ÿÿÿÿÿÿÿÿÿÿ ***Forward - to the monkey***

ÿÿÿÿ CRYSTAL START

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Simple tube phono stage

Foreword

The design of the Crystal corrector line did not proceed in the usual way: first, the most the older model, then its simplified version, and that's what I "came to". Comparing these devices with each other in terms of technical characteristics and stability is completely pointless, of course, START will lose outright. But according to the subjective perception of their sound - everything is here not so unambiguous and much depends on what sound path they are included in.

If we move away from dry objective characteristics, then the imperfection of a simple corrector can play a positive role. The inclusion of the corrector in a sufficiently high-quality path containing only solid-state devices, and a completely insignificant "color" introduced by the corrector, leads to a small miracle - the sound becomes alive and comfortable. Of course, an experienced listener will notice the introduced component, but it does not cause irritation, like a speck in the eye, and is very you just stop noticing it.

The corrector circuit is very simple and is implemented according to a well-known structure. You can find many schemes outwardly similar to this one, but the good sound of the corrector lies in the subtleties. It cannot be said that similar schemes contain gross errors, but also the features inherent in corrector schemes in they are not always taken into account. In this article, I will try to move away from the stereotype of describing a specific design, I will try to expand the description and motivate the choice of a particular solution. This will allow not only is it easy to repeat this circuit, but also make adjustments to other devices, improving their sound nie.

I want to note right away that you will not find any special revelations in this article. All these subtleties the constructions of correctors are known and, explicitly or implicitly, are scattered over various sources. Unfortunately, most novice (and not only) designers skip these requirements. deaf and try to achieve the desired parameters only by selecting some exotic lamps and components. In general, this approach is extremely inefficient, both technically and economically. points of view.

Corrector circuit

Actually, the circuit of one corrector channel is shown in Figure 1. All further conversations will be to conduct relatively simple circuits with the shortest possible audio path and first touch on the general requirements. The RIAA standard (and its derivatives) normalizes frequency correction parameters in the range from 20Hz to 20÷50kHz. To ensure high accuracy of frequency characteristics, the amplifier itself without correction must have a bandwidth of at least 50–100 kHz. This immediately makes it undesirable the use of lamps in low current modes, the use of too high-resistance grid and anode circuits, the use of cheap matching transformers. Given that the

required gain (for most types of "MM" heads) is in the region of 900 - 1000 and it is desirable to ensure a minimum noise level, it is undesirable use (especially in the first stage) octal lamps, which are generally characterized by an increased microphonic effect. In addition, it is structurally more difficult to shield an octal lamp.

The anode voltage must be carefully filtered, and it is desirable to feed the filament circuits constant filtered voltage. Moreover, the filament voltage should be close to nominal or even slightly overestimated. Low filament voltage promotes growth lamp noise in the low frequency region.

It is highly undesirable to use common feedback circuits in an amplifier to form the frequency response. Let's say the gain of the amplifier is 3000 and frequency independent. The desired module transfer coefficient at 20Hz is 900, and at 20kHz it is 9, this corresponds to the standard

characteristics of the RIAA. Knowing these parameters, it is easy to calculate the required FOS depth at different frequencies. It turns out that at a frequency of 20Hz the feedback depth is 10.45dB, and at a frequency of 20kHz it is 50.45dB. But a change in the depth of the FOS also leads to a change in other parameters of the amplifier - the input module and output impedance, harmonic coefficient. As a result, we get the frequency dependence of the amplifier parameters, which is extremely undesirable for a signal with a wide spectrum. For clarity, let's see how the output impedance of the amplifier will change with serial OOS according to
voltage (often used option) and the output impedance of the amplifier without OOS - 1 kOhm. At a frequency of 20Hz, the output impedance is 187.5 ohms, and at a frequency of 20kHz it is 3 ohms. When the gain of the amplifier without feedback is very large (for example, an op amp is used), changes in the amplifier parameters do not affect so catastrophically due to the fact that the depth of the feedback remains quite large over the entire operating frequency range. But the presence of a deep NOS gives rise to other
problems associated with the effect of "multiplication" of the spectrum, so in any case, the use of frequency-dependent feedback in the corrector is undesirable.

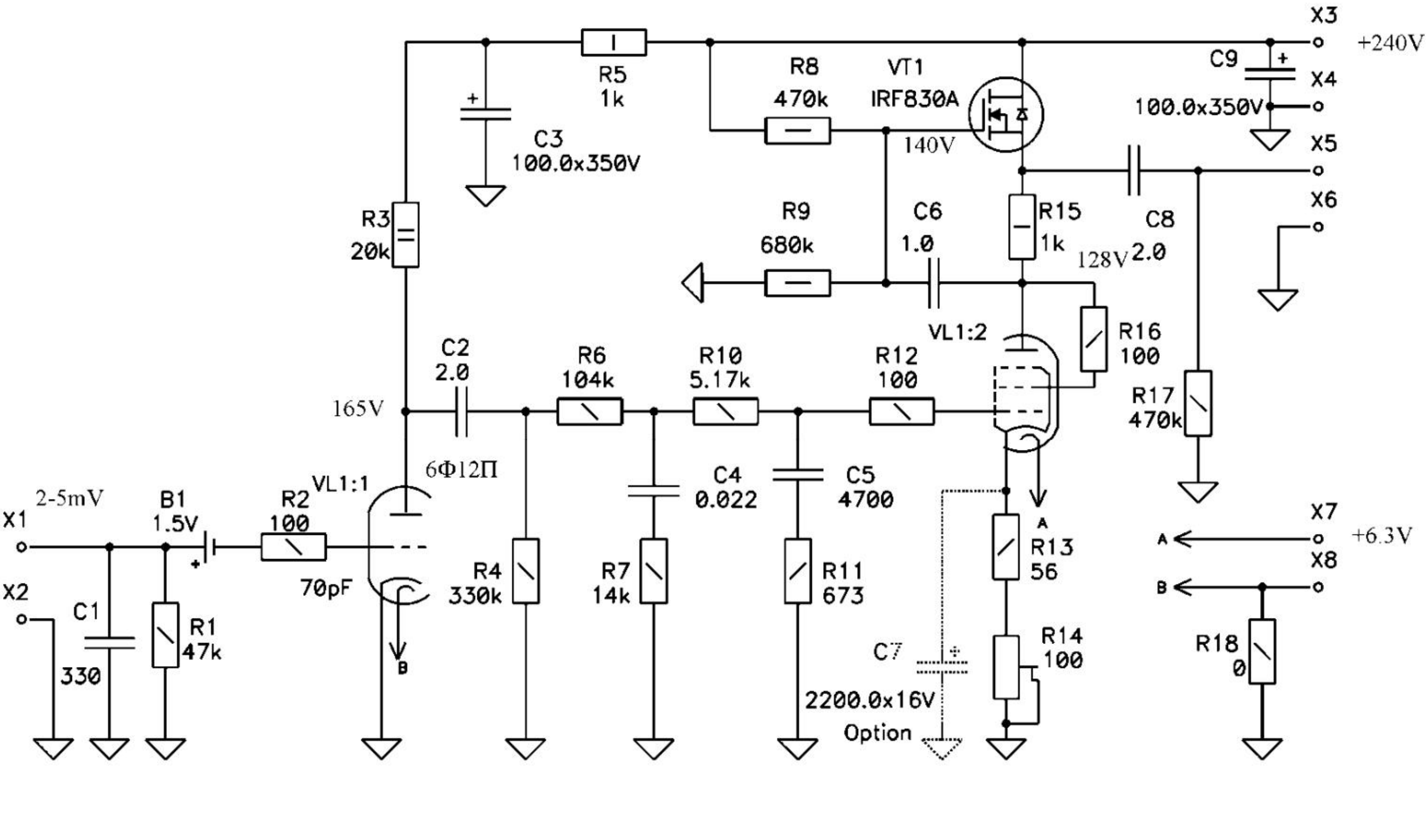

Рисунок 1

Input stage

When designing the first stage, three main questions must be resolved: which lamp to use, what amplification it should have, and how to provide the lamp with direct current.

In general, it is a postulate that the noise characteristics of an amplifier are mainly determined by the first stage and it is desirable to obtain maximum gain in the first stage. From point of view noise of the lamp itself, of course, it is advisable to use a triode with a large steepness of the characteristic. And three more factors must be taken into account: firstly, the cascade must provide a large overload ability (the signal from the head has not yet been equalized) with good linearity, secondly, we must strive to obtain a small dynamic input capacitance of the cascade, thirdly, It is desirable to have a low output impedance.

Everything is clear with the first point, but I want to pay attention to the second and third points of the requirements, since they are often forgotten about. Most cartridges have well-defined requirements for load capacitance, and the value of this capacitance determines the type of frequency response system head - corrector in the high frequencies. In the general case, the input capacitance of the stage depends not only on the parameters of the lamp, but also on the parameters of the load, that is, it is a function of frequency. Although this effect is insignificant, but with an unsuccessful combination of parameters, it can have a noticeable effect. influence on the frequency response in the high frequency region. And, by the way, one should not forget to install (and select) an additional capacitance at the input of the corrector (C1), which provides the optimal capacitance for a particular head. When calculating the additional capacitance, in addition to the input capacitance of the corrector, the capacitance of the connecting cable must be taken into account.

The low output impedance of the first stage not only expands the range of suitable ratings for the frequency correcting circuit, but also shunts the noise EMF with respect to high-resistance resistors R4, R6 through the separating capacitance C2. Note that for this grid the lamp resistor VL1: 2 (R4) is placed in front of the frequency-correcting circuit, and the capacitance value C2 is chosen deliberately more than necessary to obtain the desired frequency characteristics of the correction Torah.

According to the sum of the requirements, triodes with a slope characteristic of more than 10mA/V and a gain of more than 35 are best suited to the input stage. This makes it possible to obtain the gain of the first stage at the level of 27÷40. In fact, it turns out that the gain between the stages is distributed approximately equally.

The DC lamp operation mode can be set in two ways - using the automatic tic offset and fixed.

From the point of view of "musicality", noise characteristics, linearity of the cascade, a fixed offset is preferable. An obvious inconvenience of such a solution can be conditionally considered the need to periodically replace the battery (once every three to four years), but on the other hand, no one is embarrassed by the need to replace the battery in the watch or remote control. A less obvious inconvenience is the need to match the lamps, since the offset cannot be adjusted. These inconveniences are more than compensates for the financial issue: the equivalent cost of implementing a battery bias on the a row is cheaper than implementing an automatic offset. I want to note that the bias battery must be included in the grid circuit (as shown in the diagram). In some circuits I have seen a bias battery included in the cathode of the lamp, this solution has two negative points. Firstly, the lamp current flowing through the battery leads to its fairly rapid discharge, and secondly, the lamp current flowing through the battery (especially at the end of its service life) can lead to deterioration of the noise parameters of the corrector.

But back to automatic offset. Inclusion of a bias resistor in the cathode circuit lamp leads to the occurrence of local feedback, which degrades the noise characteristics of the cascade. There is no contradiction here, since the source of the noise EMF is located directly inside the loop OS. In addition, this leads to an undesirable reduction in the gain of the stage. To eliminate these problems, the resistor is shunted with a large capacity, but since thermal noise has a very wide spectrum, fluctuations of the lamp mode occur at infra-low frequencies (sometimes, from the speaker you can hear a sound reminiscent of the sound of the sea). In addition, resistor-based auto-bias circuits suffer from another malady—the amount of bias depends slightly on the signal level. This is due to the presence of even harmonics in the lamp current.

The problem of shifting the bias voltage from the signal level is solved quite simply - by turning on instead of the EMF source equivalent resistor (LED, Zener diode), but this does not eliminate the fluctuations in the lamp mode. Yes, and the presence directly in the signal circuit of an electrolytic capacitor, having its maximum distortion at low frequencies, is a minus.

At the input of the first stage (and in the subsequent ones too), it is imperative to include a low-ohm noise suppression resistor in the grid circuit (R2, R12). Shared with lamp input capacitance it forms a filter that suppresses high-frequency interference well. It is clear that the cascade will not amplify a signal with a frequency of hundreds of megahertz, but this interference, being detected on the nonlinearities of the lamp, generates noise and distortion in the audio frequency range. Such a long

conversation devoted to the first cascade is quite justified. The corrector has at low frequencies, there is a fairly large gain and no feedback, and everything that we “spoil” a little at the beginning will then be amplified many times over.

Frequency Correction Circuit

The corrector uses a passive corrective chain, made on the elements of R6, R7, R10, R11, C4, C5. The components R6, R7, C4 set the first two time constants in the low frequency region, and the components R10, R11, C5 set the two second time constants in the high frequency region. areas. In fact, the eRIAA feature is implemented. With the ratings indicated on the diagram, the deviation from the standard does not exceed 0.1dB. To facilitate the selection of components, the containers are selected from series E6, the resistor values correspond to the series E192, but they can be made up of several resistors connected in parallel. The accuracy of the selection of components should be within 1% up to start.

Now let's touch on the issue of choosing the values of the components of the corrective circuit. Here, there are a number of limitations associated with the input impedance of the corrective circuit and the possibility its physical implementation for given errors in the frequency response. It is quite obvious that the input impedance of the corrective circuit has a complex character and depends on the frequency. As an example, Figure 2 shows the dependence of the input module resistance versus frequency for the circuit used in the corrector.

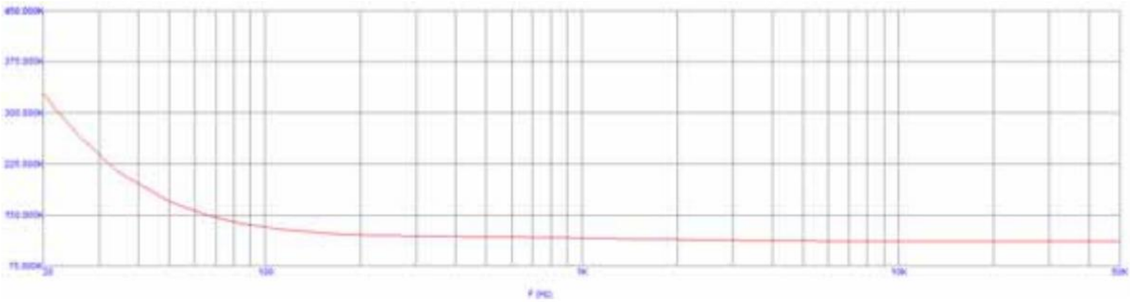

Figure 2

As you can see, in the low-frequency region, the input impedance module (the load of the first stage) changes by almost 3.5 times and, of course, this will be reflected in the parameters of the input stage. To To minimize this influence, the minimum input impedance of the circuit must be chosen an order of magnitude - two higher than the output impedance of the cascade. In the mid-range region, the input impedance of the circuit is almost completely determined by the resistor R6. Therefore, given the value of this resistor, the value of the capacitance is calculated, the nearest value is selected from the standard series and recalculated set the value of the resistor. In fact, our complex corrective chain consists of two chains and, of course, they influence each other.

Without going into a detailed and precise mathematical justification, the conditions for physical realizability can be tentatively determined very simply - the second capacitance of the corrective circuit should be less than the first at least 4 times. But it is not worth reducing the capacitance of C5 too much, since at frequencies The specified parameters of the chain will begin to have a strong influence on the capacitance of the installation and the input capacitance of the lamp. I would recommend a minimum value of 1000pF.

Output stage

In addition to signal amplification, another important function is assigned to the output stage - matching with the load. Leaving "alone" a classic resistive stage with an output impedance of several kiloohms with a complex load resistance is completely wrong, and dooms the future owner to endless torment for the selection and comparison of interconnect cables. I want to draw the attention of readers that the capacitance of the interconnect cable will affect not only the frequency characteristics of the output stage itself, but also the frequency correction parameters through the input capacitance of the lamp, which can lead to results that are completely inexplicable at first glance when using cables with different linear capacity. The most suitable

in our case would be a cascade with a dynamic load (SRPP). The cascade successfully combines increased linearity, high gain and low output impedance. Since the operation of such a cascade is described in detail in many publications, I will detain your attention only on the implementation features of this particular scheme. The main difference from the classical implementation is the replacement of the cathode follower with the source follower. *I want to say right away that the use of a source follower did not have a negative effect on the sound qualities of the cascade, I specifically checked this by direct comparison of two versions of the corrector.* The FET follower has the best characteristics, since the slope transistor, even at low currents, is much higher than the steepness of a tube triode. Coefficient the repeater transmission is close to unity, and the equivalent resistance in the anode of the lamp a sufficiently large value is obtained, this made it possible to organize an automatic shift (R13, R14) without shunt capacitor. Although the presence of an unshunted resistor in the cathode circuit introduces local feedback, its depth is very small. (0.3÷0.4dB) and has no significant effect on the parameters of the cascade. If desired, the OS can be turned off by shunting a resistor with a capacitance (C7). Another positive is that the source follower maintains linearity

at lower operating voltages, this made it possible to provide a large output voltage swing at moderate supply voltage.

Technical parameters of the corrector

Gain (1kHz) Recommended input level Input impedance THD (1kHz, Uout=1Vrms) THD (1kHz, Uout=10Vrms) Noise level (not weighted) Overload capacity Maximum output voltage Output impedance Rated load impedance Minimum load impedance Characteristic deviation from the standard (20Hz - 50 kHz)

ÿ 300
1.5÷5mV
47kÿ±1%
0.05% 0.5%
-64dB
+40dB
45Vrms ÿ
280ÿ

47kÿ
10kÿ
±0.1dB

The measurement of the corrector parameters was carried out on a load equivalent of 47kÿ, 75pF when powered by stabilized source with low noise level. The nature of the distortions introduced by the corrector at different output signal levels (1Vrms and 10Vrms) is shown in figures 3 and 4.

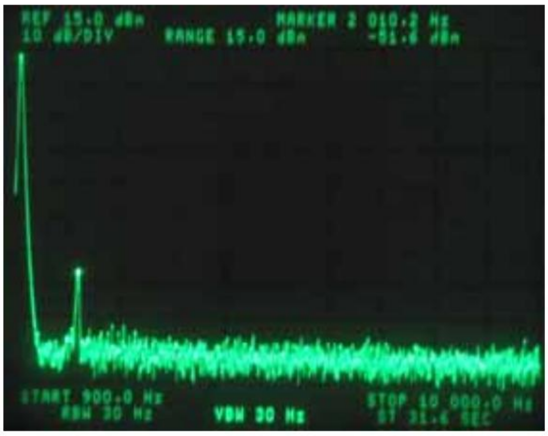

Figure 3

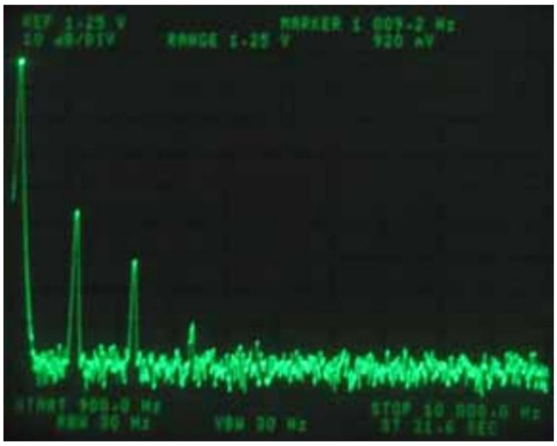

Figure 4

Now we can sum up a small intermediate result that concerns the corrector directly. Although the corrector is positioned as a simple, one might even say, entry-level, its objective characteristics go far beyond this definition. And frankly, he can give odds to many more expensive devices. A certain discussion can be caused not only by an overestimated gain, but in combination with a huge overload capacity and a low level of own noise, this turns into a virtue. The corrector can be directly connected to final amplifiers with low sensitivity, and it is able to successfully work with a wide range of heads with different output levels. The device turned out enough versatile and flexible in use.

Source of power

For a simple corrector, the power supply must also be simple. Therefore, as a base option it is supposed to use standard transformers of the TAN series. For the source, transformers will come that have two filament windings with a permissible current of more than 0.8A and a high-voltage winding with a permissible current of more than 60 mA. It means that the desired anode voltage can be obtained by connecting the secondary windings in series. These requirements fall under many types of transformers with a rated power of more than 30 watts.

The source circuit itself is shown in Figure 5. The values of the resistors R1 and R2 are not indicated and are selected depending on the transformer used to obtain the desired voltage at rated current consumption of the circuit. Two channels of the corrector consume a current through the filament circuit of approximately 0.7A, and through the anode circuit - 0.027A. And one more thing, I want to **really, really** recommend not to try to assemble a power supply on the same chassis with corrector, and make a two-block design. The blocks are connected by a multicore shielded cable, with each voltage supplied by a separate pair of wires.

It is well known that the sound quality significantly depends on the quality of the power source, and here here opens a wide field of activity to increase the overall level of the corrector. Can be on mark the main ways to improve the parameters of the power source.

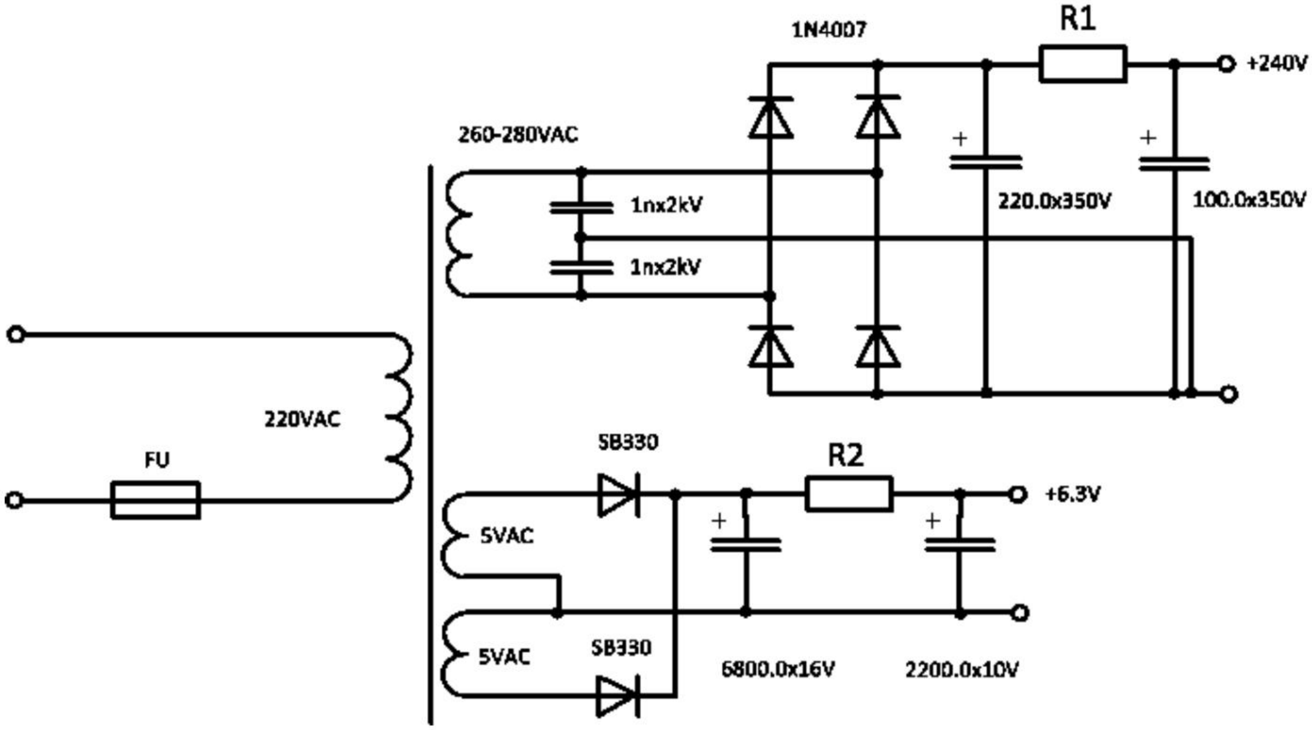

Figure 5

It is advisable to replace the resistor R1 with a choke with an inductance of 10 ÷ 15 G. If you are lucky find a transformer with two suitable identical high-voltage windings, then it is better to make a high-voltage rectifier according to the zero circuit, removing balancing capacitances. A radical improvement in the quality of the power supply and the transfer of the entire design to a higher the level by several steps at once will be given by the use of stabilizers in the filament circuit and anode voltage. To stabilize the filament voltage, you can use a standard three-terminal stabilizer (LM317), and to stabilize the anode voltage - any of the stabilizers described on the

site. The final point in improving the parameters of the source will be the replacement of the solid state rectifier to the kenotron, coupled with all previous improvements. But this will already require the manufacture of a power transformer, and the complexity of the power supply system will be higher than the corrector itself. In general, such a construction can no longer be classified as simple, and the possibility of following this path (although the result is worth it) I leave to the discretion of the readers.

Details, construction, adjustment

The choice of element types mainly depends on the task at hand.

If your main goal is to amaze the people around you with loud audio titles brands, then electrolytic capacities - Black gate; film containers - Solen, Mundorf, Jantzen; resistors: something like Allen-Bradley Carbon-composite from the 50s.

If you enjoy only music, then the choice of component types is significantly wider and more affordable prices.
Nichicon's or Panasonic's low-loss electrolytic power system tanks can, in principle, be started with the very cheap Jamicon and the like. And I'm not sure with everything that you will hear the difference. The rest of the containers, of course, film or mica
(small denominations). Of the old types of containers - FT (have awesome dimensions), K78-2, SGM, K31,

K71. Imported polypropylene (one of the best types - WIMA MKP 4, MKP 10, FKP 1) and poly styrene containers.

Resistors can be used types MOR (ROYALOHM) or their analogues C2-23. good options have resistors of type SFR (ROYALOHM), the use of this type of resistor is preferred. Excellent noise characteristics and high linearity have boron-carbon resistors of the type BLP.

Trimmer resistor - multi-turn, resistors like 3290 ÷ 3296 (Bourns) are suitable, and even better - wire resistor type SP5-2, SP5-3. Lamp sockets are better to use ceramic type PLC-9. I strongly do not recommend using modern Chinese sockets, their only advantage is their beautiful appearance, they hold the lamp poorly and the quality of the contact in the connection is doubtful.

The corrector can be mounted both on a printed circuit board and by surface mounting using part leads and intermediate jointing combs. The power dissipated by the transistor does not exceed one watt, so it can do without an additional cooler. When installing a corrector, you must adhere to the general rules for installing devices with high sensitivity.

efficiency: maximally separate the components related to the input and output circuits, the power supply must propagate towards the signal, use a sufficiently massive conductor for the common wire. The common wire must be connected to the chassis at one point in the area of \u200b\u200bthe input connectors emov.

The corrector must be well shielded, so a solid metal case (of course with blinds) is the best option. If you really want the lamps to be visible or there is a suitable open U-shaped chassis, then the lamps must be closed without fail shield caps. A good option would be to use panels of the PLC-9E type with standard screens. The body (chassis) of the corrector should be provided with soft rubber feet or legs made of thick felt to reduce the microphone effect. Microphone reduction

The effect and parasitic acoustic connections are facilitated by the placement of the corrector in a wooden decorative case (and pleases the eye) and the overall increase in the mass of the structure. The design of the power supply can be arbitrary. Interconnect power cable must be done length of at least 0.5÷0.7 meters to carry the power source away from the corrector and the player vatel.

Establishing a corrector does not cause any particular difficulties, and this requires a single instrument is a multimeter. The setup is divided into two stages.

At the first stage, it is necessary to clarify the values of the resistors R1 and R2 in the power supply. To do this, a resistor R1 is temporarily installed in the circuit, equal to 2 kOhm 2 watts, and R2, equal to 2 Ohm 5 watts. To load equivalents (9.1 kOhm, 10 Ohm) are connected to the output of the power source, and the source is connected to the network at the rated voltage. The voltage across the capacitors after the rectifier is measured (U1) and at the exit. According to the results of measurements, the required value of re is approximately determined. zistor -

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Where, Un and In are the nominal voltage and current at the output of the channel.

You may have to repeat this operation several times, since the stiffness of the rectifier is not taken into account. The final value of the resistor is specified after connecting the corrector. The rated power dissipation of the filter resistor should be 3÷4 times greater than the actual dissipation power dissipated in it.

At the second stage, the corrector operation mode is set. Resistor engine R14 installed is set to the middle position, the corrector is connected to the network, and after several minutes of warming up, a voltage of about 130 is set by resistor R14 at the anode of the lamp VL1: 2. Then the supply voltage is checked, and if necessary, it is corrected by the resistor R1 in the source, and the voltage at the anode of the lamp VL1:2 is re-set. The operation is repeated several times until rated mains voltage, the supply voltage will not be close to 240 volts, and the voltage at the anode of the lamp will not be 130 volts. A deviation of 5-6 volts is quite acceptable. After that, the filament voltage is controlled and its value is corrected, and the voltage at the anode of the lamp VL1: 1 is also checked. The voltage deviation at the anode VL1:1 by ±15% is allowed. On this, the adjustment can be considered completed. After 15÷20 hours of corrector operation (time required to stabilize the parameters of the lamp) it is desirable to adjust the voltage across lamp anode VL1:2.

Conclusion

Of course, to cover the whole range of issues related to the design and manufacture of lamp proofreaders in one article is impossible. I have tried to bring together at least the main questions and to show the biggest pitfalls and I hope that the material presented will be useful to lovers of lamp technology. I want to note that although solid-state devices have their own characteristics, many of the recommendations can be extended to them without any restrictions.

Although the corrector circuit is very simple, and after reading the article it may seem that it is very easy to repeat the device, in fact, everything is not at all like that. All sorts of minor troubles are found from the first step, starting from the lack of the necessary ratings and the dark origin of the components, ending with the need to have a dozen lamps for selection. Another specific feature of the manufacture of a corrector is the need to do everything right and right at once. Assembling the circuit on cardboard and planks is the first big step towards the first big disappointment.

And most likely this successful scheme would have suffered the fate of other designs - a limited number of people would have decided to repeat it, and a few would have brought it to the end, if not for the unexpected support from Ampearl. The company decided to take a chance and, based on this scheme, put on sale a kit for self-assembly. Naturally, this received warm support from my side. This formulation of the question significantly changes the matter, the availability of ready-made high-quality printed circuit boards and a set of parts of guaranteed quality makes it possible to assemble the corrector even for amateurs who do not have high qualifications. In addition, such a set becomes an excellent testing ground for testing the sound qualities of various types of components. And of course, the financial issue is also important here, it is simply unrealistic to purchase a ready-made corrector of this level for 576 hryvnias ($72). It is assumed that the set can be completed with ready-made cases (corrector and source power) and the release of fully finished devices with a very democratic cost.

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