

TA2022 Audio Amplifier Module v1.0

TA2022 Audio Amplifier Module is a Class T Stereo Audio Amplifier based on TA2022 digital audio power amplifier made by formerly Tripath® Company. The design of this board is in accordance with the manufacturer datasheet and recommendations, as well as the reference designs. Furthermore, some improvements has been made to make the board more compact and suitable to use both in new designs, in which the user will adopt the preferred housing, input stages and power supply, and can be used also as a drop-in replacement for existing audio amplifiers, which already have housing, transformer, and input stage.

Amplifier Features:

- Output Power: 2x75W at 4Ω, or 45W at 8Ω, with max. 0.1% THD+N, at +/- 27V Supply Voltage.
- Output Power: 2x90W at 4Ω, or 55W at 8Ω, with max. 0.1% THD+N, at +/- 31V Supply Voltage.
- Output Power: 2x100W at 4Ω, or 60W at 8Ω, with max. 0.5% THD+N, at +/- 32V Supply Voltage.
- Output Power in Bridge mode: 180W at 8Ω, with max. 0.1% THD+N, at +/- 31V Supply Voltage.
- Audiophile sound Quality: 0.02% THD+N at 68W at 4Ω or 42W at 8Ω.
- Very good efficiency: Up to 93% at 2x60W at 8Ω or up to 90% at 2x100W at 4Ω.
- Output over-current and short-circuit protected.
- Compact size, 100x85x45mm, assembled board, with integrated heat sink and speaker protection circuit.
- Auxiliary supply voltage regulator installed on-board, only need the AC symmetric supply voltage.
- Mute control and Mute status pins for controlling the amplifier status within the system.
- +5V DC at max 100mA provided from the board for powering the cooling fan or other amplifier stages.
- Board contains large capacity bypass electrolytic capacitors, close to the output stage.
- Mostly SMD components used, mounted very close to the TA2022 IC

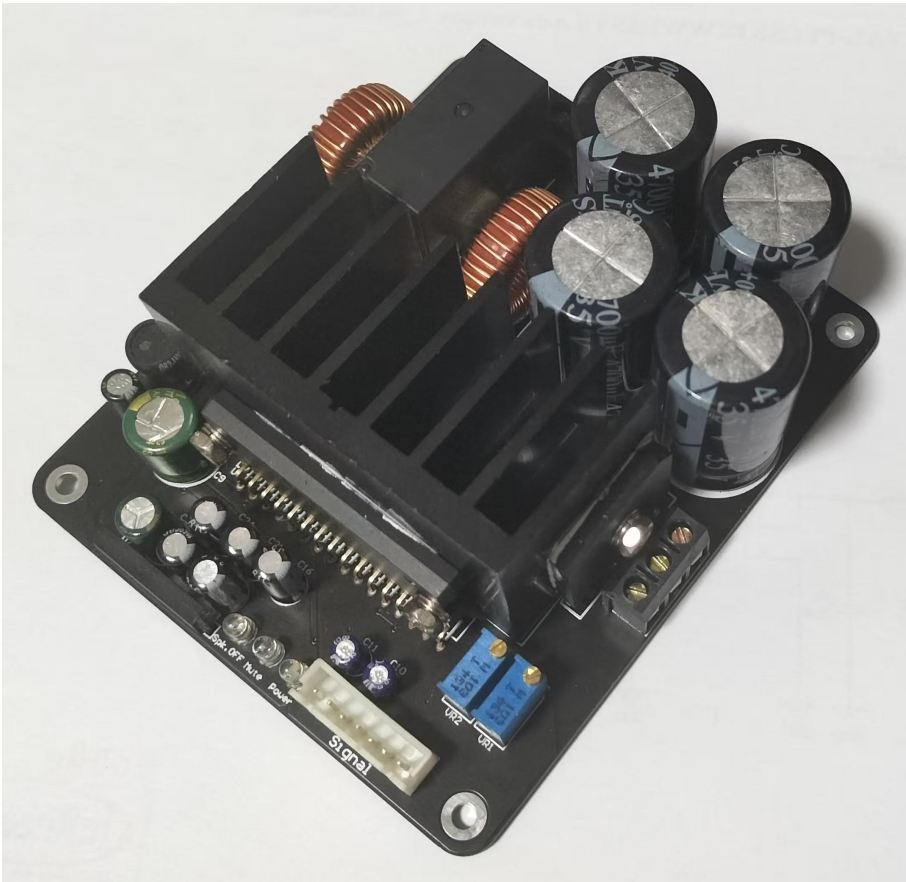


Figure 1: TA2022 Audio Amplifier Module

Amplifier Description:

TA2022 Class T Stereo Audio Amplifier is built around TA2022, dedicated digital audio power amplifier. The main blocks of this amplifier are: Input stage, driver, power stage, and Auxiliary power supply, which provide power for the drivers, logic and small signal stages. The amplifier schematic is according with the reference design provided by Tripath. In addition to this, the auxiliary supply was included onto the schematic.

The audio input signal is provided to the TA2022 IC thru plug-in type connector P1 at pin 5 for the Left channel and pin 3 for the Right channel. As can be seen from the schematic, the input pins are surrounded by GND pins for better S/N ratio. Next, the audio signal is driven to the TA2022 IC thru DC coupling capacitors, C5 and C6, which should have the value in the range of 1uF to 4.7uF, and can be polarized electrolytic or non-polar metal film. Good results can be achieved with 2.2uF non-polar metal film capacitors, which are used on most of the boards. Next, the resistors R15 and R17 are part of the input stage, and set the amplifier input impedance. The TA2022 input stage is configured as an inverting amplifier, allowing the system designer flexibility in setting the input stage gain and frequency response. The TA2022 amplifier gain is the product of the input stage gain and the modulator gain: $A_{VTA2022} = A_{VINPSTAGE} * A_{VMODULATOR}$. For this amplifier, there are two gain values. Some boards have the gain value 15V/V which is 23.5dB and some boards have the gain value 5.88V/V which is 15.4dB. On request different values can be provided, or the gain can be changed by the user in the range of 5-15 V/V or 14-23.5dB by simply changing the value of the resistors R8, and R9. Note that wider gain values are not recommended due to the stability issues which can occur for higher gain or lower gain values. The gain value can be calculated simply with the following formula: $A_{Left} = 15 * R10 / R4$ and $A_{Right} = 15 * R11 / R5$. The coefficient with the value 15 is calculated as the ratio of the modulator feedback resistors. The input stage of the amplifier is biased at approximately 2.5V DC using VR1 and VR2 variable resistors. This value is adjusted so that the output DC offset to be as close to 0V as possible (less than 40mV). The DC Offset during Mute, and without load will have about 2.5V, but will decrease to 0V after connecting the load. Note that the DC offset was set for the boards after assembly test, and does not require further adjustments. For a good S/N ratio, is recommended to use shielded signal cables for signal input, and this cables to be as short as possible, and avoid the crossing in close proximity to the power stage or output cables, which can create unwanted feedback. Pay attention to the GND loop which can decrease S/N performance.

The TA2022 Audio Amplifier Module control section consists of Mute circuit, under-voltage, lockout, over-voltage lockout, over-current and short-circuit protection circuits, as can be seen in Figure 2. When a logic high signal is supplied to Mute, on pin 2 of the connector P4, both amplifier channels are muted (both high- and low-side transistors are turned off). By default, with the help of an on-board pull-down resistor R13, a logic level low is supplied to MUTE, and both amplifiers are fully operational. There is a delay of approximately 200 milliseconds between the de-assertion of MUTE and the un-muting of the TA2022 Audio Amplifier Module. The HMute pin is a 5V logic output that indicates various fault conditions within the device. These conditions include: over-current, over-voltage and under-voltage. The HMute output is capable of directly driving an LED through a series 1KΩ resistor, and the board already has an LED for status and one for Power Supply monitor. The TA2022 Audio Amplifier Module has built-in over-current protection circuitry to protect itself and the output transistors from short-circuit conditions. The TA2022 uses internal current sense circuits, which will limit the output current at 8A for each channel. When an over-current condition occurred, the TA2022 is latched in and can be cleared by toggling the Mute input or cycling power. For the under-voltage and over-voltage lockout, the TA2022 senses the power rails through external resistor connected to VNSENSE and VPSENSE. The over- and under-voltage limits are determined by the values of the resistors in the networks, and are set within the range of +/- 23V DC to +/- 38V DC. If the supply voltage falls outside the upper and lower limits determined by the resistor networks, the TA2022 shuts off the output stages of the amplifiers. The removal of the over-voltage or under-voltage condition returns the TA2022 to normal operation. The nominal operating voltage will typically be chosen as the supply "center point." This allows the supply voltage to fluctuate, both above and below, the nominal supply voltage. VPSENSE (pin 19) performs the over and under-voltage sensing for the positive supply, V+. VNSENSE (pin 18) performs the same function for the negative rail, V-. When the current through $R_{VPSENSE}$ (or $R_{VNSENSE}$) goes below or above the normal values, (caused by changing the power supply voltage), the TA2022 will be muted. There is a hysteresis range on both the VPSENSE and VNSENSE pins. The usable supply range is the difference between the over-voltage turn-off and under-voltage turn-off for both the V+ and V- supplies. Thus, the supply voltage must be outside of the user defined supply range for greater than 200mS for the TA2022 to be muted.

The TA2022 Audio Amplifier Module driver and power stage are integrated in the TA2022 IC, this simplifying the amplifier design. The main role of the driver stage is to provide V_{GS} voltage for the output MOS-FET transistors. The driver stage is powered from the 10V DC with respect to V_N auxiliary supply. The low-side MOS-FET's are driven using the voltage provided, and high-side MOS-FET's are driven using bootstrap supply, which consist of D6, D7, C21, C22, C23, C24, R16, R18. The TA2022 IC contains also the voltage level shifter, for driving the output MOS-FET's which have floating Gate and Source voltages with respect to GND.

The TA2022 IC has fast recovery diodes connected in parallel with the output MOS-FET's for reduction of ringing. The diodes shunt the inductive energy generated in the parasitic inductance of the components leads and PCB tracks. The diodes are connected close to TA2022 IC, to minimize the ringing. The diodes are MURS120, SMD type, which have very fast switching timings and very low stray inductance.

Furthermore, for reducing the ringing, few bypass capacitors are placed close to TA2022 IC. There are 2 types of capacitors: one type is X7R material, ceramic capacitors, SMD1206 footprint placed on the bottom side of the PCB, very close to the TA2022 IC and the other type are electrolytic capacitors, for energy storage during peaks. The ceramic capacitors are connected between $V+$ and GND, $V-$ and GND and $V+$ to $V-$. They provide extremely low stray inductance and ESR, which is helpful for reducing ringing. The electrolytic capacitors acts as energy storage tank during peak power consumption, as well as minimizing the pumping effect which switching amplifiers experience at high power outputs and low frequencies. If the pumping effect is too high, this will lead to amplifier oscillations between ON/OFF states, since the under-voltage and over-voltage protection is not latched shutdown. By connecting extra high-capacity electrolytic capacitors, this phenomenon can be reduced. The PS10K40 board is a suitable match, which can provide enough filtering capacity and rectification, bypassing the onboard supply.

After switching stage, the amplified PWM Audio Signal needs to be filtered to extract the audio component. For this purpose an LC low pass filter is used, with the cut-off frequency at higher value than is used in the classic Class D amplifiers. This greatly reduces the speaker interactions that can occur with the use of lower-frequency filters common in Class-D designs. Also, the higher-frequency operation means that the filter can be of a lower order, simpler and cheaper. The values chosen for the output filter are: Inductance of the filter coil = 11 μ H, made on Micrometals T80-2 core material, by neatly winding 0.7 mm (22AWG) copper wire. Capacitor has the value of 220nF, at a working voltage of 63V. In addition to this components, the filter contains a Zobel Network also, which is required in case that the amplifier is powered without load, to decrease the Q factor of the filter circuit above 50KHz.

The speaker protection circuit is included, no additional speaker protection circuit is needed. It serves two main purposes. First, it delays the speaker connection to the amplifier for a short 2-3 seconds time to allow the amplifier to reach the steady-state operation. Second, in case of excessive DC component present on the output due to DC biased signal source or amplifier power stage failure, it disconnected the speakers immediately to avoid damage.

The auxiliary power supply provides the housekeeping supply voltages needed for proper amplifier operation. The values of this are: +5V DC with respect to GND and +10V DC with respect to $V-$. This power supply consists of integrated supply for VN10 into TA2022 IC, (10V DC with respect to negative rail) and one linear voltage regulator, LM7805 series for 5V DC with respect to GND. Since the current consumption is very low, about 50mA, is not justified to use a SMPS, which may alter the S/N Ratio. The +5V is also available on the signal connector, as auxiliary power for other small signal stages which consume under 100mA, such as preamplifier, USB DAC or a fan.

The PCB Layout design has an important contribution to the overall performance of the TA2022 Audio Amplifier Module. That's why double layer, FR-4 material with 1.6mm thickness and copper tracks thickness of 70 μ m or 2 oz was chosen. The tracks width, were calculated to withstand the currents which they have to carry, and also the distance between adjacent tracks which carries higher voltages than 20V is big enough to satisfy the clearance conditions imposed by the design standards. The size of the PCB is 100x85mm, and has 4 mounting holes, 4 holes are on the corner of the PCB and two at the top-middle side of the PCB and at the bottom-middle side of the PCB, this one is the centre of the star ground, and should not be connected to the chassis or housing if the GND was connected in other place, like the input or output connectors, otherwise the GND loop will be created, and the S/N Ratio will be deteriorated, and the amplifier may become unstable. The mounting holes are 3.2mm diameter or 0.12 inch, copper plated for better mechanical strength. The main components layout and the Input and Output connectors pin out can be seen in the Figure 4. The layout was designed to keep the vital components as close as possible to the TA2022 IC, for better performances and aesthetical reasons.

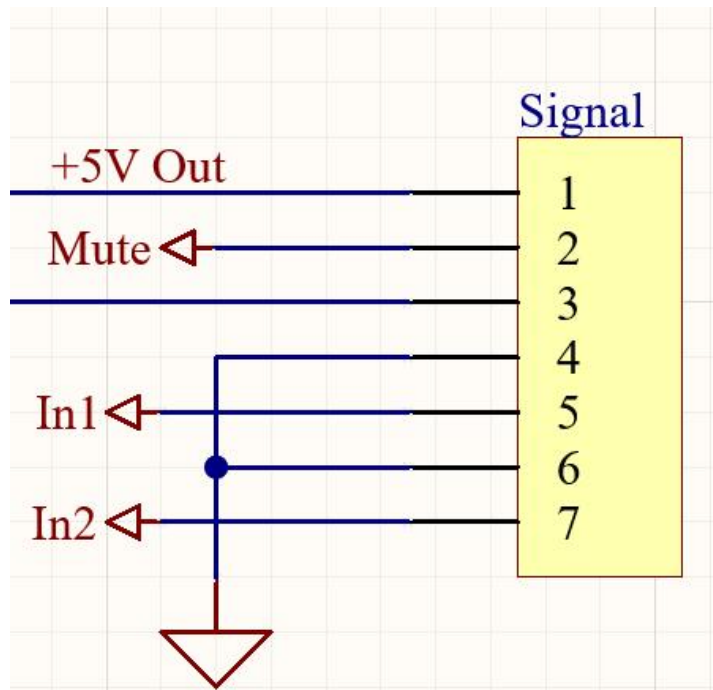


Figure 2: TA2022 Audio Amplifier Module Signal connector Diagram

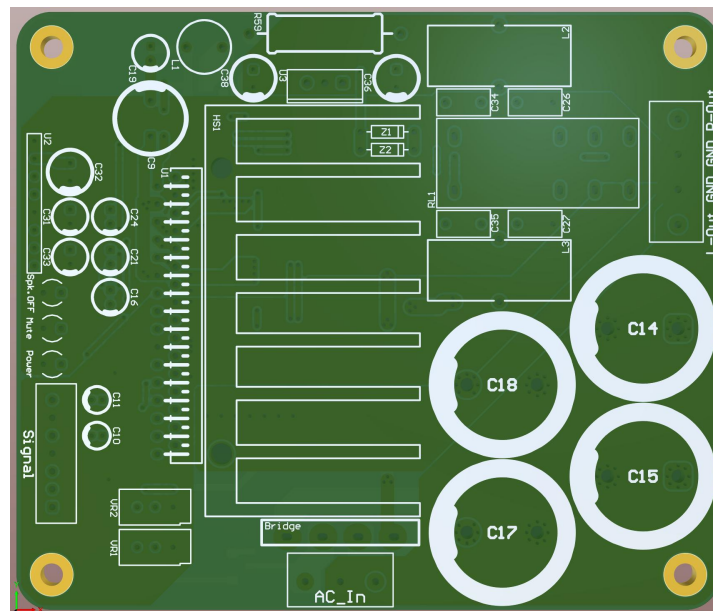


Figure 3: TA2022 Audio Amplifier Module Board layout overview and connections, top side view

The TA2022 Audio Amplifier Module can be used in bridge mode, with the output power increased considerably. There are two ways to bridge the TA2022 Amplifier: one method is to provide a 180° shifted audio signal with equal amplitude to both Left and Right channels. Another method, more simple than the previous one, and which can be implemented easy if there is no 180° shifted audio signal available, is to connect the OAUT2 pin to the input resistor at the INV1. OUT2 will then be a gained version of OAOUT2, and OUT1 will be a gained and inverted version of OAOUT1. To achieve this, a resistor with the same value as the R1 and R3, in this case $20\text{k}\Omega$, must be connected between OAUT2 (Pin 25) and INV1 (Pin 23), then the audio input signal will be provided to the Input 2 only, the Input 1 will be left unconnected. The load will be connected between the Left Output and Right Output, without connection to GND. The maximum output power will be about 110W at 4Ω or 180W at 8Ω . Note that at low impedance, the Amplifier can experience over-current protection shut-down, due to the increased current. It is recommended to not use the amplifier at load impedances lower than 4Ω .

The TA2022 Audio Amplifier Module efficiency is given by the Output Power divided to the Input Power: $\eta = P_{OUT}/P_{IN}$. The Input Power can be considered as: $P_{IN} = P_{DRIVER} + P_{SW} + P_{SMPS} + P_{+5V} + P_{OUT} \left(\frac{R_S + R_{ON} + R_{COIL} + R_L}{R_L} \right)^2$
 where: P_{DRIVER} = Power dissipated in the TA2022 = 1.6W/channel
 $P_{SW} = 2 \times (0.01) \times Q_g$ (Q_g is the gate charge of M, in nano-coulombs)
 R_{COIL} = Resistance of the output filter inductor (typically around 50m Ω)
 P_{SMPS} = Power dissipated in the Auxiliary power supply
 P_{+5V} = Power consumed by a load on the +5V output

While the Input Power Level can be measured precisely, and the Output Power can also be measured on a resistive load, driving sinus signal, the practical efficiency can be determined. Note that the efficiency is dependent on the Output power level, at low power, has low values, and is increasing as the Output Power is higher. This is mainly due to switching losses which can be considered constant, and the TA2022 power consumption which can be also considered constant. One factor which greatly influences the switching losses and the global efficiency is the dead-time setting, or BBM setting. The highest efficiency is achieved for a dead-time value of 120nS. From the practical measurements, the average achieved efficiency was up to 93% at 2x60W at 8 Ω and up to 90% at 2x100W at 4 Ω .

The TA2022 IC requires a heat sink for proper heat dissipation. This is mounted on a side of the board, and is fixed with 2 screws which tight the heatsink to the PCB. The size is: 100 mm long, same as the board, 18 mm wide and 40/50 mm tall, and has 16 fins. The thermal resistance of the heat sink is about 3.6 $^{\circ}$ C/W without forced air cooling, which means an increasing of the heat sink temperature of 3.6 $^{\circ}$ C for every dissipated Watt. This value can be enough for moderate auditions, considering that the musical signal have a lower power spectrum than the pure sine wave, but the installing space and position should been considered. For better cooling, a small 5V CPU 40 x 40 mm cooling fan can be used. The power supply can be taken from the small signal connector, which provide +5V. The fan should be mounted with the blow side towards the heat sink fins, for better cooling. A variable speed fan, depending on ambient temperature would be a good choice, to minimize the fan noise, especially at low power levels, when the heat sink temperature is also lower. If the amplifier is installed wrong in a case which doesn't allow a proper cooling, an over-temperature fault may occur if the junction temperature of the IC exceeds approximately 165 $^{\circ}$ C. this correspond to a heat sink temperature of about 120-135 $^{\circ}$ C The thermal hysteresis of the part is approximately 30 $^{\circ}$ C, the fault will automatically clear when the junction temperature drops below 135 $^{\circ}$ C.

The power supply requirement for the TA2022 Audio Amplifier Module is a dual AC 2x22 to 2x24V 3A min to 5A peak or DC from +/- 30V DC at minimum 3.5A for an Output Power of 2x90W at 4 Ω , 55W at 8 Ω to +/- 32V DC at minimum 4A for an Output Power of 2x100W at 4 Ω , 60W at 8 Ω symmetrical supply with a filtering capacitance of at least 15mF for each rail. To ensure the Output Power levels and performances, the power supply voltage should not drop more than 5-10% at maximum power. The board has a rectifier bridge installed, so AC voltage can be provided. The value should be in range of 2x21V AC at min. 4.5A to 2x23V AC at min. 5A. A thoroidal transformer with power rating of at least 150W should be used or a SMPS with a power rating of at least 240W, which will provide 2x32V DC, supplied to the power connector. In this case the rectifier bridge can be bypassed.

Disclaimer:

The TA2022 Audio Amplifier Module shall be used according with the instructions provided in this document. The user should NOT attempt to modify or change any of the parameters of this product, which can lead to malfunction. The designer and manufacturer of the product, and the official distributor, **Connexelectronic**, will not be liable for any kind of loss or damage, including but not limited to incidental or consequential damages. Due to the medium voltage levels of this board, the user should take all the caution measures needed when working with medium voltage levels, should not touch any uninsulated part of the board or connectors, or short-circuit any part of the board or connectors. Any misuse will be made on user responsibility.

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