
Analog Audio Processor for two-way speakers with Doppler compensation

Analog Audio Processor AC-AAZ01

- 12 VAC Supply Voltage
- On-board Muting/Standby-Sequencer with Audio Signal Detection (ASD) and control inputs and outputs
- Very Low Distortion and Noise
- Symmetrical Audio Input
- Adjustable Input Sensitivity
- Double Baffle Step compensation
- Adjustable Brilliance Enhancement
- Doppler Compensation (world-first) with AC-PAR75 amplifiers
- RoHS compliant, IPC-A-600 Class 2 and IPC-A-610 Class 2

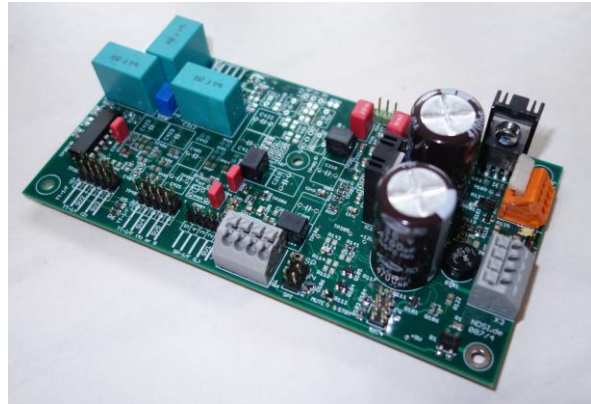


Figure 1: Analog Audio Processor AC-AAZ01

Description / Novel Features

The purpose of the compact, high-end, audio processor AC-AAZ01 is to generate the appropriate driving signals for a Doppler compensated two-way speaker system with one tweeter and one or several woofers. The AC-AAZ01 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-AAZ01 receives the audio input as single ended or symmetric signal between 200mV and 2V amplitude. A differential to single ended amplifier with high common mode rejection ratio delivers the audio signal to a variable gain stage, which allows adjusting the audio level within the processor to 2V amplitude. A band pass filter in the input circuitry determines the noise bandwidth between 3Hz and 240kHz and rejects out of band spurious signals. Sophisticated double baffle step compensation is on-board and can be easily customer tailored to the chosen enclosure.

The following crossover uses a 3rd order minimum phase and minimum delay filter. Its crossover frequency can be customer selected with a default value of 1kHz. This dedicated

filter avoids that harmonic frequencies of a music instrument are audible delayed with respect to the basic tone.

The high pass channel comprises an adjustable brilliance boost function, i.e. 0 dB to +3dB boost of frequencies above 7 kHz, which elder listeners may prefer.

In order to compensate the depth difference of the acoustical phase centers between tweeter and woofer, an adjustable delay (first order all pass section) is included in the high pass channel. The depth difference compensation can be customer selected depending on the used tweeter and woofer(s). The woofer channel comprises a 2nd order minimum phase and minimum delay high pass filter with a corner frequency of 16Hz. This filter eliminates rumble from turn tables or sub-sonic frequency content from digital recordings.

This high pass filter solely determines the lower corner frequency of the box if MFB (Motion Feed Back) amplifiers as the AC-PAR75 are used for the woofer(s).

In the woofer channel as world first novelty the physically unavoidable Doppler effect is eliminated, which is produced by any moving speaker membrane. For that purpose an analog circuit continuously computes the Doppler generated phase modulation.

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That signal is used to control a phase modulator in such way, that the Doppler effect of the speaker membrane is exactly compensated. In this way the acoustical phase center of the speaker is held at a fix location. Virtually a non-moving speaker membrane is created. This avoids completely the audible roughness of higher frequency tones through the Bessel lines that the Doppler effect would generate. As well the Doppler induced second harmonic frequency components (a.k.a. Eigen-Doppler) of the moving membrane are removed.

The internal outputs carries also MUTE and STBY signals for the AC-PAZ75 or AC-PAR75

amplifiers or other power amplifiers with similar interfaces.

The implemented digital controller is responsible for ensuring the proper ON/OFF sequence as well as a continuous monitoring of the module temperature. A further task of the on-board controller is the Audio Signal Detection (ASD) in order to handle MUTE/STBY and ON/OFF dependent of the presence of the audio signal. That function can be disabled (see description on page 5 for more details). Optionally the driver for a two-color LED and/or a display via I²C is handled by the on-board controller.

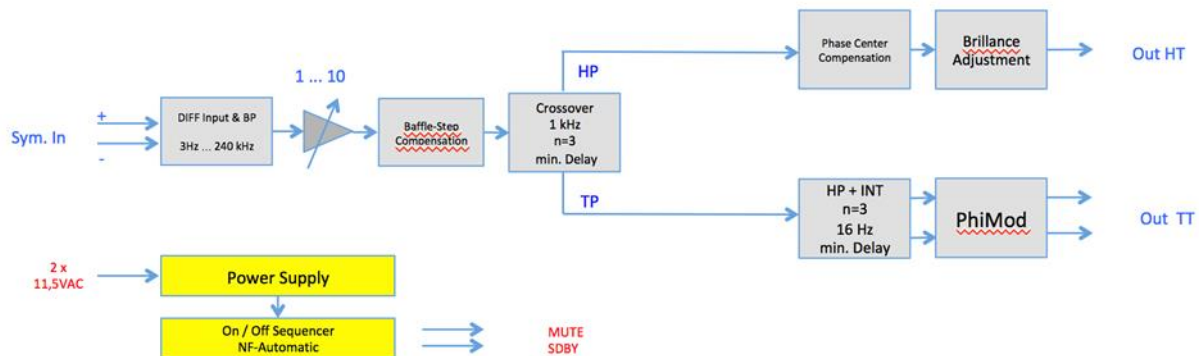


Figure 2: Functional Block Diagram of the Analog Audio Processor AC-AAZ01

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Figure 3 shows the typical implementation of the AC-AAZ01 audio processor:

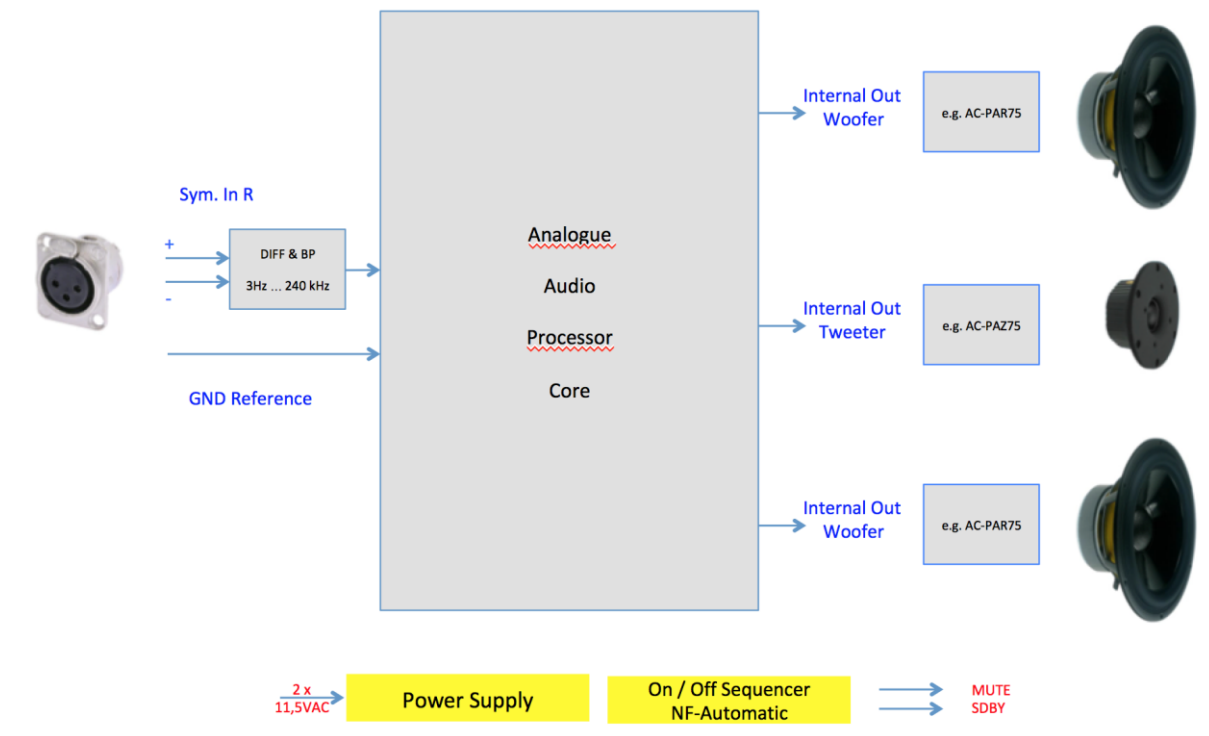


Figure 3: Typical implementation of the AC-AAZ01 Audio Processor

Figure 4 shows the frequency response of the 3rd order cross over with the default center frequency of 1 kHz. The outputs of the crossover add for all frequencies exactly to unity.

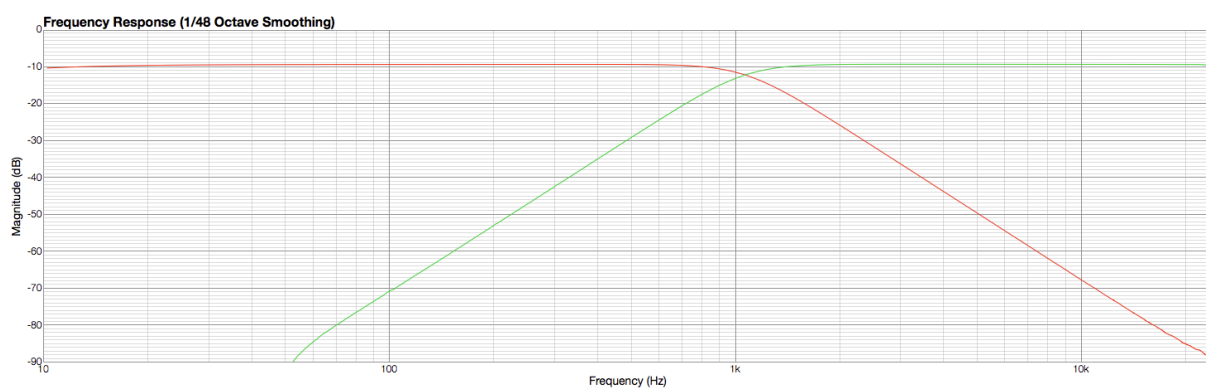


Figure 4: Frequency response of the crossover

Figure 5 shows the frequency response of the tweeter channel with the variation span of the high frequency boost between 0 dB and +3 dB. Some audience prefers that high frequency boost as it brings brilliance into the sound.

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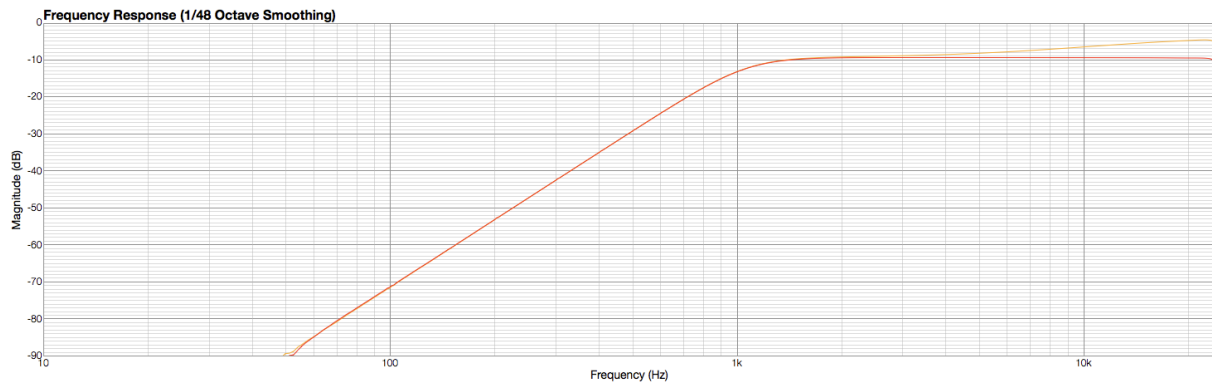


Figure 5: Frequency response of the tweeter channel

Figure 6 shows the frequency response of the woofer channel including the effect of the 16 Hz high pass filter of 2nd degree which removes rumble from turn tables and sub sonic frequencies from digital recordings.

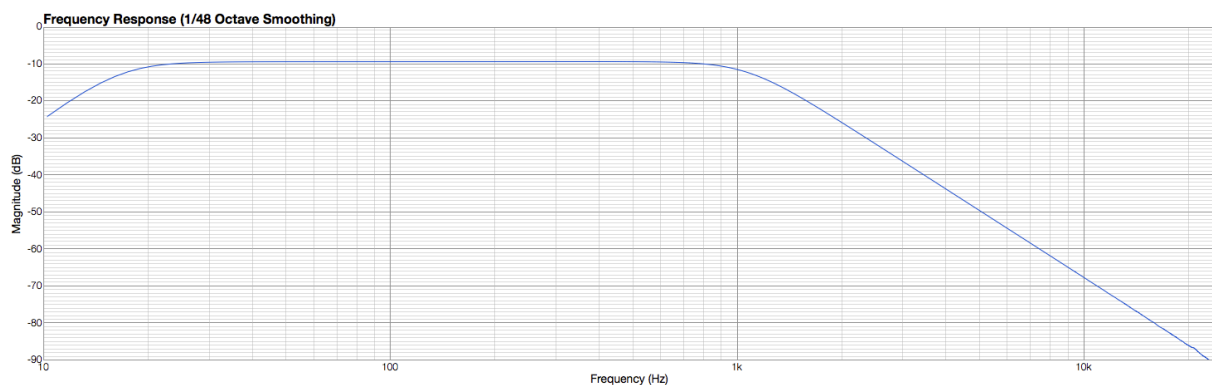


Figure 6: Frequency response of the woofer channel

Figure 7 shows the analog computed signal representing the membrane phase due to its movement towards and back from the listener. This signal is used in the AC-AAZ01 phase modulator in order to exactly compensate the phase modulation (Doppler effect) of the moving speaker membrane.

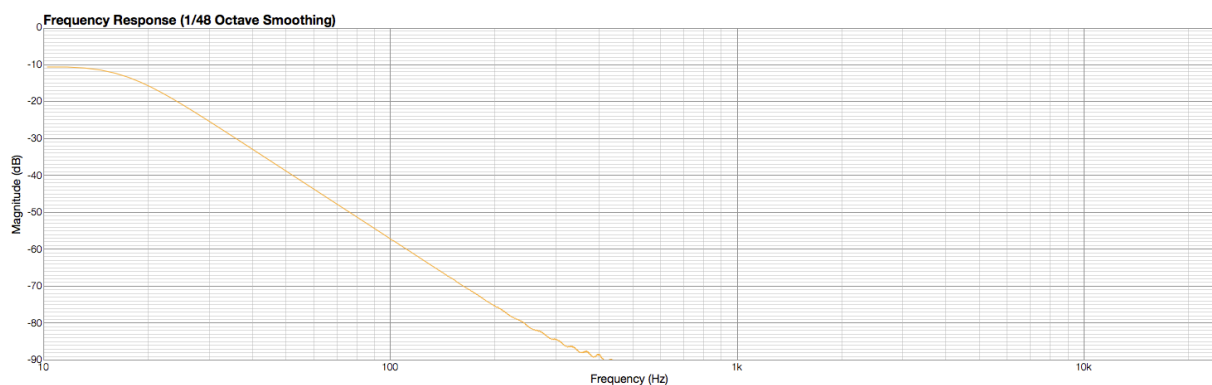


Figure 7: Frequency response of the membrane phase for the Doppler compensation

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Figure 8 shows the connections to the AC-AAZ01 Analog Audio Processor

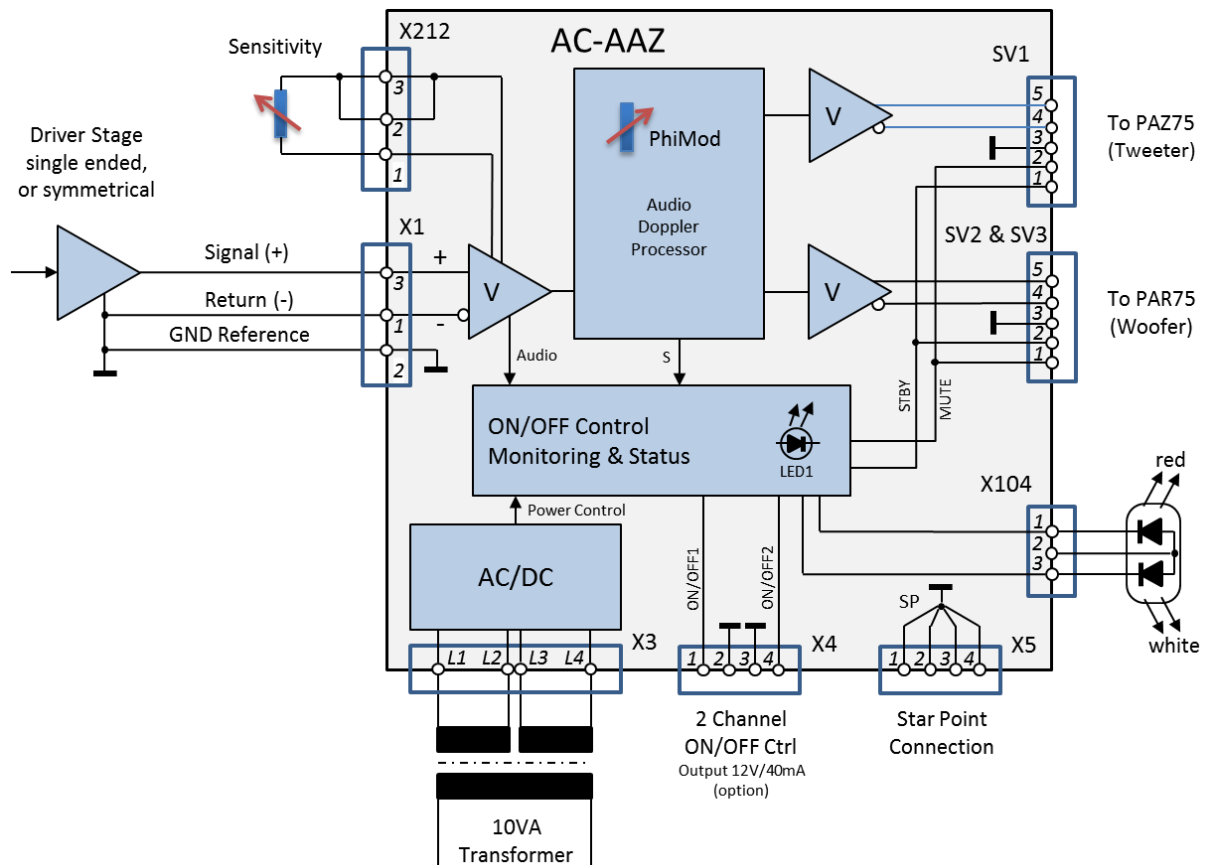


Figure 8: Typical Application for the module

Detailed description and Application Information

The AC-AAZ01 is operated typically with two equal AC voltages of 12 VAC. Two separate windings of an AC transformer are recommended, but also a middle tapped secondary winding can be used (see Figure 8 for details).

The audio input signal is feed to a differential input amplifier stage with high common mode signal rejection in order to avoid ground (GND) loops. A connection between the driving source ground and the AC-AAZ01 GND is therefore necessary in order to establish a common GND reference.

In order to simplify building a complete loudspeaker box with e.g. one tweeter and

two to four Woofers, a dedicated star-grounding scheme is implemented for an optimum result. The AC-AAZ01 board offers a star ground, which is realized by the dedicated 4-port connector X5. All GNDs from the power amplifiers (AC-PAR75 and AC-PAZ75 have differential inputs) are to be connected there. Also Pin1 of the XLR connectors should be connected there. This guarantees a single star ground without any ground loops.

The AC-AAZ01 is optimized for the combination with the amplifier modules AC-PAZ75 for the tweeter and one up to four independent AC-PAR75 as drivers for the woofer(s).

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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-AAZ01 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-AAZ01. In case the MUTE signal would be pulled down (active low), the ASD-Function is permanently disabled.

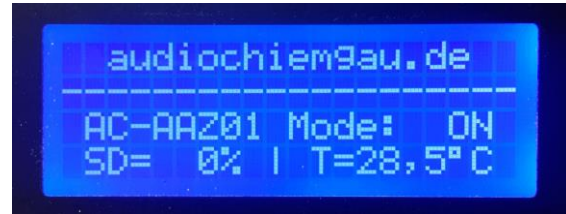
With active ASD the system will stay in ON as long as an audio signal above the implemented threshold will be detected. In case the signal is long enough and permanently under the threshold (could be adjusted by firmware) the controller changes the status to STBY after 8 minutes and after additional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

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

All implemented durations and thresholds for ON and OFF could 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 I²C 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 of such a display.



Please contact AudioChiemgau for other display colors or other changes.

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

Remote ON/OFF control outputs

Up to 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 relays direct with up to 40mA load current.

Additionally the internal supply voltage for the module itself is switched off in order to reduce power consumption in the OFF mode.

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

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Customer / User Adjustments:

1. Sensitivity (gain) of the input differential amplifier, either with the built-in potentiometer or with the optional user accessible external potentiometer
2. Customer defined brilliance boost
3. Customer defined acoustic phase center compensation between tweeter and woofer(s)
Usually not end user adjustable
4. Customer defined lower corner frequency of the SUB when the AC-PAR75 is used
Usually not end user adjustable

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Absolute Maximum Ratings ($T_{amb} = 25^{\circ}\text{C}$; unless otherwise specified)

| Symbol | Parameter | Value | Unit |
|----------------|--|----------|--------------------|
| V_S | AC supply voltage (two symmetrical transformer windings) | 18 | V _{rms} |
| T_{op} | Operating ambient temperature range | 0 to +50 | $^{\circ}\text{C}$ |
| V_{OD} | Open drain voltage in high state (MUTE/STBY) | 35 | V |
| T_{stg}, T_j | Storage temperature | + 80 | $^{\circ}\text{C}$ |

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

Electrical Characteristic ($T_{amb} = 25^{\circ}\text{C}$; $f = 1\text{kHz}$; unless otherwise specified)

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|-----|--------------|-----|------------------|
| V_S | AC supply voltage range Two identical transformer windings, or mid tapped secondary winding | 10 | 12 | 14 | V _{rms} |
| $I_{S_{OFF}}$ | Supply current in OFF | | 10 | 20 | mA |
| $I_{S_{operating}}$ | Supply current in nominal operation ¹⁾ | 90 | 110 | 130 | mA |
| P_S | Required AC power per winding | | | 5,0 | VA |
| Audio Input Left or Right Channel | | | | | |
| R_{id} | Differential input resistance (AC) | | 100 | | k Ω |
| R_{i0} | Input resistance to GND (AC) | | 50 | | k Ω |
| V_{CM} | Input common mode range | | ± 5 | | V |
| V_{IS} | Input sensitivity for 2V differential output Voltage, adjustable via internal 10 turn potentiometer or external potentiometer | 0,2 | | 2 | V |
| V_{ASD} | ASD Sensitivity/Threshold of V_{IS} (adjustable by firmware) | | 0,5 (TBC) | | mV |
| Audio Output for Left/Right/Woofer | | | | | |
| R_{od} | Differential output resistance (AC) | | 100 | | Ω |
| R_{o0} | Output resistance to GND (AC) | | 50 | | Ω |
| V_o | Differential output voltage | | 2 | 10 | V |
| Woofer cannels | | | | | |
| G_{SUB} | Variable gain | 0.9 | | 10 | |
| $\Phi_{i_{rev}}$ | Phase reverse switch | 0 | - | 180 | degree |
| $\Phi_{i_{var}}$ | Variable phase shift | 0 | | 180 | degree |
| Standby & MUTE Function (open Drain driver with pull-up) | | | | | |
| I_{OL} | Low-level sink current capability | | | 20 | mA |
| V_{OH} | Output voltage in high-state ²⁾ | 4,3 | 4,7 | 13 | V |

¹⁾ Without external loads on the remote control driver(s) and without display

²⁾ See interface description for more details

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| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|------|------------------|------|------|
| 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 ³⁾ | | mA |
| V_{out} | Output Voltage Driver active With typical supply voltage V_s | 12 | 15 | 16 | V |
| I_{max} | Max output current before switch off | | 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 |
| Over Temperature Detection and Turn ON/OFF | | | | | |
| T_{OFF} | Switch OFF temperature | +65 | +70 | +75 | °C |
| T_{ONHY} | Switch ON Hysteresis | | 4 | | K |

³⁾ Also deliverable with higher drive strength

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PCB Layout and Mechanical Support

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.

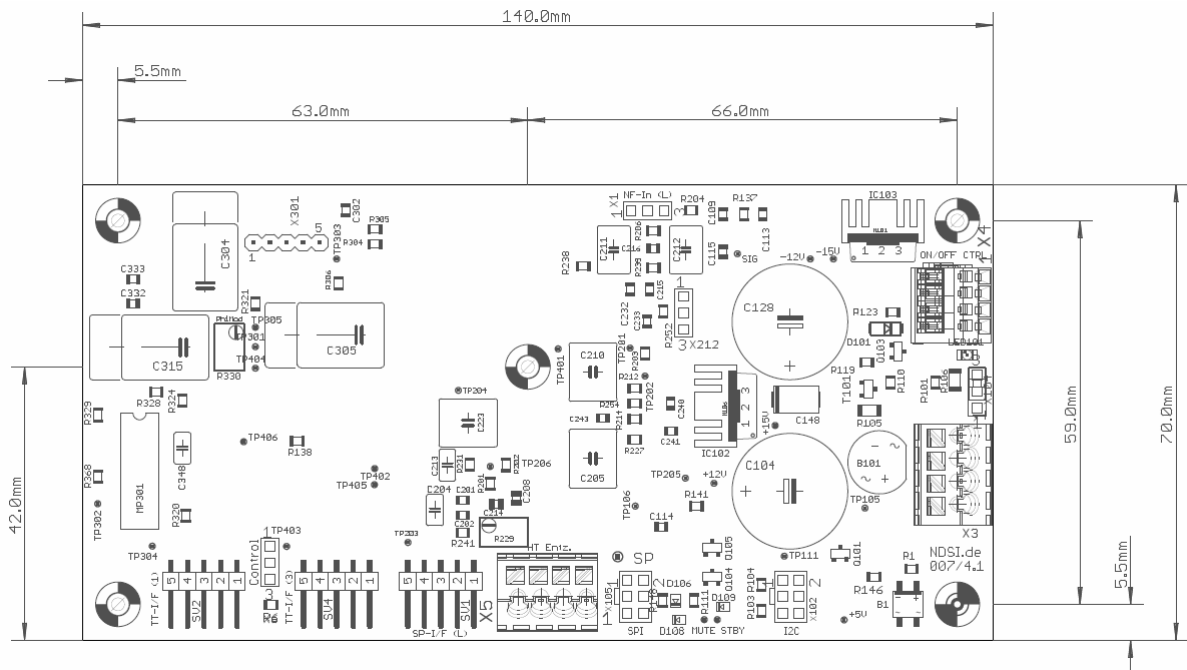


Figure 9: Layout of the PCB, top view and populated as AC-AAZ01

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

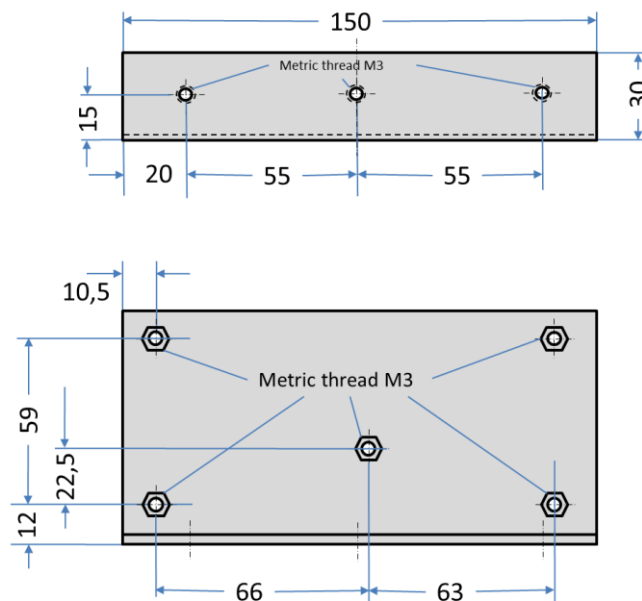


Figure 10: Optional Flange for vertical mounting of the module (preliminary)

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 (AC-AAZ01 PCB without mounting flange)

| 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 | | 38 | | mm |
| W | Module Weight (TBC) | | 95 | | g |

Additional cooling of the module is not required

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Electrical InterfacesConnector Types and Interface Description

| Connector | Parameter/Signal | Typ | Wire Size |
|--|---|-----------------------------|--|
| X1 | Audio input interface for left respectively right channel | Pin Header 1x3 RM 2,54mm | - |
| X3 | AC Power Supply | WAGO 250-204 | 0,2 – 1,5mm ² AWG 24-16 |
| X4 | Remote control output | WAGO 233-504 | 0,08 – 0,5mm ² AWG 28-20 |
| X5 | GND connection (Star Point) | WAGO 250-204 | 0,2 – 1,5mm ² AWG 24-16 |
| X6 | Connector for external control (MUTE/STBY) | Pin Header 1x3 RM 2,54mm | - |
| X102 | I ² C-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 tweeter, incl. MUTE and Standby | Pin Header 1x5 RM 2,54mm | - |
| SV2 SV3 SV4 SV5 ⁴⁾ | Audio out woofer, incl. MUTE and Standby | Pin Header 1x5 RM 2,54mm | - |

Interface: AC Power Supply and Connector Pinout (X3)

| X3 Pin | Parameter/Signal | Remark |
|--------|-------------------------------------|--|
| L1 | AC Input A (or positive DC supply) | L2 and L3 could be connected to use transformer with center tap For proper power drop detection take care of polarity in case of DC supply. |
| L2 | Return A internally connected to L3 | |
| L3 | Return B internally connected to L2 | |
| L4 | AC Input B (or negative DC supply) | |

⁴⁾ SV4 and SV5 optional and only required for more than two woofer interfaces

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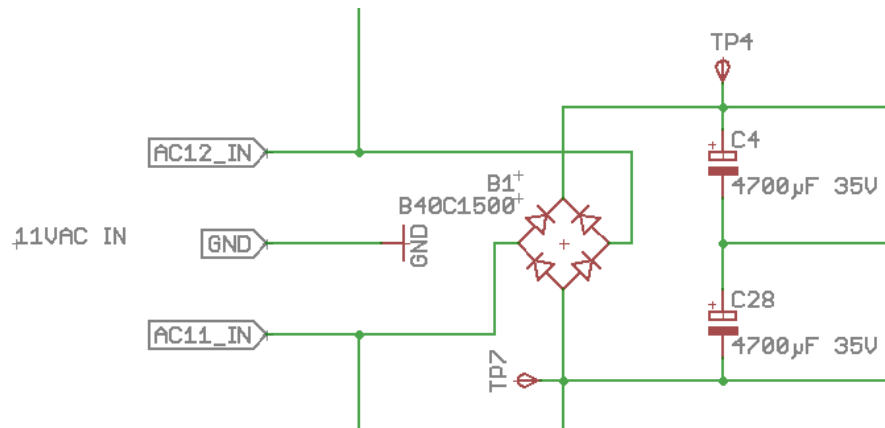


Figure 11: AC Input Circuit Diagram

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 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 |
| X104-3 | Cathode of indicator LED1 (white) | LED: Connect to additional LED for external indication |

The AC-AAZ01 (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 they 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, SV3, AV4 and SV5)

The AC-AAZ01 (V4) provides up to four interface connectors for connecting of independent woofer amplifiers (e.g. AC-PAR75) and one additional connector for the tweeter amplifier like the AC-PAZ75.

The four woofer interfaces are connected in parallel.

| SV1-5 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 | |

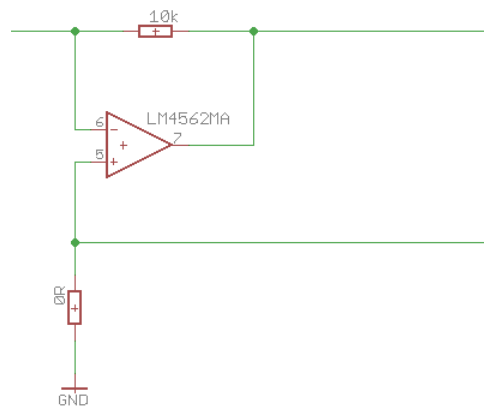


Figure 12: General Internal Audio Output Interface

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 AC-PAZ75 and/or 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

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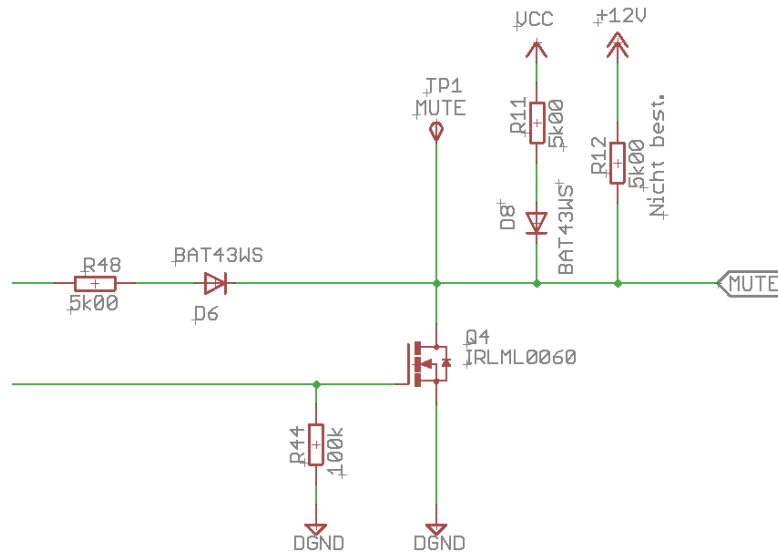


Figure 13: MUTE Output Interface (Standby identical if populated)

Normally the AC-AAZ01 (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 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 system can be activated by the MUTE switch 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-AAZ01 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 | |

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Interface: Remote Control Output (X4)

| X4 Pin | Parameter/Signal | Remark |
|--------|----------------------------------|--|
| 1 | Remote Control Out Channel 1 (P) | Normally not populated in AC-AAZ01 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.

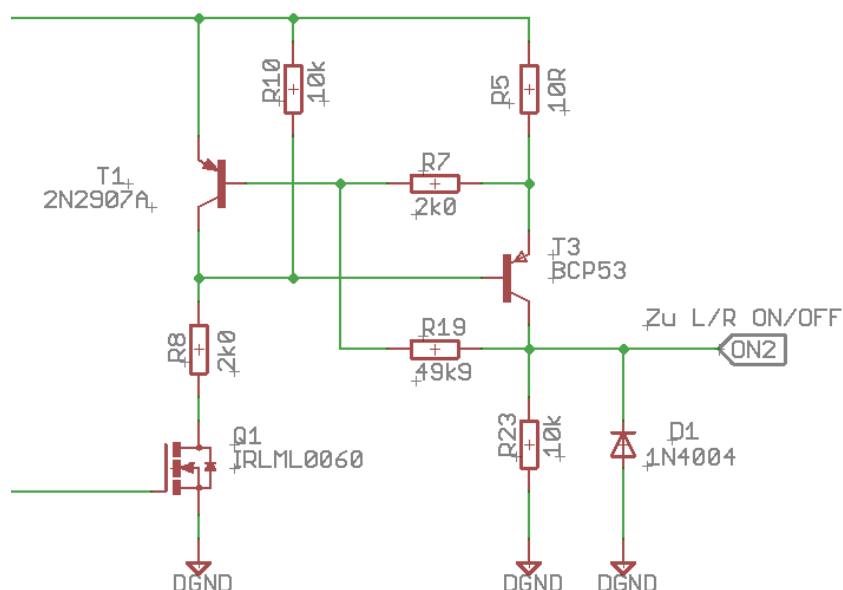


Figure 14: Relay driver stage for ON/OFF remote control (40mA configuration)

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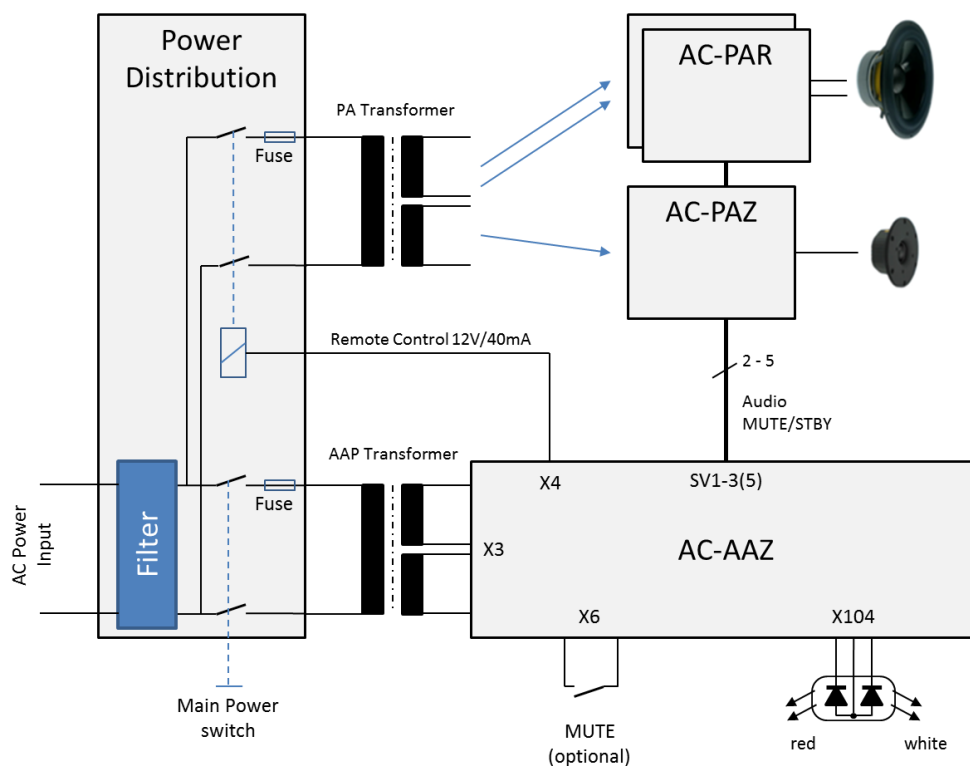


Figure 15: Recommended power distribution and control configuration

Interface: Audio Input Connector Pinout (X1)

| X1 Pin | Parameter/Signal | Remark |
|--------|----------------------|---|
| 1 | Audio Input negative | |
| 2 | GND | Signal ground, could be used for shielding |
| 3 | Audio Input positive | Commonly used with Audio Signal Detection (ASD) circuit |

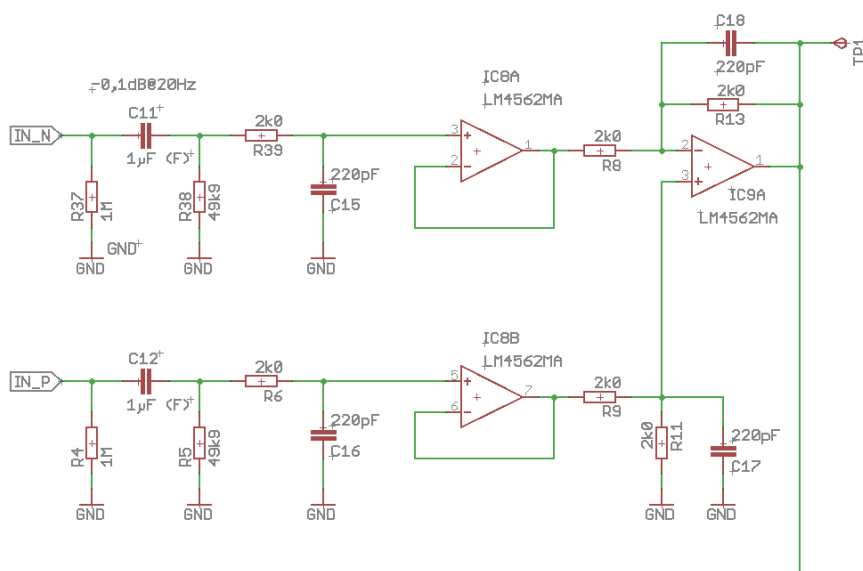


Figure 16: Audio Input Interface

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Interface: External Gain Potentiometer (X212)

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

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