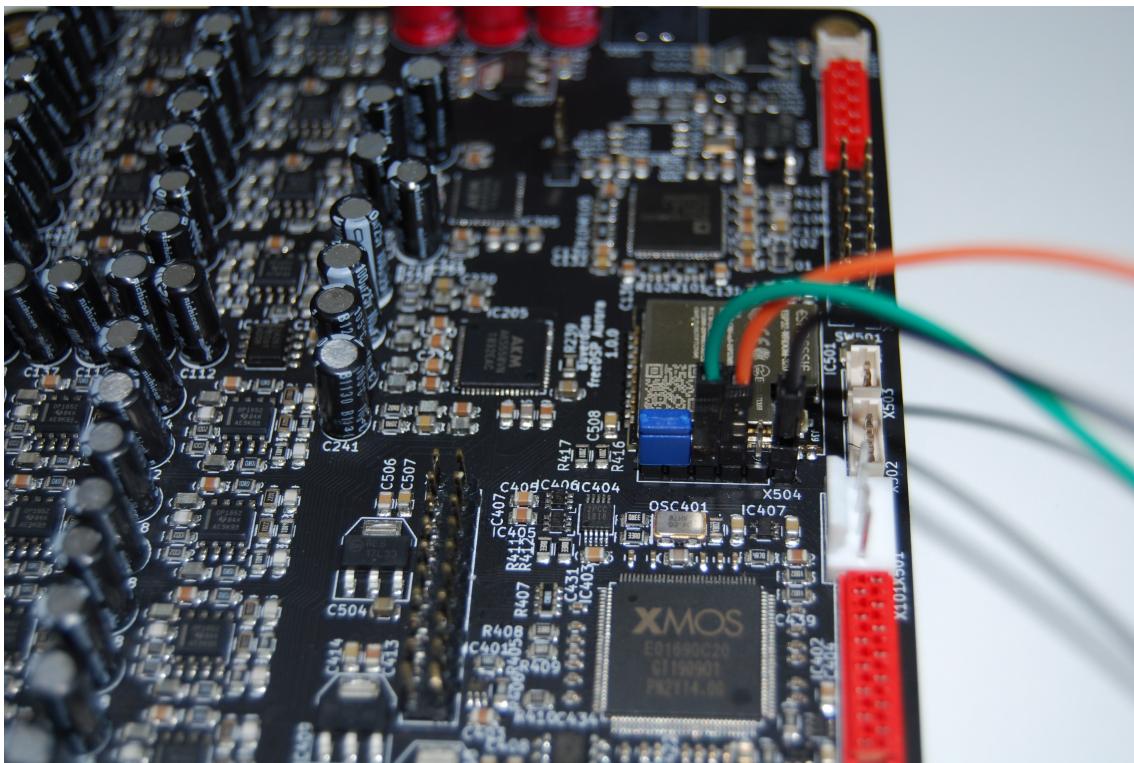
5. Connect GND of your USB2Serial module with pin 1 of X504.



6. Connect TXD of your USB2Serial module with pin 4 of X504.

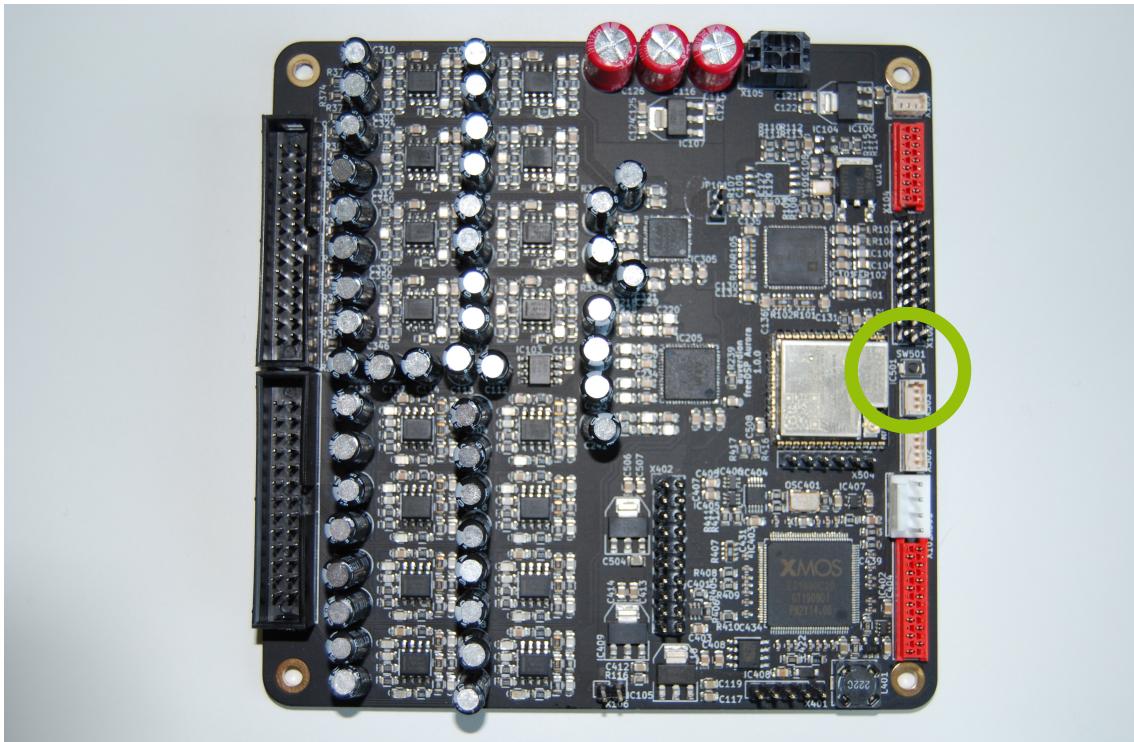


7. Connect RXD of your USB2Serial module with pin 3 of X504.



8. Connect your USB2Serial module with your computer and select it in your Arduino IDE (Menu *Tools->Port*).
  9. Open the serial monitor of your Arduino IDE (*Tools->Serial Monitor*).
  10. Power up your freeDSP-aurora.

11. Push and release button SW501.



12. You should now see the following message in the serial monitor of your Arduino IDE:

```
ets Jun  8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x3 (DOWNLOAD_BOOT(UART0/UART1/SDIO_RESET))
waiting for download
```

The screenshot shows the Arduino Serial Monitor interface. The top bar displays the port name "/dev/cu.SLAB\_USBtoUART". Below the port name is a "Senden" (Send) button. The main text area contains the boot log from the microcontroller. At the bottom, there are several configuration buttons: "Autoscroll" (checked), "Zeitstempel anzeigen" (unchecked), "Neue Zeile" (New Line), "115200 Baud" (Baud rate dropdown), and "Ausgabe löschen" (Clear Output).

If not double check your wiring. Very often RXD and TXD have been wrongly connected. Swap TXD and RXD cables on X504 and press SW501 to try again.

13. Now in your Arduino IDE click on *Sketch->Upload*. The Arduino IDE will now install the new firmware on your freeDSP-aurora.
14. After the upload has successfully finished remove all the cables and the jumper from X504. After powering off and on your freeDSP-aurora will boot with the new firmware.  
Tip: If you only remove the jumper from pin 5 and 6 you can see the boot messages from your freeDSP-aurora in the serial monitor of Arduino IDE.

## DISCLAIMER

All products, product specifications and data are subject to change without notice to improve reliability, function or design or otherwise.

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Life support policy: Use of auverdion products in life support equipment or equipment whose failure can reasonably be expected to result in injury or death is not permitted.

## WARRANTY

Auverdion warrants freeDSP-aurora to be free from all provable material and production defects for the duration of 12 months starting from sales. All damage, which is caused by wrong or inappropriate operation, incorrect connection, improper or undocumented use, modification or alteration of the board in any way is excluded from the warranty.

## REGULATORY INFORMATION

The product complies with the basic requirements of the relevant EU directives as well as the directive 2011/65/EU (RoHS) and directive 2004/108/EU (EMC) and directive 2014/53/EU (RED).

A copy of the full Declaration of Conformity may be requested by mail.

## USEFUL WEB LINKS

Please visit <https://github.com/freeDSP/freeDSP-AURORA> for updates, bugfixes and new DSP plugins.

The development story of freeDSP-aurora:

<https://www.diy-hifi-forum.eu/forum/showthread.php?15019-Verst%E4rkermodul-mit-DSP-600W-1-4Kan%E4le-low-budget-high-quality>

FreeDSP-aurora at [diyaudio.com](http://diyaudio.com):

<https://www.diyaudio.com/forums/digital-line-level/334055-freedsp-aurora-dsp-8-os-usb-audio-dif-adat-bluetooth-wifi-contro.html>

The freeDSP project:

<http://www.freedsp.cc>

How to connect to a wireless access point on iOS:

<https://support.apple.com/en-us/HT202639>

How to connect to a wireless access point on macOS:

<https://support.apple.com/en-us/HT201735>

How to connect to a wireless access point on windows 7/10:

<https://ittutorials.net/microsoft/windows-7/how-to-connect-to-a-wireless-access-point-in-windows-7/>

Enjoy your freeDSP-aurora!