Power Supply and Protection Circuit

The **Power Supply and Protection Circuit** is used for class D and class T amplifiers which requires few supply voltages, one main differential power supply for the amplifier power stage, capable to deliver up to +-65V at 15A, one 5V to 12V @ 200mA regulated power supply for amplifier input section, and one regulated, isolated bias supply voltage in range of 10-12V which can be referenced to Vnn and used for amplifier driver stage bias. In addition to the power supplies, the board also contains Mains Power Soft Start circuit, which will connect the mains transformer sequentially to mains, to limit the inrush current, and also offer the remote turn-on option. It also contains Speaker protection circuit, which has the role to connect the speakers with few seconds delay, to prevent click/pop noises and disconnect the speakers if DC component is detected at output. The board also contains a peaking detection circuit, which has the role to detect any peaking in the amplifier power stage, and to mute the amplifier if the value exceeds the threshold.

The **Power Supply and Protection Circuit** contains:

- High current rectifier bridge and 6x4700uF low-ripple capacitors for main power supply.
- Two auxiliary well regulated voltages to supply the input stage and driver stage of the amplifier.
- Suitable for 110V and 230V mains voltage, with up to 10A RMS mains transformer primary side current.
- Mains transformer primary side current limit for smooth start-up.
- Remote turn ON/OFF function allows using either a low current switch or a remote control circuit.
- Speaker Protection circuit, with delay speaker connect and DC detection speakers disconnect.
- Peaking Detection Circuit, with Mute the amplifier if excessive peaking in the amplifier power stage is detected, to protect the amplifier from failures.

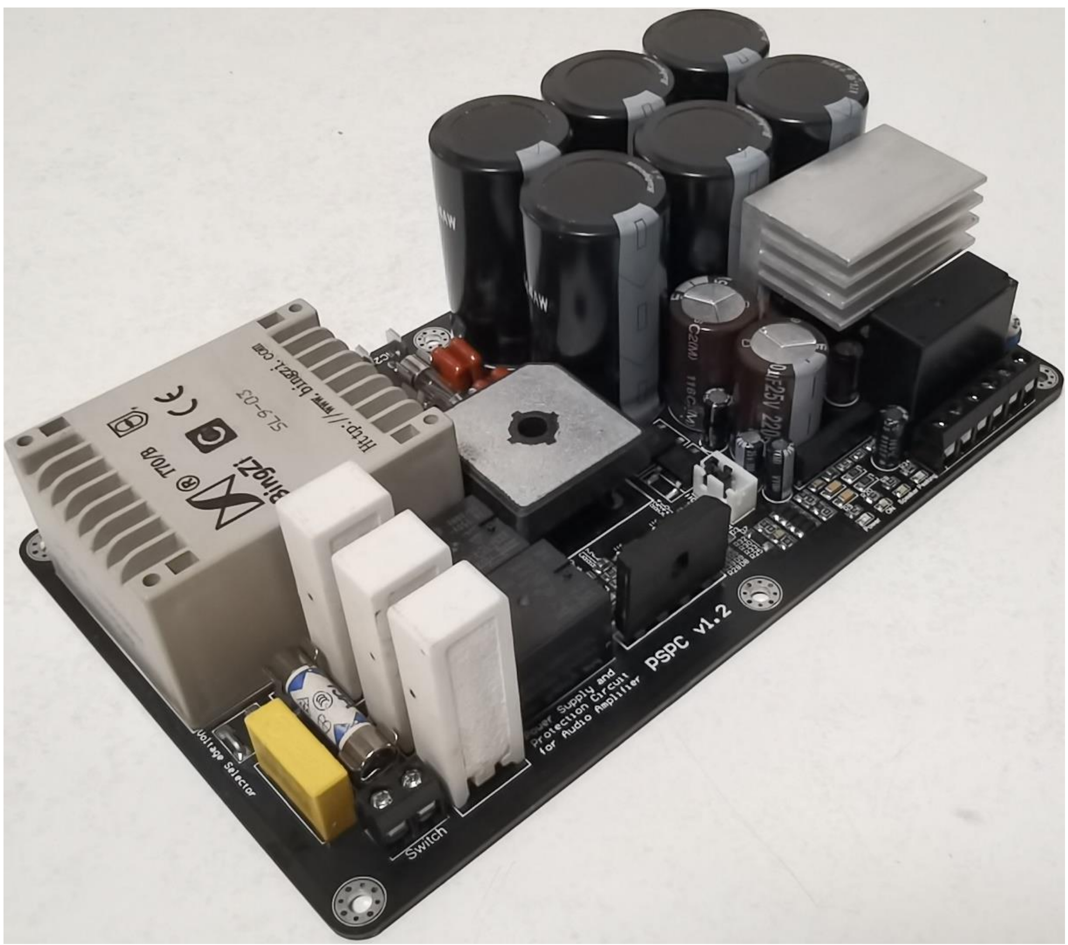

Figure 1. Power Supply and Protection Circuit board overview.

Power supply and Protection board Description:

The first stage of the **Power Supply and Protection Circuit** is the **Power Soft Start circuit** which limits the inrush current drawn from the mains by the transformer of the amplifier during power ON sequence. When the power amplifier is switched on, the initial current drawn from the mains is few times higher than the maximum current which is drawn at the full power. There are two main reasons for this: one reason is because the transformers will draw a very heavy current at switch on, until the magnetic flux has stabilized. The effect is worst when power is applied as the AC voltage passes through zero, and is minimized if power is applied at the peak of the AC waveform. This is exactly the opposite of what you might expect. Another reason is that at power on, 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 ($CU^2/2$).

Most of the high power amps used in PA and other industrial applications equipments use various types of Power Soft Start, although they are not commonly used in consumer equipment. Anyone who has a large power amp - especially one that uses a toroidal transformer - will have noticed a momentary dimming of the lights when the amp is powered up. The current drawn is so high that other equipment is affected, like computers, TV's or other equipment which are sensitive enough or have the hold-up time of the capacitors from the power supply too small to compensate the voltage fall during this transients. In addition to the unpleasant effects, the high inrush current (as it is known) is stressful on many components in your amp, especially the fuses which may blow if they are fast acting type or underrated, the transformer can be affected, the massive current stresses the windings mechanically and electrically. It is not uncommon to hear a diminishing mechanical buzz as the chassis and transformer react to the magnetic stress. The rectifier bridge must handle an initial current way beyond the normal, because it is forced to charge empty filter capacitors which look like a short circuit until a respectable voltage has been reached. The capacitors can be also damaged, as the inrush current is many times higher than the ripple current rating of the capacitors, and stresses the internal electrical connections, which may lead to premature failure. Due to this reason, some of amplifier failures occur at power on (unless the operator does something foolish). This is exactly the same problem that causes your lights at home to 'blow' as you turn on the light switch. You rarely see a light bulb fail while you are quietly sitting there reading, it almost always happens at the moment that power is applied. It is exactly the same with power amplifiers.

To avoid all the unpleasant effects which were showed above, the Power Soft Start Circuit must be used. The main role of the Power Soft Start Circuit is to limit inrush current to a safe value, of about 15A for 230V AC circuits and 8A for 110V circuits. The maximum current which the Power Soft Start Circuit can admit in normal operation is 10A RMS for 230V AC circuits and 15A RMS for 110V circuits. The maximum current thru the relays is limited at 20A, but because the power factor of the circuits is ≠ 1 this current have smaller value. A very important aspect is that the Power Soft Start Circuit must be used ONLY in AC current circuits, on the mains side and not on the secondary, or DC circuits. Misusages will lead to failure. Another important role of the Power Soft Start Circuit is that has the "remote" turn ON/OFF function, which means that the power circuit can be turned ON/OFF remote, by using a logic level control signal applied to the isolated control part of the Power Soft Start Circuit. This is particularly important when the Power Soft Start Circuit is used to control an Audio Power Amplifier which has remote turn ON/OFF function implemented or Stand-by for power saving. The idle current consumption is very small, and the power consumed is less than 1W at 230V AC and less than 0.85W at 110V AC. Although the soft start circuit can be added to any sized transformer, the winding resistance of 200VA and smaller transformers is generally sufficient to prevent a massive surge current. Use of a soft start circuit is definitely required for 400VA and larger transformers.

The principle of operation of the **Power Soft Start Circuit** is simple. The power from the mains is applied to the **Power Supply and Protection Circuit** board on the connector called **Mains** (see Figure3, at top left). The mains voltage will pass through a fuse and the mains switch which can be connected externally, at the connector called **Mains Switch**. When the mains switch is closed, the current will flow through the on-board auxiliary transformer which provides supply voltages both for on-board circuits and for auxiliary regulated power supplies. To turn on the **Power Soft Start Circuit,** the Remote Switch connected at **Remote On/Off** connector (see figure3, bottom middle) must be closed. (Pin1 and pin2 of the Remote On/Off connector must be connected together, pin3 must be left floating). The pin signification is as follows: Pin1: voltage supply to Power Soft Start circuit. Pin2: Vcc supply voltage from auxiliary power supply. Pin3: GND; used only if power is drawn for an external remote circuit. If the remote function is not used, should be disabled by installing a 4.7R resistor in place of R8.

With the Remote switch closed, the Power Soft Start circuit from the board will be supplied and start operation. In the first step, the relay RL2 will close first, allowing power to flow from the mains to the power transformer through 3 power resistors, which has the role to limit the current flowing through transformer windings in the very first seconds. The Power transformer must be connected at the connector called **Transformer** situated in the top left of the board. After approximately 2 seconds, the relay RL1 will close and few ms later the relay RL2 will open. Closing the relay RL1 will shunt the power resistors initially connected in series with the Power transformer and will allow full power to be drawn from the mains by the power transformer. Now the Power Soft start section is operating normally. The relay RL2 has been disconnected for power saving, since it's shunted already by RL1. The secondary AC voltage of the power transformer is applied to the **Power Supply and Protection Circuit** board through the fast-on clips called AC1 GND1 and AC2.

If the control circuit is mounted inside the amplifier case, and has a remote control receiver, this can be powered from the **Power Supply and Protection** circuit if the required current does not exceed 50mA. Note that the voltage is unregulated, and will vary with the **Power Supply and Protection** circuit status, when the relays are opened, the voltage will have the value between 15 to 17 V DC and will drop to about 12V when the relays are closed. When power is drawn, need to make sure that the voltage will not drop below 11V DC, otherwise the proper operation of the board might be compromised.

The second stage of the **Power Supply and Protection Circuit** is the linear Power Supply, comprised of: Power transformer (external from the board, not included) rectifier bridge D7 and the 6 large electrolytic capacitors: C24, C25, C26, C30, C31 and C32. The default configuration uses Rubycon USR series, 4700uF at 70V 6 pcs. Any other capacitors can be used instead, with the mention that their rated working voltage must be at least 10-15% higher than the maximum voltage of the linear supply and their footprint must allow proper installation, in this case they are 25mm diameter.

The secondary voltage from the power transformer is applied to the **Power Supply and Protection Circuit** board through the fast-on clips called AC1 GND1 and AC2. Next, the linear power supply is protected by two fuses, F1 and F2. The fuses current rating should be enough to withstand both the current draw of the amplifier in normal operation, during start-up, and not too large to allow them to blow in case of a short-circuit, without destroying the **Power Supply and Protection Circuit** board, the amplifier or the mains transformer. A value of 15A was chosen for the current configuration, which satisfies the conditions mentioned above.

The Linear power supply rectifies the mains AC voltage and using the electrolytic capacitors will filter to obtain a clean DC dual rail voltage. However, since this stage does not provide voltage regulation, the output voltage will drop under heavy load with up to 10-15% from the voltage value present at no-load state. This voltage drop is mainly because of the power transformer losses, its winding resistances and leakage inductance. Also, the output voltage would not be constant under load, because of the ripple voltage. Because the electrolytic capacitors are only charged when the rectified mains voltage has a value of at least or larger than their instantaneous voltage value, there will be rising and falling of the instantaneous output voltage. The frequency of the ripple is equal with double the mains voltage frequency. The ripple is not harmful for any amplifier as long as it's within reasonable limits. All the linear unregulated power supplies have ripple, without exception. Even the regulated linear power supplies and the Switched Mode Power Supplies have output voltage ripple, but much lower. The linear unregulated power supplies are used since more than a century, being the second available DC voltage supplies after batteries, or third if we consider DC current generators. Each amplifier has a parameter called PSRR (Power Supply Rejection Ratio) which tells us how much the amplifier can reject the noise induced by the ripple from the power supplies. This parameter has values of at least 50dB for a class D or T amplifier and can be up to 90dB for a good class AB amplifier. This means that few volts ripple in the power supply will be attenuated by a factor of thousands by the amplifier.

The mains voltage contains high-frequency noise which can interfere with the amplifier, resulting unwanted audible noise. There are few ways to attenuate the mains high frequency noise. The first one is to use a mains filter which can attenuate both the common mode and differential mode conducted noise. This filter usually comes in the form of a can with input, output and protective earth connecting wires, but is also available with IEC connectors at one end. A broad selection of EMI filters can be found at the following link, with parameters described for each: http://connexelectronic.com/index.php/cPath/21_26

The switching noise of the rectifier is attenuated using 4 capacitors connected across the rectifier bridge diodes, C22, C23, C28 and C29. Also, the C27 and C33 connected in parallel with the large electrolytic capacitors will further reduce the high frequency ripple and noise.

The third stage of the **Power Supply and Protection Circuit** is the **Speaker Protection Circuit,** which has two main functions: to protect the audio amplifier and the loudspeakers during start-up sequence when the amplifier output might exhibit DC voltage, during the start-up sequence and to protect the loudspeakers in the unlikely event of an amplifier power stage failure, where DC component would damage the speaker voice coil. The core of the **Speaker Protection Circuit** is the **uPC1237** dedicated circuit. 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 input connector is placed on the bottom right side of the **Power Supply and Protection Circuit** board, the Left Channel input is placed at the top, near the Pk_Dis. Jumper and the Right Channel input is placed at the bottom, near the board. The output signal is routed to the **Speaker Out** connector, with the Left Channel in the left side and Right Channel in the right side of the connector.

When the amplifier is turned ON, the **Speaker Protection Circuit** is powered ON, it starts to operate. The uPC1237 IC will monitor the output voltage of the amplifier applied to pin2 through a resistor divider and a low pass filter which remove large amplitude, high frequency signals which might false trigger the circuit. In the same time it monitors the voltage on pin 4 to detect if the AC (in fact, rectified AC voltage or DC voltage derived from the main supply) is present to enable further operation steps. If the value of the DC component at the output of the amplifier is close to zero, and the AC detect is present, the capacitor connected to pin 7 will charge through resistor R21 connected to pin 8 (Vcc) and when the threshold value is reached the output pin 6 will toggle and the relay will close, allowing the amplifier to be connected to speakers. The value of C21 and R21 determines the delay time and the values of the R15 and R16 determines the maximum DC offset voltage allowable before the **Speaker Protection Circuit** will disconnect the relay. With the current values, the delay time is aprox. 4 seconds, and can be reduced by reducing the value of the capacitor C21 or decreasing the value of R21, and can be increased by increasing the value of C21 or increasing the value of R21.

The DC protection circuit will detect any DC voltage higher than ~2V present at the output of the amplifier for more than one second, and will disconnect the speakers to avoid permanent damage of the voice coil. The offset threshold is set to about 2V with the current components values. The threshold can be increased by increasing the components values or decreased by decreasing the components values. Note that in any case, a resistor value of less than 33K should never be used as it might damage the IC in case of amplifier failure. The capacitors C18and C20 connected in parallel with the resistor R22 has the role to reduce the AC components from the audio signal, avoiding false triggering. In other words, the **Speaker Protection Circuit** will only disconnect the relay if a DC voltage is present, not AC, even if the AC component has larger amplitude than the DC threshold. When the **Speaker Protection Circuit** relays are opened, and speakers disconnected from the amplifier, the LED named **Speaker** will lit Red indicating that the **Speaker Protection Circuit** is either in the initial start-up sequence, or DC component was detected at the output of the amplifier and the speakers are disconnected for safety reason.

The relays used in the **Speaker Protection** Circuit are separate for each channel, for better channel separation and because single pole relays are able to carry more current than double pole ones. The current relays are able to switch up to 20A at 125V AC, which is more than enough for any domestic or audiophile power amplifier application. To make an idea, a 1000W on 4R audio amplifier has a RMS current of ~16A. 20A is the current provided by a 1600W audio amplifier. With the current configuration of the **Speaker Protection Circuit** it must be used with Single ended amplifiers output configuration only and not BTL amplifiers for which a different DC detection circuit must be used to avoid erroneous detection.

The fourth stage of the **Power Supply and Protection Circuit** is the **Peaking Detection Circuit**. The main role of the **Peaking Detection Circuit** is to detect the peaking of the output filter of the class D or T amplifier, a phenomenon which might have destructive effect if large amplitude is developed at the output of the amplifier. The main cause of the peaking is the resonance of the output LC low-pass filter components when the input signal amplified has high frequency and high amplitude, or in case of abnormal operation, when oscillation of the output power stage is experienced. During peaking, the output filter of the amplifier resonate at or close to it’s resonance frequency, very large currents is flowing through the filter components, and the amplitude of the voltages on the filter components can exceed the supply voltage rails, which can damage the power stage if measures to damp the oscillation are not taken.

The **Peaking Detection Circuit** detects the maximum amplitude of the output signal of the amplifier and Mute the amplifier if a specific threshold is reached. Unlike the DC component which can be detected by the speaker protection circuit, the peaking has high frequency components which would not be detected by the speaker protection circuit, and is also not desired to disconnect the speakers during peaking even, but rather Mute the amplifier instead. The threshold for peaking amplitude and frequency is determined by the values of the following components: C34, C36, R29, R35 and R36. With the current values, the peaking will be detected when the output signal amplitude will exceed 0.75xV supply at 26KHz. Note that this amplitude at this particular frequency is much higher than the amplitude of any musical signal, and below the dangerous level for the amplifier.

When peaking is detected on any of the two channels, Mute is asserted and a timer is started which will un-Mute the amplifier after about 2-3 seconds, after the oscillation has been damped already. If the peaking persists, the cycle will repeat. An on-board Orange LED will lit when Peaking is detected and Mute is asserted. There are few ways to implement the mute circuit for the audio amplifier. On the current board, the 5V supply voltage for the input section bias will be disconnected when peaking is detected. This is the easiest straightforward way to implement because it does not require any additional wiring, and less chance of mistakes are present.

If peaking function is not required to Mute the amplifier when is detected, a jumper called Pk_Dis. Must be set on the board, on the right side, between the speaker input connector and Auxiliary supply connector. The Peaking detection circuit will be still active, but will not Mute the amplifier, but just indicate the state with the LED.

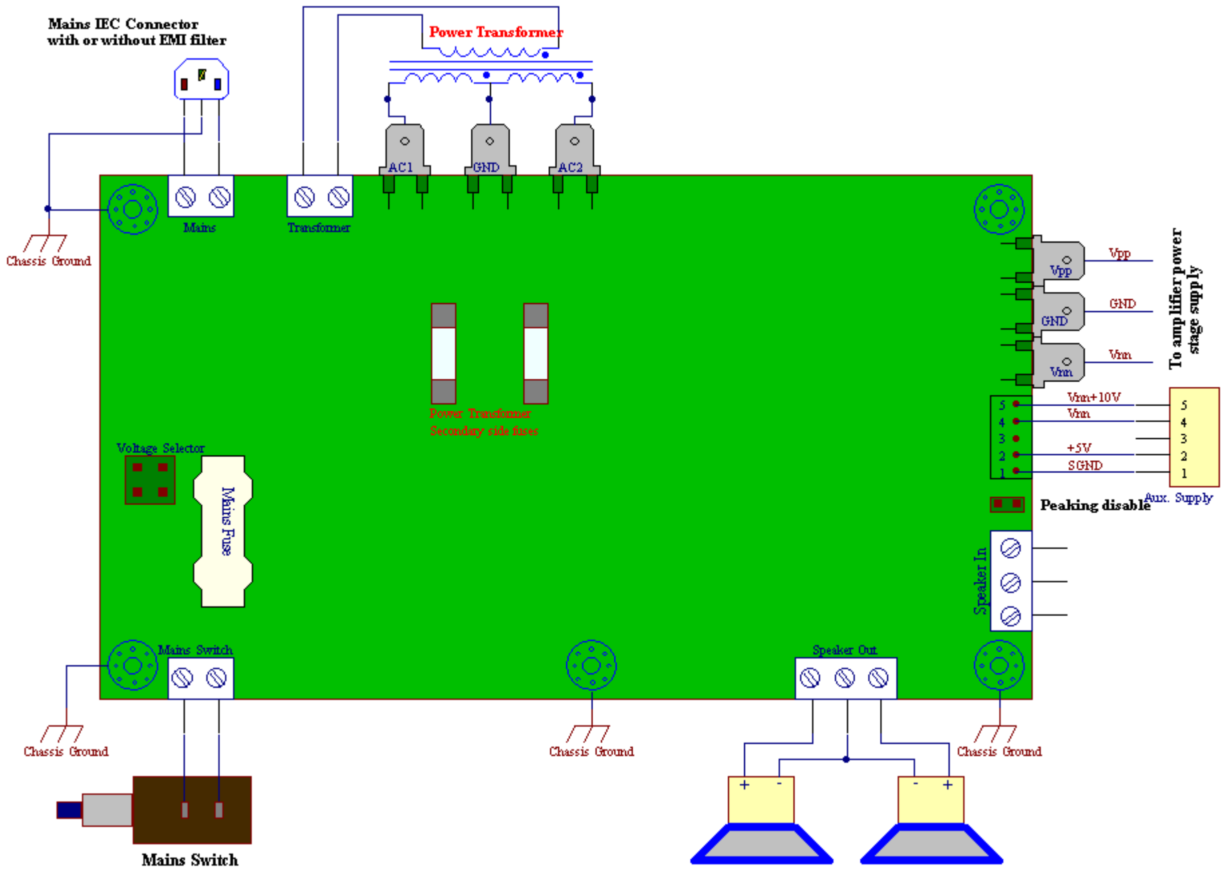

Figure2. Power Supply and Protection Circuit board interconnection diagram.

As can be seen in the Figure2 above, the installation and interconnection of the **Power Supply and Protection Circuit** board is simple and straightforward. The mains voltage is supplied at the **Mains** connector from the top left side, the **Mains switch** is connected at the bottom left side of the board and the **Power transformer** (Not included) is connected at the top left second connector for the mains supply and the three fast-on blade connectors for secondary side. The **DC voltage** for the amplifier power stage can be found at the top right corner of the board, on the three fast-on blade connectors. The **Aux. supply** connector for the input stage and driver stage of the amplifier can be found at the right side, middle, then next is the **Peaking_Disable** Jumper. The **Speaker input** connector (output from amplifier) can be found at the bottom right of the board and the **Speaker Out** connector (where speakers should be connected) can be found at the bottom right of the board.

For best performances and low noise, it is strongly recommended that the board to be supplied with mains voltage through a standard EMI filter, such as CW1D-6A, CW2A-10A or BIT IF-0633-W. A broad selection of EMI filters can be found on the website, at the address: http://connexelectronic.com/index.php/cPath/21_26

Warning:

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

The Power Supply and Protection Circuit is supplied with mains voltage and has hazardous and potentially lethal voltages of up to 250V 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.

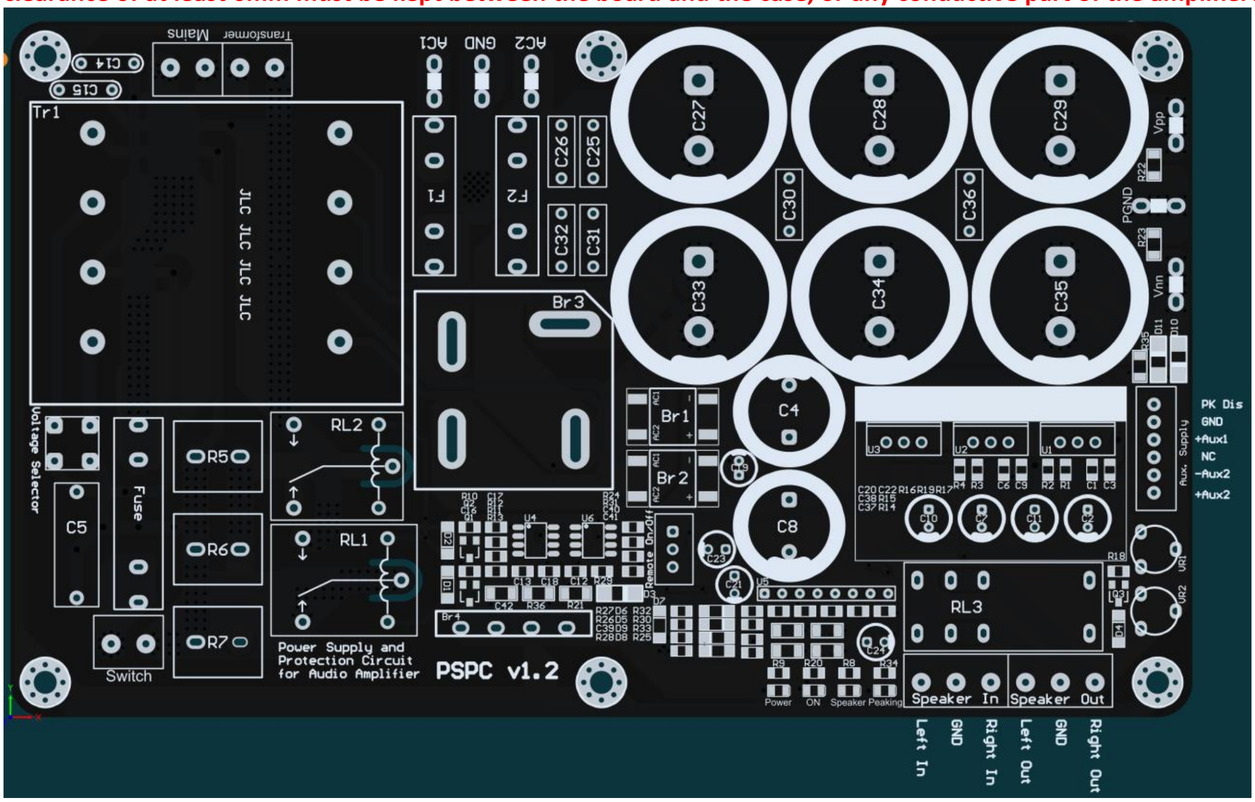

Figure 3. Power Supply and Protection Circuit board layout.

Disclaimer:

The **Power Supply and Protection Circuit** 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, **Connexelectronic**, or the official distributors, 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 uninsulated part of the board or connectors, or short-circuit any part of the board or connectors. Any misusage will be made on user responsibility.

The designer and manufacturer **Connexelectronic** reserve the right to make changes or modifications on both the product functions and performances without notice. The **Power Soft Start Circuit** schematic and PCB design is proprietary of **Connexelectronic** and shall not be distributed, copied or published without the **Connexelectronic** written agreement. **Connexelectronic** reserves the right to offer limited support for the boards purchased directly from **Connexelectronic** or official distributors, and no support at all for the similar boards which aren't purchased directly from **Connexelectronic** or official distributors, or future listed resellers, and from various reasons they look or pretend to be similar, exactly same, or improved version products. Purchasing the product means that you are aware and agree with all this conditions.