

# TA3020 Audio Amplifier Module v4b

The TA3020v4b Audio Amplifier Module is a complete assembled Class T Stereo Audio Amplifier with on-board Switched Mode Power Supply based on TA3020 digital audio power amplifier driver made by formerly Tripath® Company and a new, state-of-the-art fully regulated Resonant SMPS Topology. The amplifier is available in two versions, one version with output power of 2x300W at 4Ω or 160W at 8Ω the TA3020v4b-300 and another version with output power of 2x400W at 4Ω or 205W at 8Ω the TA3020v4b-400. The TA3020v4b amplifier board offers a complete solution for a compact, medium to high power audio amplifier system, which can be used for newly built custom amplifiers or for an OEM amplifier module in an OEM product.

## Amplifier Features:

- Output Power: 2x306W at 4Ω, or 162W at 8Ω, with max. 0.1% THD+N, for the TA3020v4b-300 version.
- Output Power: 2x414W at 4Ω, or 211W at 8Ω, with max. 0.1% THD+N, for the TA3020v4b-400 version.
- Output Power in Bridge mode: 940W at 4Ω or 520W at 8Ω with max. 0.1% THD+N for the TA3020v4b-300 version and 1240W at 4Ω or 780W at 8Ω with max. 0.1% THD+N for the TA3020v4b-400 version.
- Maximum output power which can be achieved in subwoofer application, BTL mode, is 1080W at 4Ω or 590W at 8Ω with max. 1% THD+N for the TA3020v4b-300 version and 1340W at 4Ω or 860W at 8Ω with max. 1% THD+N for the TA3020v4b-400 version.
- Audiophile sound Quality: 0.02% THD+N at 186W at 4Ω or 112W at 8Ω for the TA3020v4b-400 version.
- Very good global efficiency: Up to 90.4% at 2x160W at 8Ω or up to 88.3% at 2x300W at 4Ω.
- Universal mains voltage compliant, default 220V AC 50Hz, 110V AC 60Hz one jumper configurable.
- Mute control and Mute status pins for controlling the amplifier status within the system.
- Compact size 100x230x38mm, assembled board, with integrated heat sinks and variable speed cooling fan and high power density of more than 1.5W/cm<sup>3</sup> or 30W/in<sup>3</sup>.



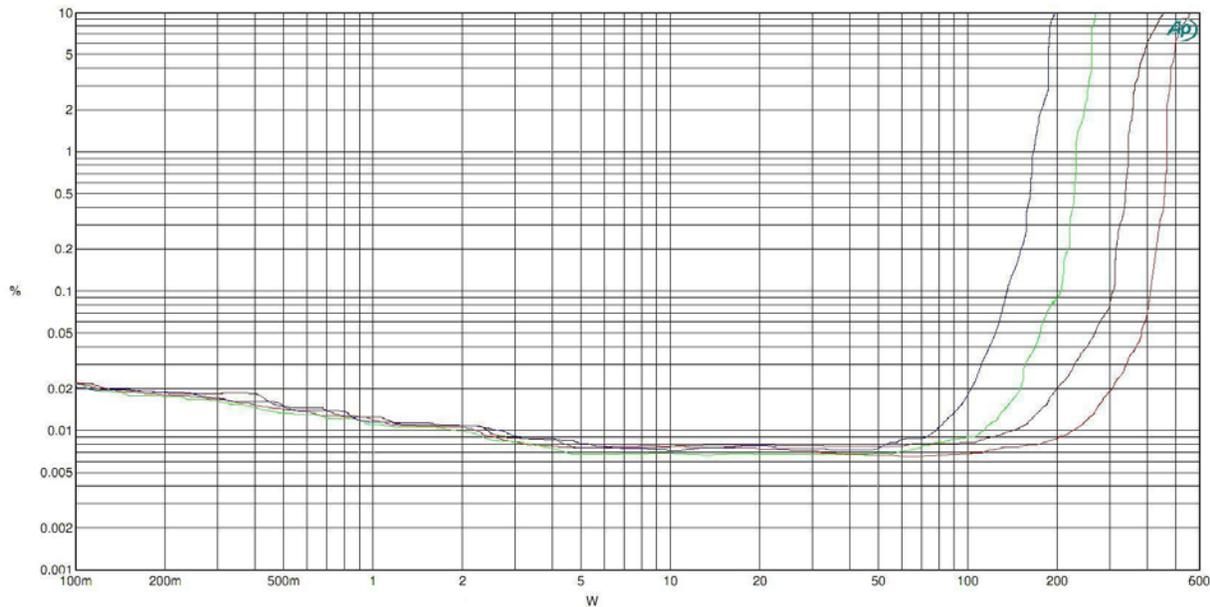
**Figure 1: TA3020 Audio Amplifier Module v4**

## Amplifier Description:

The TA3020v4b Class T Stereo Audio Amplifier is built around TA3020, dedicated digital audio power amplifier driver. The main blocks of this amplifier are: Input stage and driver, which uses TA3020 IC, power stage, which uses 4 pcs. Power MOS-FET's, and an on-board Switched Mode Power Supply, which provide power for the amplifier power stage, drivers, logic and small signal stages. The amplifier schematic is according with the reference design provided by Tripath. In addition to this, the Switched Mode Power Supply was included onto the amplifier board for easier installing and application. Compared to the previous versions, the TA3020v4b amplifier board has all the necessary circuitry for a complete amplifier stage, from the input signal to the output power including the speaker protection and delay circuit, this allowing the user to build a complete amplifier with minimal external components, reducing the amplifier total size and weight.

Audio Precision

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Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Brown	Solid	2	Anlr.THd+N Ratio	Left	4R 1kHz 2x300W Version
2	1	Blue	Solid	2	Anlr.THd+N Ratio	Left	8R 1kHz 2x300W Version
3	1	Red	Solid	2	Anlr.THd+N Ratio	Left	4R 1kHz 2x400W Version
4	1	Green	Solid	2	Anlr.THd+N Ratio	Left	8R 1kHz 2x400W Version

THD vs Power 4&8R 300&400W Versions

**Figure 2: TA3020v4 Amplifier THD vs Power measured for each power version and load impedances**

**Input Stage:** The audio input signal is provided to the TA3020 IC thru the SIGNAL connector at pin 5 for the Left channel and pin 7 for the Right channel. The input GND pins are pin 4 and pin 6. Next, the audio signal is driven to the TA3020 IC thru metal film DC coupling capacitors. Good results had been achieved with 2.2uF non-polar metal film capacitors. The TA3020 input stage is configured as an inverting amplifier, allowing the system designer flexibility in setting the input stage gain and frequency response. The TA3020 amplifier gain is the product of the input stage gain and the modulator gain:  $AV_{TA3020} = AV_{INPUTSTAGE} * AV_{MODULATOR}$ . For this amplifier, there are two gain values. Some boards have the gain value 11.1V/V which would give a sensitivity of 3.1 V for 300W version or 3.6V for 400W version for full output power, and some boards have the gain value 27 V/V which would give a sensitivity of 1.28 V for 300W version or 1.48V for 400W version for full output power. On request different values can be provided. Note that wider gain values are not recommended due to the stability issues which can occurred for higher gain or lower gain values. For good S/N ratio, is recommended to use very short or shielded signal cables for signal input, and avoid the crossing in close proximity to the power stage or output cables, which create unwanted feedback. Pay attention to the GND loop which can decrease S/N performances lead to instability and

increased output noise. The DC Offset during Mute, and without load will be about 2.5V due to the feedback loop bias resistors, and will decrease to adjusted value, close to 0V after connecting the load. Thus the Speaker Protection circuit section will disconnect the speakers during MUTE or in any situation if the DC Offset exceeds 500mV to protect the speakers. Note that the DC offset is already set for the boards after assembly, and does not require further adjustments. A DC offset larger than 100mV can lead to excessive bus pumping, and amplifier enter in OVP mode, and must be avoided. The main cause of excessive DC offset is running the amplifier with input capacitors removed, with so-called “servo preamplifier circuits” or whatever preamplifier which theoretically can provide a DC floating input signal without the need of a coupling capacitor. Due to the bus-pumping issue present to all single-ended class D amplifiers, as well as very low supply voltage for the TA3020 input section (just 5V which limit the excursion of input voltage) running the amplifier without input capacitors, or other capacitors than originally used on the board is strictly prohibited otherwise damage might occur.

**Driver Stage:** The TA3020 Audio Amplifier Module driver is integrated in the TA3020 IC, this simplifying the amplifier design, increasing performance and reliability, and reducing the overall size and weight. The main role of the driver stage is to provide  $V_{GS}$  voltage for the output MOS-FET transistors. The low-side MOS-FET's are driven using the voltage provided, and high-side MOS-FET's are driven using bootstrap supply. The TA3020 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 driver's pins from the TA3020 IC are connected to the output MOS-FET's through resistors and diodes, which are used to control MOSFET switching rise/fall times and thereby minimize voltage overshoots. They also dissipate a portion of the power resulting from moving the gate charge each time the MOSFET is switched. If  $R_G$  is too small, excessive heat can be generated in the driver. Large gate resistors lead to slower MOSFET switching, which requires a larger break-before-make (BBM) delay. The diodes which are connected in parallel with the gate resistors have the role of fast discharging of the gate charge during switch-off, and they must have very fast switching timing. Also the dynamic resistance of the diodes helps in limiting the discharge current of the MOS-FET's gates.

**Power Stage:** The amplifier power stage comprises of 4 Power MOS-FET transistors, which provide the switching function required of a Class-T audio amplifier. They are driven directly by the TA3020 through the gate resistors. The devices used on this amplifier are STW34NB20 for the 300W amplifier version and IRFP4228 for the 400W amplifier version. The key parameters to consider when selecting which MOSFET to use with the TA3020 are drain-source breakdown voltage ( $BV_{DSS}$ ), gate charge ( $Q_g$ ), and on-resistance ( $R_{DS(ON)}$ ). The  $BV_{DSS}$  rating of the MOSFET was selected to accommodate the voltage swing between  $V_{SPOS}$  and  $V_{SNEG}$  as well as any voltage peaks caused by voltage ringing due to switching transients. Due to the good circuit board layout, the  $BV_{DSS}$  was selected only 25% higher than the VPP and VNN voltage swing, reasonable value. Ideally a low  $Q_g$  (total gate charge) and low  $R_{DS(ON)}$  are desired for the best amplifier performance. A lower  $R_{DS(ON)}$  means lower  $I_2 R_{DS(ON)}$  losses but the associated higher  $Q_g$  translates into higher switching losses (losses =  $Q_g \times 10 \times 1.2\text{MHz}$ ). The IRFP4228 was chosen for the 400W amplifier version since it has the best FOM for the 150V MOS-FET's.

**Dead-time:** The output power MOS-FET's require a so called dead-time between the moment when one transistor is turned off and the other one is turned on in order to minimize shoot through currents. The amplifier uses the Break-before-make setting, BBM0 and BBM1 which are logic inputs (connected to logic high or pulled down to logic low) that control the break-before-make timing of the output transistors according to the required dead-time for proper amplifier operation and minimum THD values.

BBM values are set to default values during manufacturing and testing. No user intervention is required. Note that for 80nS can be used as well for the 300W version, but the idle current consumption will be higher due to increased shoot-through of the MOS-FET transistors. Lower values than 80nS are NOT recommended, because they can lead to lower efficiency, overheating, and eventually failure of the power stage, and there is no significant increase in the audio performance more than the 80nS setting. For this reason, the BBM1 connection was left connected to GND permanently. Typical values for the BBM settings are 120nS for the 2x300W amplifier version and 80nS for the 2x400W amplifier version.



**Figure 3: Amplifier BBM Setting**

**Output Filter:** 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 a lower order filter with lower losses and better performances can be used. The values chosen for the output filter are: Inductance of the filter coil = 11uH, made on Micrometals T106-2 core material, by winding 30 turns of 1.2 mm (16AWG) copper wire. High quality high-frequency, high pulse current and very low ESR and ESL capacitors are used for the Low-pass filter, 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 and damp the oscillations which may occur in some situations. An important aspect of the output filter is that, although the amplifier uses a pre-filter feedback topology, the switching frequency and filter cut-off frequency gives this amplifier remarkable performances, comparable with the top-end post-filter feedback class D amplifiers, which has almost flat and load independent frequency response and a high damping factor, enabling the amplifier to drive large low-impedance subwoofers without degrading the performances.

**Speaker protection circuit:** During turn ON and OFF, the amplifier may generate turn ON and OFF noise such as Click and Pop noises, frequently caused by external circuitry of the amplifier, such as input stages or power supply, or charging the input capacitor to the normal bias voltage. The solution which completely eliminates this problem is the on-board integrated Speaker Protection circuit. It is based on the very popular circuit uPC 1237, which contains all the necessary stages needed for efficient and reliable smooth turn ON-OFF and also speaker protection in case of power stage failure. The principle of operation is relatively simple, the relay is connected between the amplifier output and the loudspeaker, and the relay is connected with a delay of about 3 seconds after the power supply voltage has been correctly applied to the board. In this time, the amplifier transient noises are gone and the amplifier is ready for normal operation. When the power supply is turned off, the speaker protection circuit immediately disconnects the loudspeakers from the amplifier, preventing the audible noise which might occur when power supply voltage decrease under a certain value and the amplifier might become unstable. Also, when the amplifier is in Mute condition, either because of an external Mute control or because of an onboard mute condition generated by an over-current, overvoltage or under-voltage condition, the Speaker Protection circuit will disconnect the relays connected in series with the speaker, until the Mute condition is cleared. One of the most important speaker protection features is the loudspeaker protection in case of DC component on the amplifier output. If the amplifier will have DC component at the amplifier output, the speaker protection will disconnect the loudspeaker from the amplifier, protecting the speakers from dangerous DC levels. To restart normal operation, must toggle the supply voltage or Mute pin.

**Thermal Management:** The operating temperature of the amplifier must be kept within normal limits. For this purpose, an active cooling system was implemented. The system comprises of two heatsinks for active semiconductor devices and a silent variable speed fan which allows enough airflow to keep the temperature low. The speed of the fan is continuously controlled and monitored so that the fan will operate at lower speed most of the time, and only when the temperature of the heat sink increase, the fan speed increase too. In this way, the acoustical noise generated by the fan is minimal, and cannot be heard even at low audition levels. The fan is mounted on the amplifier heat sink, blowing the air from upside towards the front of the amplifier and the rear, where the Power Supply heat sink is installed, cooling this heat sink too. The cooling fan air intake must be kept clear, so that the air will easy circulate and allow cooling of the amplifier. If the amplifier board is installed into a narrow case, with height not more than 50mm, then is strongly recommended to drill some holes on top of the case, just above the cooling fan, and holes at the bottom of the board, just under the power supply heatsink, where there are 9 slots in the pcb to allow air to circulate. If the amplifier is not proper cooled, can overheat more than the maximum allowable limits and in the first stage, the over temperature protection will trip and shut down, and require restart after the temperature drop with at least 25°C, to 60°C or below. As additional measure of protection against thermal runaway, the amplifier has an latching over-temperature protection, which will trip when the temperature of the power supply heat sink reach about 90°C. The amplifier will shut down, all the LED's will be off, and the power must be disconnected for at least few minutes, until the heat sink temperature will decrease to a level will allows the amplifier to operate normally.

**Power Supply:** The last but not least part of the amplifier is the Power supply which has the role of providing all the necessary voltages for all stages of the amplifier, within the preset limits. The amplifier requires multiple voltages, such as +54V for the power stage for the 300W version, or +60V for the 400W version, V<sub>nn</sub>+12V for the driver stage, 5V for the input stage, 12V for the speaker protection circuitry and active cooling fan and the bias voltage for the primary side SMPS controller, which is isolated from the secondary side. Because the amplifier has the power supply mounted onboard, there is no need for any other kind of external power supply, either linear or SMPS. The amplifier requires just the mains voltage supply, by default 220V, or within 200-250V AC range at 50 or 60Hz. For the 110V mains voltage range, (100-127V AC) must connect a jumper on the power supply which will allow operation at this supply voltage levels.

The current for the audio amplifiers producers, both in HI-FI or Pro-Audio field, is to use a hard-switching unregulated SMPS or at most a Quasi-Resonant unregulated SMPS. The main reason behind this is the cost, which is much lower for such power supplies than for a regulated one; another reason is for easier synchronization of the power supply switching frequency with the half of the amplifier switching frequency to avoid beating. In this case, is not possible, and unnecessary. First, the amplifier run at variable switching frequency, which depends on the input signal (spread spectrum modulation) and have value in range of 500 KHz to 1.5 MHz, for each channel independently, then the SMPS also run at variable frequency, depending on the load value, typically in range of 110KHz to 250KHz. Being soft commutated, the SMPS intermodulation noise which might occur has very low value, below the S/N ration threshold, thus inaudible. The third reason for using unregulated SMPS for those amplifiers is that most of the class AB amplifies has high power supply rejection ratio which allows using an unregulated power supply. But for the class D and class T amplifiers, this might be not enough, especially if Audiophile Sound Quality is required. Unlike many other amplifiers which are using SMPS, this Power Supply has regulated output voltage, providing a constant output voltage, from zero load to full load which translates in cleaner sound, without peaks and drops, without hard clipping and distortions and true, real deep bass.

The topology used for the TA3020v4b Amplifier SMPS is Series Resonant Converter or LLC Converter. It was chosen due to its many advantages compared with all other topologies. Among the advantages, we consider that the most important are superior efficiency, lower EMI and noise, compact size and reasonable complexity. The operation principle of this converter was described in many papers, application notes, and reference designs. Although is not a relatively new technology, being discovered more than 15 years ago, until recently, the lack of knowledge, documentation and availability of good characteristic electronic components such as hig-speed MOS-FET's or IGBT's prohibited this topology to spread like other hard switched topologies. Only after the LCD and Plasma TV's came-up and initiatives to increase efficiency of the consumer products such as 80+, 90+ were imposed, engineers had to look towards other solution than the current mature topologies, which are using hard-switching techniques and they can't break the 90% efficiency barrier without significant cost increase and size. For an LLC resonant converter, efficiencies greater than 92% are common and even 95-96% can be achieved if the DC-DC converter is supplied from the output of an PFC pre-regulator capable to supply a constant 400V DC. In our case, the PFC stage is not required, due to the purpose of the application and because similar efficiencies can be achieved without using a complicated PFC circuitry which would increase the size of the amplifier board and decrease the S/N performance due to the fact that the available space is limited and the PFC inductor might interfere with the amplifier operation.

An important aspect which must be considered when the amplifier is powered ON, the initial current drawn from the mains is few times higher than the maximum current which is drawn at the full power. The reason for this is that the filter capacitors are completely discharged, and act as a short circuit for a brief period. The current is higher as the capacitors capacity and voltage is higher, and is proportional with the capacitor stored energy ( $CU^2/2$ ). To prevent harmful effects which this high value inrush current might have to the Amplifier Power Supply components, a thermistor was used to limit the inrush current to a lower value than the mains fuse will trip or might damage any components from the Amplifier Power Supply. This thermistor is a passive component which has the property to decrease its resistance when the temperature increases. It has higher Ohmic resistance at low temperature, thus reducing the inrush current, and when the current which passes through, will heat-up the thermistor, the resistance will decrease, and the dissipated power will be reduces. One drawback might be the increased operating temperature, especially when the Amplifier delivers high output power. The thermistor is placed on the edge of the board close to the Mains input connector, this avoiding to heat-up other temperature sensitive components. Note that there is no need to use any other external power soft-start circuit when the amplifier is powered from standard mains supply voltage of 110 or 220V AC.

## Amplifier Connection and Operation:

In order to fully benefit from the performances of the TA3020v4b Class T Stereo Audio Amplifier, the amplifier module must be used according to the following instructions and recommendations.

**Input signal source:** For proper operation and best performances, the TA3020v4b amplifier requires to be supplied with an unbalanced audio signal with the maximum amplitude in range of 1.28V to 3.6V depending on the gain setting, which might be fixed or can be set on request. The audio signal must be applied at the input of the Amplifier, on the small 6 pins connector, at pin 4 for the Left Channel and pin 6 for the Right Channel. To be able to conveniently adjust the listening volume it is strongly recommended to use a potentiometer, logarithmic type with value of 50K $\Omega$  or maximum 100K $\Omega$ . The potentiometer must be connected as in the following schematic:

The input signal can be supplied to the amplifier through standard Chinch connectors for Unbalanced Input signal, or if Balanced Input signal is used, the BIPS module should be used between the signal source, potentiometer and TA3020v4b Audio Amplifier.

**Mute control:** When the pin1 and pin2 of the Signal connector, are connected together, both amplifier channels are muted. By default, with the help of an on-board pull-down resistor, 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 TA3020 Audio Amplifier Module. The HMute pin is a 5V logic output that indicates various fault conditions within the device. These conditions include: over-current, overvoltage and under-voltage. The HMute output is capable of directly driving an LED through a series 2.2k $\Omega$  resistor; the board already has a 470 $\Omega$  resistor, which can be enough for LED's with built-in resistors. When the amplifier is Muted, either from an external Mute control signal, or due to an over-current, overvoltage or under-voltage condition, the Speaker Protection circuit will disconnect the relays connected in series with the speaker, until the Mute condition is cleared.

**BTL operation mode:** If the output power delivered by the amplifier in Single-Ended operation mode is not enough for a given application, the TA3020v4b amplifier can be used in BTL mode with the addition of **BIPS** (Balanced Input Phase Shifter) board. The theoretical output power in BTL mode is 4 times the power of a single channel on the same load, but practical output power which can be achieved with THD within low limits are between 3 to 3.5 times the output power of a single channel. Operating the amplifier in BTL mode will minimize the Bus-Pumping phenomenon due to the fact that each channel is driven with 180° out of phase Audio Signal, and at any time power will be drawn from both supply rails, by each channel power stage. The **BIPS** can features switches to select Balanced or Unbalanced input signal as well as Single-Ended or BTL operation mode.

**Status LED's:** The TA3020 Audio Amplifier Module has built-in 2 LED's, one Green which indicate that the Amplifier module is powered ON and one Red which indicate that the speakers are disconnected.

When the amplifier is connected to the Mains supply voltage, the Green LED will light up to indicate the presence of power. If the amplifier has shut-down due to an Over temperature latch-up, the Green LED will not light until the amplifier temperature has dropped below the Over temperature protection latch-up threshold, and mains power was disconnected for at least one minute. This operating mode was implemented as a supplementary protection measure against failures due to over temperature, and abuse which can lead to amplifier failure.

The Red LED will be ON when the relays are opened and the speakers are disconnected from the amplifier, either due to a Mute command or an overvoltage, under-voltage, over-current condition. Also, when the amplifier is powered ON, the Red LED will be ON for about 3 seconds, while the speaker protection relays are opened.

**Over-current Protection:** The TA3020 Audio Amplifier Module has built-in over-current protection circuitry to protect itself and the output transistors from short-circuit conditions. The TA3020 uses the voltage across a resistor  $R_s$  (measured via OCS1HP, OCS1HN, OCS1LP and OCS1LN) that is in series with each output MOSFET to detect an over-current condition.  $R_s$  and  $R_{OCR}$  are used to set the over-current threshold. The OCS resistors are made using microstrip technology on the pcb tracks and are Kelvin connected for proper operation. The over-current threshold for 2x300W version is set to 38A and for the 2x400W version is set to 46A.

**Under-voltage and Overvoltage Protection:** The TA3020 senses the power rails through external resistor networks connected to VNNSENSE and VPPSENSE. The under-voltage and over-voltage thresholds are determined by the values of the resistors in the networks, and are set within the range of +/- 43V DC to +/- 65V DC. If the supply voltage falls outside the upper and lower limits determined by the resistor networks, the TA3020 shuts off the output stages of the amplifiers. The removal of the over-voltage or under-voltage condition returns the TA3020 to normal operation. Please note that trip points specified in the Electrical Characteristics table are at 25°C and may change over temperature. The TA3020 has built-in over and under voltage protection for both the V+ and V- supply rails. 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. VPPSENSE (pin 29) performs the over and under-voltage sensing for the positive supply, V+. VNNSENSE (pin 30) performs the same function for the negative rail, V-. When the current through  $R_{VPPSENSE}$  or  $R_{VNNSENSE}$  goes below or above the normal values (caused by changing the power supply voltage value), the TA3020 will be muted. VPPSENSE is internally biased at 2.5V and VNNSENSE is biased at 1.25V. Once the supply comes back into the supply voltage operating range (as defined by the supply sense resistors), the TA3020 will automatically be un-muted and will begin to amplify. There is a hysteresis range on both the VPPSENSE and VNNSENSE pins. If the amplifier is powered up in the hysteresis band the TA3020 will be muted. Thus, 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. It should be noted that there is a timer of approximately 200mS with respect to the over and under voltage sensing circuit. Thus, the supply voltage must be outside of the user defined supply range for greater than 200mS for the TA3020 to be muted.

**Mains power supply:** To operate the TA3020v4b Audio Amplifier, the board must be connected to Mains Power, with the nominal voltage in range of 100-127V for 110V version or 200 to 240V for 220V version. Mains frequency should be in range of 47 to 63 Hz, which allows operation anywhere in the world. The Amplifier must be connected to Mains Voltage through a proper rated Power switch, rated at min. 10A at 250V AC and a standard IEC Mains Power connector. The power supply connector has 3 pins: 2 pins for Mains Voltage and one pin for protective Earth connection. The protective Earth connection is very important for the safety of the amplifier and user, and must be proper connected; otherwise damage to the unit may occur. The protective Earth is connected the Amplifier secondary GND through a low value resistor, and an 0.1uF capacitor to suppress noise which might appear due to parasitic coupling between primary and secondary side of the power transformer. This connection wasn't made directly to avoid potential dangerous Earth loop which might be created if the protective Earth potential finds a return path through the rest of the audio equipment connected with the amplifier.

**Bus Pumping:** An unwanted and potentially troublesome phenomenon in single-ended Class D and Class T amplifiers is the power supply pumping effect. It is caused by the flowing of the current from the output filter inductor into the power supply filter capacitors in opposite direction as the DC load sink current. The phenomenon is more evident at low-frequency and high amplitude signals, and if is not prevented it will trip the Overvoltage protection circuit, causing the amplifier to enter in Mute state until the supply voltage drop below the lower overvoltage protection threshold. Another cause of the Bus pumping is the DC offset which if is larger than 100-200mV, opposite voltage rail will start increasing the voltage until the Overvoltage protection circuit will trip, and Mute the amplifier.

There are 2 solutions to reduce the Bus-pumping. The first solution is to use large Electrolytic capacitors on each power supply voltage rail to absorb the pumped supply current and to use-it in the next switching cycle. This method is less efficient when the output amplitude increase and the frequency decrease, being ineffective with DC signal. The best solution to avoid Bus-Pumping is to drive one amplifier channel 180° out of phase with respect to the other. This setup will reduce the Bus-pumping because each channel is pumping out of phase with the other, and the net effect is a cancellation of pumping currents in the power supply. The phase of the audio signals needs to be corrected by connecting one of the speakers in the opposite polarity as the other channel. To achieve the phase shift, the Balanced Input Phase Shifter module (BIPS) can be used. This also has both balanced and unbalanced inputs, suitable for using the amplifier with differential audio signal input.

Note that the Bus-pumping doesn't occur in BTL mode if the amplifier is driven symmetrically.

**EMI Reduction:** Each power MOS-FET has a fast recovery diode connected in parallel for reduction of ringing on the outputs of the MOS-FET's. They shunt the inductive energy generated in the parasitic inductance of the components leads and PCB tracks. The diodes are connected close to MOS-FET transistors, in "Drain to Drain" and "Source to Source" topology to minimize the ringing. The diodes are MURS120, SMD type, which have very fast switching timings and very low stray inductance. For the IRFP4228 amplifier version, the diodes are redundant since the MOS-FET's body diodes are hyper-fast type and external diodes are not absolutely required.

Furthermore, for reducing the ringing, few bypass capacitors are placed close to output power MOS-FET's. 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 output MOS-FET's 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 using high-capacity electrolytic capacitors, this phenomenon can be reduced. In the unlikely event that this phenomenon still occur, or when the output power demand is high, as in the BTL mode configuration, should increase the value of the electrolytic capacitors from the amplifier board, or use an external power supply unit is connected to this board, by bypassing the rectifier bridge. The Power Supply board which can be used is PS10K63, PS10K80, or even PS18K71. If an SMPS is the preferred choice, the A1000SMPS or the SMPS500 are suitable for this amplifier, depending on the required output power. In case of using an external Power supply, either linear or SMPS, bypassing the rectifier bridge is strongly recommended to eliminate the voltage drop and adding more capacitance to the voltage rails.

**Amplifier Efficiency:** The overall efficiency of TA3020v4b Audio Amplifier Module efficiency is given by the Output Power divided to the Mains Input Power:

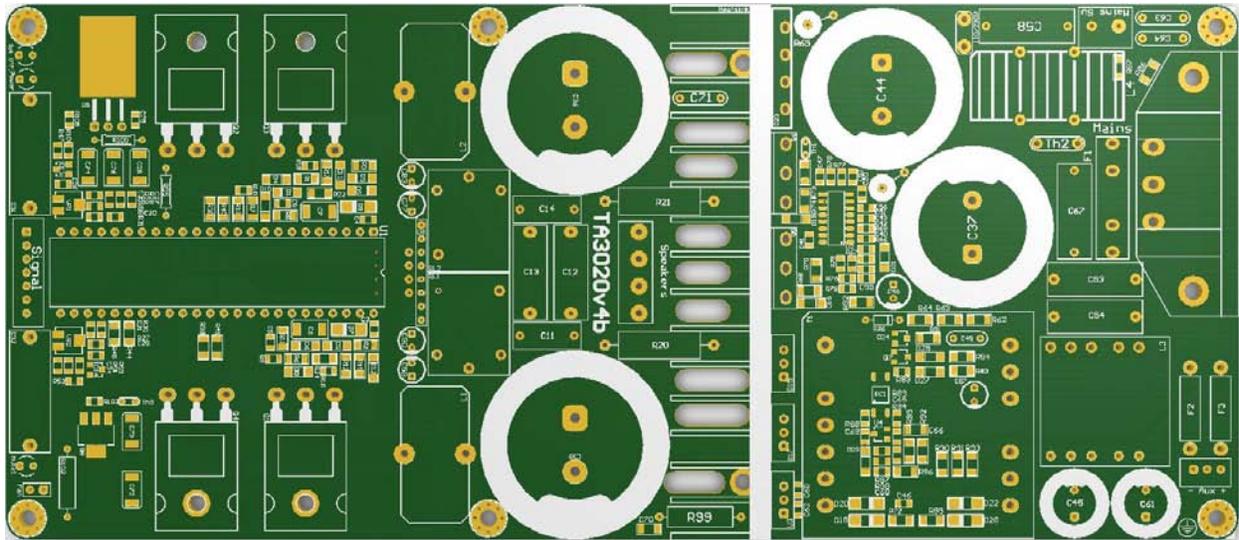
$$\eta = P_{OUT}/P_{IN}. \eta = P_{dSMPS} + P_{dAmplifier}/ P_{IN}$$

$$\eta = (U_{xL_{load}} + U_{xI_{R_{load}}})/ U_{mains} \times I_{mains} \times PF$$

- $P_{IN} = U_{mains} \times I_{mains} \times PF$ .
- PF = Power factor, typically 0.55 to 0.7
- $P_{dSMPS}$  = Power dissipated by the power supply alone.
- $P_{dAmplifier}$  = Power dissipated by the amplifier stage alone.
- $P_{out}$  = Output Power available at the speakers output.

While the Input Power Level can be measured precisely, the Output Power can be measured on a resistive load, driving sinus signal, the practical efficiency can be determined. Note that these measurements must be done in laboratory controlled environment, as the amplifier is not able to sustain full output power within full audio frequency span and the crest ratio (peak to average output power level) is maximum 3. The efficiency is dependent on the Output power level, at low power, has low values, and is increasing as the Output Power is higher, mainly due to switching losses which can be considered constant, and the TA3020 power consumption which can be also considered constant. Idle power consumption is 5W at no input signal and amplifier Muted and 8.5W without input signal and amplifier Un-muted (Run mode). With BIPS board connected the idle consumption increase with ~2W. The maximum efficiency was up to 90.4% at 2x160W at 8Ω or up to 88.3% at 2x300W at 4Ω. Average power consumed with normal music program listened to reasonable levels is within 50-100W, while at maximum levels the consumption rise to 300-350W for 2x400W SE mode and up to 500W in BTL mode driving subwoofers.

**Layout:** The PCB Layout design has an important contribution to the overall performance of the TA3020 Audio Amplifier Module. That's why double layer, FR-4 material with 1.6mm thickness and 2oz thickness copper tracks of 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 50V is big enough to satisfy the clearance conditions imposed by the design standards. The size of the PCB is 100 x 230 mm or 4 x 9 inch, and has 6 mounting holes, 4 holes are on the corner of the PCB and one at the top-middle side of the PCB. The mounting holes are 3.2mm diameter or 0.12 inch. The main components layout and the Input and Output connectors pin out can be seen in the Figure 4. The mounting holes must be connected to chassis The heat sink for power supply and amplifier section is mounted directly onto the PCB and does not require additional support. Also the pinout for the input and output connectors can be seen. It is recommended to use heavy gauge wires for Power Supply and Loudspeaker Output and short shielded cables for Audio Input.

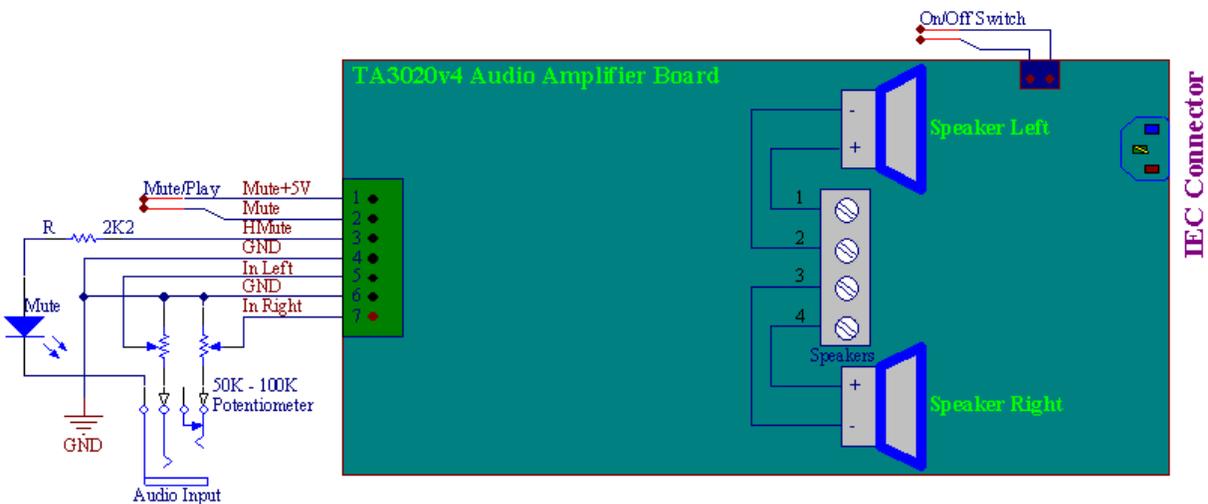


**Figure 4: TA3020 Audio Amplifier module Board layout**

**Balanced Input Phase Shifter:** In some cases, the amplifier is used with balanced input signals, and for this, the **BIPS** board must be used. Besides the main advantage of providing the balanced input option for the amplifier, it has the advantage that will reduce the Bus-pumping due to the fact that the signal is 180\* shifted for one channel. The BIPS board requires a differential voltage in range of +-25 to +60V at max. 10mA for proper operation and this voltage can be derived from the main amplifier supply voltage. The volume potentiometer can be connected between the **BIPS** and the TA3020v4b amplifier, allowing the master volume to be adjusted both for balanced and unbalanced inputs in the same time.

### Installation and application Information:

The TA3020v4b Audio Amplifier Module can be connected in several configurations, depending on the system requirements. The most common and simple configuration uses a mains transformer, input-output connectors, a potentiometer, and optional Mute Button and LED indicator. As can be seen in the **Figure 5**, the amplifier can be supplied either with AC voltage, from a mains transformer, which can provide 2x30V AC to 2x43V AC at minimum 5A for the lower power version or 8A for the higher power version. The main transformer AC voltage output must be connected at the pins AC1 and AC2 and the centre tap at GND. In the primary side of the mains transformer is strongly recommended the use of the **Power Soft Start** and a mains Switch capable to disconnect the full mains current when the amplifier is not used but connected to the mains.



**Figure 5: TA3020v4b Amplifier Connection Diagram**

**Wiring** the amplifier to connectors, potentiometers, transformers, auxiliary boards, must be done with proper size wires and the cables must be laid carefully to avoid parasitic couplings, both capacitive and inductive, which will degrade the S/N ratio and amplifier performances. The input cables should be wired with shielded cables as short as possible, far from the amplifier output section or **SMPS**. Note that the default signal cable which comes with the **TA3020v3b** amplifier is not shielded and can be used if the length of wires does not exceed 20 cm and they are routed further away from the power stage. Do not add extra wires to the existing ones if the length is not enough, instead replace them with shielded wires for signal input path, as follows: Left channel shield connect to pin4, central wire (signal) connect to pin 5, then Right channel shield connect to pin 6 and central wire connect to pin 7. The power connections, to the loudspeakers and **SMPS ON/OFF** Switch must be wired with wires which are able to carry currents in excess of 10A. **Attention** must be paid to insulation, especially for the mains powered wires, where double insulation wires must be used. All the 6 pcb mounting holes must be connected to the electrically conductive metallic chassis which will serve as Protective Earth. Follow the instructions written on the backside of the PCB.

On the **SMPS** section of the board there are two solder pads marked as 110/230V. To configure the board for 110V operation, a jumper must be soldered to join these two connections. By default are left unconnected and they should be connected only when using the board at 100-120V mains otherwise damage might occur if 230V is applied with jumper set for 110V. **Never** connect to a mains voltage higher than 127V with jumper in place.

## Connectors Pinout:

The **Signal** input connector pinout is as follows:

- Pin 1: 5V supply from the TA3020v3b board to aux circuits, or mute control and LED's max. 50mA
- Pin 2: Mute In – a logic 1 on this pin will bring the amplifier in Mute state.
- Pin 3: Mute Status – this pin will toggle to logic 1 is when the amplifier is Muted
- Pin 4: GND Signal
- Pin 5: Input Left – audio signal Input Left
- Pin 6: GND Signal
- Pin 7: Input Right – audio signal Input Right

**Note:** 7 wires, 200mm long, 2.54 Header and connector are included.

The **Speaker Output** connector pinout is as follows:

- Pin 1: Left Loudspeaker Output
- Pin 2: Left Loudspeaker GND
- Pin 3: Right Loudspeaker GND
- Pin 4: Right Loudspeaker Output

**Note:** For BTL mode applications, the loudspeaker must be connected across Left Loudspeaker Output and Right Loudspeaker Output without Left or Right Loudspeaker GND being connected. Detachable 4 poles 16A Terminal Block type connector included.

The **-Aux+** Voltage Supply connector for **BIPS** provide +/-60V at max. 500mA fused

- Pin 1: Negative Supply
- Pin 2: GND
- Pin 3: Positive Supply

**Note:** 7 wires, 200mm long, 2.54 Header and connector are included. Use **ONLY** for **BIPS** supply.

The **Mains switch** connector is used to connect a 250V Ac 6.3A min. rated, dedicated mains switch.

The **FAN** connector pinout is as follows:

- Pin 1: Fan- (close to the edge of the board)
- Pin 2: Fan+ (towards inside of the board)

**Note:** The fan is installed and wired by default, NO user intervention is required. The FAN is supplied from the Vdrive voltage, thus the potential measured on any of the fan connections to GND is within 50-60V below GND. It should NEVER be connected to GND or any other parts of the circuits from the board or external, otherwise damage might occur.



## Warning:

Before you proceed with installation, make sure you have read this warning:

The TA3020v3b contains potentially hazardous voltages up to 330V DC or 350V AC. This voltage levels are present on the top and bottom of the board, and during installation and operation should never touch any part of the board while it is connected to the mains and at least 5 minutes after complete disconnect from mains. If any adjustment or reconnection needs to be done, disconnect the unit from the mains and allow all capacitors to discharge for at least 5 minutes before handling it. Any ignorance of this warning will be made on user's responsibility, and can lead to serious injuries and possible death by electrocution if is handled improperly. This product has no serviceable parts other than the on-board mains fuse. In case of blown fuse, only replace the fuse with the same type and rating. Do not attempt to change any other component from the board. A safety clearance of at least 6mm must be kept between the board and the case, or any conductive part of the amplifier.

## For best performances and long term reliable operation read before proceed!!!

Peaking phenomenon might occur when the amplifier input is connected or disconnected while the amplifier is powered ON or the input is touched by hand to "test" if the amplifier is working. This is a very bad mistake for any kind of amplifier, as the body static voltage corroborated with the voltage induced by the near electromagnetic field, less than ideal mains to amplifier ground isolation, will lead to high voltages build-up usually tens of volts which have 90% chances to damage any kind of amplifier with input impedance higher than 10KΩ. Although the mains hum is dominant when "testing" the amplifier using this brutal method, there is a full, rich spectrum of frequencies up to tens or hundreds of KHz, something which any normal amplifier should never expect during normal operation. To prevent the amplifier failure, and making it "idiot-proof", a more or less complex input filter circuit can be employed but this will reduce its performances and sound quality, and due to this fact we strongly believe that the user know what (s)he's doing and will avoid torturing the amplifier for its own good.

Although the amplifier comes with optimized components, yet some peoples still want to "improve the improvements". The very common mistake found on Class D and T amplifier while tuning the amplifier, is to replace the input capacitors with bigger size, sometimes as big as a lemon or kiwi input capacitors. This is one of the biggest mistakes which can be possibly done on such amplifier. Not only that these placebo capacitors will not improve the sound, they will make it worse, and in some cases will damage the amplifier. Because as I wrote few rows above, the input should not be touched by hand or tools while is working, NEVER!!! (and this is often done during the tuning process) and these capacitors with their large volume and area will act like antennas which will pick-up the switching noise from the power stage, from the power supply, from environment, and also common mode noise from the amplifier housing made of metal if they are touching the case, even without electrical contact due to the stray capacitance between the capacitor and metal parts in close proximity.

## Disclaimer:

The TA3020v4b Audio Amplifier 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, PCBstuff, 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 mains voltages of this board, the user should take all the caution measures needed when working with mains voltages, should not touch any unisolated 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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