MEASURING FILTER

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The article shows the circuit and design of the filter for measuring very low levels of non-linear distortions.

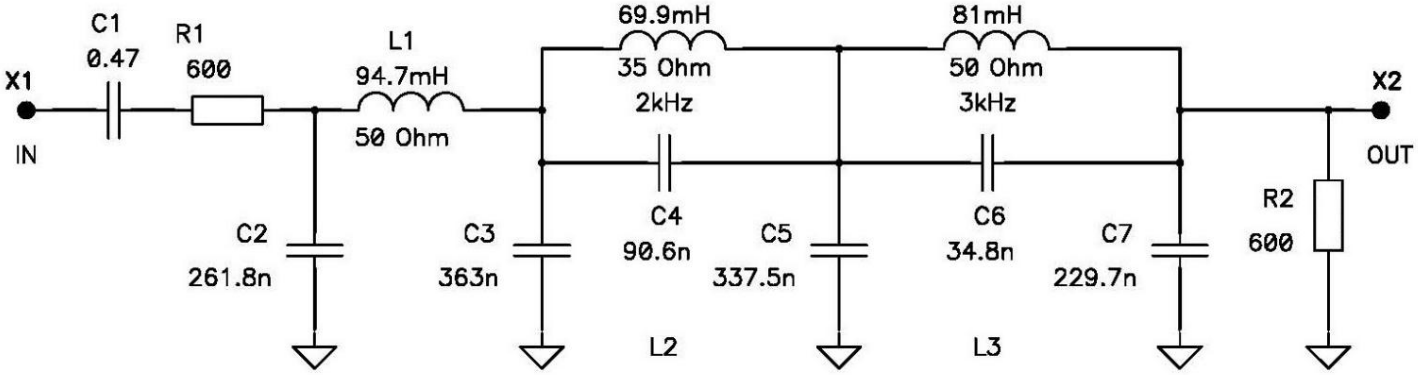
Basically, this article is intended for those who are involved in the design and configuration audio equipment professionally, but may well be useful to enthusiasts who want to get adequate result. When measuring non-linear distortions at the level of thousandths and ten-thousandths fractions of a percent, there are two problems - an insufficiently “clean” test signal and an uncalibrated measuring path. As objective measurements have shown, sound cards themselves can introduce distortions at the level of -80 ÷ -90 dB, despite the declared range, and have a noisy output signal. The situation is even worse with digital oscilloscopes that have a function FFT, where the level of introduced distortion can reach -70 dB and significantly depends on the total gain of the oscilloscope path.

To some extent, these problems can be solved using this filter and get a sufficiently “clean” test signal and calibrate the path. With a little trickery, you can directly assess the level of distortion introduced by passive components.

Initially, the filter is designed to work with the G3-118 generator, which does not exclude its use with any other type of generators. Such a “popular” measuring frequency, 1 kHz, was chosen for the filter. When working with a tuned oscillator, the output is a signal with all harmonics below -140 dB.

Filter scheme.

This is a 7th order LPF with a Chebyshev approximation and a cutoff frequency of 1.4 kHz with two additional zeros at frequencies of 2 and 3 kHz (Figure 1), which provides suppression of the second harmonic. by 60 dB and the third by 80 dB (actually measured values). Estimated characteristic of the display filter in Figure 2.



Picture 1

Nominal resistance of the signal source and load - 600 Ohm. Capacitor C1 is not directly related to the filter and does not affect its operation, but protects the filter from the constant component. A free additional benefit from it is a high-pass filter formed with the input impedance of the filter and partially suppresses low-frequency noise and interference. Resistor R1 is the output resistance of the signal source. If you are planning on running a generator with a low output impedance, then the resistor must be physically present in the circuit. But nothing too terrible will happen if it is always present, just the suppression at a frequency of 1 kHz will be more calculated. Resistor R2 is the load resistance if you plan to work on a real load more than at least once every 15-20, then the resistor can be installed permanently. If the load resistance will be comparable with the nominal value for the filter, then it is necessary to connect in parallel with the load an additional terminating resistors to obtain the nominal value.

The diagram shows the exact values \u200b\u200bof the components, in real life - preferably stay within 1% error. Next to the nominal value of the coil, their active resistances are indicated, it is undesirable to exceed these values, if a little less, it is not fatal. In any case, before using the filter, it is necessary to measure its actual parameters.

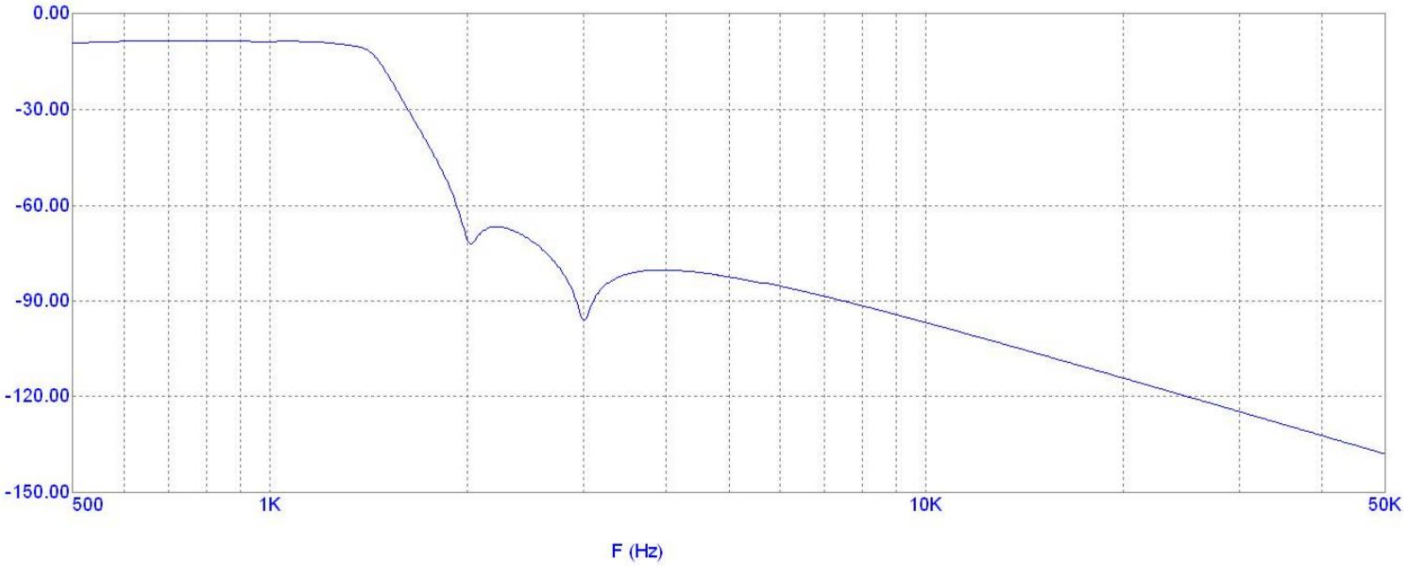


Figure 2

Figure 3 shows the actual frequency response of the filter, and Figures 4÷6 illustrate its operation in conjunction with generator.

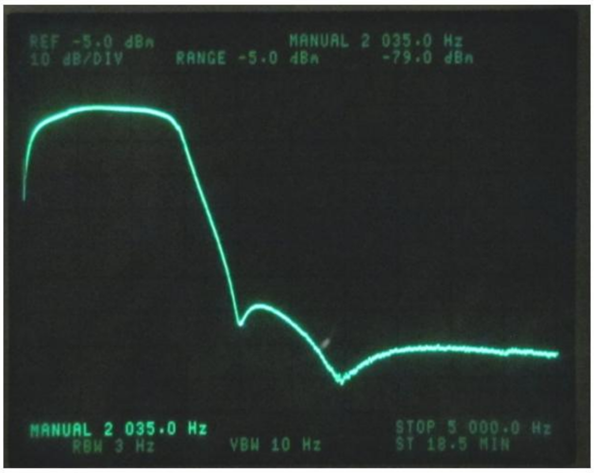


Figure 3

To see the real picture, the fundamental frequency was suppressed by a notch filter based on double T-bridge. I want to note right away that for means of measuring the level of harmonics, this is not at all best option due to very significant suppression on the second and third harmonics. The second harmonic will suppressed by about 9 dB, and the third - about 5 dB, which significantly distorts the overall picture. Real harmonic levels start from 5 ÷ 6. And if to carry out measurements at frequencies of 10 kHz or more using a sound card, it is impossible to see anything at all. For this needs a different notch filter, but that's the topic another article.

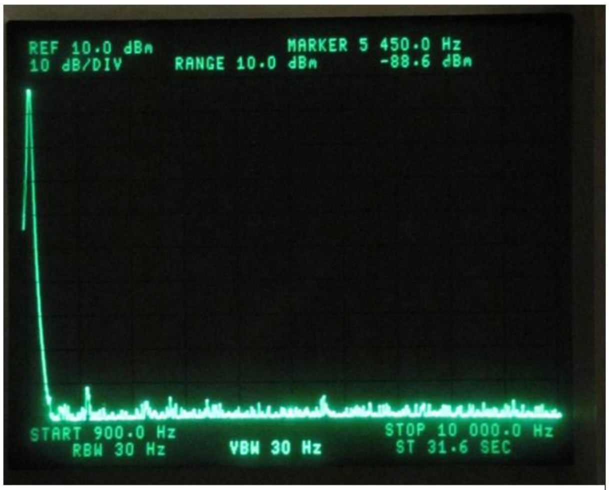


Figure 4

Figure 4 shows the original generator signal with explicitly distinguishable several harmonics at the level of -80 dB.

After suppressing the fundamental frequency by 60 dB (Figure 5), we already see a whole "fence" of harmonics. Which, in general, is typical for amplifiers with very deep feedback.

And Figure 6 shows the signal after the filter, where it is already all the ugliness is gone. But we see hints on the filter itself, multiples of the frequency of 50 Hz, these are shielding shortcomings.

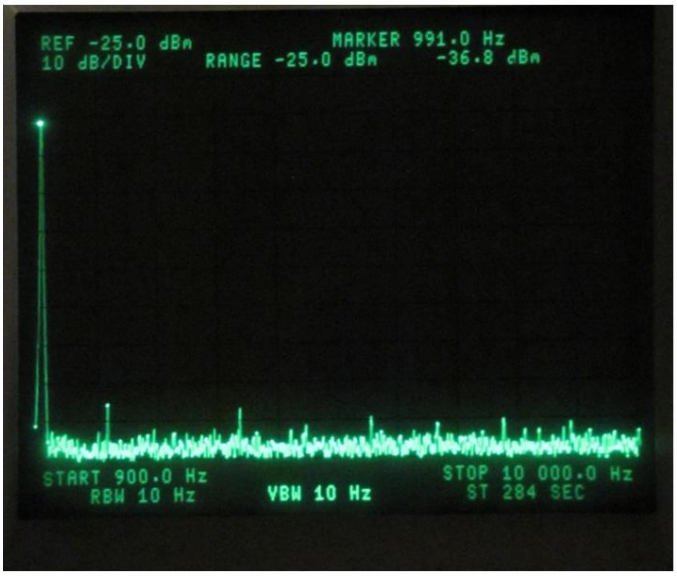


Figure 5

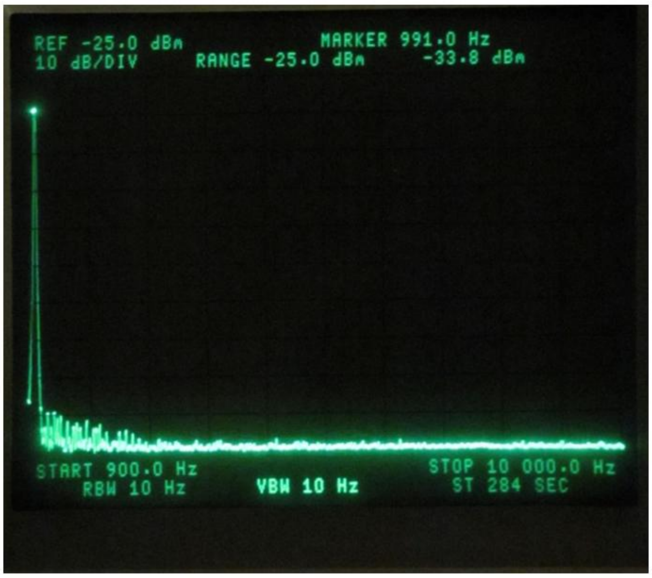


Figure 6

This can be partly compensated by the correct placement of the filter in space, although these pickups and do not interfere with measurements, since they are suppressed at the frequency of the 2nd and 3rd harmonics. Extra "Sticks" are rather annoying. The cardinal solution to the issue is magnetic shielding, and why am I he refused, it will be clear in the future.

Construction and details.

The choice of components must be taken very seriously, forget about audiophile myths with past and be guided solely by technical parameters.

Resistors. The best option is metal foil, metal-dielectric (MFR) precision groups “A” are quite suitable. I used C2-36

Capacitors. Polystyrene, fluoroplastic, polypropylene. We need to focus on minimum losses at frequencies of 1 and 10 kHz and minimum self-inductance. Were containers of the type K71-7, MKP 10, FKP 1 were used. To obtain the desired capacity, you can use parallel connection of several pieces.

inductance. Inductors are air and are the main "headache" when filter manufacturing. Unfortunately, the use of ferromagnetic cores (any), even in very weak fields, leads to the appearance of harmonics in the output signal. reverse side ideal linearity of the air coil we have - significant dimensions, extraordinary sensitivity to interference, strong mutual influence, high sensitivity to the presence nearby simply massive conductive surfaces, not to mention materials that have clearly pronounced magnetic properties. I had to come to terms with this and sacrifice all conveniences linearity.

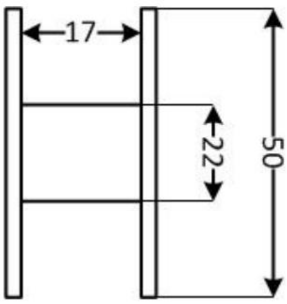


Figure 7

Coils are wound on polystyrene frames (Figure 7) from coils with solder of the Polish production. These dimensions are not dogma, and having other frameworks close size, there is no problem to recalculate the number of turns and the diameter of the wire when given inductance and resistance. It is desirable that in the section the coil turned out closer to the square.

Coils L1 and L3 are wound with wire Ø 0.29mm, coil L2 Ø 0.335mm.

Coil L1 has 2036 turns, coil L2 has 1720 turns and coil L3 has 1895 turns. Coils are wound coil by coil. I want to draw your attention to the fact that these are approximate values, since the resulting inductance will depend on both the type of wire and the winding density. When winding, it is advisable to increase the number of turns by 3–4 percent and adjust the inductance to

the desired denomination, winding the extra turns.

The most important step is to find out the relative position of the coils. The general rules are as follows: for coils that are in the same plane, the axes are mutually perpendicular, the third coil is displaced into another plane parallel to the first, the distance between the centers of the coils is not less than 100 mm. On the Figure 8 shows the design of the filter.

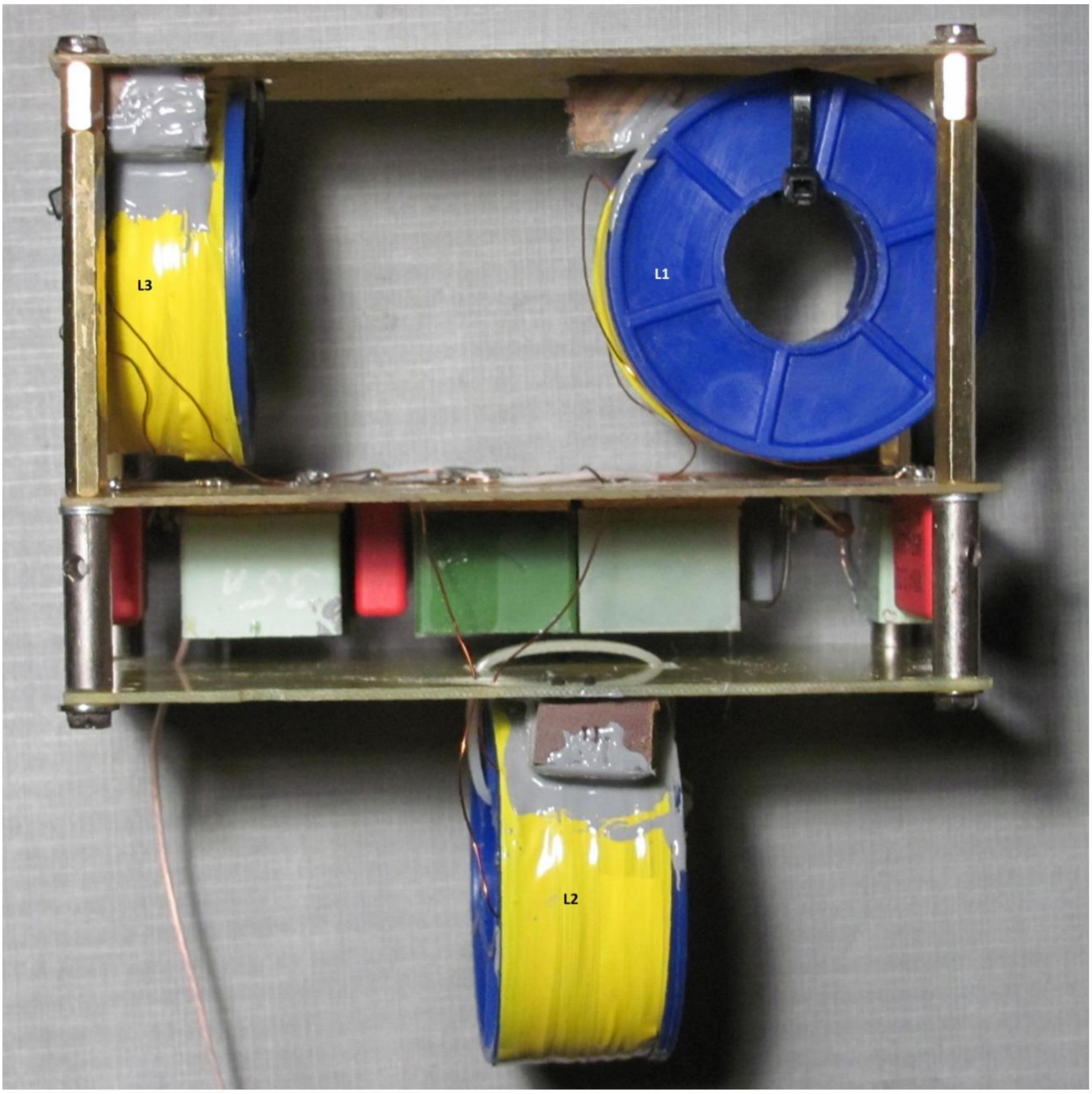


Figure 8

The filter is assembled on textolite boards, and two of them are enough. The third board with capacitances turned out for me by chance, I underestimated the mutual influence of the coils on each other. Any special requirements there are no capacitances for placement, “caps” are installed on the board in the right places, the wiring is done partly with component leads, partly with bare solid wire. You can just containers stick to the board. Standard wiring rules for small signal devices. Before just placing the containers, it is necessary to determine the position of the coils. A whatnot is assembled from boards (all fasteners are not magnetic), coil L1 is attached to the board, it is supplied from the generator with the maximum possible voltage with a frequency of 1 kHz.

An oscilloscope is connected to the L3 coil and moved until the minimum possible induced signal, it is temporarily attached to the board. Now connect the generator to L2, and the oscilloscope to L1 and L3 (here it is convenient to have two beams), and move it until the minimum possible induced signal on the other coils is obtained. After that, the containers are placed and the installation is partially done, not connecting coils. The filter is collected and the coils are re-adjusted; it should be borne in mind that even a slight displacement of the coils or rotation can lead to a change in the mutual influence in times. The coils are finally fixed (I used adhesive sealant) and the installation is completed. After that, the frequency response of the filter is checked.

By controlling the frequency response of the filter, it was experimentally found that the distance between the edge of the coil and the conductive non-magnetic surface should be at least 15-20 mm, and if the surface massive and has magnetic properties, then 120-150mm. So, the dimensions of the filter turned out to be small, and if you also make magnetic shielding, then it just turned out to be a giant box that would not fit either on a table or in a rack with appliances.

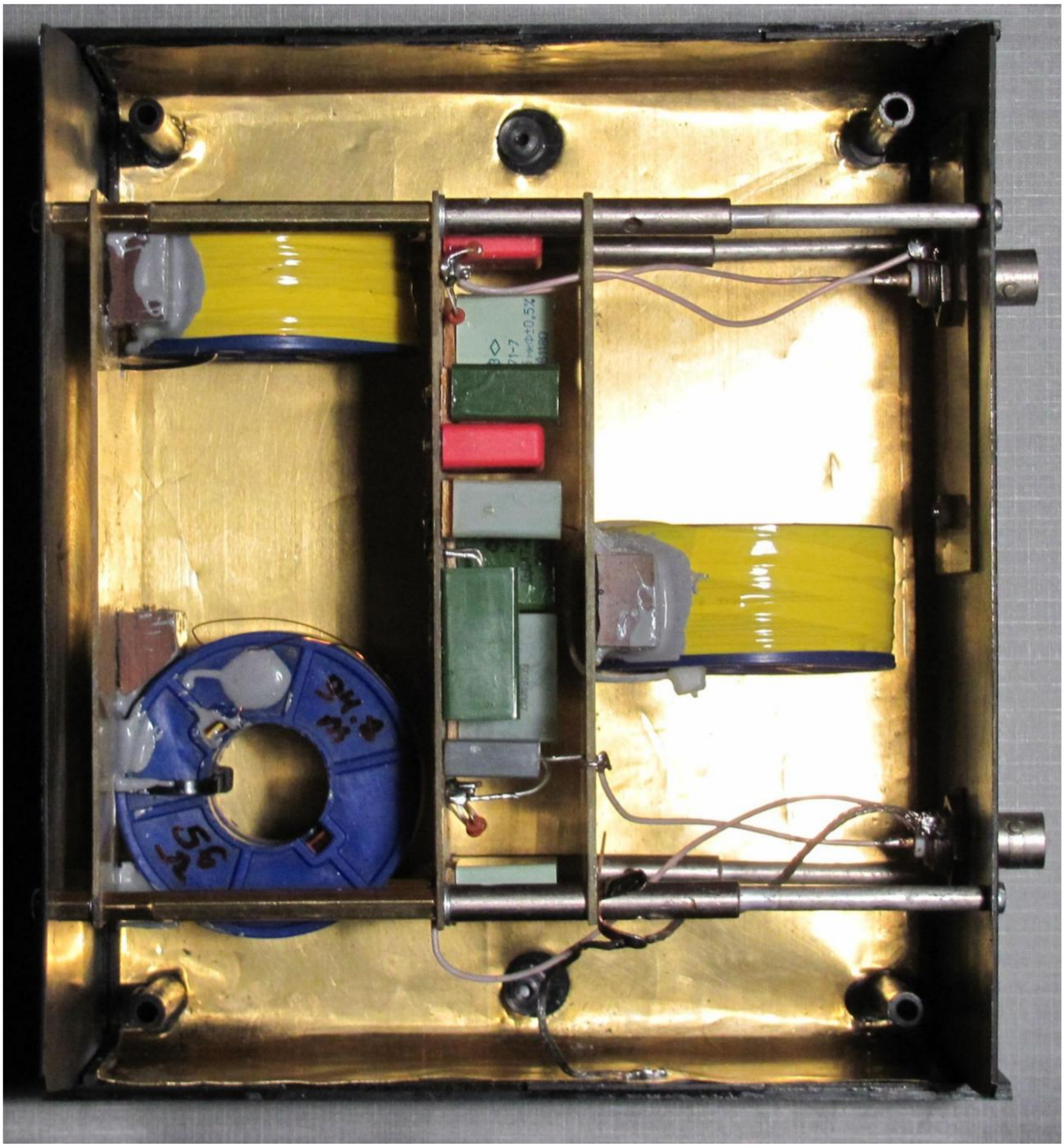


Figure 9

Reluctantly, I abandoned this idea and limited myself to a non-magnetic screen. Filter installed into the body, shown in figure 9

For the case, a plastic blank measuring 180x170x85 mm was used. Plastic the front and back panels were replaced with duralumin ones, brass foil was used as a screen (copper is better, but, unfortunately, it was not found under the table) 0.5mm thick, which is glued to housing covers from the inside and is connected to the common wire of the filter. The filter is connected using standard bayonet RF connectors. If necessary, you can install a pair of switches for switching resistors R1 and R2. The design itself is described rather schematically, since special there are simply no requirements, except for the distance between the coils and their distance from the screen. Quite you can use improvised materials.

Conclusion

In general, the whole design is very simple, with an accurate selection of components and proper installation, it does not require adjustment, but it is very troublesome to manufacture. If you have to measure the level of distortion often enough, then all the costs will pay off a hundredfold - both in the convenience of work and in the accuracy of the results obtained.