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FLICKER-NOISE. FEATURES, DIVERSITY AND MANAGEMENT

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Abstract. The article refers to the field of research of noise fluctuations or flicker-noises in electronic amplifiers. The variety of flicker-noise in the energy and frequency dimension is shown, that the manifestation of flicker-noise is not limited to ultra-low frequency range, but under certain conditions can extend to medium and high frequencies. Some areas of radio electronics exposed or using flicker-noise properties are illuminated. It is shown that flicker-noises have a limit level of build-up in accordance with the energy and frequency band forming its thermal and fractional noises. It is shown that for electronic amplifiers flicker-noise is impractical to approximate the simplified ratio of 1/f. Methods of elimination or leveling of flicker-noise are given.

Keywords: flicker-noise, 1/f - approximation, fluctuation noise, thermal noise, fractional noise, nonlinearity, drift, displacement, zero component.

Introduction

A previous article [1] was devoted to determining the physical nature of flicker-noises in electronic amplifiers. It has been shown that on the non-linear transition of the transistor, any signals, including thermal and fractional noises, are distorted with an additional zero component. The zero components, which is edifying from non-linearity, integrates, accumulates on the dividing capacitor and is held for the duration of the integration of its chain. The constant potential accumulated on the separation capacitor leads to an additional positive shift of the emitter-base transition, which in turn leads to an increase in the permanent component of the base and corresponding collector's current of the transistor and a proportional increase in the gain. As a result, there is an amplified ultra-low-frequency noise signal or flicker-noise, with all manifestations of random magnitude, as it is formed from accidental heat and fractional noise.

The same can be described differently. The noise brought to the input of the amplifier is separated by the emitter-base transition of the transistor from the cumulative noise generator, the input transistor collector and all subsequent noisy elements of the electrical circuit, up to the load. From the cumulative noise generator, the energy of noise through the emitter-base transition and passive circuits gets to the input dividing capacitor, essentially, is an analog detector. The separation capacitor accumulates a permanent or zero component from the noise detectors that affect the analog detector. The level of accumulated zero component is determined and changed in accordance with the energy of the cumulative noise generator, formed from heat and fractional noise, which is a flicker-noise.

In other words, the impact of the signal on the non-linear element results in the work point drift controlled by this signal by adding its zero component to the electrical power of constant displacement. In the event that the non-linear element, in addition to the electric propulsion force of constant displacement, is affected only by the heat and fractional noise generated by the noise drift of the working point and is a flicker-noise.

The LTspiceXVII technology tool of the American corporation Linear Technology is used [1] to analyze electrical values and characteristics, including noises. This allows you to rely on a reputable technical tool in assessing physical values and processes and not to be distracted from their goals. Noise analysis here is carried out taking into account the noise contribution of all elements of the electric scheme of medium integration, including the contribution of electrical connections. The choice of this tool is additional convenient because it will allow you to check the results without significant resource costs.

1. Features and variety of flicker-noise

In practice, it is not only the physics of the processes that are taking place that is of interest, but also the applied possibilities of its understanding and application. This explains some of the features of flicker-noise based on an understanding of the physics of the processes taking place [1]. Various practical applications including the use of flicker-noise physics are given. An understanding of the varieties and significance of fluctuating noises is formulated.

For further proceedings, it is convenient to use [1, 2] the electric scheme of the amplifier "100W" Fig.1 and its necessary modifications again.

From the original [2], the electric diagram of Fig.1 differs from the change in the face value of the resistor R16, from 1 kOm to 10 kOm. This replacement is necessary because it is noted that the current stabilizer performed on the transistors Q9 and Q10 (with appropriate strapping) after the inclusion of the V1 and V2 voltage is in normal mode of stabilization of the current with some delay of 8-10 mc. Depending on which of the power sources is included first, during this delay, the emitter-base transitions of transistors Q7 and Q8 are exposed to reverse potentials within 43±2 V, which is an order of magnitude higher than the allowable value for a silicon transistor. With the face value of the resistor R16 in 10 kOm, this phenomenon is completely excluded.

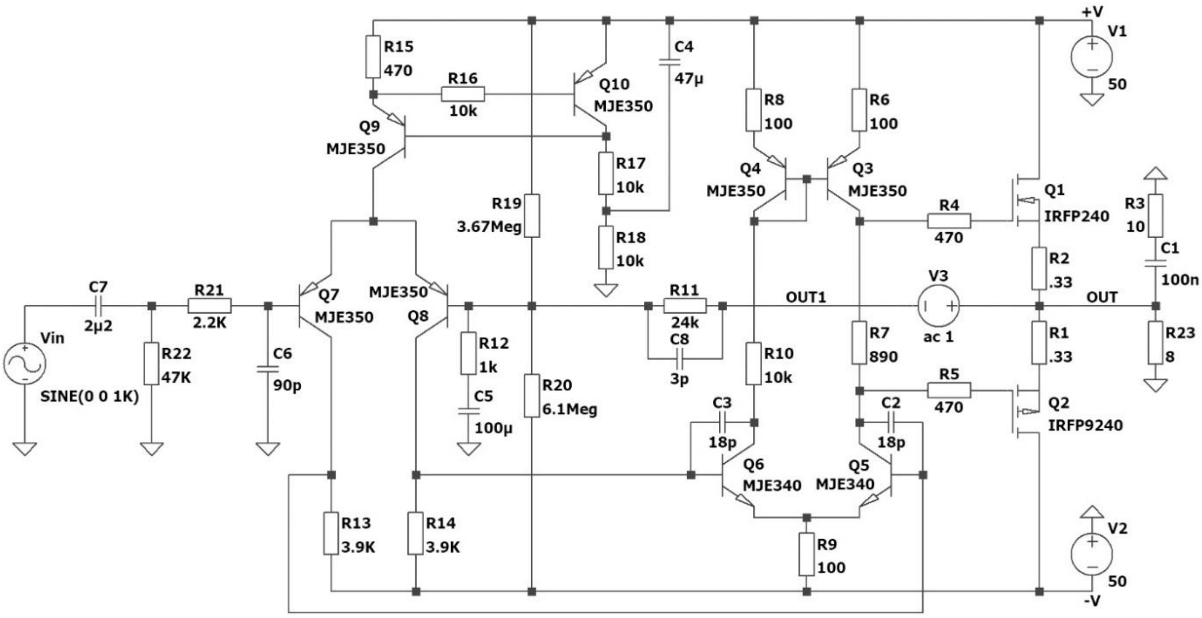

Fig.1. Electrical circuit power amplifier "100W" of Linear Technology.

We modify or modify the electric circuit of the "100W" amplifier, as shown in the Fig. 2 and call it "100WE". Low and upper frequency cuter filters, performed on C5 capacitors for low frequencies and C6 for high frequencies, is excluded here. The denominations of the R19, R20 balance sheets have been changed and R24 has been added, the R12 face denomination has also been changed to 2 kOm, so that the total resistance of the R19, R20, R24 and R12 resistors remains the same value of 1 kOm, for the convenience of the operational calculation of the Ku gain factor (1kOm + R11)⁄1kOm. In the Fig.2 variants of the Ku=3 electric circuit and can be easily modified if necessary.

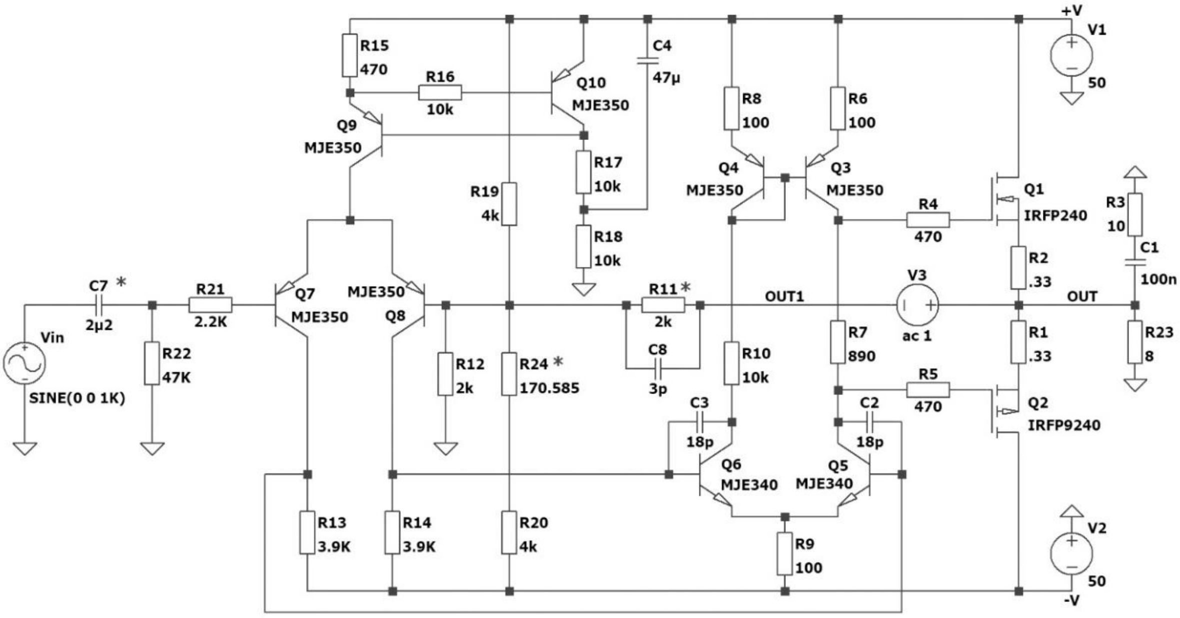

Fig.2. Electric scheme of the "100WE" amplifier.

Again, as in the work of [1, Fig.7] on Fig. 3 Shows a family of "100WE" amplifier noise graphs for different C7 capacitor values, not equivalent to input noise, but noise on the amplifier load. The noise intensity has increased by the Ku=3 gain factor and it is important to take into account that this is noise on load 8Om. The ratio of flicker-noise to total heat and fractional noises remained eleven times.

Now it is appropriate to pay attention to the fact that the measured flicker-noise is very approximated by the linear ratio of 1⁄f, and only on a very small section of the graph. In fact, flicker-noise increases exponentially and further exponentially approaches asymptotically approaching its maximum level, defined in the work of the [1] in accordance with the frequency band and the energy level of thermal and fractional noises. The process of flickering noise occurs for different sizes of the C7 capacitor at different frequencies.

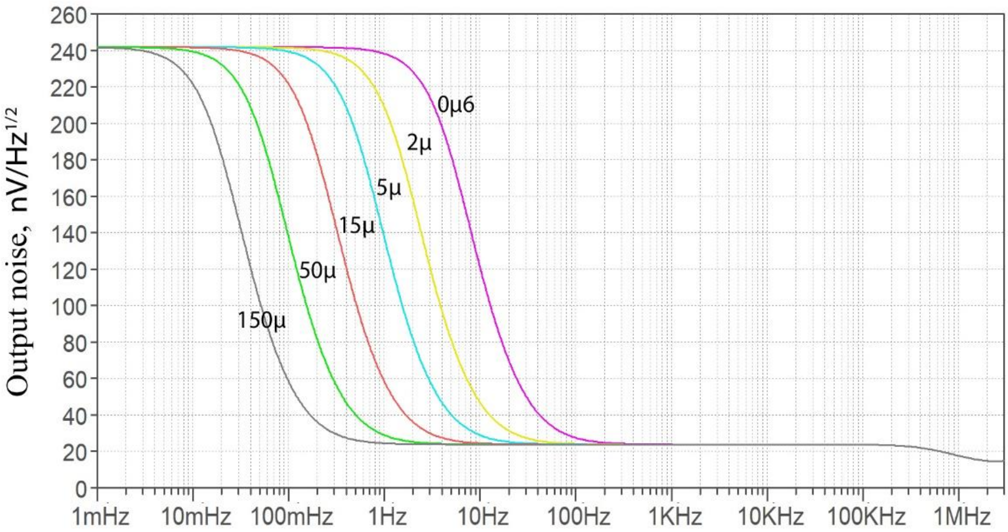

Fig. 3. "100WE" amplifier noise graph for different C7 values.

To form a flat section of flicker-noise, it is necessary and sufficient for the phase shift on the C7 capacitor to be close to 0^{O} at the corresponding frequencies of the analyzed range. Inside the 0^{O} - 90^{O} phase shift interval, there is a non-linear change in flicker-noise levels from maximum to thermal and fractional white-noise levels. Where the phase shift of the C7 capacitor is close or equal to 90^{O}, there is no flicker-noise. It is impossible to integrate the dynamic constant component of thermal and fractional noise, as the reactive resistance of C7 at these frequencies is too small, excludes the accumulation of asymmetric charge on the linings of the capacitor.

We will reduce the size of the capacitor C7 and get on Fig. 4 extended family of flicker-noise graphics. On Fig. 5 Shows the noise graph of the amplifier "100WE" for only one magnitude capacitor C7 = 0n001, here the cumulative white noise contains 92% flicker-noise and only 8% is accounted for by thermal and fractional noises. It's basically white flicker-noises in the frequency band over a megahertz. Fig.6 shows an oscillogram of this noise.

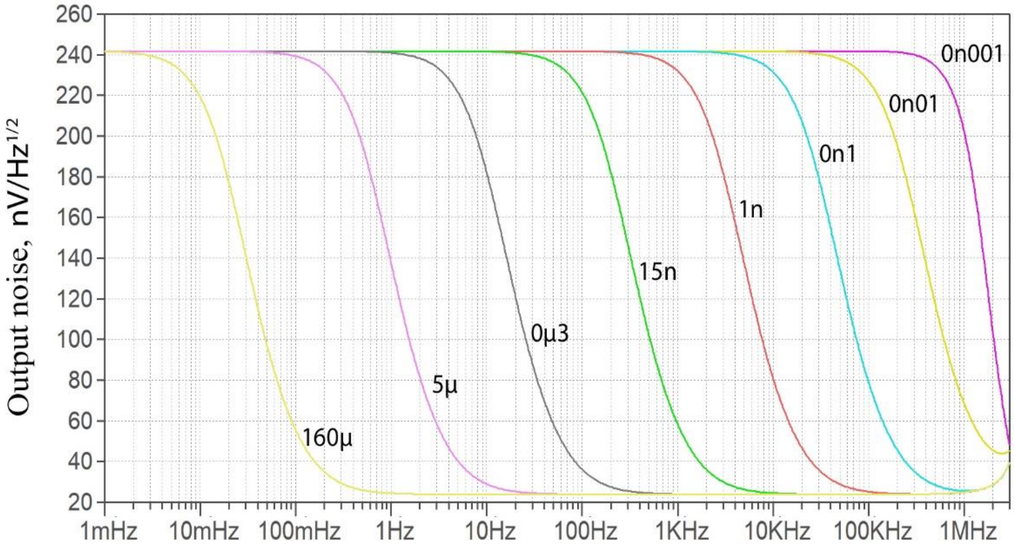

Fig.4. Extended amplifier noise graph for different C7 values.

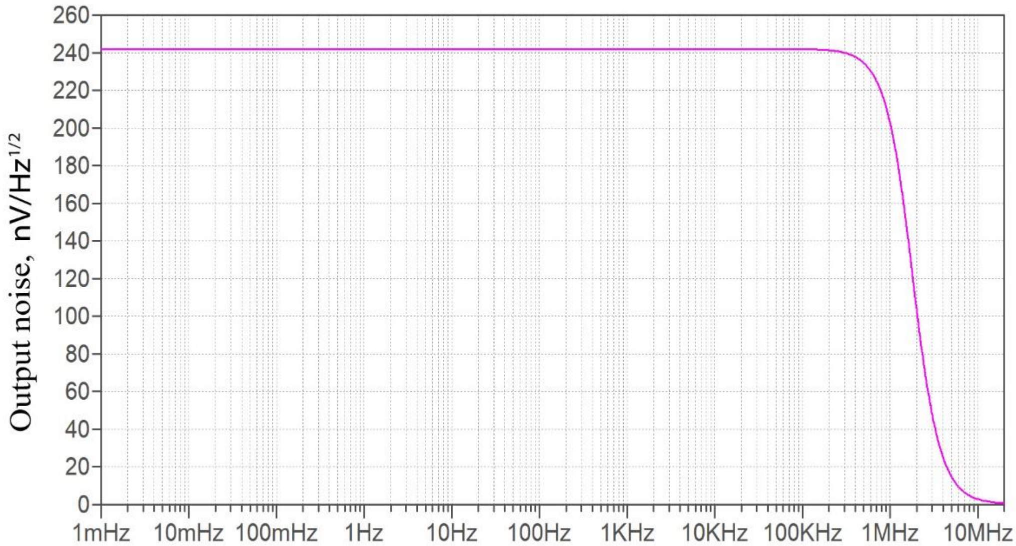

Fig. 5. "100WE" amplifier noise graph for C7 = 0n001.

We will increase the gain factor to Ku=50, for which in the amplifier "100WE" we will replace the denominations of the adjustment elements by the following values: R24=113.67495213 Om; R11=49 kOm. Again we'll get a graph of rice noises Fig.7 “100WE” amplifier.

Now we can state the fact that we have got a completely competitive white noise generator, which consists of 92% of fluctuating noises or flicker-noises. Fig. 8 provides the information about the operation of such a white noise generator in the conditions of changes in the temperature of the environment from -30 to +110 degrees Celsius, with a step of 20 degrees Celsius.

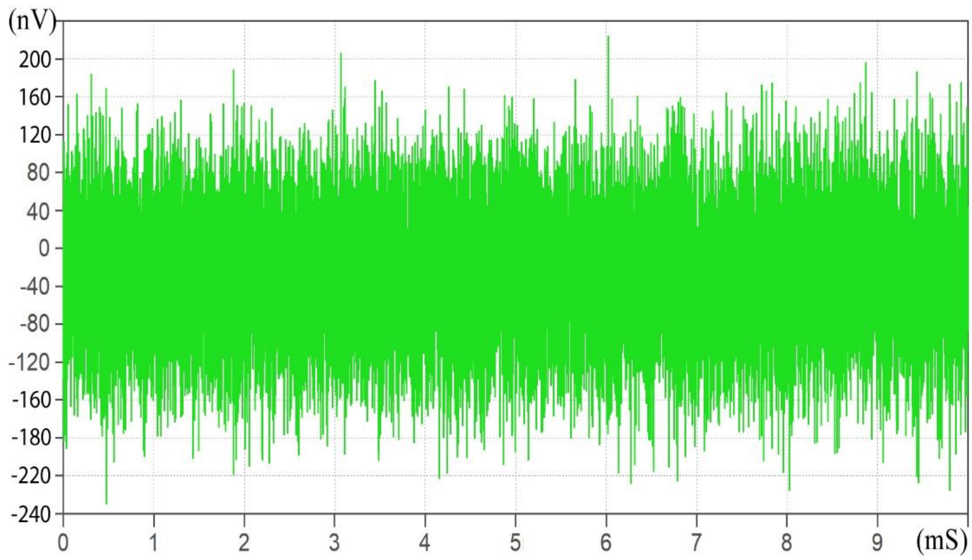

Fig.6. Oscillogram of total white noise with 92% flicker-noise and 8% heat and fractional noise.

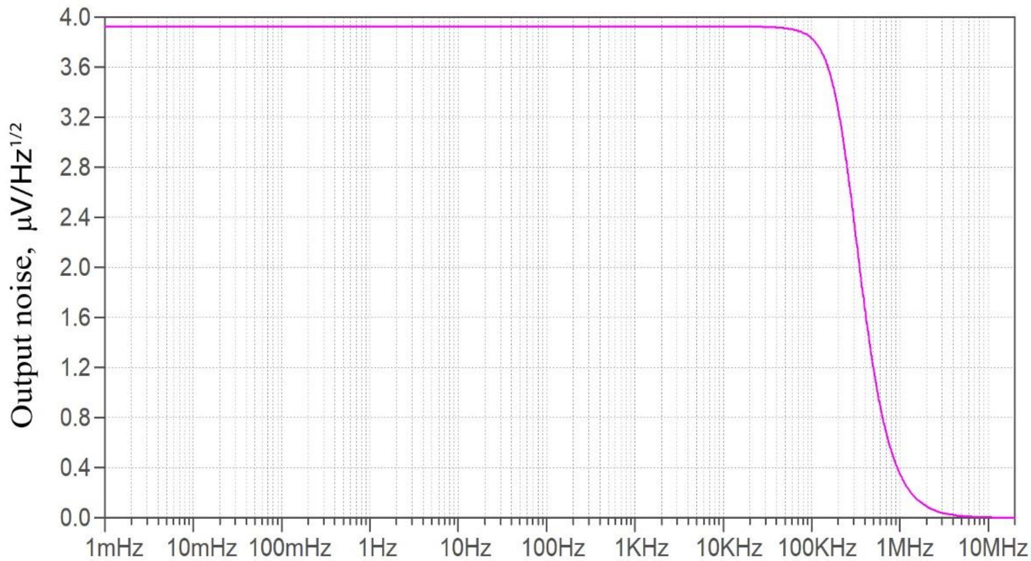

Fig.7. White noise of a fluctuation noise generator.

It should be noted that such noise generators intuitively, without understanding the physics of the formation of such broadband white noise were built for their needs by developers of different organizations back in the 70÷80 years of the last century. Technical solutions with the actual use of broadband flicker-noise can also be found in the works [3-5].

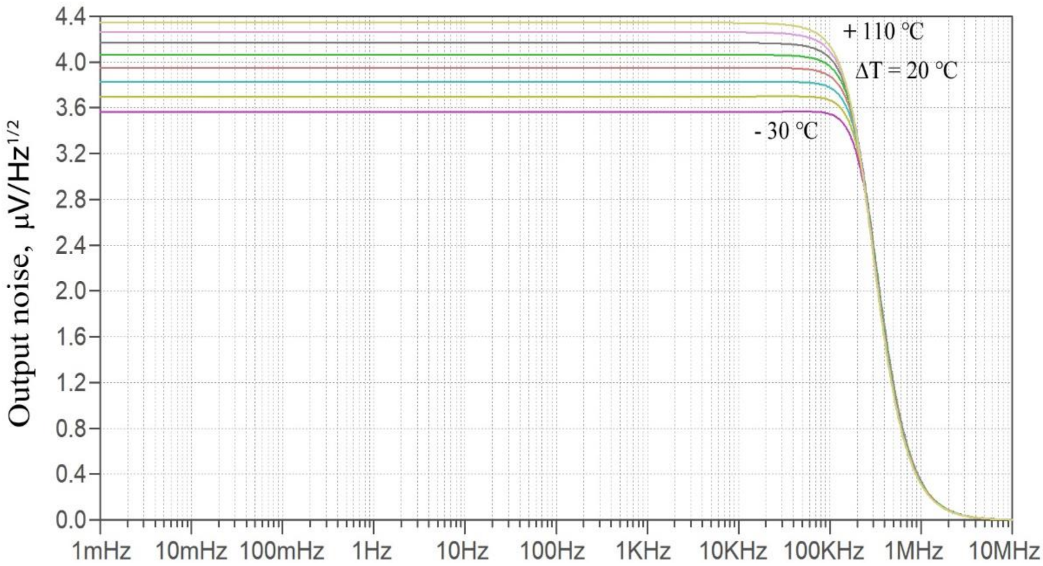

Fig.8. White noise of a fluctuating noise generator in the range of temperatures from -30 to +110 degrees Celsius.

Understanding the physics of flicker-noise [1] and signal-driven drift of electronic devices helps solve some of the challenges of designing, implementing, and regulating various electronic devices. Understanding the fact and numerical definition [1, 6] of the fact that the impact of the signal on the non-linear element leads to the signals controlled drift of the work point by adding its zero components to the electrical power of constant displacement has already helped [6] to understand some issues of the stability of electronic devices. Previously, in my work [6], I was able to obtain a simple and exceptionally useful dependence $\alpha \geq k$ for the condition of compliance with the Rays-Hurwitz criterion in low-power amplifiers with deep positive feedback, where α is a stabilization factor for the constant component of the transistor collector's current; k - signal regeneration factor. The results of the $\alpha \geq k$ ratio were fully confirmed experimentally in a wide range of temperature, constructive and other destabilizing factors.

We believe that in the future, the developers of electronic devices, based on an understanding of the physics of flicker-noise and controlled fluctuations of the offset point [1, 6], will solve many problems that are not solvable earlier, and some tasks will be significantly simplified.

Understanding the physics of flicker-noise and signal-driven drift of electronic devices helps solve some of the challenges of designing, constructing, and regulating electronic devices. If necessary, you can get rid of the flicker-noise, which will be shown next.

2. Flicker-noise control

To explore the possibility of getting rid of flicker-noise, we use the "100W" amplifier with some changes in the face value of its elements. We will receive (see Fig.9) a family of output noise charts of the "100W" amplifier for the conditions of application of different denominations of the C7 capacitor capacity.

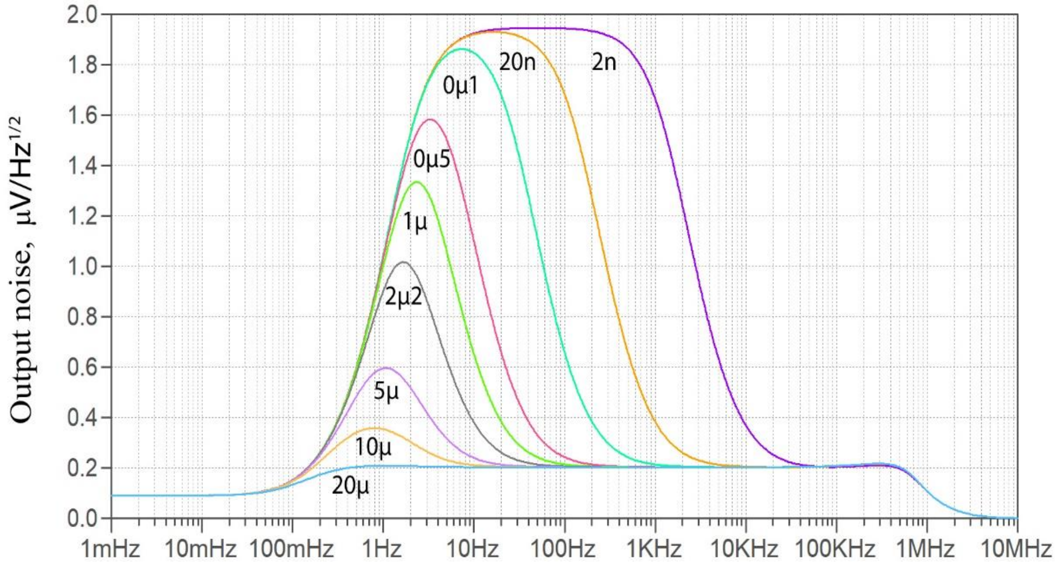

Fig. 9. Output noise graphs of the "100W" amplifier for different C7 values.

We will increase the C5 capacity tenfold to 1000 μF and re-analyze the flicker-noise for different denominations of the C7 capacitor capacity, which is reflected in the graph of Fig.10. The left boundary of the flicker-noise graphics family has shifted one order to the lower frequencies. If earlier on Fig. 9, flicker-noises are completely leveled at the C7 face value of 20 μF, now even the C7 face denomination at 160 μF does not reduce flicker-noise completely.

The left front of the frequency limitation of the flicker-noise family forms the integral chain R12,C5. It simply crushes the lower frequencies, including flicker-noise, if it falls into the suppression zone. The right-hand front of the frequency limitation of the flicker-noise family forms the integral chain R22,C7. When the constant times of these integral chains approach each other, a bell-shaped flicker-noise is formed when they overlap, the flicker-noise is leveled.

For example, to eliminate flicker-noise in the "100W" amplifier, it is enough to increase the value of the C7 capacity to 21 μF, or without changing the capacity of the C7 - to reduce the face value of the C5 capacity to 10.5μF. In one and the other case, we get a graph where the flicker-noise is completely leveled.

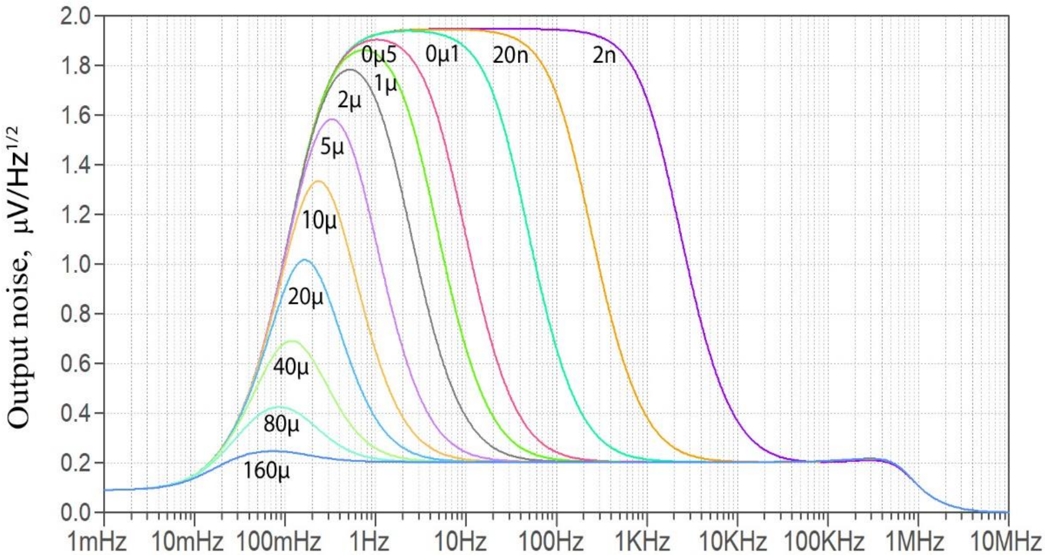

Fig.10. Graph of the equivalent input noise of the "100W" amplifier for different C7 and C5=1000μF values.

Fig.11 shows a family of "100W" amplifier noises at C7=21μF and different gain factor values, for which the R11 denomination changes. It demonstrates the work of a low-frequency cutter filter in the flicker-noise area. In this area, the gain factor always remains close at different values of the total Ku.

This method allows the amplifier to completely level the flicker-noises for the ratios of the overall gain of large or equal ratios of thermal and fractional noises brought to the level of flicker-noise brought to the input.

I'll call it the first method of leveling flicker-noise.

The second method, the most radical, is to get rid of the dividing container, to make the amplifier galvanic, as it is done in the amplifier "100WG" (see Fig.12). In such an amplifier, flicker-noises are completely absent at any allowable temperature and any allowable gain factor (see Fig.13). There is no element for the accumulation of zero components, formed on nonlinear heat and fractional noises; accordingly there is no noise drift of the working point or otherwise flicker-noise.

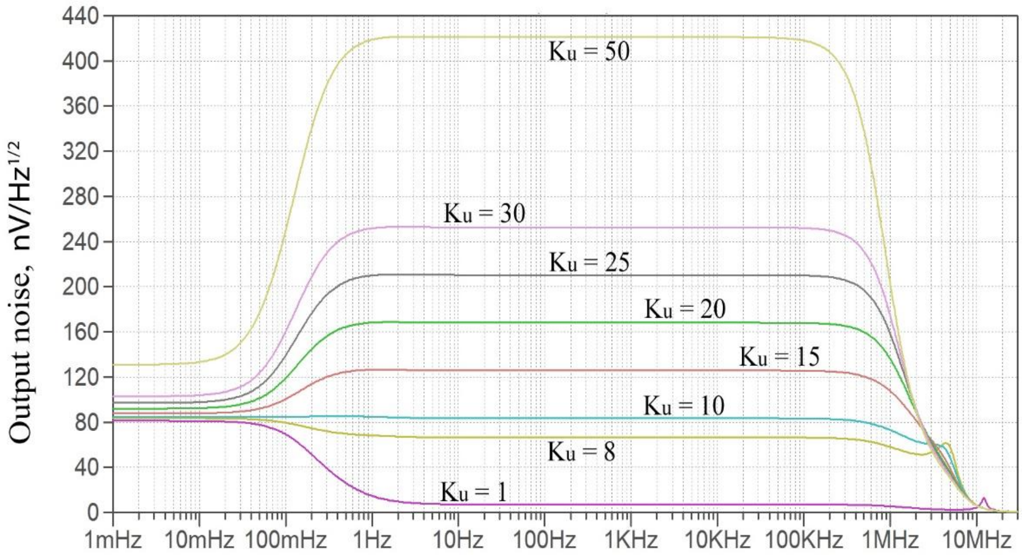

Fig.11. "100W" amplifier noise graphs for different Ku from 1 to 50.

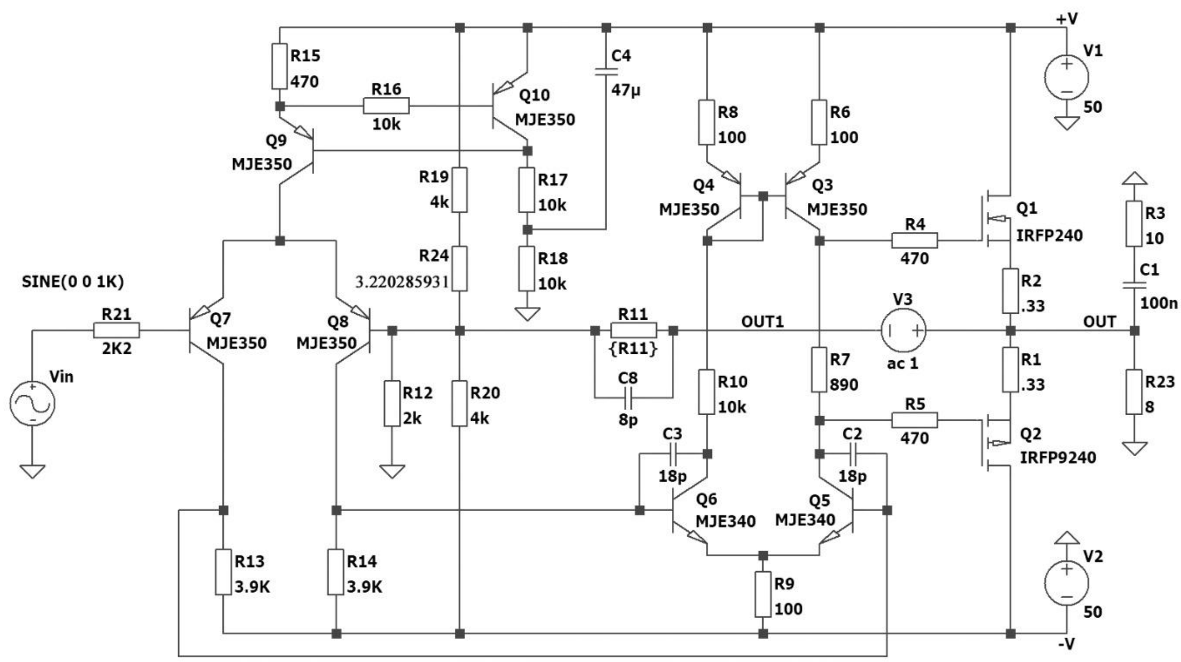

Fig.12. Galvanic amplifier "100WG."

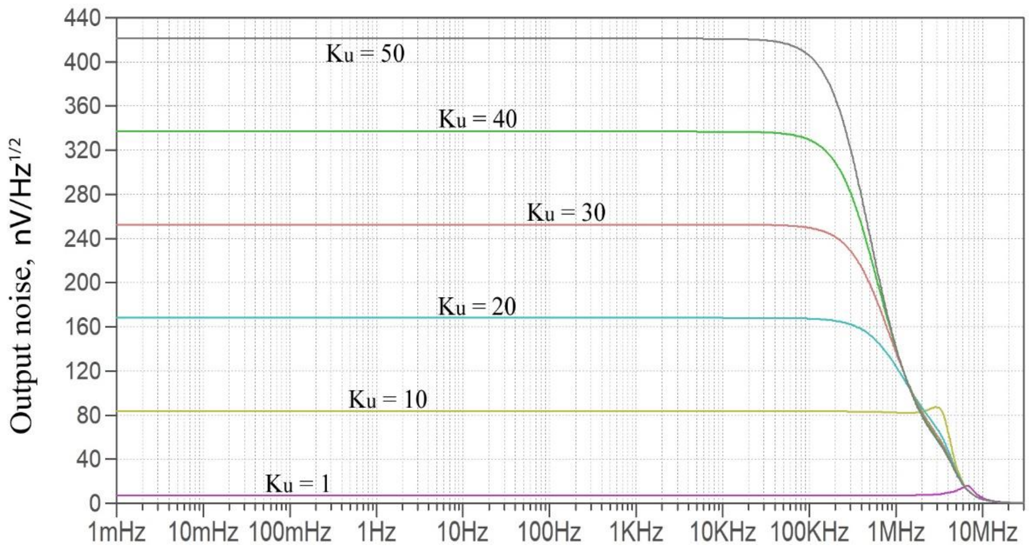

Fig.13. "100WG" amplifier noise graphs for different Ku from 1 to 50.

The third method is that instead of the C7 dividing container, the “100WL” amplifier uses a dividing transformer, as shown in Fig.14. In this case, in displacement voltage chains, as in the previous case, there is no zero-component accumulation element and no necessary conditions [1] for the formation of flicker-noise, as confirmed by the charts Fig.15.

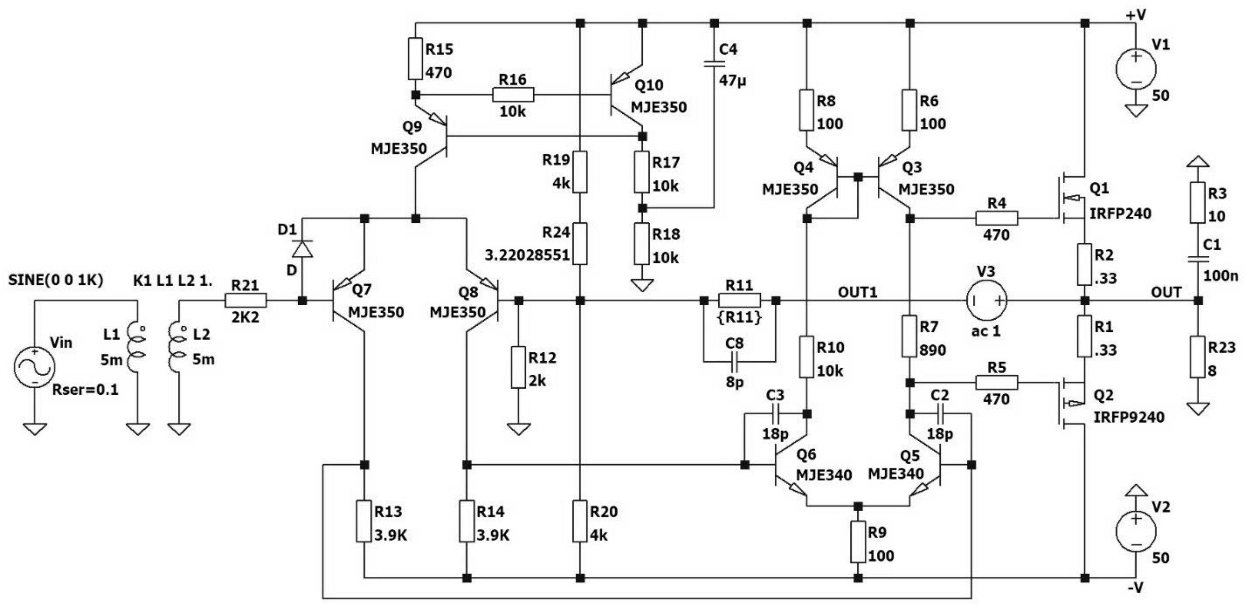

Fig.14. "100WL" amplifier with a dividing transformer.

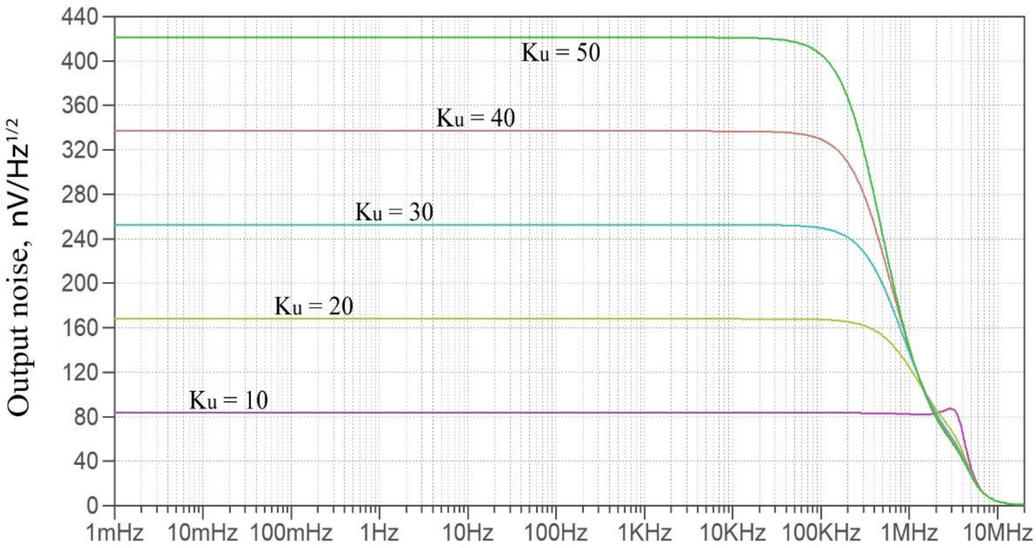

Fig.15. 100WL amplifier noise graphs for different Ku.

You can also offer a fourth option to get rid of flicker-noise, and with the preservation of the C7 dividing container, as shown in Fig.16 for the electric circuit of the amplifier "100WQ". Here, the L1 inductivity blocks the constant component of the transistor's thermal and fractional noises of the transistor Q7. The zero components from the thermal and fractional noise charges the lining of the C7 capacitor, but does not lead to the drift of the transistor's working point, but is blocked by a throttle. As a result of throttle locking, flicker-noise is not formed.

Fig.17 shows a graph of the equivalent input noise of the “100WQ”. It is noteworthy that the equivalent input thermal and fractional noises of this amplifier are four times lower than in the previous (7.1÷8.2 nV/Hz$^{1/2}$) electrical circuits. You can clearly see the bypass effect of throttle on flicker-noises. Fig.18 shows a family of output noise charts for the 1 to 50 Ku gain ratios. In the entire frequency lane, with the gain rates of large units, the level of output noise is less than twice as much as in previous amplifiers. There are no flicker-noises in the “100WQ” amplifier.

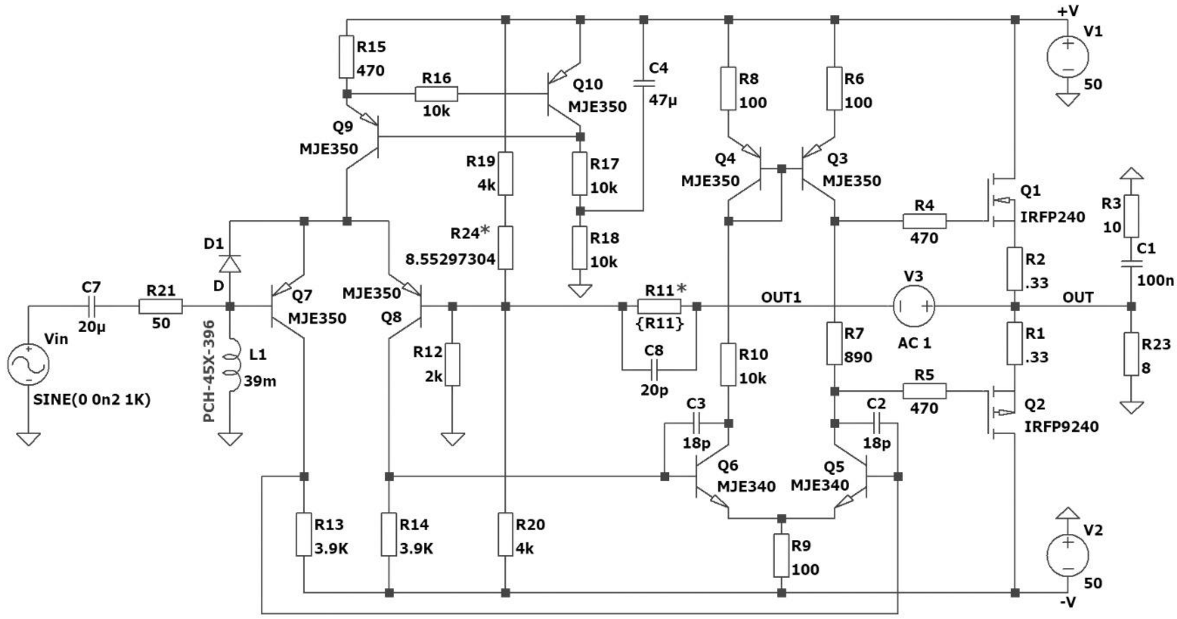

Fig.16. Electric scheme of the "100WQ" amplifier.

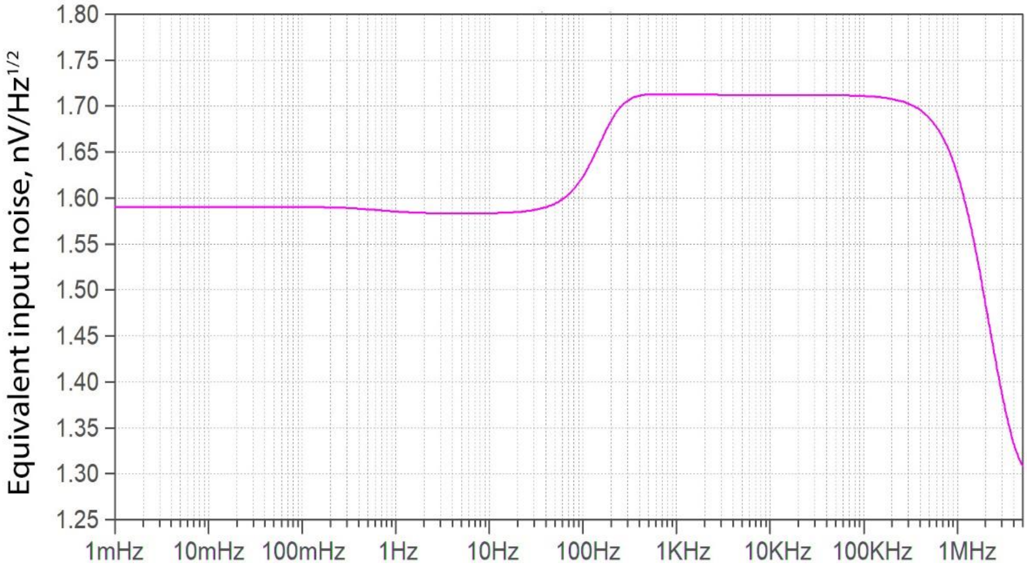

Fig.17. The graph of the equivalent input noise of the "100WQ" amplifier.

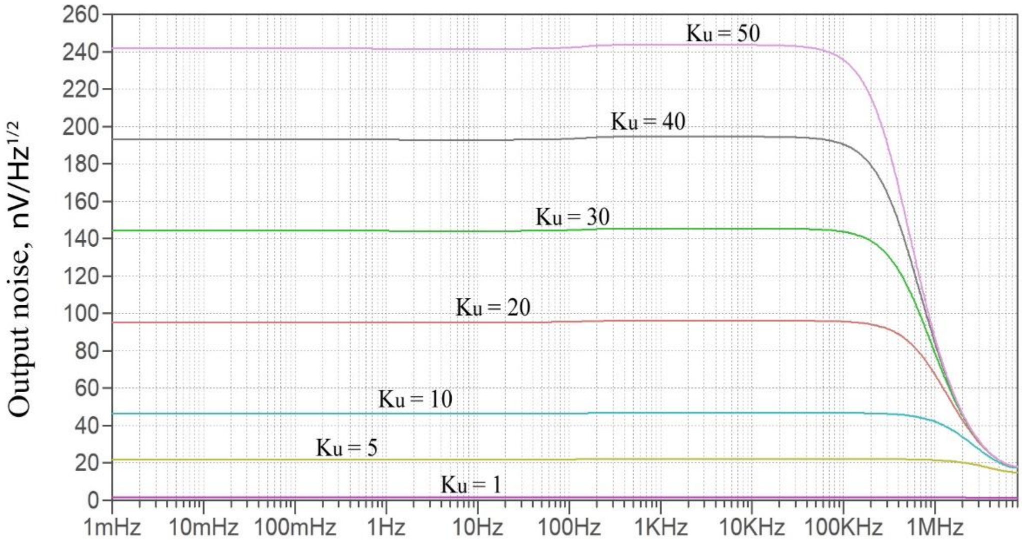

Fig.18. Noise graphs of the "100WQ" amplifier for different Ku.

Conclusions

The four methods shown to influence flicker-noise are based on the application of understanding [1] of its physics. Undoubtedly, it is possible to develop and present additional technical methods and methods of impact on the level of flicker-noise, both for the purpose of avoiding its manifestation, and for the purpose of its increase and application in special devices. There are significant opportunities to apply the knowledge gained in the field of study and construction [6] of the specified stability and other parameters of various electronic systems of amplification, modulation and other signal processing.

The article shows the diversity of the flicker-noise form in the energy and frequency dimension. Some areas of radio electronics exposed or using flicker-noise properties are illuminated. It is shown that the manifestation of flicker-noises is not limited to ultra-low frequency range, but can spread to medium and high frequencies. It is shown that flicker-noises have a limit level of build-up [1] in accordance with the energy and frequency band forming its thermal and fractional noises. It is shown that for electronic voltage amplifiers and power, flicker-noise cannot be approximated by a simplified ratio of 1 ⁄ f.

Methods of elimination or leveling of flicker-noise are given.

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