Analog Audio Processor for the phase coherent operation of the side speakers with one, or more SUB channels with Doppler compensation

Analog Audio Processor AC-AAS01

- AC Supply Voltage
- On-board Muting/Standby-Sequencer
- Very Low Distortion and Noise
- Adjustable Input Sensitivity
- Differential Audio Inputs
- Differential Audio Outputs
- Doppler Compensation (world first)
- RoHS compliant, IPC-A-600 Class 2 and IPC-A-610 Class 2

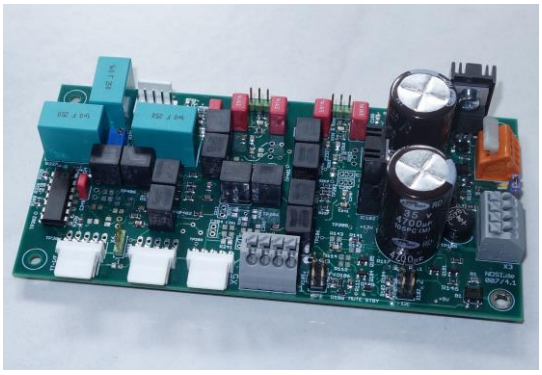

Figure 1: Analog Audio Processor with SUB

Description / Novel Features

The purpose of the compact, high-end, audio processor AC-AAS01 is to generate the appropriate driving signals for a fully Doppler compensated High-End speaker system comprising two full range side speakers and one or several sub-woofers.
The AC-AAS01 shows an excellent linearity and low distortion, combined with a perfect flat audio frequency response, and low noise.
The block diagram in Figure 2 visualizes the main processing steps.

The AC-AAS01 receives the left and right audio channels either as single ended, or as symmetric signals.
An input band pass filter determines the noise bandwidth from 3 Hz up to 240 kHz and rejects far out-of-band spurious signal.
The SUB audio band is extracted using two 3rd order minimum phase / minimum delay filters. This dedicated filter avoids that the basic tone of a music instrument is too much delayed with respect to its harmonic frequencies.
The SUB signal is computed as the sum of the two extracted low pass signals. A volume control allows emphasizing or reducing the volume of the SUB cannel with respect to that of the side speakers. In case other than the AudioChiemgau recommended components for the side speakers are used, a variable phase control between 0 and -180 degree and in addition a phase reversal switch are foreseen in order to adjust the phase between unknown side speakers and the SUB channel.

The signal for the two side speakers is computed for each channel by coherently adding back at a reduced level (e.g. -6 dB) the extracted low pass signals to the extracted high pass signals. These signals for the side speakers are available at the left and right output terminals as symmetric signals.

This processing scheme is a novelty with the advantage, that not only the SUB, but also the two side speakers produce coherently low frequency sound pressure, using the full membrane area of all speakers. In other words, the sound pressure vectors of one, or several SUBs and of the side speakers add exactly to 1 for all frequencies. Of course the side speakers need to be able to produce low frequency sound pressure, which is, however, easily achievable with the recommended AC-PAR75 MFB System.
This is a clear differentiation to usual 2.1 systems with the advantage, that the SUB cannot be localized, is fast with respect to group delay and allows significant freedom for its placement. AudioChiemgau recommends, however, keeping the depth distance between SUB and side speakers within one meter in order to maintain the correct phase

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relationship between the different sound sources.
The SUB output is in addition filtered with a 2nd degree minimum phase / minimum delay high pass filter with a corner frequency of 16 Hz (-3 dB) in order to avoid problems with infra-sound content, which may be generated by turn tables but may also exist in some high quality digital recordings.

As further novelty and a world-first the unavoidable Doppler effect, produced by every moving speaker membrane, is completely eliminated in the SUB channel. For that purpose an analog circuit continuously computes the movement generated phase modulation. That signal is used to control a phase modulator in such way, that the Doppler effect of the speaker membrane is completely eliminated.

In this way the phase center of the sound source is held at a fix location – a virtually non-moving speaker membrane is created.

This avoids completely the roughness of higher frequencies through the non-harmonic Bessel lines that the Doppler effect would otherwise generate. Also the Doppler generated second harmonic frequency component (a.k.a. Eigen-Doppler) of any tone is removed.

The SUB output carries also MUTE and STDBY signals for the AC-PAZ75 or AC-PAR75 amplifiers in order to remotely control the side speakers.

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The AC-AAS01 fits to various amplifier/speaker configurations:

One SUB and two side speakers, or one SUB per side speaker, or several distributed SUBs with two side speakers.

Figure 2 shows the typical implementation of the AC-AAS01. The left and right Audio signal are fed to the corresponding inputs comprising differential amplifiers with high common mode rejection. That avoids ground loops. The processed output signals for the left and right side speakers are available as low impedance symmetric signals at the respective outputs. The SUB channel is usually directly connected to a MFB (Motion Feed Back) power amplifier driving the SUB woofer.

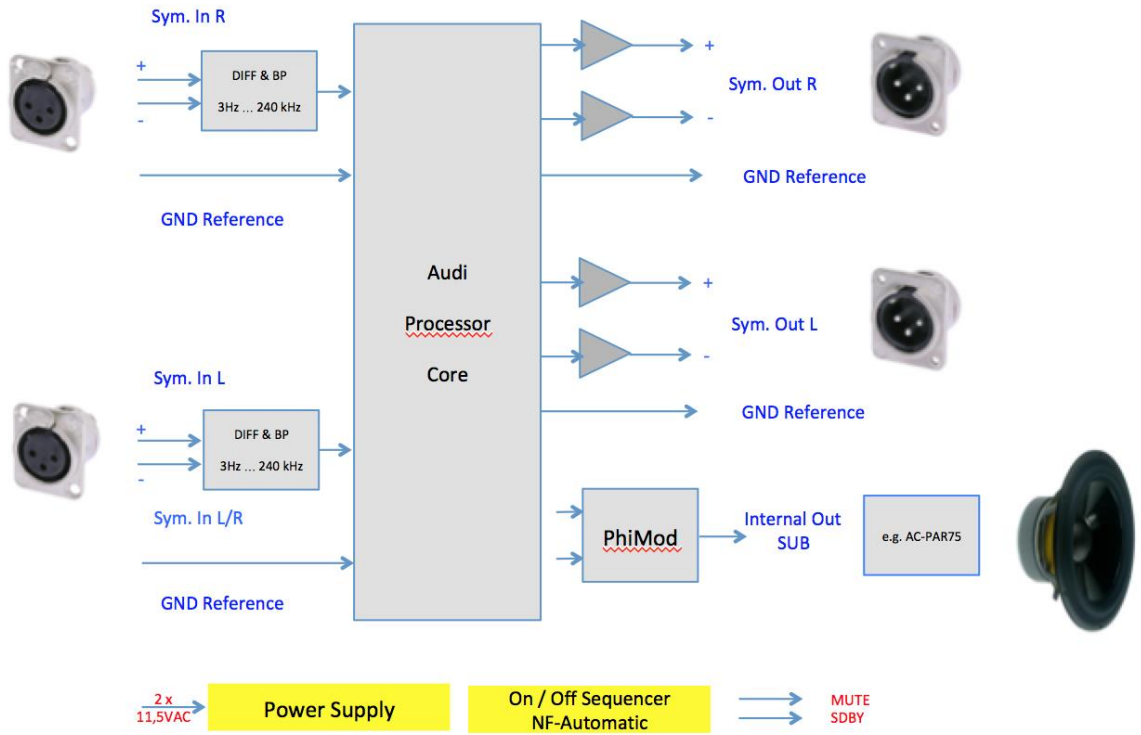

Figure 2: Typical Implementation of the Analog Audio Processor Module AC-AAS01

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Figure 3 shows the frequency response of the 3rd order cross over with the chosen center frequency of 80 Hz (customer selectable). The outputs of the crossover add for all frequencies exactly to unity.

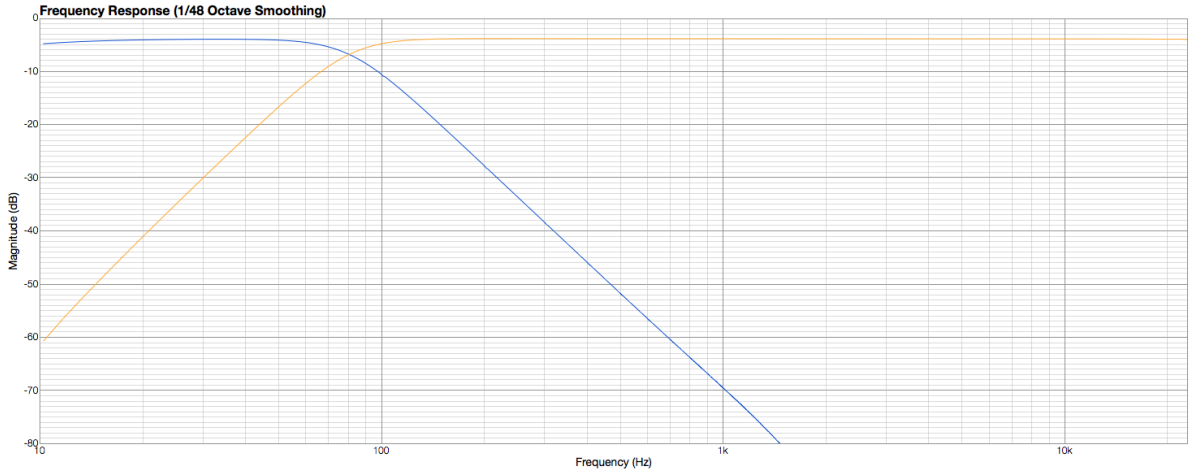

Figure 3: Frequency response of the SUB cross-over

Figure 4 shows the frequency response of the SUB channel including the 2nd order high pass at 16 Hz. The high pass filter determines solely the lower frequency response of the SUB in case the MFB (Motion Feed Back) power amplifiers of AudioChiemgau are used. The filter helps to avoid problems through sub-sonic frequency components which are frequently generated by turn tables, but which may also exist in high quality digital recordings too.

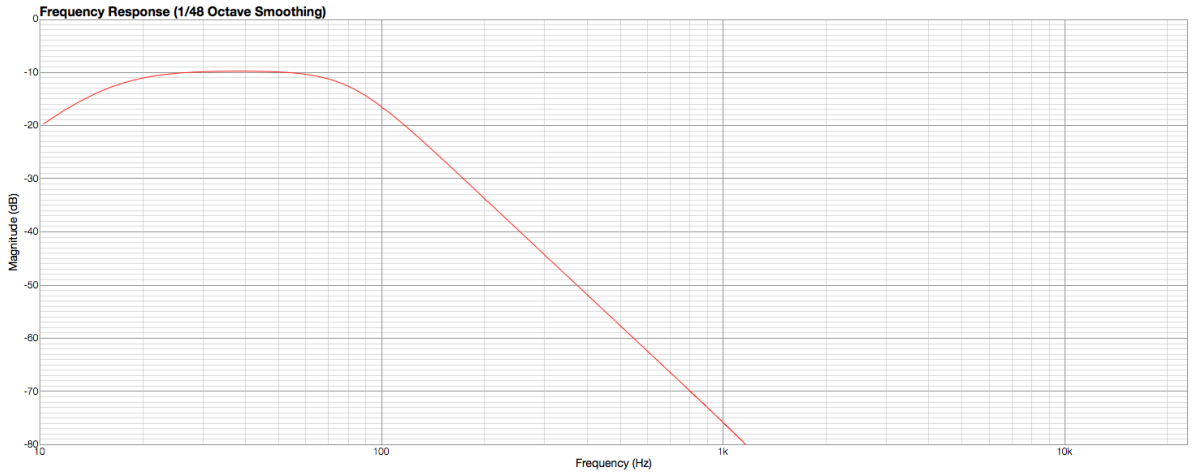

Figure 4: Frequency response of the SUB channel including the 2nd order High pass at 16 Hz

Figure 5 shows the possible volume variation by the SUB volume control potentiometer

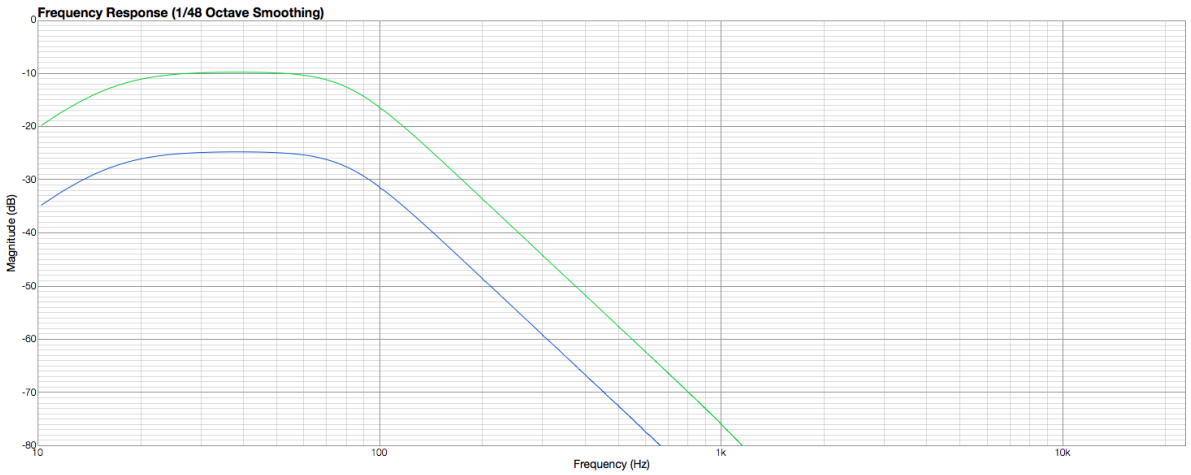

Figure 5: Potential volume control area for the SUB channel

Figure 6 shows the extracted high pass channel for the side speakers. This signal is further processed.

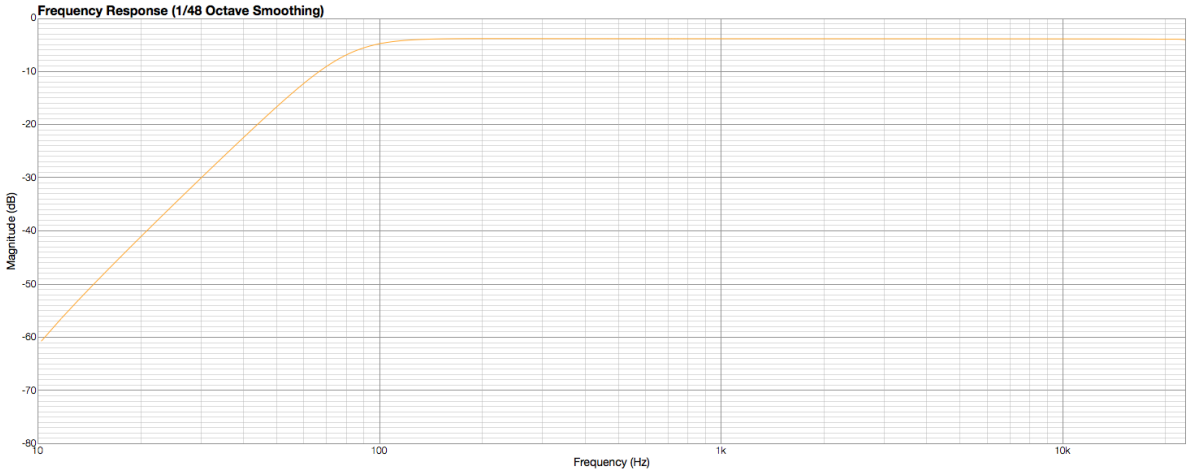

Figure 6: Extracted high pass signal for further internal processing

Figure 7 shows the further processed signal for the side speakers. The low pass signal of the two SUB channel filters is coherently added back with a reduced (-6dB) level to the two side speaker channels. In that way all woofers of the system (SUB as well as side speakers) contribute to the reproduction of low notes. As the side speakers have usually smaller diameter woofers, a lower sound pressure level at very low frequencies is sensible. The SUB compensates and adds to the desired sound pressure level at low frequencies.

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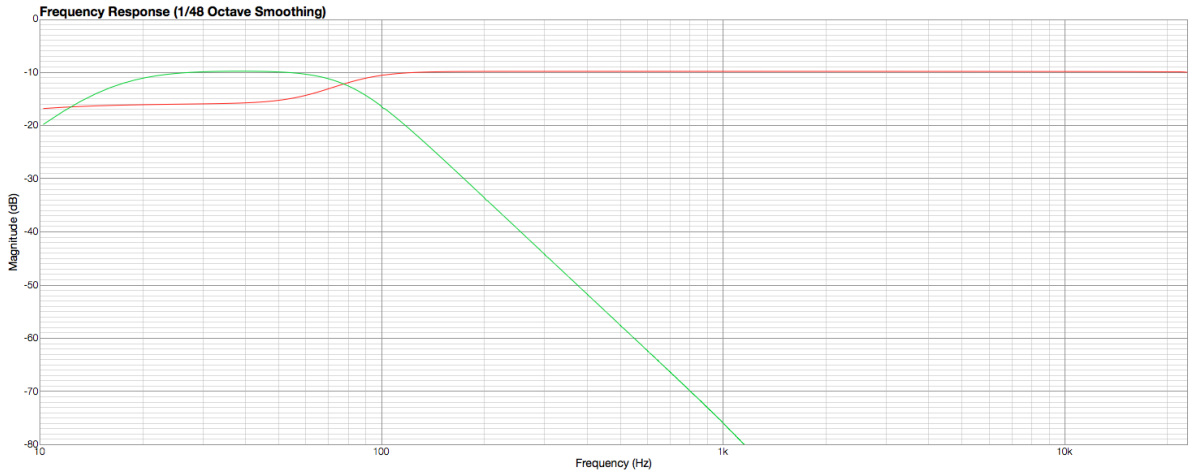

Figure 7: Red: Output signal for the side speakers. low frequencies are added at a reduced level (-6 dB) to the high pass signal. Green output signal of the SUB channel, which adds coherently to the output signals of the two side speakers. The 2nd order high pass filter at 16 Hz defines lower SUB corner frequency.

Figure 8 shows the connections to and pin assignments for the AC-AAS01 Analog Audio Processor.

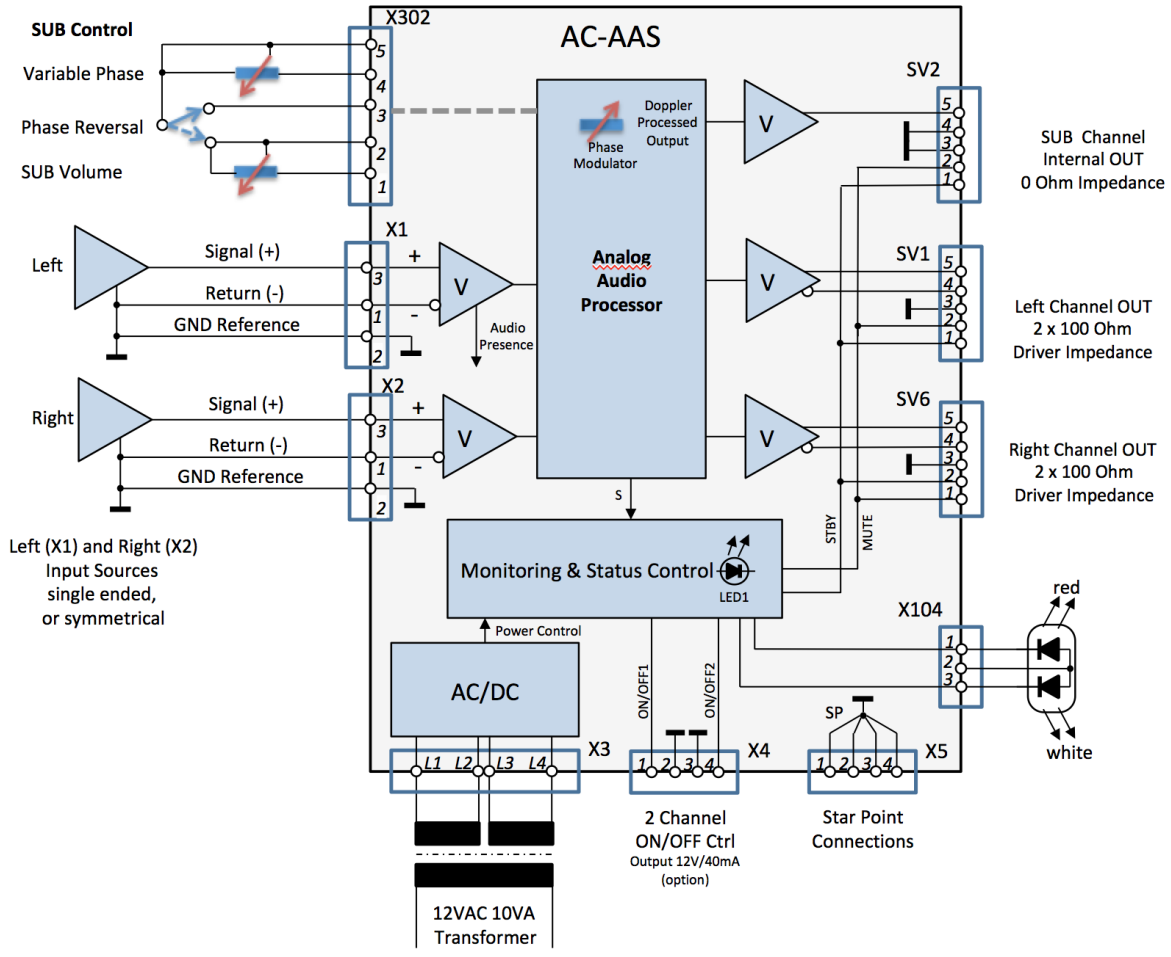

Figure 8: Connections and Pin Assignment of the AC-AAS01 module

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On-Board controller

An on-board microprocessor serves inter alia as sequencer for the handling of the STBY and MUTE function as well as signaling of operation mode and status. The AC-AAS01 features an auto on function through the detection of the input signal and an auto off function after 10 Minutes without input signal. This function is dubbed Audio Signal Detection (ASD).

To enable the ASD function, the MUTE-Signal must be floating (not pulled down by external equipment) during power-on sequence of the AC-AAS01. In case the MUTE signal would be pulled down (active low), the ASD-Function is permanently disabled.

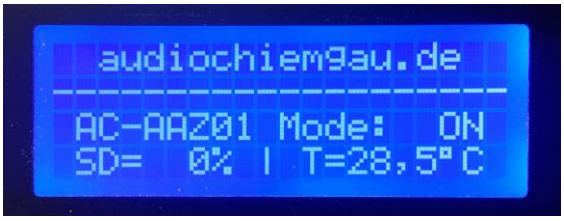
With active ASD the system will stay in ON as long as an audio signal above the implemented threshold will be detected. In case the signal is long enough under the threshold (can be adjusted by firmware) the controller changes the status to STBY after 8 minutes and after additional two minutes the system switches to OFF.

In case the ASD is disabled the system can be controlled by the MUTE signal. In case the MUTE signal is pulled down for more than 10 minutes, the controller will switch the system OFF.

All implemented durations and thresholds for ON and OFF can be changed easily in the firmware of the on-board controller.

Mute (MUTE), standby (STBY) and OFF will be indicated by different signals of the connected LED (see table on page 13).

An I^2C on-board interface allows connecting a 4 line alphanumeric display showing the operating mode, the temperature, the audio level and a customer defined logo. See the following example for a possible implementation and display content of such a display.



Please contact AudioChiemgau for other display colors or content changes.

An over temperature monitoring of the module is implemented. In that case the module as well as all external connected equipment will be switched OFF via the remote control lines (see below). After cooling down, the system will reactivate. Over-temp condition will be indicated by the status (LED2) or the display if connected.

Remote ON/OFF control outputs

Two remote control lines (ON/OFF) for external equipment (side speakers) are also available. The outputs are under control of the on-board processor, are short circuit protected and designed to drive 12V 40mA relays directly.

In the OFF mode, additionally the internal supply voltage for the module is switched off in order to reduce the power consumption.

The background illumination of an optionally connected display will also be switched off 15 seconds after the system switches to OFF.

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Absolute Maximum Ratings (T_{amb} = 25°C; unless otherwise specified)

Symbol	Parameter	Value	Unit
Vs	AC Supply Voltage (two symmetrical transformer windings)	16	Vrms
T_{op}	Operating Ambient Temperature Range	0 to +50	°C
T_{stg}, T_j	Storage Temperature	+ 80	°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the module.

Electrical Characteristic (T_{amb} = 25°C; f = 1kHz; unless otherwise specified)

Symbol	Parameter	Min	Typ	Max	Unit
Vs	AC Supply Voltage Range Two identical transformer windings, or mid tapped secondary winding	10.5	11.5	12.0	Vrms
Is	AC Supply Current for each winding		300	350	mA
P_S	Required AC Power per Winding	3,5			VA
Audio Input Left or Right Channel					
R_{id}	Differential Input Resistance (AC)		100		kΩ
R_{i0}	Input Resistance to GND (AC)		50		kΩ
V_{CM}	Input Common Mode Range		± 5		V
V_{IS}	Input Sensitivity for 2V differential Output Voltage, adjustable via 10 turn potentiometer	400 mV		2.4 V	V
Audio Output Left or Right Channel					
R_{od}	Differential Output Resistance (AC)		200		Ω
R_{o0}	Output Resistance to GND (AC)		100		Ω
V_o	Differential Output Voltage		2	6	V
SUB Channel Gamin and Phase Control					
G_{SUB}	Variable Gain		20		dB
Phi_{rev}	Phase reverse Switch	0		-180	degree
Phi_{var}	Variable Phase Shift	-2		-180	degree
External Error and Status Indicator					
I_{LED1}	LED operating current		3		mA
I_{LED2}	LED operating current		3		mA
Remote Control Output Driver					
I_{NOM}	Nominal driver capability		40 [1])		mA
V_{out}	Output Voltage Driver active with typical supply voltage Vs	12	15	16	V
I_{max}	Max output current before fold back		65		mA
I_0	Short circuit output current (fold back)			10	mA
V_{OFF}	Output Voltage Driver OFF	-0,5	+0,2	+0,5	V

[1]) Also available with higher drive power

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Over Temperature Detection and Turn ON/OFF					
T_{OFF}	Switch OFF temperature	+65	+70	+75	°C
T_{ONHY}	Switch ON Hysteresis		4		K

Customer Adjustments:

1. Gain of the SUB cannel.

2. Phase reversal Switch (0 or 180 degree) for the SUB channel.
   Possibly used for other manufacturers side speaker. Zero for AudioChiemgau components.

3. Potentiometer for a continuous 180 degree phase variation of the SUB channel.
   Possibly used for other manufacturers side speaker. Zero for AudioChiemgau components.

Customer selections:

1. Center frequency of 3rd order cross-over (default 80 Hz)

2. Add-back of low pass signal to high pass signal for side speakers (default -6 dB)

3. Lower corner frequency of system 2nd order high pass – (default 16 Hz)

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Mechanical Layout (PCB)

The complete circuit is realized on a multi-layer PCB with the dimensions of 140mm x 70mm. The PCB provides five mounting holes as shown in the figure below.

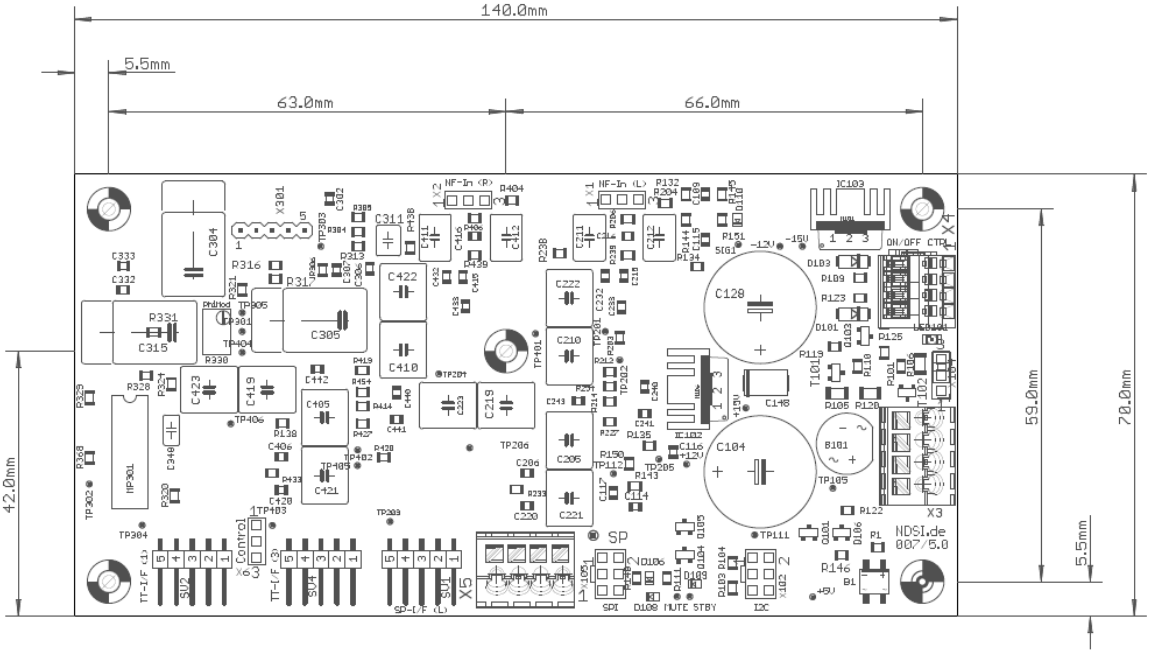

Figure 9: Mechanical Layout of the PCB, top view and populates as AC-AAS01

Figure 10 shows an optional flange for vertical mounting of the module.

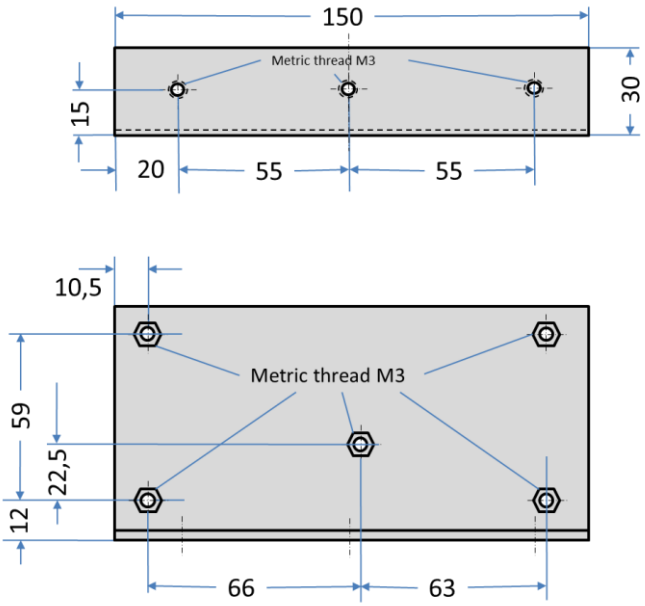

Figure 10: Optional Flange for vertical mounting of the module (preliminary)

The mounting flange provides on the small side (upper sketch) three metrical threads M3.

Both sides have flat surfaces; there are no protruding elements.

The flange is not necessary for any cooling purpose.

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Mechanical Characteristic

Symbol	Parameter	Min	Typ	Max	Unit
X	Module Dimension X	139	140	141	mm
Y	Module Dimension Y	69	70	71	mm
H	Module Height H		35		mm
W	Module Weight (TBC) without optional mounting flange		95		g

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Electrical Interfaces

Connector Types and Interface Description

Connector	Parameter/Signal	Typ	Wire Size
X1	Audio input interface for left channel	Pin Header 1x3 RM 2,54mm	-
X2	Audio input interface for right channel	Pin Header 1x3 RM 2,54mm	-
X3	AC Power Supply	WAGO 250-204	0,2 – 1,5mm² AWG 24-16
X4	Remote control output	WAGO 233-504	0,08 – 0,5mm² AWG 28-20
X5	GND connection (Star Point)	WAGO 250-204	0,2 – 1,5mm² AWG 24-16
X6	Connector for external control (MUTE/STBY)	Pin Header 1x3 RM 2,54mm	-
X102	I^2C-Interface (reserved)	Pin Header 2x3 RM 2,54mm	-
X104	Connector for external LED (option)	Pin Header 1x3 RM 2,54mm	-
X105	SPI-Interface (reserved)	Pin Header 2x3 RM 2,54mm	-
X212	Interface for external gain potentiometer	Pin Header 1x3 RM 2,54mm	-
X302	Interface to woofer control elements	Pin Header 1x5 RM 2,54mm	-
SV1	Audio out left, incl. MUTE and Standby	Pin Header 1x5 RM 2,54mm	-
SV4	Audio out right, incl. MUTE and Standby	Pin Header 1x5 RM 2,54mm	-
SV2	Audio out woofer, incl. MUTE and Standby	Pin Header 1x5 RM 2,54mm	-

>0,5mm² are recommended for X3

Interface: AC Power Supply and Connector Pinout (X3)

X3 Pin	Parameter/Signal	Remark
L1	AC Input A (or positive DC supply)	Use L2 or L3 for transformer with center tap DC polarity essential for power drop function
L2	Return A internally connected to L3	
L3	Return B internally connected to L2	
L4	AC Input B (or negative DC supply)	

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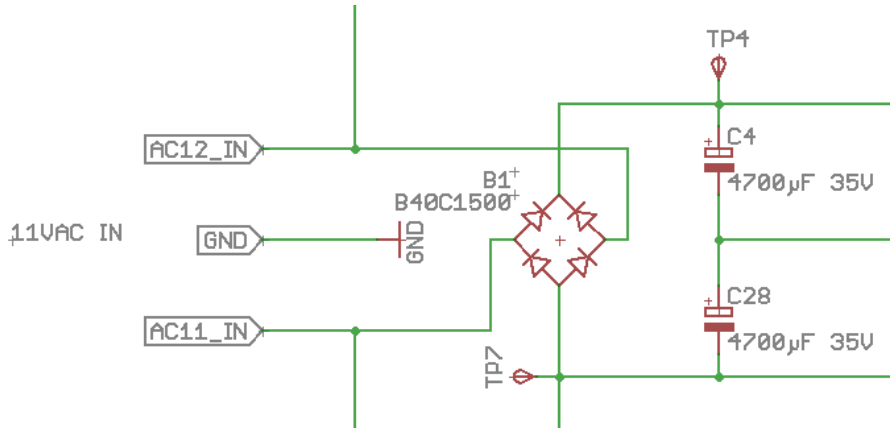

Figure 11: AC Input Circuit Diagram

Interface: Optional Status Indicator LED Connector Pinout (X104)

The module offers a status indication output for an external LED (e.g. white LED) and a second LED interface for fault condition indication (e.g. red LED). If not used, short the connector of the white LED in order to activate the on-board LED, or let the connector open if no indication is required. Both LEDs could be realized with a two-color LED with common anode (e.g. OptoSupply, Part Number OSRMMA7K91B).

X104 Pin	Parameter/Signal	Remark
X104-1	Cathode of indicator LED2 (red)	If no second (red) LED is implemented the LED1 will flash in case of failure condition
X104-2	Common contact (anode) for both LEDs	Open: on-board indicator disabled Closed: on-board indicator active LED: Connect to additional LED for external indication
X104-3	Cathode of indicator LED1 (white)	

The AC-AAS01 (V4) provides a status indication by the internal LED1 and an optional external LED supported by a second LED2, which could be connected to the module. Both will be used for signaling of the different states of the audio processor and the connected equipment. In nominal operation the white LED is permanently on and it will flash for signaling of certain nominal operating states or during failure condition:

Flashing	Status	Remark
1 (white)	System in MUTE	System in nominal operation (no failure condition)
2 (white)	System in Standby	
3	-	Not implemented, reserved
4 (red)	Over Temperature (>60°C)	Over temperature detected - module switched to OFF for its own protection

OFF: The LED1 (white) will “breathe” every 10 seconds to indicate a powered system.

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Interface: Audio Out and Control Connector Pinout (SV1, SV2 and SV4)

The AC-AAS01 (V4) provides up to four interface connectors for connecting independent woofer amplifiers (e.g. AC-PAR75) and one additional connector for the tweeter amplifier (e.g. AC-PAZ75).

The four woofer interfaces are connected in parallel.

SV1/SV2/ SV4 Pin	Parameter/Signal	Remark
1	MUTE Output	Could be used to control external power amplifiers like AC-PAZ75 and AC-PAR75 (see chapter below for more details)
2	STBY Output	
3	GND	
4	NF (Audio) Output negative	
5	NF (Audio) Output positive	

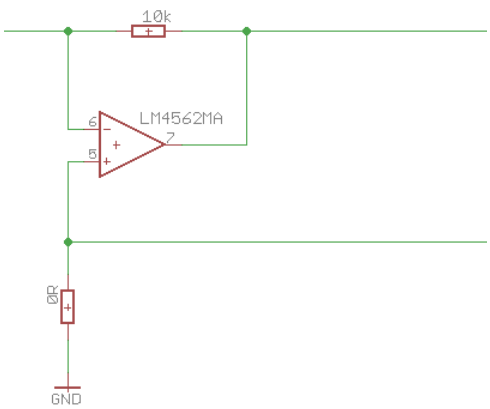

Figure 12: Audio Output Interface for SUB (SV2)

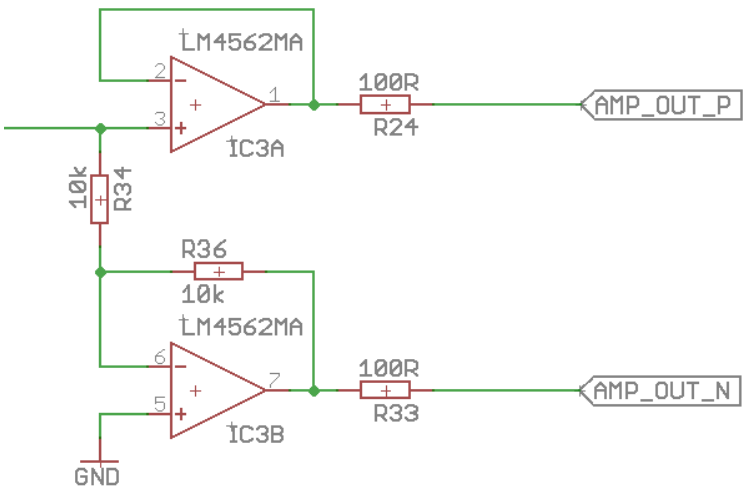

Figure 13: Audio Output Interface for Left/Right (SV1/SV4)

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Standby (STBY) and Muting (MUTE)

The module offers two independent output lines for Standby and Muting. Both outputs are realized as Open Drain outputs with implemented pull-up resistors and are active low. They can serve as outputs in order to synchronize external power amplifiers like the AC-PAZ75 and/or the AC-PAR75.

The circuit dedicated to the switching on and off of the amplifier has been carefully optimized to avoid any kind of uncontrolled audible transient at the output during settling of the internal control loops, especially for the amplifiers AC-PAZ75 and AC-PAR75.

If not used, both control outputs may be left open

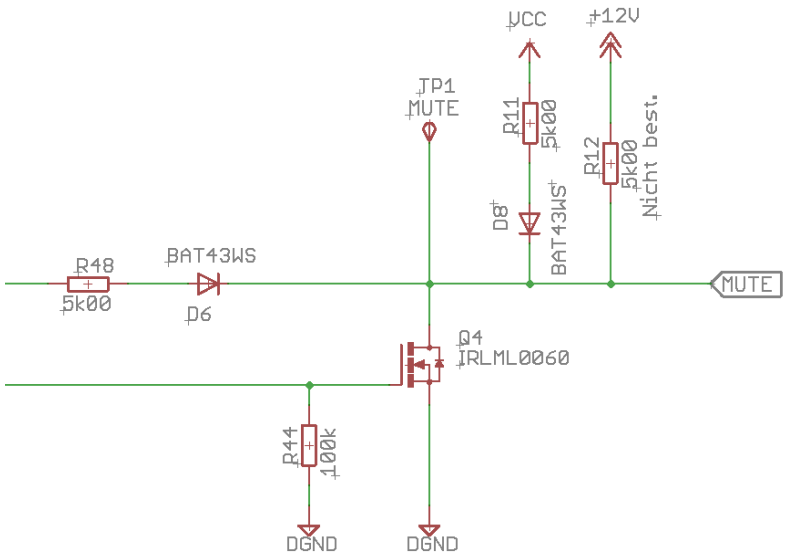

Figure 14: MUTE Output Interface (Standby identical if populated)

Normally the AC-AAS01 (V4) delivers 5V in high-state (R12 not populated) but external pull-up resistors can be used to handle external receivers with higher input voltages

System with MUTE-Switch or Audio Signal Detection (ASD):

Optionally the system may be controlled by an external (manual) MUTE switch, which may be connected to X6.

In case the MUTE switch is closed and the system will be powered the equipment will stay in OFF and the Audio Signal Detection (ASD) will be ignored. After the turn-on sequence the system will stay in MUTE until the MUTE switch will be opened. With closed MUTE switch the system will turn automatically in STBY after 8 Minutes and change to OFF after 10 Minutes. Then the MUTE switch can activate the system again.

In case the MUTE switch is open during power on the equipment will turn to ON immediately and the Audio Signal Detection (ASD) will be enabled. This will initiate a sequence to turn on the whole equipment including external equipment under control of the remote control output(s) on X4. Is no audio signal detected above the threshold for 8 Minutes the system will change to STBY and after

further two minutes the on-board controller of the AC-AAS01 will turn OFF the system. X6 provides the interface to connect external switches to handle MUTE and/or STBY.

Interface: External MUTE/STBY (X6)

X6 Pin	Parameter/Signal	Remark
1	MUTE	Connect MUTE (Pin1) and/or STBY (Pin3) to GND to activate the function Could be used to connect external switch(es)
2	GND	
3	STBY	

Interface: Remote Control Output (X4)

X4 Pin	Parameter/Signal	Remark
1	Remote Control Out Channel 1 (P)	Normally not populated in AC-AAS01 configuration
2	DGND (return)	
3	DGND (return)	To be used for power switching of the transformer for power amplifier(s)
4	Remote Control Out Channel 2 (P)	

The module offers up to two independent high-side drivers for control (switch ON/OFF) of unit internal or external equipment. Both outputs are under control of the on-board processor and its firmware. The outputs are capable to drive relays directly and are short circuit proof with fold-back characteristic.

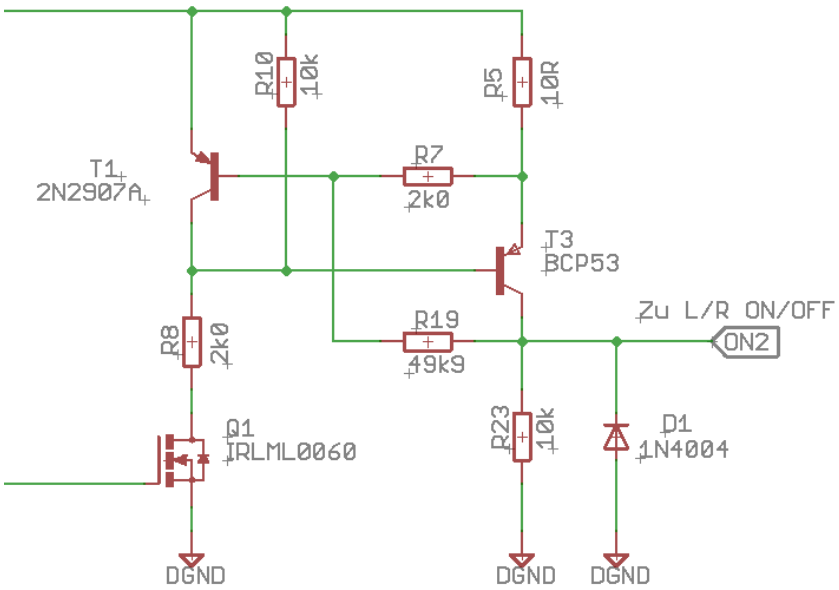

Figure 15: Relay driver stage for ON/OFF remote control (40mA configuration)

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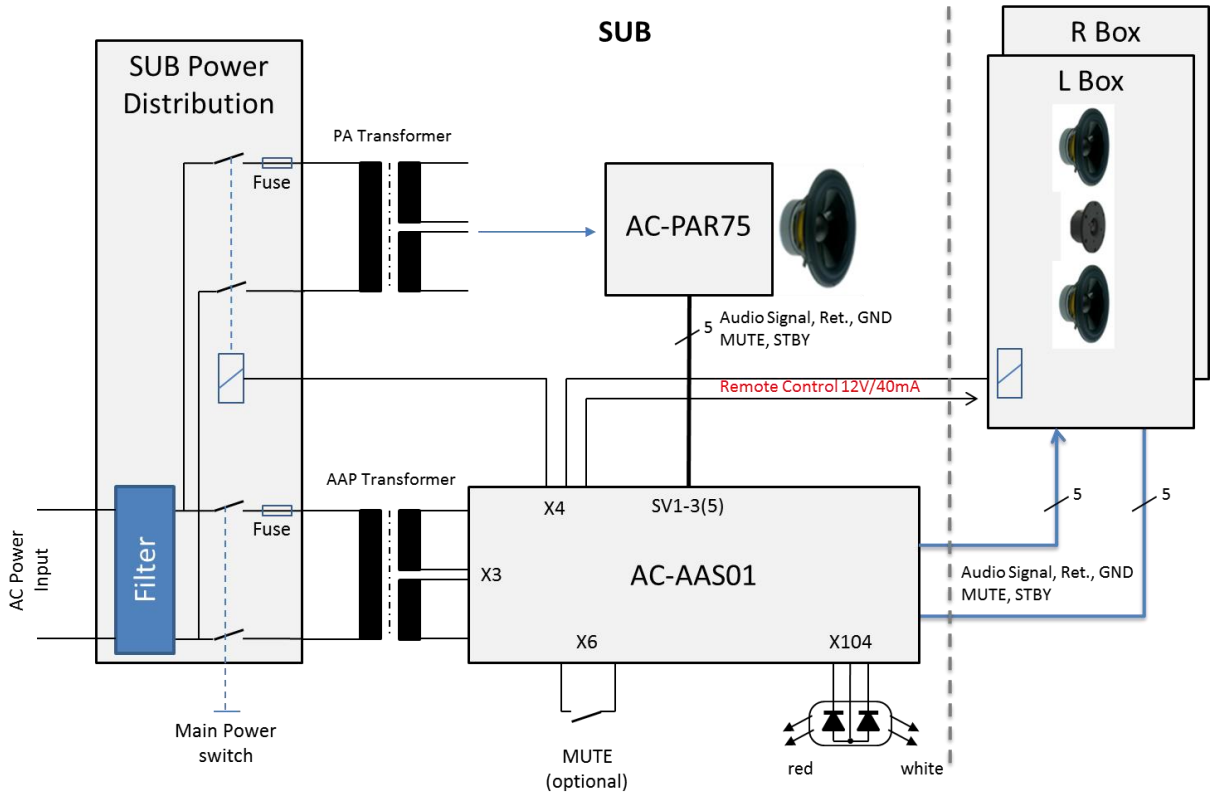

Figure 16: Recommended power distribution and control configuration (distribution of MUTE and/or STBY optional)

Interface: Audio Input Connector Pinout (X1 and X2)

X1/X2 Pin	Parameter/Signal	Remark
1	Audio Input negative	
2	GND	Signal ground / shield
3	Audio Input positive	Used by Audio Signal Detection (ASD) circuit

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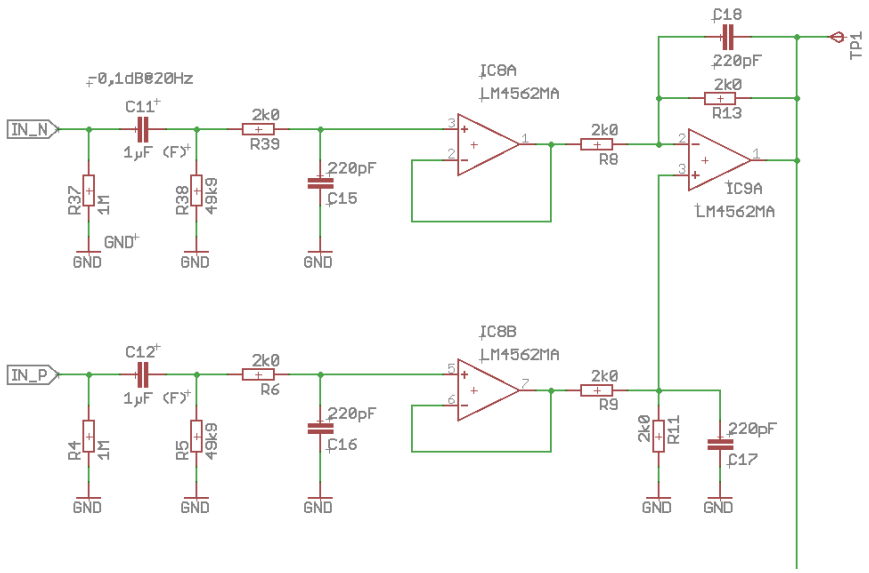

Figure 17: Audio Input Interface

Interface: External Gain Potentiometer (X212)

X212 Pin	Parameter/Signal	Remark
1	Potentiometer low	External Gain potentiometer 10kΩ
2	Commonly used for potentiometer center tap and max	
3		

Remark: Internal potentiometer R244 should not populated if external potentiometer will be used

Interface: Control Elements (X302)

X302 Pin	Parameter/Signal	Remark
1	SUB Volume control (10k)	See Figure 8 for details
2		
3	Phase Reversal	
4	Variable Phase (10k)	
5		