TBPI Audio Module User Manual

Version 1.00 – 6th January 2024
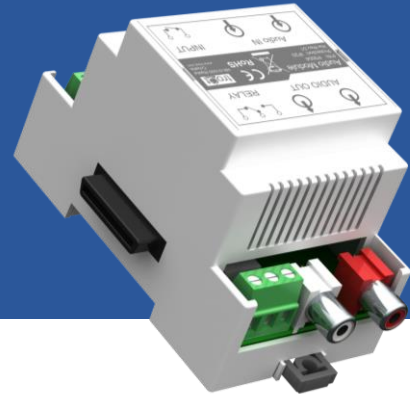
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2.   Introduction

TBPI Audio module is modular, easy to use audio coded expansion for TeddyBearPi compute module hardware, designed to help individuals, professionals, and companies in the development of various market products.

Various expansion modules enable rapid software and hardware development for home, IoT, light industrial or industrial installations.

Enclosure of the unit is snap fit modular design, molded in light grey UL94-V0 flame retardant polycarbonate designed for 35mm DIN rail installation or mounted directly to flat surface. Enclosures are designed to ensure sufficient cooling of the unit, either by ventilation grids for passive cooling or closed design to ensure air flow direction.

The electrical interface of the TBPI Audio Module to TeddyBearPi Module via 32-pin expansion connector, providing connections for Power, 2S, GPIO, UART, I2C, SPI and other interfaces.

3.   Features

TBPI Audio Module has following features:

- 24-bit high quality audio ADC
- 100 dB SNR stereo audio playback
- Low-power PLL provides system clocking and audio sample rate flexibility
- I2S/PCM Digital Audio Interface (DAI) supports sample rates between 8 kHz and 96 kHz
- Built-in 5-band equalizer, ALC and noise-gate functions
- Ultra-Low Power Always-On mode 650µW
- Built-in beep generator
- Integrated system controller to eliminate pops and clicks
- Wall/Desk or DIN rail mounting

3.1.   Block diagram
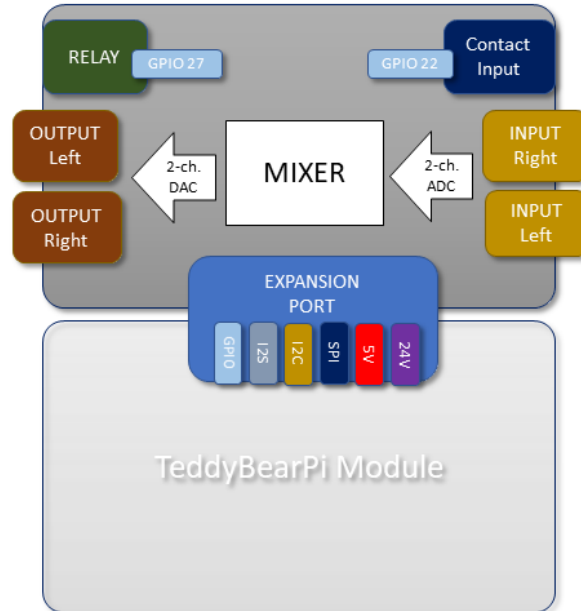
3.2.   Board layout

TBPI Audio Module has following layout
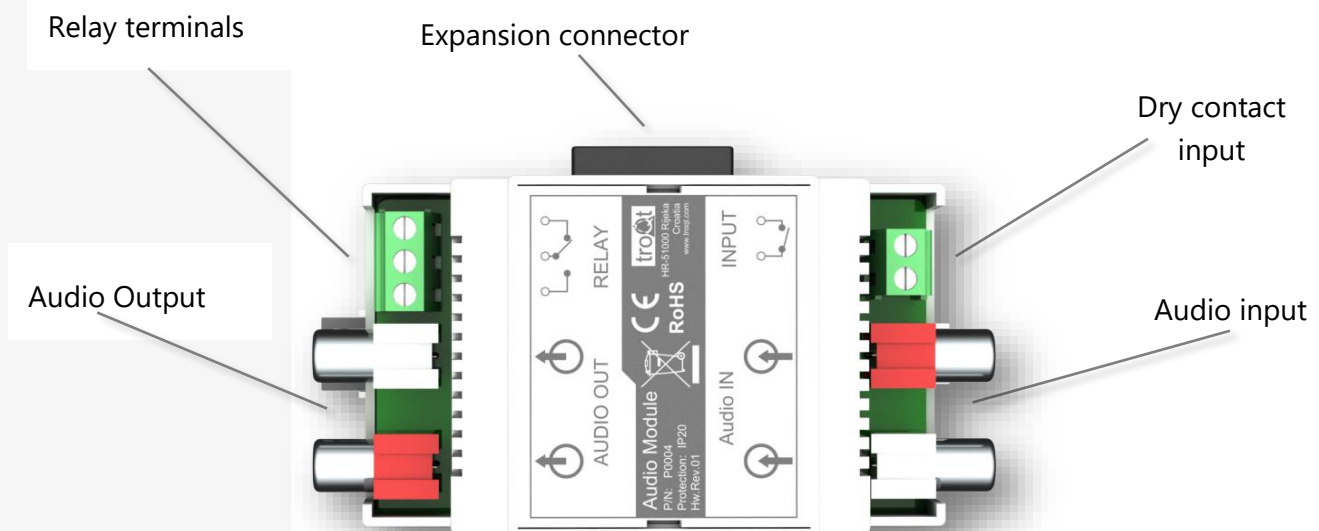
3.3. Technical specification

Enclosure dimensions (DxWxH mm)	90 x 53 x 58 mm
Enclosure material	UL94-V0 flame retardant polycarbonate
Color	Light grey
Mount type	35mm DIN-Rail or Wall/Desk mounting
Weight	75g
IP protection	IP20
Working Temperature	-20℃ to 40℃
Power supply	Powered from TBPI Module
Max. power consumption	50mA

3.4. ADC specification

TBPI Audio Module has following ADC values

Vmax Full-scale input signal	5,28V @ Digital output level = 0 dBFS
SNR Signal to noise ratio	90 dB A-weighted no input selected
THD+N Total harmonic distortion plus noise	-85 dB 44.1 kHz slave mode
Group delay mismatch between channels	2 µs

3.5. DAC specification

TBPI Audio Module has following DAC values

Vmax Full-scale input signal	Vmax Full-scale input signal
SNR Signal to noise ratio	100 dB A-weighted no input selected
THD+N Total harmonic distortion plus noise	-90 dB 44.1 kHz slave mode
Group delay mismatch between channels	2 µs

3.6. Mechanical
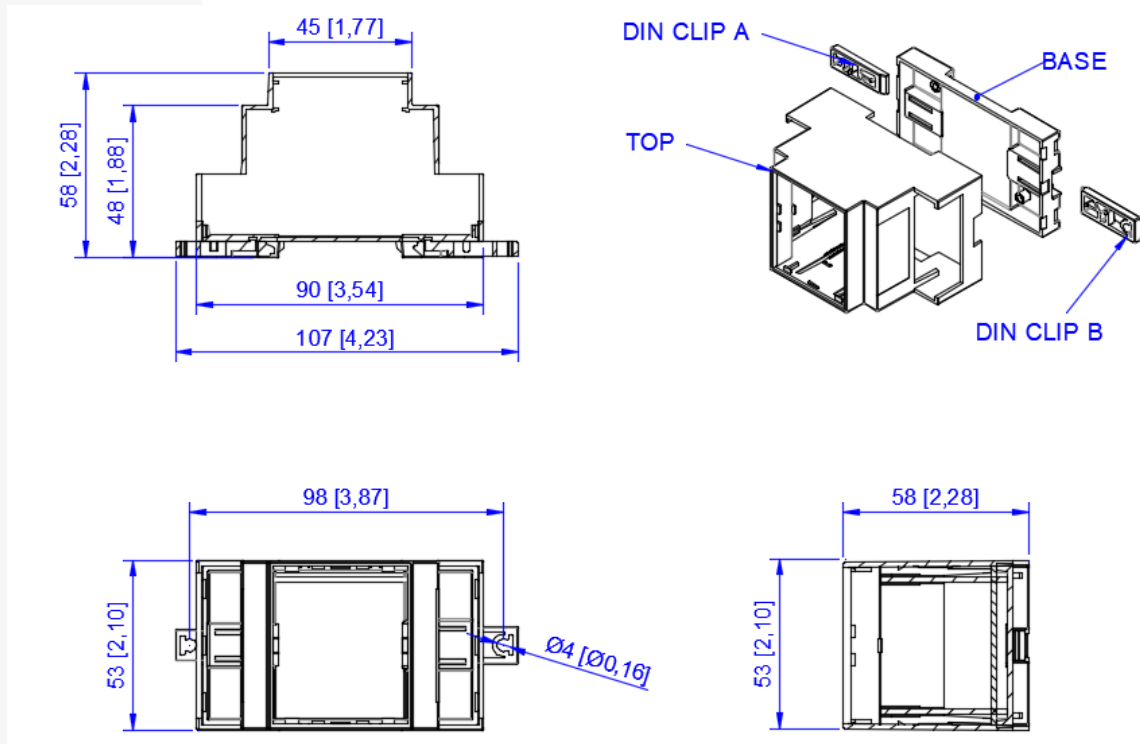
Picture 1 – Enclosure dimensions

3.7. Installation

TBPI Audio Module is installed by attaching it to TeddyBearPi module expansion connector.

Unit should be firmly attached, it is recommended to use DIN rail end stop to protect unit from disconnecting and loosing connection to main module.
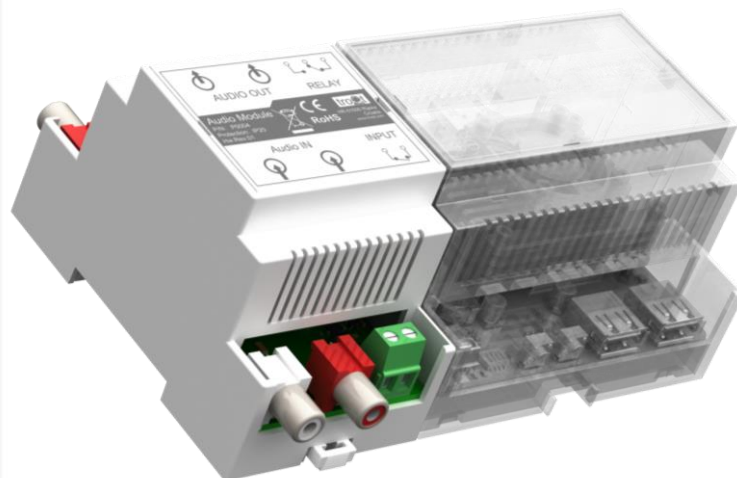
4. Connectors / interfaces

A main board has following connectors / interfaces available:

Audio input	Left / Right Cinch (RCA) connector
Terminal Input	2-pole terminal for Dry contact input
Audio Output	Left / Right Cinch (RCA) connector
Relay	3-pole terminal NO/COM/NC Relay

4.1. Audio Input connectors
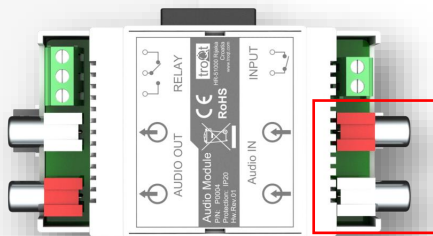
Two Cinch (RCA) connectors are used for Audio input signals. Standard analogue sources (for example FM radio) are supported via the AUX stereo line inputs.

Unit includes a low power 24-bit high quality audio ADC that supports sampling rates from 8 kHz to 96kHz.

Auxiliary inputs are enabled by AUX_L_AMP_EN / AUX_R_AMP_EN. They can be summed with each other which enables flexible audio mixing.

Each channel includes individual gain settings in 1.5 dB steps from -54 dB to +15 dB using AUX_L_AMP_GAIN and AUX_R_AMP_GAIN. The auxiliary amplifiers can be muted by asserting AUX_L_AMP_MUTE_EN and AUX_R_AMP_MUTE_EN. Changes in gain can be synchronized with zero-crossing by asserting the AUX_L_AMP_ZC_EN and AUX_R_AMP_ZC_EN bits. If no zero-crossing is detected within approximately 85 ms, the gain change is applied unconditionally. The sensitivity of the zero-cross detector is maximised by automatic selection of whether the zero-cross detection is performed at the input to the AUX amplifier, or the output from it. This is configured using the AUX_L_AMP_ZC_SEL and AUX_R_AMP_ZC_SEL controls.

Input mixer

Unit has two second level input amplifiers (MIXIN_L and MIXIN_R) that mix the analogue inputs as well as providing up to 18 dB extra gain. They are enabled by asserting the controls MIXIN_L_AMP_EN and MIXIN_R_AMP_EN. Gain can be controlled in 1.5 dB steps from 4.5 dB to +18 dB using the MIXIN_L_GAIN and MIXIN_R_GAIN register bits.

The left mixer accepts inputs from AUX_L_AMP and from either or both of the microphone PGAs (MIC_1_AMP and MIC_2_AMP), as well as from the right mixer MIXIN_R for stereo-to-

mono conversion. Similarly the right mixer accepts inputs from AUX_R_AMP as well as from the left mixer MIXIN_L for stereo-to-mono conversion. Input channel selection is determined by MIXIN_L_MIX_SELECT and MIXIN_R_MIX_SELECT.

The mixers can be muted using the MIXIN_L_AMP_MUTE_EN and MIXIN_R_AMP_MUTE_EN controls. The currently active gain settings are stored in MIXIN_L_AMP_GAIN_STATUS and MIXIN_R_AMP_GAIN_STATUS registers.

Automatic Level Control

For improved sound recordings of signals with a large volume range, unit offers a fully configurable automatic recording level control (ALC) for microphone inputs. This is enabled via the ALC_L_EN and ALC_R_EN controls, and can be enabled independently on either left or right channel. It is recommended that the ALC is only enabled in stereo as this applies the same gain to both channels and so protects the pan of stereo signals.

The ALC monitors the digital signal after the ADC and adjusts the microphones' analogue and digital gain to maintain a constant recording level, whatever the analogue input signal level.

> **Note:** For Input mixer configuration, see **ALSA configuration** section:

4.2. Audio Output connectors

Two Cinch (RCA) connectors are used for Audio Output signals that can be connected directly to an external receiver or as a differential line output. The integrated stereo DAC is suitable for high quality audio playback. The left and right channels of the DAC can be individually enabled using controls DAC_L_EN and DAC_R_EN.
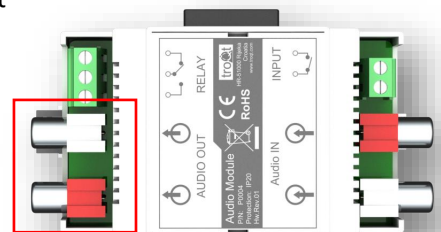
Each channel includes individual gain settings that are controllable in 0.75 dB steps from -78 dB to 12 dB using DAC_L_DIGITAL_GAIN_STATUS and DAC_R_DIGITAL_GAIN_STATUS.

A digital high-pass filter for each DAC channel is implemented with a 3 dB cut-off frequency controlled by DAC_AUDIO_HPF_CORNER. The high-pass filter is enabled by control DAC_HPF_EN. After Reset, the high pass filters for both channels are enabled by default.

Output has 3 dB cut off frequency of the low pass filter (20 Hz for audio applications)

The output voltage can reach 2 volts peak-to-peak with levels referenced to −10 dBV (300 mV) at 10 kΩ. The frequency response is at least 20 Hz to 20 kHz Line outputs are intended to drive a load impedance of 10 kΩ, which even at line out's highest voltages only requires a negligible current.

Output mixer

For playback, the output mixer amplifier is enabled using MIXOUT_L_AMP_EN and MIXOUT_R_AMP_EN. The audio signal can be mixed from all sources, and can be output simultaneously to both headphones and speakers. The mixing takes place only after asserting the control MIXOUT_L_MIX_EN and MIXOUT_R_MIX_EN. The output mixer is configured using register MIXOUT_L_SELECT and MIXOUT_R_SELECT. This output-mixer control is independent of the input path, so recording of one audio signal while listening to another signal such as FM Radio or an MP3 file is possible. The playback sound can be mixed with background signals or with inverted background microphone signals (side tone) to enable a basic headphone environmental noise reduction, or to compensate for unwanted damping of environmental sound while listening with sealed headphones. Playback signals coming from the AUX input channels can be individually inverted before being mixed out to the left and right channel (see MIXOUT_L_SELECT and MIXOUT_R_SELECT registers).

A stereo to mono conversion can be implemented by using either the input or the output mixer. This allows direct feeding of high power speaker amplifiers and other mono devices with the complete audio content.

Note: For Output mixer configuration, see **ALSA configuration** section:

4.3. Relay terminals

The RBPI Audio module has integrated relay for custom purposes. This relay can be used for various integration purposes like public address activation or muting of external equipment.

Integrated miniature signal relays offer a super compact case size in a slim package, complying with International Safety Standards and Ratings UL Recognized (UL508), CSA Certified (CSA 22.2 #14) and TUV Certified (EN61810)
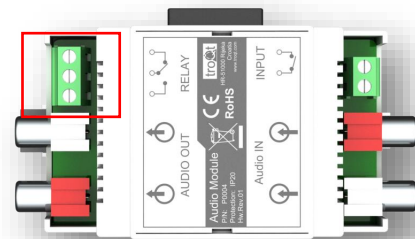
Contact specifications of relay are following:

Maximum Switching Power	30 W, 37.5 VA
Maximum Switching Voltage	220 VDC, 250 VAC
Maximum Switching Current	1 Amp.
Maximum Carrying Current	1 Amp.
Contact Material	Silver alloy with gold alloy overlay
Withstand Voltage	1,000 VAC (for one minute), 1,500 V surge (160 µs)

Relay is internally wired to TeddyBearPi GPIO 27

Note: For GPIO configuration, see **GPIO configuration** section:

4.4. Dry contact input terminals
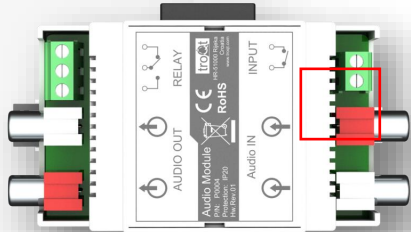
Unit has one dry contact input for custom purposes. This input can be used for various integration purposes, for example: Playing audio when contact is closed. These are passive contacts, and no energy should be applied to the contacts.

This input is internally wired to TeddyBearPi GPIO 22

Note: For GPIO configuration, see **GPIO configuration** section:

4.5. Expansion connector

Expansion connector is used to connect TBPI Audio Module to TeddyBearPi compute module.

No additional hardware or software configuration is needed for this port to operate.

Following power and communication pins are available:

- 24V DC power (1A max. current)
- 5V DC power (500mA max. current)
- Multiple GPIO - General Purpose Input/Output
- I2C – Inter-integrated circuit
- UART – Universal Asynchronous Receiver/Transmitter
- PCM – Pulse Code Modulation
- SPI (Serial Peripheral Interface)
- I2S – Serial Audio Interface
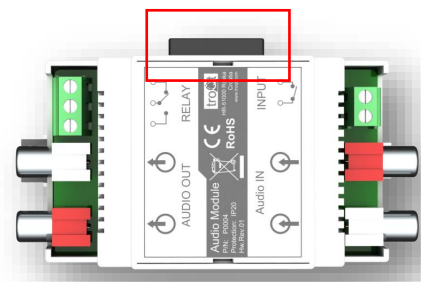
5. Software configuration

This section describes configuration on TeddyBearPi module that comes with Raspberry Pi OS preinstalled, supporting hardware libraries and examples.

Latest version will be installed but it is highly recommended to update software to latest version once you start using your unit.

Operating system

TeddyBearPI is delivered with Raspberry Pi OS system pre-installed but if you need to flash Compute Module eMMC, use a micro USB cable to connect the onboard micro USB slave port to the host device.

It is recommended to use PC with Linux system (Ubuntu) or a Windows system PC (Windows 10 or higher).

BOOT DIP switch should be in ON position to enable USB Boot, you can follow procedure described at RaspberryPI web site

The default login username and password are:

Username: pi

Password: raspberry

Note: Raspberry OS images don't include supporting libraries and code examples for TeddyBearPi board. Upon flashing new images, libraries and examples can be downloaded from github.

Enabling sound card

TeddyBearPi boot configuration should be updated to enable Audio driver loading on system boot. This is done by editing */boot/config.txt* file, entering command:

```
sudo nano /boot/config.txt
```

Following command should be added to /boot/config.txt file, under *[all]* section:

```
[all]
dtoverlay=rpi-codeczero
```

To disable HDMI audio output, comment line *dtoverlay=vc4-kms-v3d* by adding # in front of the line and add command below so that lines have following text:

```
#dtoverlay=vc4-kms-v3d
dtoverlay=vc4-kms-v3d,noaudio
```

Same should be done to disable system audio by adding # to line:

```
#dtparam=audio=on
```

Check other lines in this file, related to i2C and i2S configuration. Below lines should exist in /boot/config.txt file:

```
dtparam=i2c_arm=on
dtparam=i2c_vc=on
```

```
dtparam=i2s=on
dtparam=spi=on
```

When file is edited according to above instructions, file should be saved by pressing CTRL+X, you will be prompted to save changes, press Y and Enter to confirm.

For additional configuration options, some utilities can be installed. Use below command to install RPI Audio utilities:

sudo apt install rpi-audio-utils

RPI Audio utilities can be accessed with command:

sudo rpi-audio-flash

Audio driver will be loaded on system startup so please reboot your unit for the settings to take effect.

Sound configuration

Sound configuration of the unit can be changed in Linux user interface by right click on speaker in system tray and selecting Device profiles. However, settings in GUI does not have advance setting possibility so device configuration should be done with ALSA mixer. See section ALSA configuration for more details.

Network configuration

Network configuration can be important if you will use Audio Module for streaming audio from input source. Since TeddyBearPi has two Ethernet interfaces, streaming software like VLC of FFMPEG will stream on default interface. If both Ethernet interfaces ETH0 & ETH1 has default gateways configured, streaming software will stream on first interface that is registered, usually ETH1.

This can be sorted out by different approaches, depending on configuration requirements:

- Defining lower "meter" settings for Ethernet interface
- Removing default gateway on one of the Ethernet interfaces
- Setting stream output device in software (for example: --miface eth1 command in VLC)

Playing audio files

You can use integrated audio player to play audio files. Use below command to play audio file to Audio output:

aplay --device hw:CARD=Zero,DEV=0 *filename*.wav

Setting *–device* defines output hardware tthat will be used to play audio file, Audio output (Line out) of the TBPI Audio Module in this case.

Replace *filename* with WAV audio file that you want to play.

VLC Streaming example

You can use software to stream audio from Input to the network. Here is example how to stream audio from Audio input to network by using VLC program. For this example, we will use VLC from terminal (cvlc) since running VLC from the terminal gives you access to many commands and features in VideoLAN which you would not otherwise have. See the VLC command-line help page to find out more about options from the command line.

Here is command to stream Audio input signal to network as UDP transport stream:

```
cvlc -vvv --miface eth1 alsa://plughw:0,0 –sout #transcode {acodec=mpga, ab=320,
channels=2, samplerate=44100}:standard{access=udp,dst=239.1.1.10:1234}'
```

Definition of each section of above command is:

clvc	# starting VLC from command prompt, without graphical interface
-vvv	# Detailed Verbose output with debug info will be displayed
--miface eth1	# Select Ethernet card 1 where output will be streamed
alsa://plughw:0,0	# Selected audio hardware source: ALSA mixer port 0,0
--sout	# Stream output
transcode	# Transcode stream output (stream_out_transcode)
acodec=mpga	# Destination audio codec MPEG Audio
ab=320	# Audio bitrate 320 kBs - Target bitrate of the transcoded audio stream.
channels=2	# Number of audio channels in the transcoded streams (0 .. 9)
samplerate=44100	# Audio sample rate (0 .. 48000)
standard access udp	# Output access method UDP
dst=239.1.1.10:1234	# Output destination IP address : Port

e useradd and userdel commands to create and delete user accounts. Be sure to reference the main page of these commands to set relevant access privileges for the account. Following example shows how to create a tbpi1 user in the sudo group whose default login shell is bash and has home directory at /home/tbpi1:

```
tbpi@tbpi:~# sudo useradd -m -G sudo -s /bin/bash tbpi1
```

To change the password for tbpi1, use the passwd option along with the new password. Retype the password to confirm the change.

```
tbpi@tbpi:~# sudo passwd test1
Enter new password:
```

Retype new password:
passwd: password updated successfully

To delete the user tbpi1, use the userdel command.

ALSA configuration

ALSA or Advanced Linux Sound Architecture provides audio and MIDI functionality to the Linux operating system. ALSA mixer is used to configure Audio Module input, output and mixer settings under Linux environment.

ALSA mixer can be accessed by entering following command:

sudo alsa-mixer
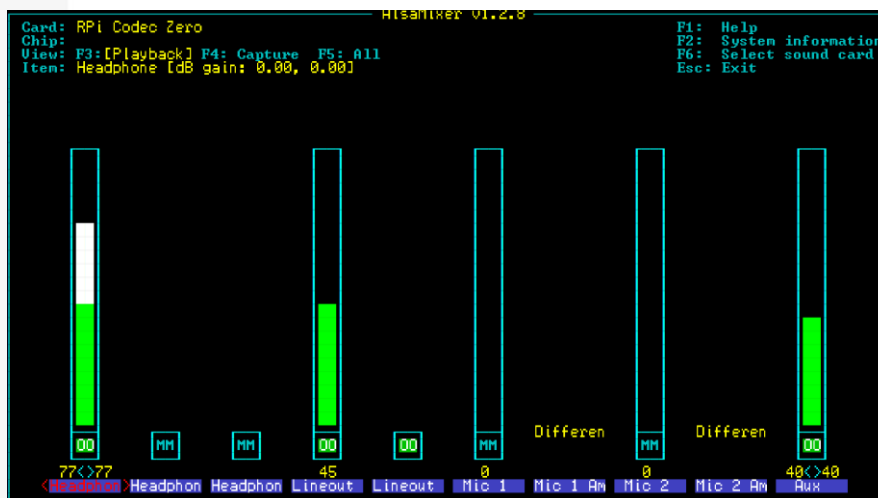
Move with arrows left <> right to select input arrows Up/down for increasing/decreasing volume level, button "M" to mute channel, ESC to exit ALSA Mixer.

Use button F6 to select Audio card – RPI Codec Zero

Use button **F3** to select Playback device, **F4** Capture (Input) device settings or **F5** to see all settings.

ALSA mixer configuration can be stored to file with following command (replace *filename* with name of the file and path that you want to store):

*sudo alsactl store -f *filename*.state*

Following settings are directly related to TBPI Audio Module operation:

ALSA Playback configuration

Headphone

Default value: 77 [dB Gain 0.00, 0.00]

Headphone physical connection is not available on the unit but this configuration uses same Audio path as AUX Output so it should be left Enabled

Headphone Gain Ramping

Default value: Mute [Off, Off]

Headphone ZC

Default value: Mute [Off, Off]

Lineout

Default value: 45 [dB Gain -3.00]

Lineout setting defines Line output signal level

Lineout Gain Ramping

Default value: Mute [Off, Off]

Mic 1

Default value: Mute

Microphone input is not used on TBPI Audio Module so it can be muted.

Mic 2

Default value: Mute

Microphone input is not used on TBPI Audio Module so it can be muted.

Aux

Default value: 45 [dB Gain -6.00, -6.00]

Aux setting defines signal input level connected to stereo Input RCA jacks. This setting can be adjusted based on output from external hardware.

Aux Gain Ramping

Default value: Mute [Off, Off]

Aux ZC

Default value: Mute [Off, Off]

Mixin Gain Ramping

Default value: Mute [Off, Off]

Mixin Left Aux Left

Default value: Enabled

Enable Left AUX (Line Input) channel input to Mixer

Mixin Left Mic 1

Default value: Mute [Off]

Mixin Left Mic 2

Default value: Mute [Off]

Mixin Left Mixin Right

Default value: Mute [Off]

Mixin PGA

Default value: 40 [dB Gain 0.00, 0.00]

Mixin PGA ZC

Default value: Mute [Off, Off]

Mixin Right Aux Right

Default value: Enabled

Enables Right AUX (Line Input) channel input to Mixer

Mixin Right Mic 1

Default value: Mute [Off]

Mixin Right Mic 2

Default value: Mute [Off]

Mixin Right Mixin Left

Default value: Mute [Off]

Mixout Left Aux Left

Default value: Mute [Off]

Mixout Left Aux Left Invert

Default value: Mute [Off]

Mixout Left DAC Left

Default value: Enabled

Enables Left Line output channel from DAC to Line Out

Mixout Left Mixin Left

Default value: Mute [Off]

Mixout Left Mixin Left Invert

Default value: Mute [Off]

Mixout Left Mixin Right

Default value: Mute [Off]

Mixout Left Mixin Right Invert

Default value: Mute [Off]

Mixout Right Aux Right

Default value: Mute [Off]

Mixout Right Aux Right Invert

Default value: Mute [Off]

Mixout Right DAC Right

Default value: Enabled

Enables Right Line output channel from DAC to Line Out

Mixout Right Mixing Left

Default value: Mute [Off]

Mixout Right Mixin Left Invert

Default value: Mute [Off]

Mixout Right Mixin Right

Default value: Mute [Off]

Mixout Right Mixin Right Invert

Default value: Mute [Off]

ADC

Default value: 65 [dB Gain 0.00, 0.00]

Setting value of ADC converter, Line Output conversion level

ADC Gain Ramping

Default value: Mute [Off, Off]

ADC HPF

Default value: Mute [Off]

ADC HPF Cutoff [Fs/240000]

Default value: Fs / 24000

ADC Voice Cutoff [2.5 Hz]

Default value: 2.5 Hz

ADC Voice Mode

Default value: Mute [Off]

ALC

Default value: Mute [Off, Off]

ALC Anticlip level

Default value: 0

ALC Anticlip Mode

Default value: Mute [Off]

ALC Attack Rate [44/fs]

Default value: 44 / fs

ALC Hold Time [62/fs]

Default value: 62 / fs

ALC Integ. Attack Rate [1/4]

Default value: ¼

ALC Integ. Release Rate [1/4]

Default value: 1/4

ALC Max Analog Gain

Default value: 0 [dB gain: mute]

ALC Max Attenuation

Default value: 0 [dB gain: 0.00]

ALC Max Gain

Default value: 0 [dB gain: 0.00]

ALC Max Threshold

Default value: 0 [dB gain: -94.50]

ALC Min Analog Gain

Default value: 0 [dB gain: mute]

ALC Min Threshold

Default value: 0 [dB gain: -94.50]

ALC Noise Threshold

Default value: 0 [dB gain: -94.50]

ALC Release Rate [176/fs]

Default value: 176/fs

AUX Jack

Default value: Enabled

Enables or disables Line IN input

DAC

Default value: 65 [dB Gain 0.00, 0.00]

Setting value of DAC converter, Line Output conversion level

DAC EQ

Default value: Mute [Off]

DAC EQ1

Default value: 0 [dB gain: -10.50]

DAC EQ2

Default value: 0 [dB gain: -10.50]

DAC EQ3

Default value: 0 [dB gain: -10.50]

DAC EQ4

Default value: 0 [dB gain: -10.50]

DAC EQ5

Default value: 0 [dB gain: -10.50]

DAC Gain Ramping

Default value: Mute [Off, Off]

DAC HPF

Default value: Mute [Off]

DAC HPF Cutoff [Fs/24000]

Default value: Fs/24000

DAC Invert

Default value: Mute [Off, Off]

DAC Left Source MUX

Default value: DAI Input Left

DAC Mono

Default value: Mute [Off, Off]

DAC NG

Default value: Mute [Off]

DAC NG OFF Threshold

Default value: 0

DAC NG OFF Threshold

Default value: 0

DAC NG Rampdown Rate [0.64 ms/dB]

Default value: 0.64 ms/dB

DAC NG Rampup Rate [0.02 ms/dB]

Default value: 0.02 ms/dB

DAC NG Setup Time [256 Samples]

Default value: 256 Samples

DAC Right Source MUX

Default value: DAI Input Right

DAC Soft Mute

Default value: Mute [Off]

DAC Soft Mute Rate

Default value: 1

DAC Voice Cutoff [2.5Hz]

Default value: 2.5Hz

DAC Voice Mode

Default value: Mute [Off]

DAI Left Source MUX

Default value: ADC Left

DAI Right Source MUX

Default value: ADC Right

DMIC

Default value: Mute [Off, Off]

Gain Ramping Rate [nominal rate * 8]

Default value: nominal

HP Jack

Default value: Mute [Off]

MIC Jack

Default value: Mute [Off]

Onboard MIC

Default value: Mute [Off]

ALSA Capture configuration

Onboard MIC

Default value: 77 [dB gain: 0.00, 0.00]

Lineout

Default value: 50 [dB gain: -1.00]

Mic 1

Default value: 0 [dB gain: -6.00]

Mic 2

Default value: 0 [dB gain: -6.00]

Aux

Default value: 40 [dB gain: -6.00, -6.00]

Mixin PGA

Default value: 20 [dB gain: 0.00, 0.00]

ADC

Default value: 65 [dB gain: 0.00, 0.00]

ALC Anticlip Level

Default value: 0

ALC Max Analog Fain

Default value: 0 [dB gain: mute]

ALC Max Attenuation

Default value: 0 [dB gain: 0.00]

ALC Max Gain

Default value: 0 [dB gain: 0.00]

ALC Max Threshold

Default value: 0 [dB gain: -94.50]

ALC Min Analog Gain

Default value: 0 [dB gain: mute]

ALC Min Threshold

Default value: 0 [dB gain: -94.50]

ALC Noise Threshold

Default value: 0 [dB gain: -94.50]

DAC

Default value: 65 [dB gain: 0.00, 0.00]

DAC EQ1

Default value: 0 [dB gain: -10.50]

DAC EQ2

Default value: 0 [dB gain: -10.50]

DAC EQ3

Default value: 0 [dB gain: -10.50]

DAC EQ4

Default value: 0 [dB gain: -10.50]

DAC EQ5

Default value: 0 [dB gain: -10.50]

DAC NG OFF Threshold

Default value: 0

DAC NG ON Threshold

Default value: 0

GPIO Configuration

There are two GPIO (General Purpose Input Outputs) used on this module: GPIO 22 is used for Relay and GPIO 27 is used for contact input.

First we will set GPIO 22 as input and GPIO 27 as output with these two commands:

```
sudo pinctrl set 22 ip
sudo pinctrl set 27 op
```

Now we can turn on Relay by entering this command (dh – Drive High):

```
sudo pinctrl set 27 dh
```

We can turn off Relay by entering this command (dl – Drive Low):

```
sudo pinctrl set 27 dl
```

For reading Input status, we can read status of input port 22:

```
sudo pinctrl get 22
```

Result we will get is "*pd | hi*" or "*pd | lo*", depending of input status (High or Low)

6. Ordering information

TBPI Audio module have following ordering information

Product number	Product Name	Package dim.	Package weigth
P0004	TBPI Audio Module	15x15x11 cm	150 g