The phonobox story

In the April 2002 I had bought Pro-ject phono box for my friend, as a gift. When I bring it home, at first I opened it. Then I made some shots, but later I had found much better photos made by Stefan Bauer: http://home.arcor.de/bauer77/_private/project_phono_box.htm Here they are:
At first I measured the phonobox frequency response with the active inverse RIAA circuit [1] and found the deviation above 1kHz about 1.2 dB, while in manual [2,3] it is stated that deviation from standard RIAA curve should be less than 0.5dB.

My further step was reverse engineering. The op amps data is listed in [5,6]. The phono box and power supply circuit schematic is shown below.
The RIAA time constants are

\[
\tau_1 = R_{13} C_9 = 39 \cdot 10^3 \cdot 82 \cdot 10^{-9} = 3198 \, \mu s
\]

\[
\tau_2 = \frac{(R_{10} + R_{11} + R_{12})R_{13}}{R_{10} + R_{11} + R_{12} + R_{13}} C_9 = 4.56 \cdot 10^3 \cdot 82 \cdot 10^{-9} = 374 \, \mu s
\]

\[
\tau_3 = \frac{R_9 R_0}{R_9 + R_0} C_6 = 4.27 \cdot 10^3 \cdot 18 \cdot 10^{-9} = 76.9 \, \mu s
\]

They should be
\[
\tau_1 = 3180 \, \mu s
\]
\[
\tau_2 = 318 \, \mu s
\]
\[
\tau_3 = 75 \, \mu s
\]

The second time constant has an error of 18%. For correction the value of \( R_{12} \) should be 1.5\( k\Omega \). Another evident engineering error is that the right side of the resistor \( R_9 \) should be connected to ground, in that case \( R_9 C_7 \) will be a rumble filter. Otherwise, the elements \( R_9, C_7 \) should be omitted, and the value of \( R_8 \) should be 4.3\( k\Omega \) for correct time constant. The circuit of the phonobox after revision is shown below.
My next step was the input stage with mysterious connection of $R_6, C_5$. Having in mind that the input resistance should be $47\, \Omega$, $R_6, C_5$ should be connected in series with $C_4$. The input resistance of the phono stage is

$$R_{in} = \frac{R_5}{1 + \frac{R_4}{R_3}} = 39\, k\Omega$$

The $R_5$ could be increased up to $1.3\, M\Omega$. This is so called 'electronic cooling'.

From Marcel van de Gevel EW paper [6]: "When the input stage and feedback network are properly designed, the thermal noise of the 47k resistor shunted across the input is usually the largest remaining noise contribution in the RIAA amplifier itself". Such connection will lower noise current spectral density from $47\, \Omega$ resistor $1 + \frac{R_4}{R_3}$, but overall s/n ratio will improved 1-3 dB.

Smiffy aentity@**.com reported (Nov. 2003) another set of component values in his phono box

- C2 is 33nf
- C4 is 0.47
- C5 is 10nf
- C9 68nf
- R5 1.2M
- R6 220K
- R7 220k
- R13 47K

In this case the RIAA time constants are correct

$$\tau_1 = R_{13}C_9 = 47 \cdot 10^3 \cdot 68 \cdot 10^{-9} = 3196\, \mu s$$

$$\tau_2 = \frac{(R_{10} + R_{11} + R_{12})R_{13}}{R_{10} + R_{11} + R_{12} + R_{13}} C_9 = 4.66 \cdot 10^3 \cdot 68 \cdot 10^{-9} = 317\, \mu s$$
\[ \tau_3 = \frac{R_4 R_9}{R_8 + R_9} C_6 = 4.27 \cdot 10^3 \cdot 18 \cdot 10^{-3} = 76.9 \mu s \]

I would like to thank Stephan from Hamburg, who reported (July 2004) the correct values of \( C_2, C_3 \), then checked his own Phonobox and found \( R_6, C_5 \) connected in series with \( C_4 \), as shown by red wire.

References
2. Pro-ject phono box owner manual
3. Pro-ject phono box short info
4. NJM4580 – dual operational amplifier
5. TL061 - J-FET operational amplifier