LME49810 Audio Amplifier Module v1.0

LME49810 Audio Amplifier Module is a single channel Class AB Audio Amplifier based on LME49810 audio power amplifier driver made by National Semiconductor® Company. The LME49810 is a high fidelity audio power amplifier driver designed for demanding consumer and pro-audio applications. Amplifier output power may be scaled by changing the supply voltage and number of output devices. The LME49810 is capable of delivering in excess of 300 watts per channel single ended into an 8 ohm load in the presence of 10% high line headroom and 20% supply regulation, if enough power transistors are paralleled. The design of this board is in accordance with the manufacturer's datasheet and recommendations, as well as the reference designs.

Amplifier Features:

■ 300W LME49810 Amplifier: Output Power: 170W at 8Ω, or 327W at 4Ω at 0.1% THD+N, +/-61V Supply Voltage for Power Stage and +/-67V Supply voltage for Driver stage.

■ 500W LME49810 Amplifier: Output Power: 318W at 8Ω, or 569W at 4Ω at 0.1% THD+N, +/-78V Supply Voltage for Power Stage and +/-84V Supply voltage for Driver stage.

■ Audiophile sound Quality: 0.0012% THD+N at 120W at 8Ω, or 235W at 4Ω for 300W version and 220W at 8Ω, or 425W at 4Ω for 500W version.

■ Very good Signal to Noise Ratio, over 120dB.

■ Compact size, 180x80x25mm for the 300W version and 220x80x25mm for 500W version, without heat sink.

■ Separate Driver and Power Stage Supply voltage ensure maximum power without losing performances.

■ Clip indicator pin for monitoring the amplifier status within the system.

■ Board contains low ESR bypass electrolytic capacitors, close to the output stage.

■ Double layer, 1.6mm thick PCB with 2 oz copper traces minimizes inductances and optimize performances.
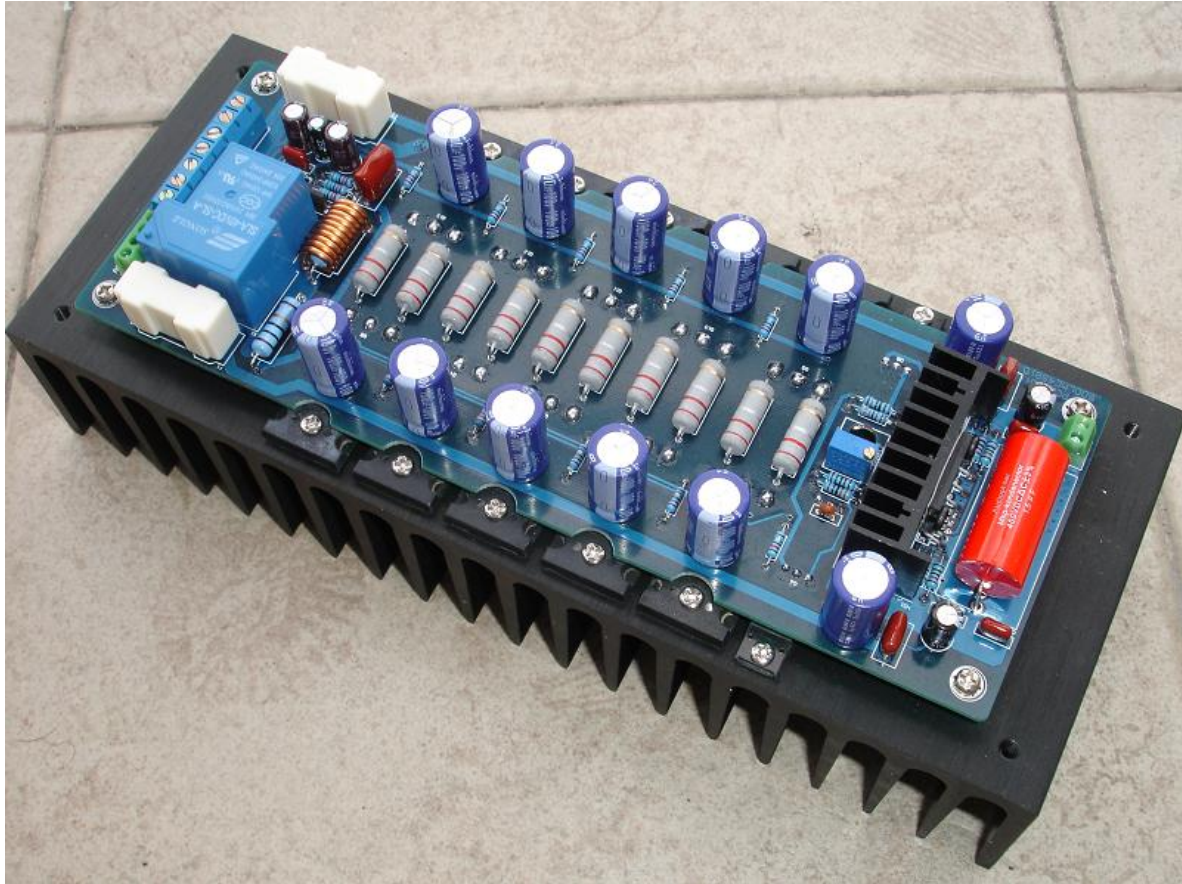

Figure 1: 500W RMS LME49810 based Audio Amplifier Module

Amplifier Description:

General Description:

LME49810 Class AB Audio Amplifier is built around LME49810, dedicated audio power amplifier driver. This circuit contains the main blocks of the amplifier: Input stage, driver, Mute control, Thermal protection and shut-down. The amplifier schematic is according with the reference design provided by NS® Company. The audio input signal is provided to the LME49810 IC thru small plug-in type connector P1 at pin 1 for the Left channel and pin 5 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 LME49810 IC thru DC coupling capacitors, C7 and C8, which should have the value in the range of 1uF to 4.7uF and 0.1uF, and can be polarized electrolytic or non-polar metal film. Good results can were achieved with 2.2uF non-polar metal film capacitors paralleled by 0.1uF miniature film capacitor for bypassing the high frequencies. This arrangement is used on most of the boards.

Different circuit components used in the LME49810 amplifier were evaluated, and the DC blocking capacitor on the input of the LME49810, no matter how good it is, can degrade sound quality. The negative effects of even the best film and foil polystyrene DC blocking input capacitors in the audio signal path is confirmed. It is therefore recommended that DC blocking capacitors not be used in the signal path for high-end audio equipment. Where DC offset from another signal source may be a problem then the use of a DC servo circuit that keeps DC offset from appearing at the output of the amplifier is recommended. All of the passive components used in the amplifier are high quality parts and selected for better characteristic match. The output transistors and the driver transistors are selected to have the same parameters, this giving the amplifier a better linearity and performances.
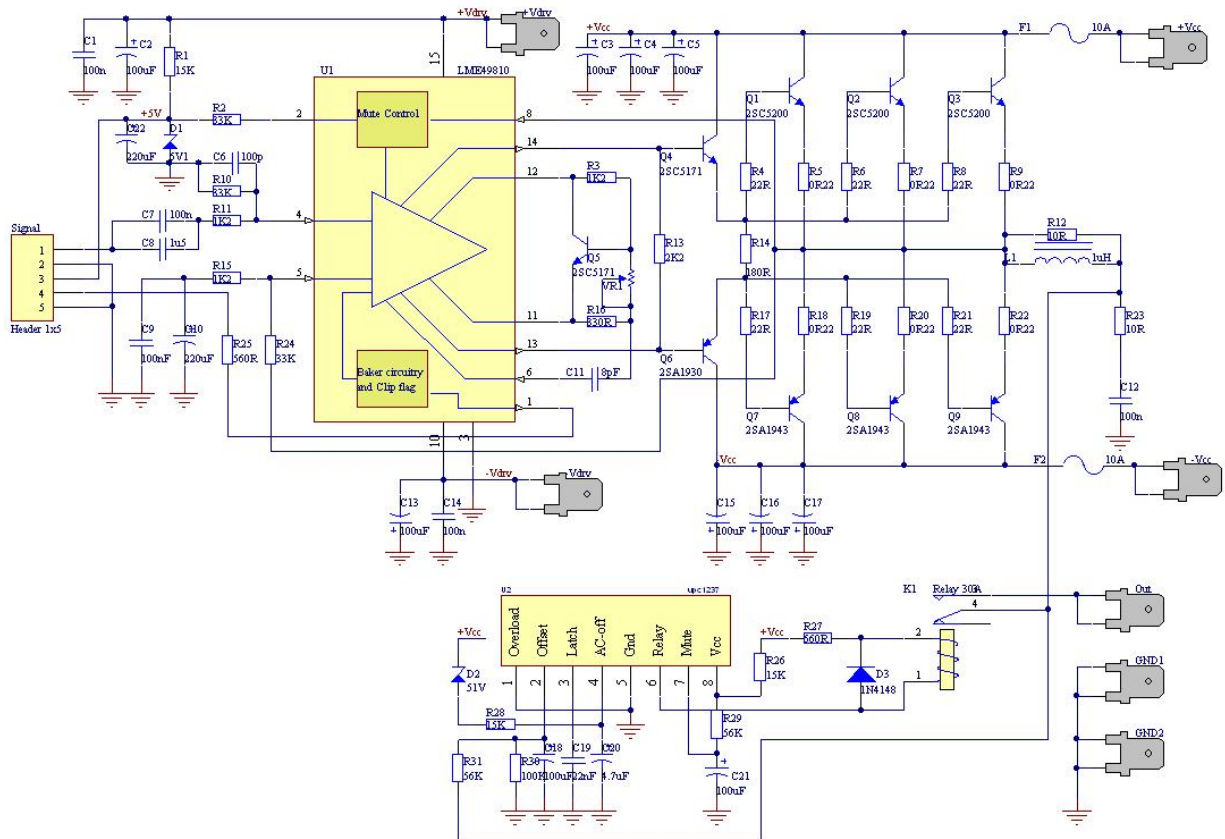

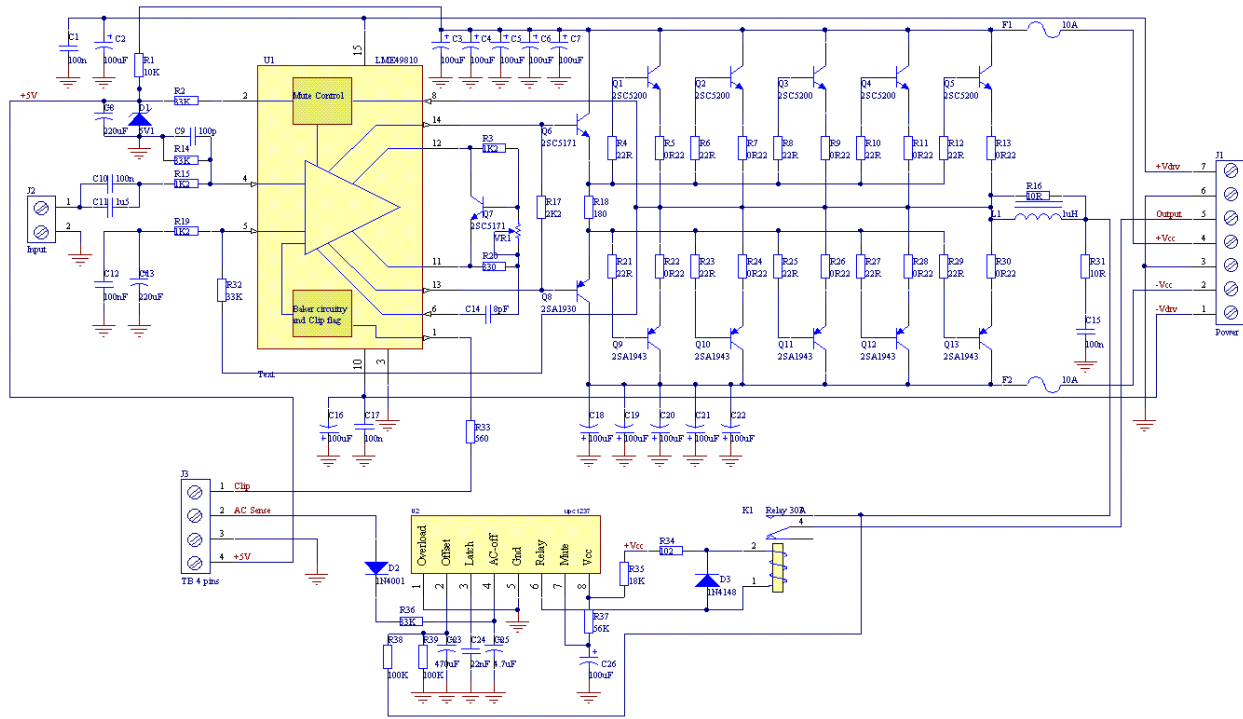**Figure 2: LME49810-300W Audio Amplifier Module Schematic Diagram**

Figure 3: LME49810-500W Audio Amplifier Module Schematic Diagram

Amplifier Input Stage:

The resistors R10 and R11 are part of the input stage, and set the amplifier input impedance and the amplifier DC bias point. The LME49810 input stage is configured as non-inverting amplifier, allowing the system designer flexibility in setting the input stage gain and frequency response. The LME49810 amplifier gain is given by the ratio of R24/R15 for the 300W module and R32/R19 for the 500W nodule. Commonly the amplifier gain is 32 (V/V), 30dB. On request different values can be provided, or the gain can be changed by the user in the range of 20-40 V/V or 26-32dB by simply changing the value of the resistors R15, or R19. For best noise performance, lower values of resistors are used. A value of 1KΩ and 3KΩ is commonly used for Ri and then setting the value of Rf for the desired gain. For the LME49810 the gain should be set no lower than 26dB. Gain settings below 26dB may experience instability. The combination of Ri with Ci (see Figure 1) creates a high pass filter. The low frequency response is determined by these two components. The -3dB point can be found from $F_i = 1/(2\pi R_i C_i)$ (Hz). If an input coupling capacitor is used to block DC from the inputs as C9 and C15, there will be another high pass filter created with the combination of Cin and Rin. When using a input coupling capacitor Rin is needed to set the DC bias point on the amplifier's input terminal. The resulting -3dB frequency response due to the combination of Cin and Rin can be found with: $F_i = 1/(2\pi R_i C_i)$ (Hz). With large values of Rin oscillations may be observed on the outputs when the inputs are left floating. Decreasing the value of Rin or not letting the inputs float will remove the oscillations. If the value of Rin is decreased then the value of Cin will need to increase to keep the same -3dB frequency response.

Mute Function:

The amplifier Mute function is controlled by the amount of current that flows into the mute pin. If there is less than 1mA of current flowing into the mute pin, the amplifier will be muted. This can be done by shorting the mute pin to ground. If there is between 50uA and 100uA of current flowing into the mute pin, the amplifier will be in play mode. This can be done by floating the mute pin or connecting to +5V. It is highly recommended to switch between mute and play modes fast. Slowly increasing the mute current may result in undesired voltages on the outputs of the LME49810, which can damage an attached speaker if a speaker protection circuit is not used.

The LME49810 features a Baker Clamp function with corresponding CLPFLAG output pin. The clamp function keeps all transistors in linear operation when the output goes into clipping. In addition, when the output goes into clipping, a logic low level appears at the CLPFLAG pin. The CLPFLGAG pin can be used to drive an LED or some other visual display. The value of logic low voltage varies and depends on IFLAG. For example, if IFLAG is 4.7mA then a voltage (VBC) of 0.4V will appear at the CLPFLAG output pin. The CLPFLAG pin can source up to 10mA, and since

the CLPFLAG output is an open collector output, and it should never be left to float under normal operation. If CLPFLAG pin is not used, then it should be connected through a resistor to a reference voltage so that IFLAG is below 10mA. For example, a resistor of 1k can be used with a 5V reference voltage. This will give the IFLAG of 4.7mA. In a typical LED setup, if +5V reference voltage is not available, the following circuit using a Zener diode can be used to power the CLPFLAG pin from the higher supply voltage rails of the LME49810. The power dissipation rating of RZ will need to be at-least ½W if using a 5V Zener Diode. Alternately, the following basic formula can be used to find the proper power rating of RZ : PDZ = (VCC -VZ)2/RZ (W). This formula can also be used to meet the design requirements of any other reference voltage that the user desires.

Thermal Protection:

The LME49810 has a thermal protection scheme to prevent long-term thermal stress of the device. When the temperature on the die exceeds 150°C, the LME49810 goes into thermal shutdown. The LME49810 starts operating again when the die temperature drops to about 145°C, but if the temperature again begins to rise, shutdown will occur again above 150°C. Therefore, the device is allowed to heat up to a relatively high temperature if the fault condition is temporary, but a sustained fault will cause the device to cycle between the thermal shutdown temperature limits of 150°C and 145°C. This greatly reduces the stress imposed on the IC by thermal cycling, which in turn improves its reliability under sustained fault conditions. When in "play" mode, the LME49810 draws a constant amount of current, regardless of the input signal amplitude. Consequently, the power dissipation is constant for a given supply voltage and can be computed with the equation PDMAX = ICC * (VCC – VEE). For a quick calculation of PDMAX, approximate the current to be 11mA and multiply it by the total supply voltage (the current varies slightly from this value over the operating range). Since the die temperature is directly dependent upon the heat sink used, the heat sink chose in the 300W and 500W LME49810 Amplifier versions has low enough thermal resistance, so that thermal shutdown is not activated during normal operation.

Choosing the proper heatsink for the amplifier modules:

A Power Audio Amplifier must use a heat sink for it's power dissipating components, such as Output Power transistors, to keep the working temperature within normal limits. There are few aspects which must be considered. First, the total dissipated power, which can be determined as a difference of power between the Supply Power and the load delivered power. Such calculation is not very easy to make, so approximation can be used. Class AB Power Audio Amplifiers has maximum theoretical Efficiency of about 70%. This value is almost impossible to achieve in practice with good THD values and linearity. So, a compromise should be made, in favor of the sound quality. This will lead to a lower electrical efficiency, especially at low Output Power. The main reason for lower efficiency is the idle current and losses which occur in the signal and driving stages of the amplifier. The maximum dissipated power, will occur at High Output Power Levels, when the amplifier drives low impedance loads with high signal amplitude. It was calculated that with +/-61V supplies for the power stage, worst case dissipation occurs at 170W into 8Ω load Impedance, of 145W. Most of this dissipated power is dissipated by the output transistors, which share equally the dissipated power. However, audio signal power spectrum is much poorer than the pure sine wave signal, usually just ⅛ of the power of the pure sine wave and with peaks of ⅓ of the pure sine wave. In order to remove the heat generated by this power dissipation, an external heat sink with thermal resistance of maximum 0.6 °C/W is required.

The choice of a heat sink for a high-power audio amplifier is made entirely to keep the die temperature at a level such that the thermal protection circuitry is not activated under normal circumstances. The thermal resistance from the die to the outside air, θJA (junction to ambient), is a combination of three thermal resistances, θJC (junction to case), θCS (case to sink), and θSA (sink to ambient). The thermal resistance, θJC (junction to case), of the LME49810 is 4°C/W. Using Thermalloy Thermacote thermal compound, the thermal resistance, θCS (case to sink), is about 0.2°C/W. Since convection heat flow (power dissipation) is analogous to current flow, thermal resistance is analogous to electrical resistance, and temperature drops are analogous to voltage drops, the power dissipation out of the LME49810 is equal to the following: PDMAX = (TJMAX−TAMB) / θJA (2) where TJMAX = 150°C, TAMB is the system ambient temperature and θJA = θJC + θCS + θSA. Once the maximum package power dissipation has been calculated using Equation 2, the maximum thermal resistance, θSA, (heat sink to ambient) in °C/W for a heat sink can be calculated. This calculation is made using Equation 3 which is derived by solving for θSA from Equation 2. θSA = [(TJMAX−TAMB)−PDMAX(θJC +θCS)] / PDMAX (3). Again it must be noted that the value of θSA is dependent upon the system designer's amplifier requirements. If the ambient temperature that the audio amplifier is to be working under is higher than 25°C, then the thermal resistance for the heat sink, given all other things are equal, will need to be smaller, resulting a larger heat sink needed.

A good choice is an extruded aluminum heat sink profile with vertical fins and with the size of at least 180x100x40mm, or horizontal fins option, if is intended to be mounted inside amplifier housing and use forced air cooling. Test results proved that the maximum temperature rise of the heat sink when the amplifier is used to play moderate volume of music on 8Ω load impedance is maximum 43˚C. This means that on an ambient temperature of 30˚C the heat sink temperature will be 73˚C. For higher power levels or 4Ω load impedance, forced air cooling may be required, to maintain the heat sink temperature under 85˚C. The 300W LME4981 Amplifier module uses a 182x100x45m finned heat sink and the 500W LME49810 Amplifier use a larger heat sink, 254x100x50mm finned heatsink. This heatsinks should be installed in a vertical position, with the fins outside the case, vertically, or if they are used inside the case, forced air cooling might be required to keep the amplifier maximum temperature within normal operating limits.

WARRNING !!! A heatsink temperature above 55˚C is perceived by the human skin as "very hot" and can cause burns, so the heat sink should not be touched when amplifier is in operation and at least 20-40 min. after turn-off to allow the heatsink to cool down to a moderate temperature. It is normal that a heatsink to have temperatures within 70-90˚C in normal operating conditions without causing problems to the semiconductors installed on it which can work safely up to 125˚C.

Amplifier Power Stage:

The LME49810 Audio Amplifier Driver is limited to 60mA of output drive current capability. To achieve the desired output power of up to 500W per channel, external transistors must be used. The output stage comprises of few pairs of power bipolar transistors driven with a driver stage. As can be seen in the schematic from above, this are complementary NPN and PNP transistors. The Power stage is made using the famous 2SA1943 and 2SC5200 transistor pair, and the driver stage contains 2SA1930 and 2SC5171 bipolar transistors. Each power transistors have a 3W 0.22Ω power resistor connected on the emitter, for better current sharing and thermal runaway diminution. One of the main problems of the Power Bipolar transistors is that they suffer from thermal runaway, which is the result of the thermal dependence of V_{BE}. As temperature rise, increases, V_{BE} decreases. In practice, current flowing through a bipolar transistor heats up the transistor, which lowers the Vbe. This in turn increases the current again, and the cycle repeats. If the system is not designed properly, this positive feedback mechanism can destroy the bipolar transistors used in the output stage. One of the recommended methods of preventing thermal runaway is to use a heat sink on the bipolar output transistors. This will keep the temperature of the transistors lower. A second recommended method is to use emitter degeneration resistors (R5, R7, R9, R18, R20, R22, on 300W version). As current increases, the voltage across the emitter degeneration resistor also increases, which decreases the voltage across the base and emitter. This mechanism helps to limit the current and counteracts thermal runaway. A third recommended method is to use a "V_{BE} multiplier" to bias the bipolar output stage. The V_{BE} multiplier consists of a bipolar transistor and and two resistors, one from the base to the collector and one from the base to the emitter. The voltage from the collector to the emitter (also the bias voltage of the output stage) is Vbias = V_{BE} (1+Rb2/Rb1), which is why this circuit is called the V_{BE} multiplier. When V_{BE} multiplier transistor is mounted to the same heat sink as the bipolar output transistors, its temperature will track that of the output transistors. Its V_{BE} is dependent upon temperature as well, and so it will draw more current as the output transistors heat it up. This will limit the base current into the output transistors, which counteracts thermal runaway and gives amplifier stability.

Amplifier Output Section:

To be able to take advantage of the full performances of this amplifier, the short-circuit and over-current protection was not included. The reason is because this may trip at the peak levels of the sound, and also can introduce distortions. In fact, most of the High-End audio amplifiers doesn't have the over-current and short-circuit protection included onto the amplifier board, but it has on an external board dedicated for this purpose. When using this amplifier, special care should be taken to not overload the amplifier with very low load impedances, the minimum load impedance should be 4Ω, but is preferable to use 8Ω load impedance, since the amplifier will have the best performances.

To avoid the unpleasant bump noise which may ocure when the amplifier is turned ON or OFF, as well as to protect the loudspeakers from damage in the unlikely event that the output power stage fails and the power supply doesn't disconnect the power fast enough, the Speaker Protection Circuit is implemented on the amplifier board. The output signal from the Power Amplifier Module is routed through a speaker protection circuit. The power supply voltage needed for the Speaker Protection Circuit is taken from the amplifier main supply voltage,

thus simplifying the connection of the amplifier. It only needs a connection to the main secondary winding of the power transformer to detect when the mains transformer is powered, to be able to disconnect the loudspeakers when the mains power is turned OFF before the power supply capacitors are discharged and the amplifier hs not enough voltage to work properly.

Installation Guide:

To set-up and run this amplifier, need to follow some basic steps. First the amplifier module needs to be installed into a case, preferable with the heatsink in vertical position for natural convection cooling. Note that should avoid covering the top and bottom of the heat sink fins, by the case cover or by stacking the amplifier in an audio system. In some cases, if the amplifier is used to play high level of audio signal for long time, the heat sink may get very hot, too hot to be touched. In this case, forced air cooling may be an option, using a small DC Brushless Fan, like those used on the computer power supply. For the amplifier modules which are purchased without heatsink, a proper heat sink must be used, which have a thermal resistance under 0.6°C/W.

Next step is wiring the amplifier to the power supply, signal source, and output to the loudspeakers output terminals. First of all, need to use a rectified and well filtered Linear DC Power Supply or SMPS. To supply power for the amplifier, 4 voltages are needed. Two positive voltages and two negative voltages with respect to GND. The value of these voltages needed for the 300W amplifier version are: +-61V DC for the Power Stage, and +-67V DC for the Driver Stage and for the 500W amplifier version, the voltages are +-78V for the Power Stage and +-84V for the Driver Stage. The reason why two different supply voltage values were chosen, is that the Amplifier Driver IC to be able to provide enough voltage excursion for the Power stage, to avoid early clipping and saturation of the amplifier.

The input signal path should pass thru a volume potentiometer, to be able to adjust the output power, and volume to the desired value. The signal cables and connectors should be very good quality, shielded, and with shield connected to Signal GND in a single point, avoiding Ground loops which will drastically decrease performances, increase noise, and make the amplifier unstable, allowing high-frequency oscillations to occur and possible damage the amplifier if measures are not taken to avoid this. The input signal cables should be very short, and routed far from the mains transformer or the output section or output wires to avoid interferences which will lead to noise and instability.

Power Supply Choice:

A good choice of the Power Supply can be for the 300W amplifier version the **Power Supply 4x18000uF at 71V + 2x18000uF at 71V** or **Power Supply 4x10000uF at 80V + 2x10000uF at 80V** and for the 500W amplifier version **Power Supply 4x10000uF at 100V + 2x10000uF at 100V**. All this Linear Power Supplies are available for purchasing on the www.connexelectronic.com. The Linear DC Power Supply should be powered from a mains transformer, preferable Thoroidal or R-core type, since this type of transformers have improved performances for Audio Amplifiers. The size and power rating of this transformer depends on the required Output Power Lever. Few examples will be given in next: For the 300W amplifier version, to get 170W at 8Ω load impedance the transformer should have at least 320VA Power rating and have two identical windings of 44V AC at 4A and another two identical windings which can provide 48V and least 100mA. If such transformer is not available, two transformers can be used, one which is at least 300VA Power and can provide 2x44V AC at 4A, and another one, smaller, just 10-15W and which can provide 2x43V and least 100mA. After rectification and filtering the Power Stage Voltage value will be +- 61V DC and +-67V for the Driver stage. To get 320W at 4 Ω, the transformer should be rated at at least 600VA, the output voltage must be the same as for 8Ω version, just the current must be accordingly higher, at least 6.5A for the 2x44V AC and for the aux. winding same as before, 100mA. For the 500W amplifier version, to get 320W at 8Ω load impedance the transformer should have at least 600VA Power rating and have two identical windings of 56V AC at 4A and another two identical windings which can provide 60V and least 100mA. To get 570W at 4Ω load impedance the transformer should have at least 1000VA Power rating and have two identical windings of 56V AC at 9A and another two identical windings which can provide 60V and least 100mA.

Using two or more identical transformers instead of one, is not necessary for a single channel amplifier, since the LME49810 IC requires power supply from the same source one channel, but is recommended to be used in a stereo or multichannel amplifier, where every amplifier module has its own transformer and power supply board. The main advantage of this arrangement is that the channel separation is improved with at least 12dB and the weigh is distributed evenly in the amplifier case. When using a mains transformer and a power supply board to supply the amplifier, it is strongly recommended to use a **Power Soft Start** circuit as well. This circuit will reduce

the inrush current when the transformer is powered up to a reasonable value to not damage any component or blow the fuses. The **Power Soft Start** module has remote function also, which allows to turn ON/OFF the amplifier without using high current rating switches which are expensive, not always reliable and they look not always nice.

An alternative to the linear supply is to use a **SMPS**. The main advantage is that the SMPS is more compact and lightweight compared with classical linear supply and have load and line regulation. When choosing a SMPS for a linear amplifier, few things must be considered: first, the output voltage of the SMPS must be in range of the voltage needed by the amplifier. Then the power rating of the SMPS must be high enough to be able to sustain the long term average current consumption without entering in over-temperature shut-down and short term peak current demand without entering prematurely in over-current protection mode. There are two types of SMPS's which can be used: with regulated output and without regulated output. The reason why and unregulated output SMPS would be chosen is that this topology allows simple construction and high efficiency when QR topology is used. The amplifier has high enough PSRR to not be negatively influenced by a small supply voltage variation, from an unregulated SMPS. In fact, any mains transformer plus rectifier and filter capacitor has the same or even worst behavior than an unregulated SMPS. In case of using a regulated voltage SMPS, the supply voltage can be with 5-10% smaller, since the voltage of the. SMPS will not drop at peak power as it may happen with unregulated linear supply. Few models of SMPS are available on the www.connexelectronic.com website.

For LME49810-300W Amplifier Module, SMPS500R or SMPS500QR is the minimum choice for one channel, while for LME49180-500W the SMPS800RE is the minimum choice for one channel. ASMPS2000R can be used for Two channels LME49810 amplifier, Three or up to four channels LME49810-300W amplifiers.

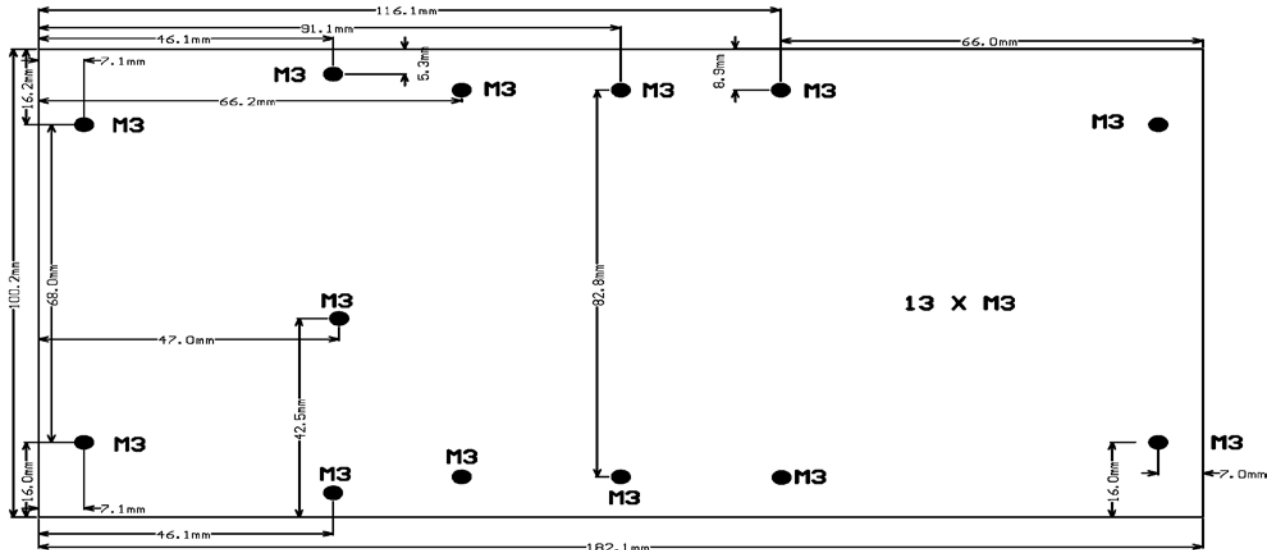For larger systems, SMPS4K8 can be considered, which can power up to 6 LME49810-500W modules.

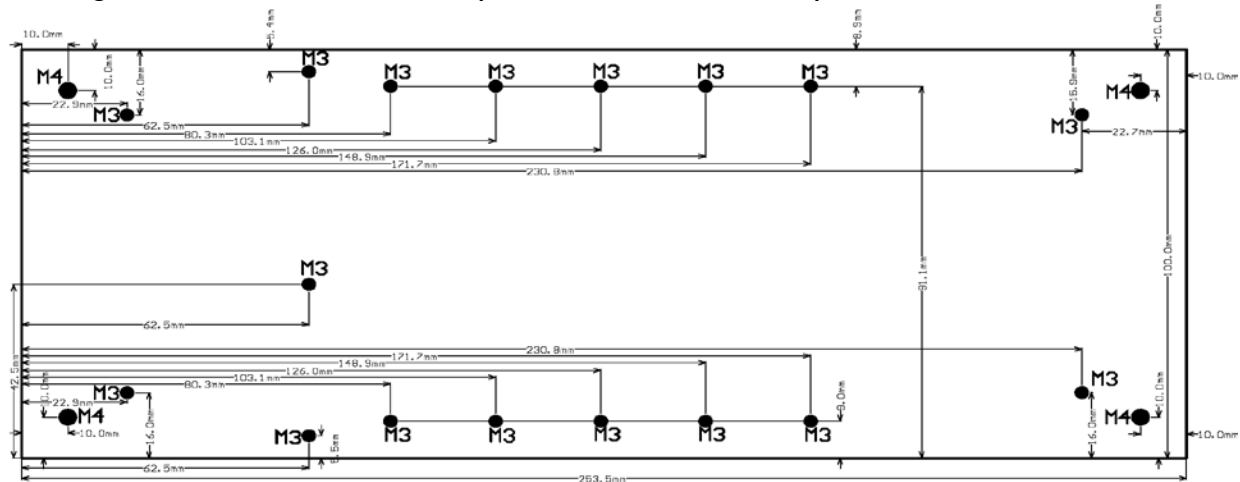**Figure 4: 300W LME49810 Audio Amplifier Module heat sink holes position and distances**

Figure 5: 500W LME49810 Audio Amplifier Module heat sink holes position and distances
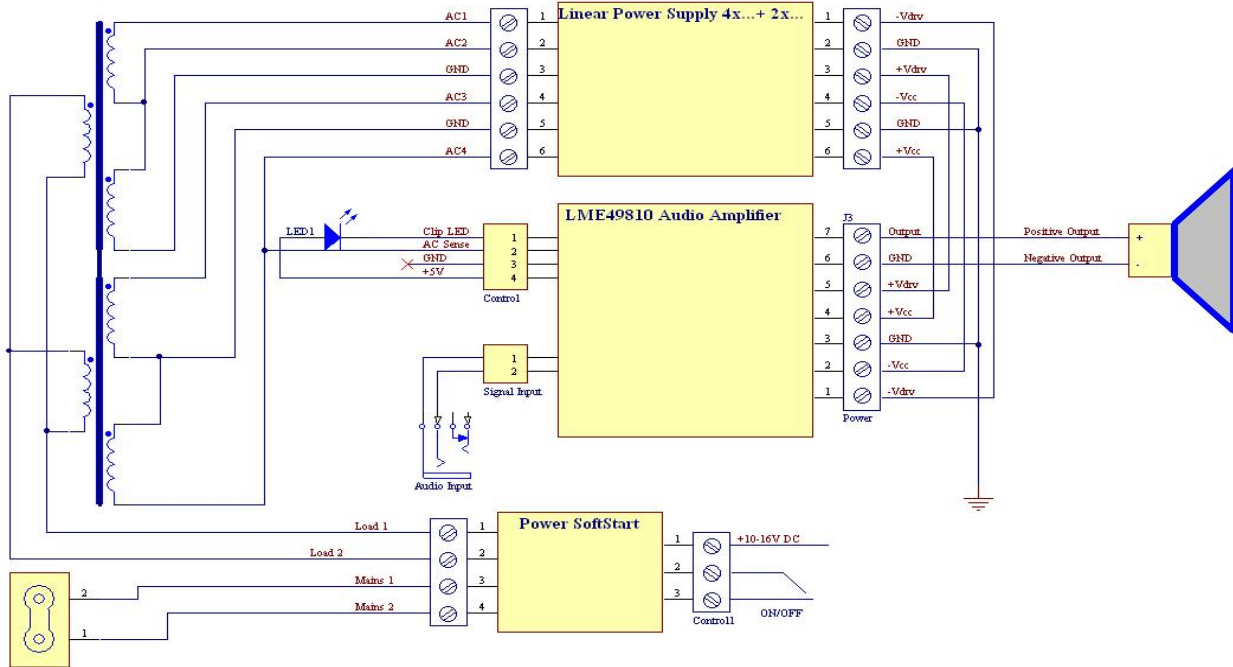
Figure 6: LME49810 Audio Amplifier System Connection Diagram using a mains transformer supply
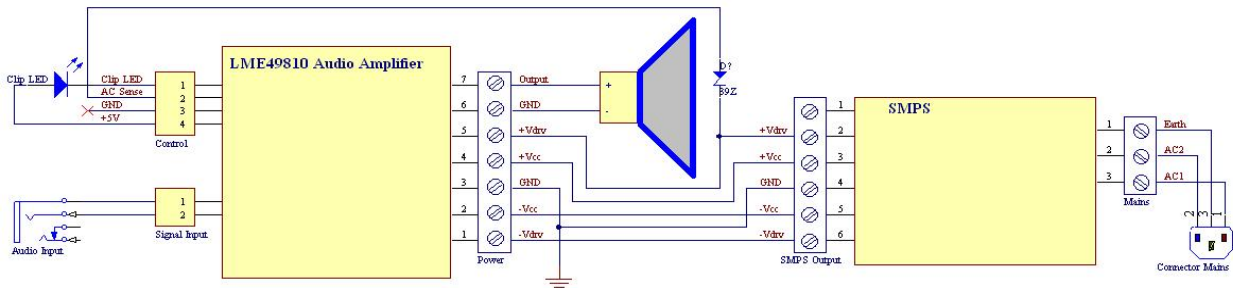

Figure 7: LME49810 Audio Amplifier System Connection Diagram using a SMPS

Disclaimer:

The LME49810 Audio Amplifier modules 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 misusage will be made on user responsibility.

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