LM4702 BPL Audio Amplifier Module v1.0

LM4702 BPL Audio Amplifier Module is a Class AB Stereo Audio Amplifier based on LM4702 audio power amplifier driver made by National Semiconductor® Company. The LM4702 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 LM4702 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. 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: 2x110W at 8Ω, with max. 0.1% THD+N, at +/- 52V Power Stage Supply Voltage.
- Output Power: 2x90W at 8Ω, with max. 0.1% THD+N, at +/- 46V Power Stage Supply Voltage.
- Audiophile sound Quality: 0.006% THD+N at 100W at 8Ω, at +/- 53V Power Stage Supply Voltage.
- Very good Signal to Noise Ratio, over 118dB.
- Compact size, 144x60x25mm, assembled board, with available heat sink and optional power supply.
- Separate Driver Supply voltage ensure maximum power without losing performances.
- Mute control pin for controlling 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.

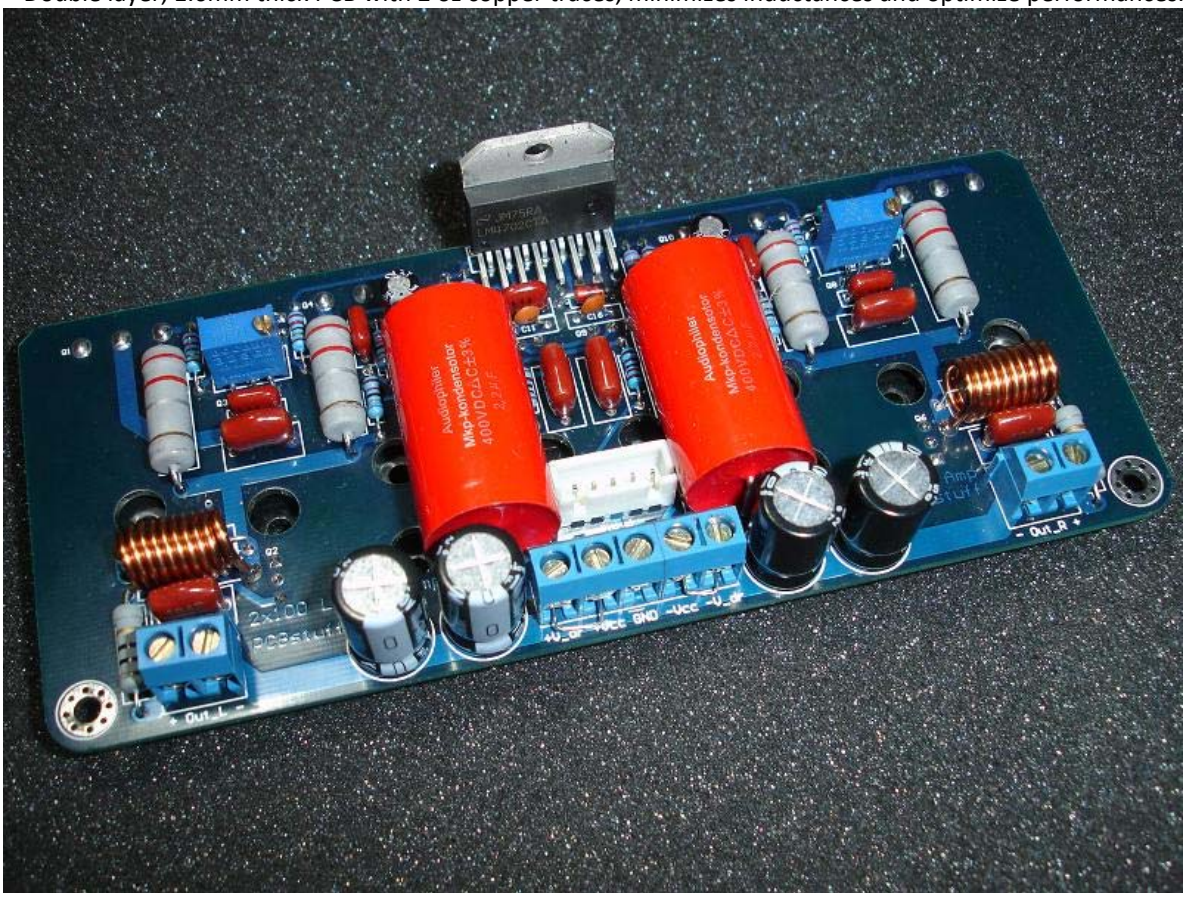

Figure 1: LM4702 Audio Amplifier Module

Amplifier Description:

LM4702 Class AB Stereo Audio Amplifier is built around LM4702, 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 LM4702 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 LM4702 IC thru DC coupling capacitors, C9 and C14, 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. Different circuit components used in the LM4702 amplifier was evaluated, and the DC blocking capacitor on the input of the LM4702, 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 standard, commercially available parts.

Next, the resistors R14 and R15 are part of the input stage, and set the amplifier input impedance and the amplifier DC bias point. The LM4702 input stage is configured as non-inverting amplifier, allowing the system designer flexibility in setting the input stage gain and frequency response. The LM4702 amplifier gain is the 1+R3/R11 for the Left channel and 1+R25/R19 for the Right channel. 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 R3, and R25. 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 LM4702 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.

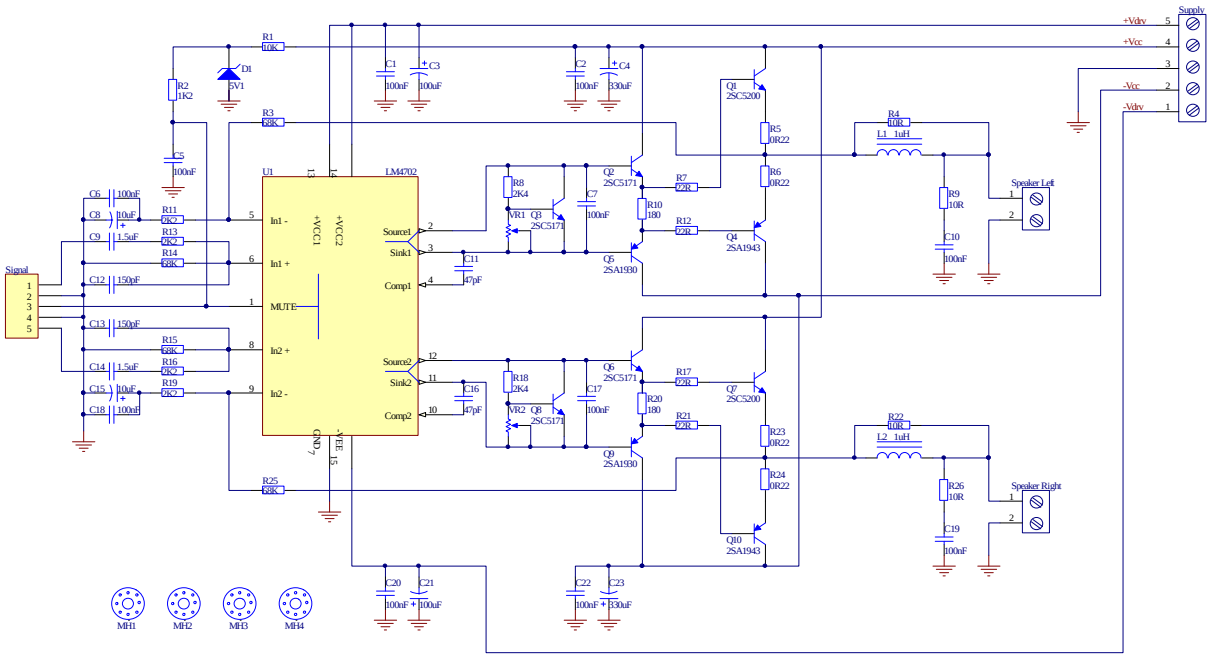

Figure 2: LM4702 Audio Amplifier Module Schematic Diagram

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 1mA and 2mA 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 LM4702, which can damage an attached speaker if a speaker protection circuit is not used.

The LM4702 Audio Amplifier Driver is limited to 5mA of output drive current capability. To achieve the desired output power of 100W per channel, external transistors must be used. There are few options which can be considered. First, to use Bipolar Power transistors, driven with a bipolar transistors driver stage. Second option, to use enhanced Bipolar Darlington Transistors, with thermal compensation diodes and emitter resistors included. The third option was to use MOS-FET transistors, both vertical or lateral MOS-FET's can be used.

This amplifier was built using Bipolar Power Transistors and Bipolar 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 diminuation. One of the main problem 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, R6, R23, R24 in Figure 2). 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 (see Figure 2). The V_{BE} multiplier consists of a bipolar transistor (Qmult, Q3 for Left channel and Q8 for Right channel see Figure 2) and two resistors, one from the base to the collector (R8, R18, see Figure 2) and one from the base to the emitter (VR1, VR2, see Figure 2). 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.

In play mode, the LM4702 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 25mA and multiply it by the total supply voltage (the current varies slightly from this value over the operating range). 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. Once the maximum package temperature has been reached, the circuit will shut-down. The LM4702 has a sophisticated thermal protection scheme to prevent long-term thermal stress of the device. When the temperature on the die exceeds 150°C, the LM4702 shuts down. It 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 in a Schmitt Trigger fashion 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. Since the die temperature is directly dependent upon the heat sink used, the heat sink should be chosen so that thermal shutdown is not activated during normal operation. Note that in applications where the output power is up to 100W, or the supply voltage for the IC is up to +-60V DC, the heat sink can be omitted. In this case, need to monitor carefully the IC temperature when the amplifier is installed in the case, and if higher temperatures than 100°C are observed, a small heat sink should be attached to the LM4702 IC.

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 +/-52V supplies, worst case dissipation occurs at 90W into 8Ω load Impedance, of 65W. 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 1.2 ˚C/W is required. A good choice is an extruded aluminum heat sink profile with vertical fins and with the size of at least 144x60x40mm, 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.

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 15 min. after turn-off.

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. If over-current and short-circuit protection is requires, please check the "Speaker Protection Circuit" and "Amplifier Protection Circuit" from Audio Amplifiers Accessories Section.

Installation Guide:

To set-up and run this amplifier, need to follow some basic steps. First the amplifier module need to be installed into a case, preferable with heatsink vertically 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.

Next step is wiring the amplifier to the power supply, signal source, and output to the protection board and loudspeakers output. First of all, need to use a rectified and well filtered Linear DC Power Supply. To supply power for the amplifier, 4 voltages are needed. Two positive, and two negative with respect to GND. The value of this voltages needed to achieve output power of 100W are: +-52V DC for the Power Stage, and +-60V DC for the Driver Stage. The reason for 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. A good choice can be either **Power Supply 4x10000uF at 63V + 2x10000uF at 80V** or **Power Supply 4x15000uF at 63V + 2x15000uF at 63V** or even **Power Supply 4x18000uF at 71V + 2x18000uF at 71V**. 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 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. For 100W at 8Ω load impedance the transformer should have at least 360VA Power rating and have two identical windings of 38V AC at 5 A and another two identical windings which can provide 43V and least 100mA. If such transformer is not available, two transformers can be used, one which is at least 350W Power and can provide 2x38V AC at 5 A, 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 +- 52V DC and +-60V for the

Driver stage. Using two identical transformers instead of one, is not necessary, since the LM4702 IC requires power supply from the same source for both channels. An alternative to the linear supply is to use a **SMPS** (Switched Mode Power Supply). The main advantage is that the SMPS is more compact and lightweight compared with classical linear supply and have load and line regulation. Some of them, those who have active PFC will allow universal mains input voltage as well, which is good to take into account when the amplifier is used in various places, with different mains voltages available. In case of using a regulated voltage SMPS, the supply voltage can be with 10-15% 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 website.

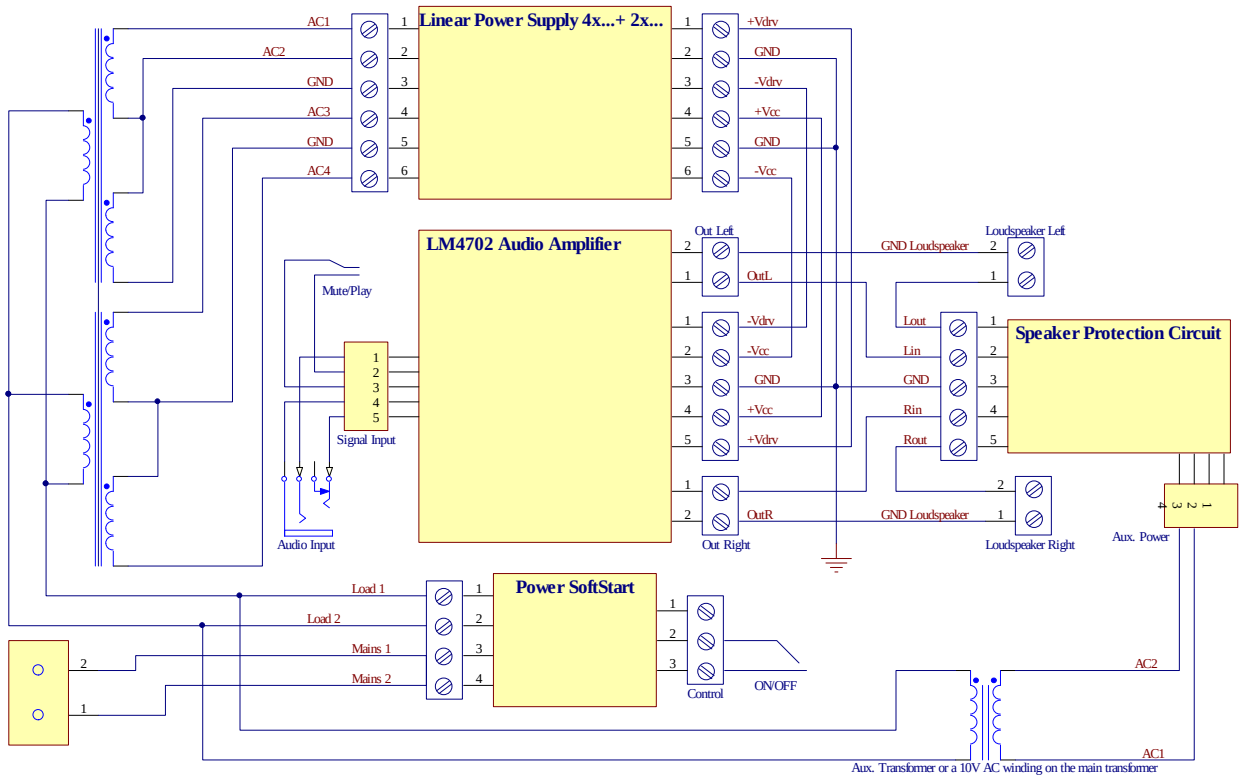

Figure 3: LM4702 BPL Audio Amplifier System Connection Diagram

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. 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.

The output signal from the Power Amplifier Module should be routed thru a speaker protection board who has the role to delay the amplifier connection to the loudspeaker to prevent the click and pop noise when power ON or OFF the amplifier, and to protect the loudspeakers in case of amplifier malfunction when DC component may be present on the amplifier output. To use the **Speaker Protection Circuit**, just connect the outputs of the amplifier to the inputs of the Speaker Protection Circuit for both Left and Right Channels. The Speaker Protection Circuit requires an auxiliary voltage to be provided from a winding of the mains transformer, the value of this voltage should be between 9V AC to 12V AC. For higher voltage values, some components from the Speaker Protection Circuit board need to be replaced. The schematic of the Speaker Protection Circuit can be seen in the Figure 4.

Another useful module for the amplifier will be Power Soft Start Circuit, which will allow the slow start the mains transformer until the Filtering Capacitors are charged and also remote control the amplifier startup. For more information about the Power Soft Start Circuit, please visit the product page at www.connexelectronic.com.

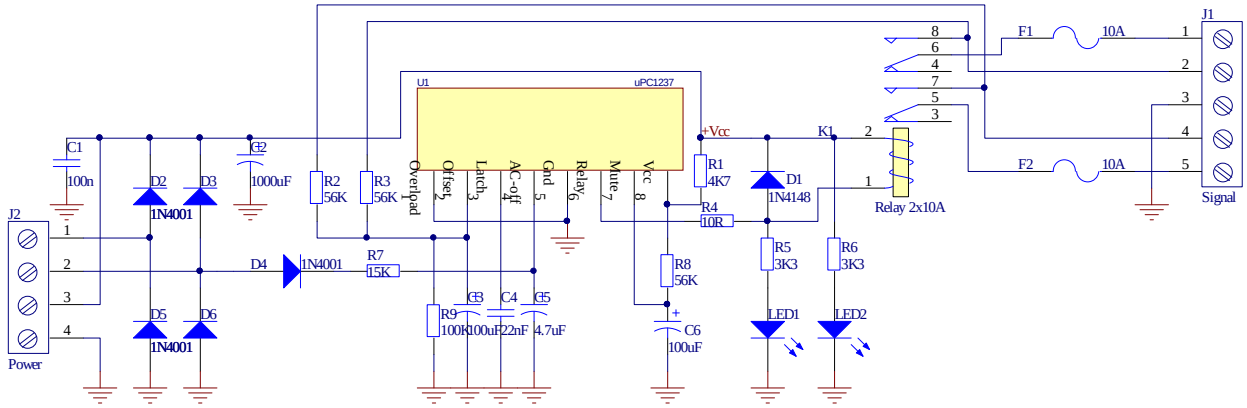

Figure 4: Speaker Protection Circuit Schematic

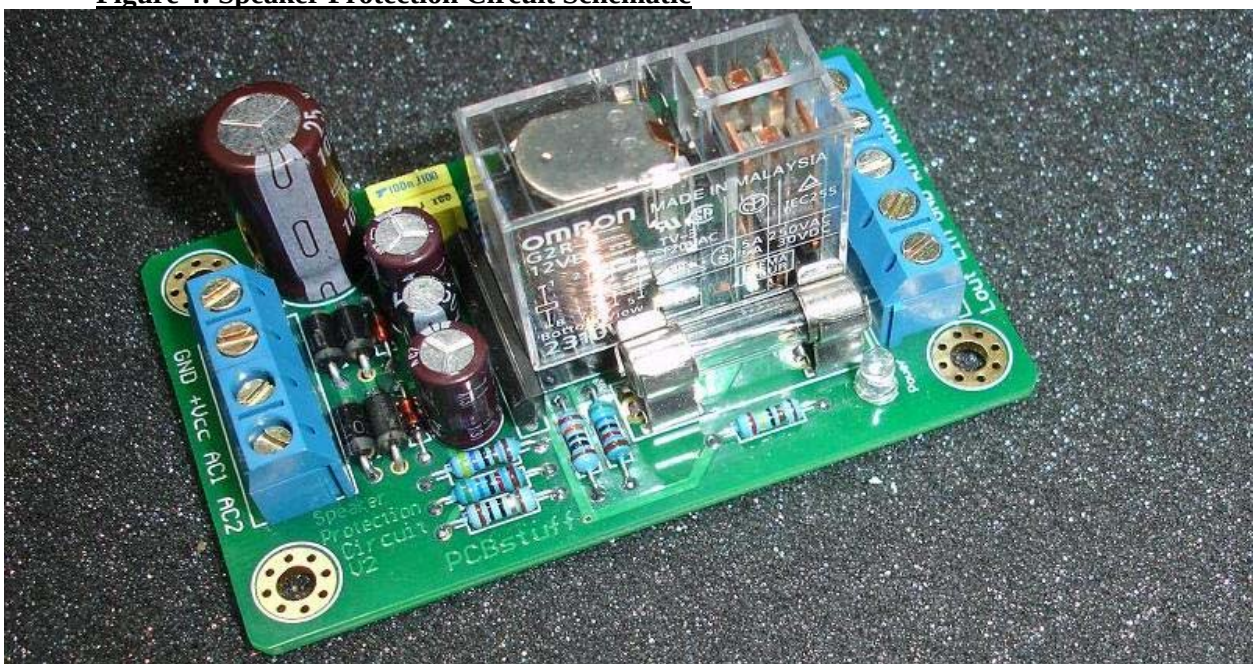

Figure 5: Speaker Protection Circuit Photo

Disclaimer:

The LM4702 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, **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 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 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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