You Can DIY!

# The PR-3

## A High-Quality Stereo Preamplifier

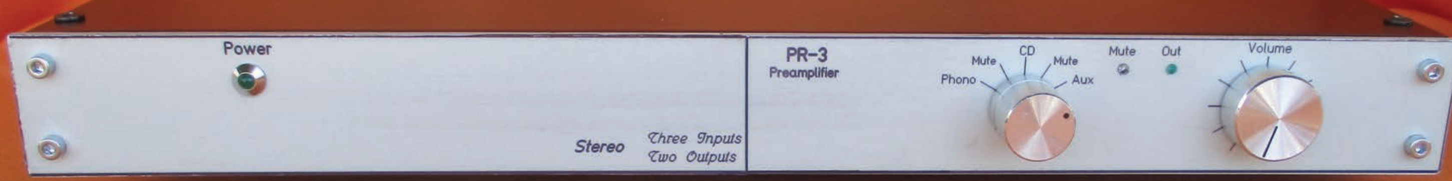


Photo 1: The front view of the preamplifier

In this article, George Ntanavaras describes the design and the construction of a high-quality stereo analog preamplifier that he calls the PR-3. Most of the components for this design are contained on a single PCB, which simplifies the construction.

By
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This project, the PR-3 preamplifier, provides three high-level analog unbalanced stereo inputs and two unbalanced stereo outputs. A potentiometer at the input of the preamplifier adjusts the volume of the output signal, while the amplification stage is based on a top-quality single op-amp supplied with very low noise regulators.

Most of the preamplifier's circuitry is contained on one circuit board for ease of construction. The circuit board is double-sided and extensively covered with a copper ground plane. The selection of the op-amp was one of the most important decisions for the design. After some investigation, I selected the Texas Instruments (TI) precision field-effect transistor (FET) op-amp, the OPA627. It is a single op-amp with a Difet input circuitry, which offers high accuracy, extremely low input bias current, and very low noise performance.

The completed preamplifier is shown in **Photo 1**. While the simplified block diagram of **Figure 1** shows the parts consisting the preamplifier—on the top is the signal circuit, in the middle is the power supply circuit, and at the bottom are the relays circuit and the muting circuit.

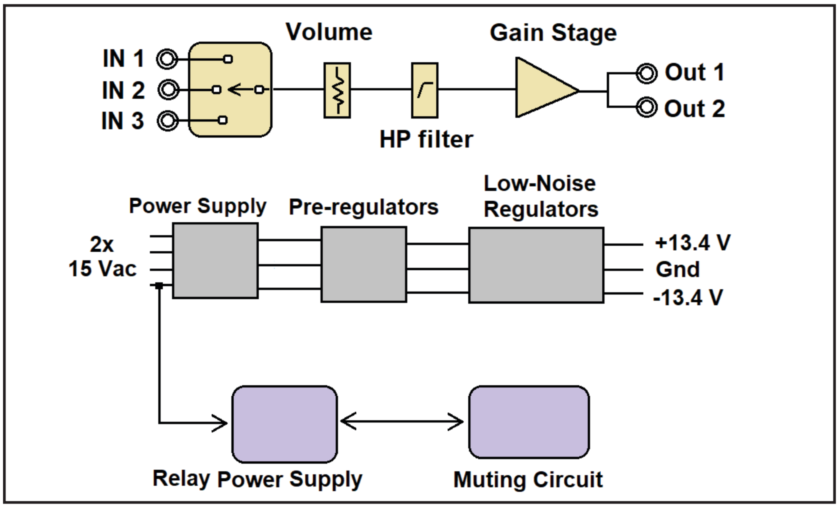


Figure 1: The block diagram of the preamplifier

### The Preamplifier Circuit

The complete electronic schematic of the PR-3 preamplifier for both channels is shown in **Figure 2**. A more detailed description of the preamplifier's operation follows. The description refers only to the Left channel, since the other channel is identical.

The selection of the input signal of the preamplifier is performed by three high-quality relays per channel. Each input has one dedicated double-pole relay that completely connects or disconnects both the positive and the negative part of the signal from the preamplifier circuitry. I used high-quality relays from Panasonic, type TXS2-12V-1 with AgPd contacts suitable for use in low-level load analog circuits.

Resistors R2, R3, R4 with capacitor C6 form a low-pass filter at about 500 kHz (assuming that the previous stage's output impedance is not greater than 500 Ω) to attenuate any electromagnetic interference (EMI) that could enter the circuit. Next, there are four pins to connect the volume control potentiometer, which is placed on the preamplifier's front panel. The volume control's position at the input protects the preamplifier from any possible overload that could be caused by high level input signals. For the volume control, I used a high-end rotary stereo logarithmic potentiometer from Alps (type RK27112-LOG50k). The capacitor C5 is included for DC protection of the circuitry. This is the only capacitor used in the preamplifier's audio signal path. Resistor R6 needs to ensure a DC path for the circuit's proper operation.

The main preamplifier stage is based on a non-inverting op-amp circuit. The gain G is defined by resistors R7 and R8 as follows: G = 1 + (R7/R8). With the values shown on the schematic the gain is x12 or 21.6 dB.

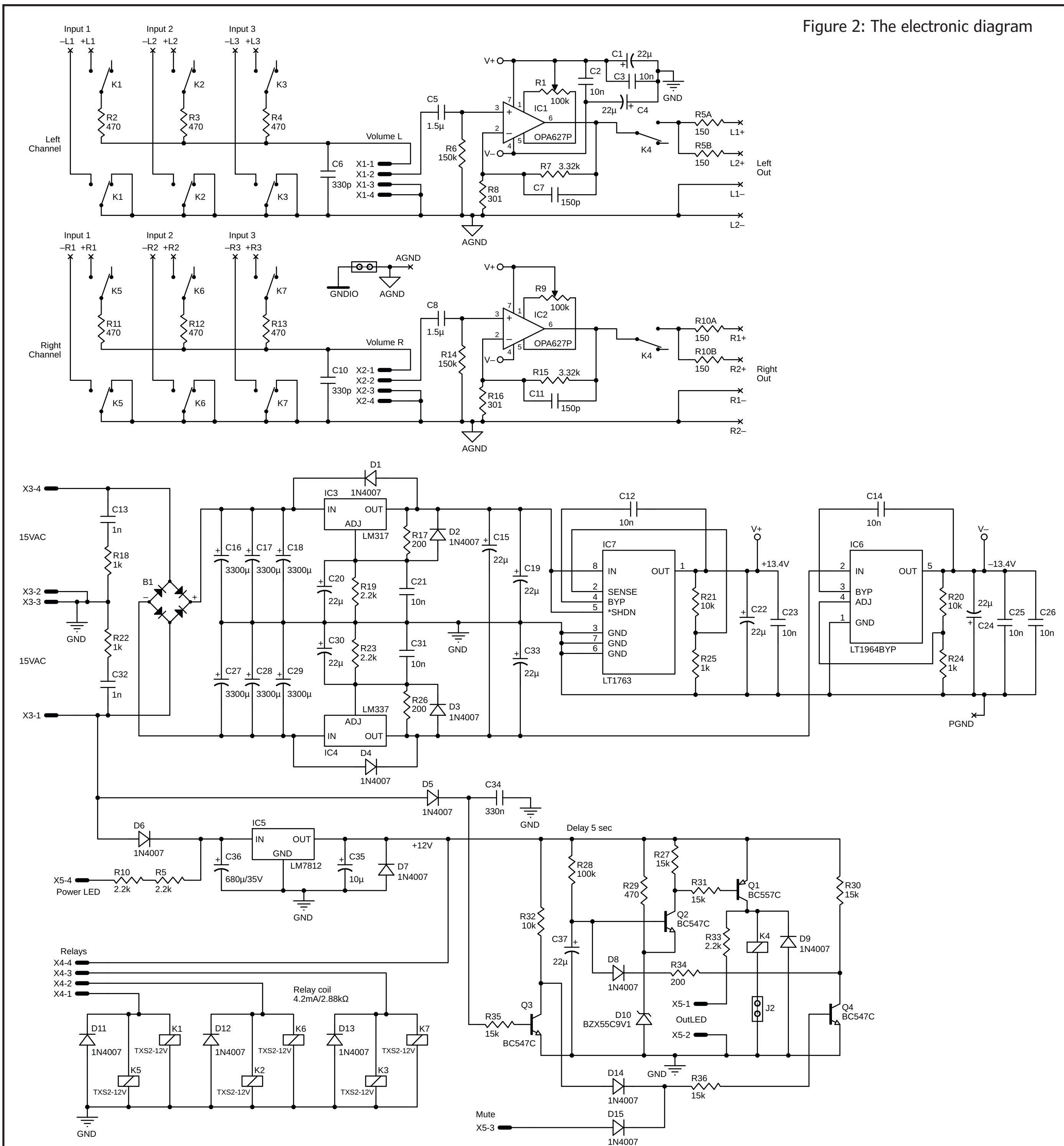

Figure 2: The electronic diagram

For the resistor R8, I chose a low value for minimum noise contribution to the circuit. I selected the value of capacitor C7 so that the roll off of the high-frequency response will be at about 320 kHz.

Although the OPA627 is laser-trimmed for very low offset voltage and drift, I also included the trimmer R1 to precisely adjust the output offset to zero volts.

I used a combination of Panasonic OS-CON electrolytic aluminum organic polymer capacitors and COG multi-layer ceramic capacitors to bypass the power supply pins of the OP627, providing a very low impedance.

Resistors R5A and R5B buffer the two outputs of the preamplifier from capacitive loads in case long cables have to be connected from the preamplifier to the power amplifier. The outputs are isolated from the circuit through relays, which close with a short delay during the power up and disconnect very quickly during power down. Also, they can be manually disconnected when the MUTE switch is energized.

I didn't use a capacitor at the output of the preamplifier, because the equipment to which the preamplifier was connected had a DC blocking capacitor at its input. If not, a high-quality DC blocking capacitor of 10 µF or larger should be placed at the preamplifier's output for protection against any possible circuit malfunction that could happen at its output with the full DC power voltage.

Relays K1-K3 and K5-K7 are used to select the preamplifier's input signal. I used a protection diode (D11-D13) across the coil of each relay.

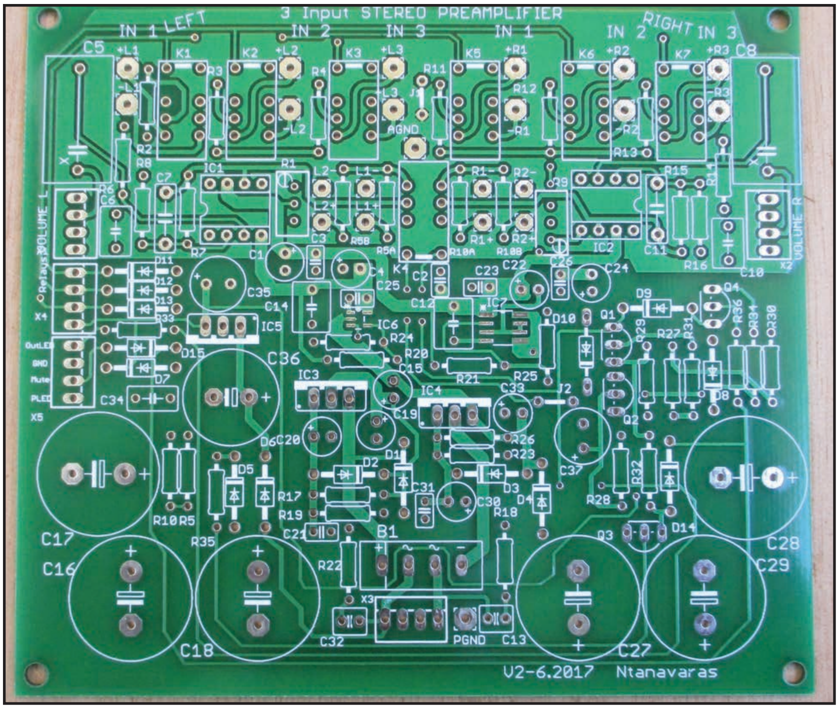


Photo 2: I used a high-quality PCB for the PR-3 preamplifier's construction.

## The Power Supply

For the PR-3 preamplifier's supply, I used a low-noise toroidal transformer with a nominal output voltage of 2x 15 VRMS at 15 VA. The transformer actually gave a larger voltage 2x 17.4 VRMS, since the PR-3 preamplifier's required power was much lower than 15 VA.

Resistor R18 with capacitor C13 and R22 with C32 are used as damped snubbers/Zobels across each transformer secondary to prevent any ringing when the diodes switch off due to the combination of the transformer's leakage inductance and the rectifier's diode capacitance (see Resources).

The power transformer feeds a 2 A full-wave bridge rectifier that is terminated in a filter of six 3,300-µF capacitors. I measured ±22.3 VDC at the input of the regulators when the mains voltage was set with my Variac auto transformer at the 230 VRMS nominal value.

Keeping in mind that the tolerance of the 230 VRMS mains voltage is ±10%, the mains voltage may change from 207 to 253 VRMS. Using the Variac, I set the mains voltage at 200 VRMS and I measured ±19.1 VDC at the input of the regulators. When I set the mains voltage at 255 VRMS, I measured +24.9 VDC and -25.2 VDC, respectively.

The output voltages of the pre-regulators LM317 and LM337 were set to ±15 V by resistors R17,R19 and R23,R26, respectively. Their output drives the inputs of the surface-mount device (SMD) regulators LT1763 and LT1964. These are micro-power, low-noise, low-dropout regulators with adjustable outputs. The LT1763 has an output drive capability of 500 mA, while the LT1964 has one of 200 mA. Output noise is very low for both at 20 to 30 µV over a 10 Hz to 100 kHz bandwidth. Resistors R21,R25 and R20,R24 set the output voltage to ±13.4 VDC. The output of these regulators supply only the critical signal circuits.

The power supply of the relays and the muting circuit is completely separate from the supply of the signal circuitry to eliminate any possible interference between them. Diode D6 rectifies the AC voltage and charges the capacitor C36. The IC5 is a standard LM7812 regulator, which produces +12 VDC to supply the relays. Capacitor C35 improves the stability and the transient response of the regulator. Diode D7 protects the circuit of any reverse voltage. A power LED, placed on the preamplifier's front panel, is fed from resistors R5,R10 and illuminates to indicate that the preamplifier is powered on.

## The Muting Circuit

This circuit supports several functions. When the preamplifier is powered on, it connects the output

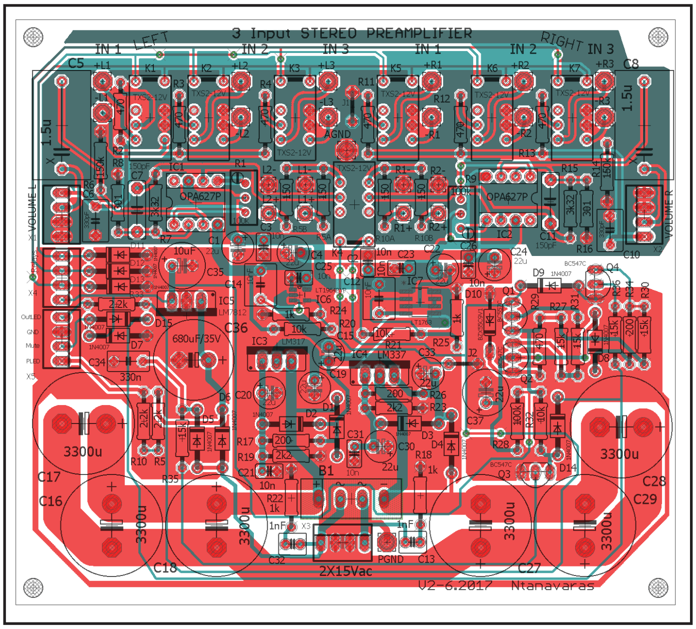


Figure 3: The PCB layout

through a relay after a short delay to avoid any transient noise to the following equipment. It quickly disconnects the output relay when the preamplifier is powered off or when a sudden power loss happens.

Additionally, a manual MUTE switch can disconnect the output. The circuit doesn't protect against a malfunction that could give DC voltage at the preamplifier's output, so if the device to which the output of the preamplifier is connected does not include a DC blocking capacitor, it is necessary to include a 10 µF or greater capacitor at the output of the preamplifier for protection.

When the power is applied to the circuit, the components D5, C34, R35, and Q3 detect the presence of the 50 Hz line voltage and set the transistor Q3 to the ON state. This short circuits the diode D14 to the ground, deactivating the transistor Q4.

The Zener diode D10 generates a 9.1 VDC constant voltage, which is used for the output relay's activation in conjunction with the capacitor C37's voltage, which is increased slowly by R28. When it reaches about 9.6 VDC, the transistor Q2 is activated and turns on the transistor Q1, which turns on the relay K4 with the R-C time constant delay of R28 and C37. The OutLED is connected in parallel with the output relay through the current limited resistor R33. When this LED illuminates, it indicates that the output is normally connected.

Diode D15 is used to activate the transistor Q4 when an external voltage comes from the manual MUTE switch. In this case, Q4 is turned On and discharge C37 through diode D8. Then, transistors Q2 and Q1 deactivate relay K4, which disconnect the output.

## Preamplifier Construction

As I previously mentioned, one of my design objectives was to have all the preamplifier's components placed on a single PCB, simplifying its construction. I used the demo version of the Eagle PCB software for the design, which has a limitation on the PCB's maximum dimensions, but this was not a problem for this design. The outcome was a 90 mm × 115 mm double-sided PCB with ground planes on the top and the bottom layers. One PCB has the components for both the Left and the Right channels. When the design was completed, I ordered and received a few high-quality PCBs (see **Photo 2**). The board material is from FR4 of 1.6 mm thickness and 35 µm copper.

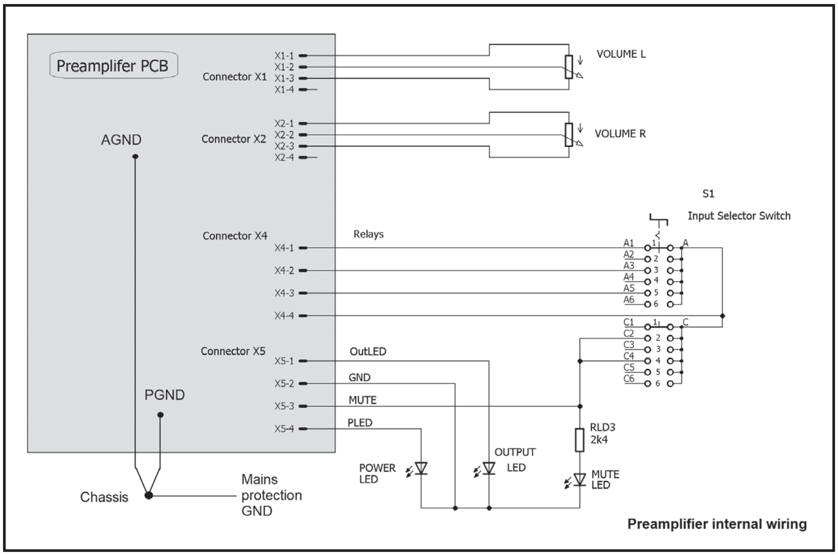


Figure 4: The internal wiring of the preamplifier

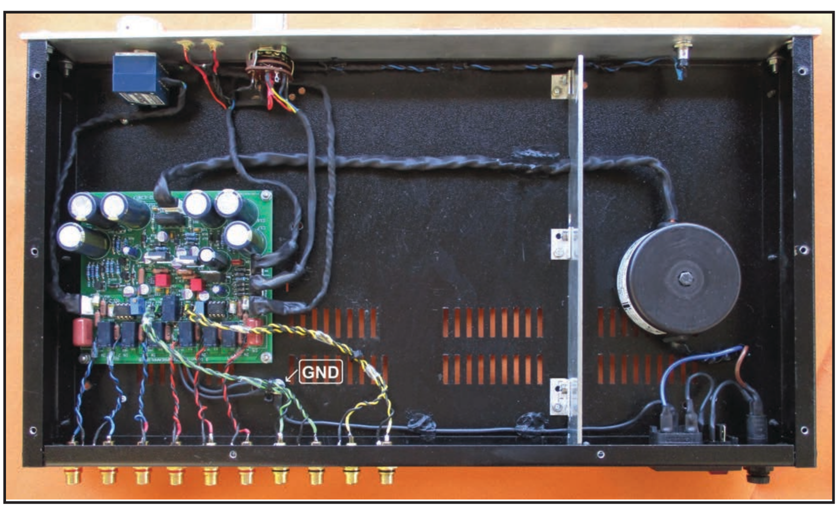


Photo 3: The internal of the preamplifier

Photo 4: The back panel of the preamplifier

## About the Author

George Ntanavaras graduated from the National Technical University, Athens, Greece, in 1986 with a degree in Electronic Engineering. He currently works in the Development Department for a Greek electronics company. He is interested in the design of preamplifiers, active crossovers, power amplifiers, and most loudspeakers. He also enjoys listening to classical music.

They have plated through-holes, solder resistant on both sides, and a silkscreen on the top side.

**Figure 3** shows the PCB's complete guide assembly. The parts list, included in the Supplementary Material section of the *audioXpress* website, shows what is required to build the preamplifier. I used high-quality parts for the preamplifier's construction (e.g., 0.1% resistors, polypropylene capacitors, very low ESR electrolytic capacitors, COG ceramic capacitors, and relays especially designed for switching low-level signals).

For the PCB's assembly, the first components that should be soldered are the two SMD regulators, IC6 and IC7. IC6 (LT1964) is a five-lead plastic SOT-23 package and requires more attention to be soldered than the IC7 (LT1763), which is an eight-lead plastic S8 package. I didn't have a lot of experience on the soldering of SMD components and when I was designing the preamplifier, I was very skeptical about using these components. But after the completion of this preamplifier, I have to admit that it was much easier than I imagined. I used my standard soldering iron with a thin tip and a solder wire of 0.38 mm external diameter. A desktop magnifier with a LED light helped me do the job correctly.

The assembly of the other through-hole components was easy and should be done from the smaller to the larger components. I used a metal enclosure with an aluminum front panel to house the preamplifier's components. The enclosure had the following external dimensions: width = 440 mm, depth = 240 mm, and height = 45 mm.

The Signal Ground (AGND) and the Power supply ground (PGND) are separate on the PCB to minimize the noise and the interference. They are connected together at a single point along with the Chassis ground and the Mains protection ground as shown in **Figure 4**.

The wiring of the PCB with the volume potentiometer, the switches, and the LEDs is also shown in Figure 4. The connectors X1 and X2 are used for the connection of the PCB with the potentiometer, which is placed in the front panel. The input selector switch and the three indication LEDs are connected to connectors X4 and X5. I gave the following names to the three inputs: PHONO, CD, and AUX. The preamplifier cannot directly accept the low output of a phono cartridge and I used my MC-100 preamplifier (see Resources) connecting its output to the PHONO input of this preamplifier.

To eliminate any possible noise at the output signal when switching between the three inputs, I inserted two extra MUTE positions between them. For example, to switch from CD to the AUX input, the switch passes from the MUTE position, which disconnects the preamplifier's output, and then this the switch goes to the CD position where the output is connected again with a small delay.

The PR-3's front panel is shown in Photo 1. On the left side of the panel, a blue LED indicates the operation of the preamplifier. The Input Selection switch and the Volume potentiometer are on the right side. Between them, two 3 mm LEDs indicate when the muting circuit is energized and when the output in active.

The text on the front plate was created using the "Front Panel Designer" program (see Sources). The file that was created was printed on a transparent self-adhesive sheet with my ink-jet printer.

**Photo 3** shows a clear internal view of the preamplifier. The power transformer was mounted on the same box with the gain circuits. I was a little worried about that and my first thought was to use a separate enclosure for the transformer. I used a very high-quality toroidal power transformer, which according to the manufacturer has an extremely low-radiated magnetic field and it is suitable for the supply of sensitive electronics. I mounted it as far as possible from the preamplifier's electronics parts to avoid any possible interference due to the high voltage gain of the preamplifier's circuits. Additionally, I used a metal sheet for shielding between the power transformer and the PCB to eliminate any possibility of interference. My efforts were very effective and no mains noise interference

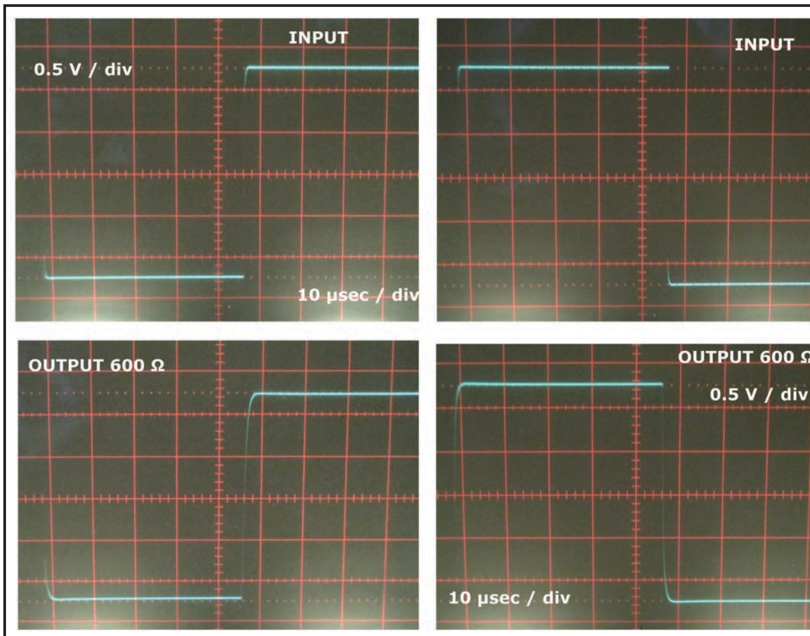


Figure 5: The responses of the preamplifier to a 10 kHz square wave

was detected at the preamplifier's output, even with the volume potentiometer at its maximum position.

PR-3's back panel is shown in **Photo 4**. The components for the preamplifier's mains supply and the necessary fuse protection are on the right side. First, the IEC socket for the 230 V mains with the integrated mains switch and then the fuse holder. The protection ground of the 230 VAC is connected directly from the mains socket to the preamplifier's chassis, as shown in Photo 3.

On the left side, there are 10 gold-plated RCA female connectors for the preamplifier's inputs and the outputs. They are placed in the same order as that of the PCB and this provides very neat wiring, as shown in Photo 3.

For the preamplifier's op-amps, I used high-quality IC sockets with gold-plated pins. This facilitates the testing and the repair of the preamplifier, in case there are any problems.

When I powered on PR-3 for the first time, I used my Variac, which I turned up slowly and confirmed that all the power supply voltages for both channels were as specified in the electronic diagram. I also checked all the outputs of all regulators with an oscilloscope to verify that they are clean, without any noise and oscillations.

I strongly recommend that you check that the voltages on pins 7 and 4 of IC1 and IC2 are very close to ±13.4 V before the expensive op-amps are inserted into their sockets.

Trimmers R1 and R9 are used for the output offset adjustment in order to measure 0 VDC at the preamplifier's output without any signal at its input. The trimmers should be readjusted over the course of an hour or two. It is also a good idea to re-check it and adjust the offset, if necessary, after the preamplifier has operated for a few weeks.

| Volume position (dB) | Left channel output (mVrms) | Right channel output (mVrms) | Imbalance between channels (dB) |
|---|---|---|---|
| 0 | 2000 | 2000 | 0.00 |
| -5 | 1122 | 1137 | 0.12 |
| -10 | 621 | 632 | 0.15 |
| -15 | 355.9 | 365.2 | 0.22 |
| -20 | 201.5 | 207.9 | 0.27 |
| -25 | 112.2 | 116 | 0.29 |
| -30 | 63.1 | 64.6 | 0.20 |
| -35 | 35.4 | 36 | 0.15 |
| -40 | 19.9 | 20.4 | 0.22 |
| -50 | 6.3 | 6.3 | 0.00 |
| -60 | 2.4 | 2.4 | 0.00 |

Table 1: Channel imbalance measurement

## Project Files

To download the Parts List and additional material,
visit: http://audioxpress.com/page/audioXpress-Supplementary-Material.html

## Resources

M. Jones, "Rectifier snubbing – background and best practices," *Linear Audio*, Volume 5.

G. Ntanavaras, "The MC100, A High-Quality Moving Coil RIAA Preamplifier," *audioxpress*, March 2014, available online at:
https://www.audioxpress.com/article/the-mc100-a-high-quality-moving-coil-riaa-preamplifier

## Sources

**Eagle PCB design software**
Autodesk, Inc. | www.autodesk.com/products/eagle/overview

**Front Panel Designer**
Schaeffer AG | www.schaeffer-ag.de

## Preamplifier Measurements

The PR-3's maximum gain is 21.6 dB. The input impedance ranges from 37 to 50 kΩ, depending on the position of the Volume potentiometer. The output impedance is 150 Ω. The frequency response is from 0.7 Hz up to 240 kHz (-3 dB). The maximum output voltage is 6.1 VRMS at 600 Ω, 7.3 VRMS at 2 kΩ, and 7.9 VRMS at 10 kΩ. The reduction of the output level at the lower loads is due to the PR-3's 150 Ω output impedance, which is in series with the load resistance and makes a voltage divider.

Square wave response provides a quick check and shows many things of interest. Although the measurement doesn't give any actual numbers, it can show very quickly if something is unusual. The parameters that can be tested include frequency response, the transient response, the group delay, and the distortion. **Figure 5** shows the PR-3's excellent response for the rising and the falling part of the 10 kHz square wave. The PR-3's output drives a load of 600 Ω. The top part of the figure is the input while the bottom part is the output, which is almost identical to the input even when the frequency is very high.

I performed the usual distortion measurements to check the PR-3's performance. Unfortunately, the capabilities of my distortion analyzer proved to be very limited since it was not possible to detect any additional distortion from the preamplifier.

A very important issue that affects the quality of the stereo reproduction is the imbalance between the PR-3's two channels. This is mainly due to the volume potentiometer since the gain of the preamplifier is set with high-accuracy resistors. I measured this by setting the volume potentiometer to its maximum position and adjusting the level of the input signal

| Frequency (Hz) | 200 | 500 | 1k | 2k | 5k | 10k | 20k |
|---|---|---|---|---|---|---|---|
| Right Channel output (mVrms) | 0.1 | 0.7 | 1.4 | 2.5 | 5.6 | 9.4 | 11.8 |
| Cross-talk (dB) | -94.0 | -77.1 | -71.1 | -66.0 | -59.0 | -54.5 | -52.5 |
| Worst case: preamplifier cross-talk between two channels: Right channel Input open circuit. Left channel Output = 5000 mVrms at 10 kΩ. The Volume potentiometer full clockwise. Both channels drive 10 kΩ load at the output. | | | | | | | |

Table 2: These are the results of the preamplifier crosstalk.

until I measured 2 VRMS at the output of the Left channel. Then I reduced the output level by moving the potentiometer to various positions as indicated in the **Table 1**. From these measurements, the maximum imbalance between the two channels was measured at 0.29 dB.

The preamplifier uses a common PCB for both channels and I took every precaution during the design to avoid any interference from one channel to another. Testing the cross-talk between the channels proved that the result was successful. It was not possible to detect any interference from one channel to another in both directions (from the Left to the Right channel and vice versa). The test was performed from 20 Hz to 20 kHz with the output of one channel driving 5 VRMS/10 kΩ and the input of the other channel short circuited. Only when I left the input of the not driven channel open did I measure some interference from one channel to the other. **Table 2** shows the results of this measurement. Even at 20 kHz the cross-talk is better that -50 dB.

## Conclusion

The PR-3 is an easy-to-construct high-quality preamplifier. It has three inputs and two outputs that can easily drive any power amplifier. It is dead quiet and offers excellent transparency. If you need a preamplifier, I am sure you will enjoy building and listening to this one.

*Author's Note: I have available a few PCBs for the construction of the preamplifier. Anyone who is interested can please send me an email at gntanavaras@gmail.com*