Registration and Measurement of Low Alternating Voltages

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***Abstract*— The article describes the selective low – noise amplifier for the measurement of low alternating voltages with value of one to tens nanovolts. The frequencies at which the measurements are made switch discretely in the range 5Hz … 20 kHz.**

Keywords—method of measuring ; low electric signals ; selective amplifier

I. Introduction

Scientific experiments often require us to register and measure low electric signals. As a rule, alternating voltage amplifiers are used to do this. In order to increase sensitivity of an amplifier, it is necessary to reduce its own noise. Therefore they are often designed as narrow- band, registering signals of certain frequency. Besides, special circuit elements are used in input steps – principally low noise chips or transistors [1]. In this article we offer a short description of a selective amplifier with discrete switch of gain frequencies.

II. Construction of amplifiers

The amplifier consists of two blocks: a preamplifier with a voltage gain coefficient K ≈ 30, and a main narrow – band amplifier with a gain coefficient K = (3…5) x 10^4 for frequencies in the range of 5 Hz … 20 kHz.

Preamplifier block is made in a screened box, separate from the main amplifier. In the input step (OP1 – see Fig.1) an operational amplifier with ultralow noise voltage AD797 is used. Typical value of the input-referred spectral noise density at the frequency 1 kHz for it is D = 0.9 nV/$\sqrt{Hz}$. Starting from frequency 100 … 200 Hz, this value starts to increase and at frequency of 10 Hz this parameter is already twice as big [2]. From the input step a signal is given on the buffer-follower (OP2). As well as all other steps, it is based on the low noise operational amplifier TS921. The preamplifier box also contains its power supply, which consists of eight AAA batteries.

In certain cases it is desirable for the input step to have low input resistance R. Input resistance may be changed by means of S1 switch. When the switch is in top position, OP1 works in regime of noninverting amplifier (R = 100 kΩ). With a switch in lower position it works as an inverting amplifier (R = 10 Ω) [3].

From a buffer output signal is given on an input of the main selective amplifier. Operational amplifiers of this block work from an unipolar power supply. For this noninverting inputs of operational amplifiers are at the potential of +6 V. Selective gain at the certain chosen frequencies from the mentioned range is provided via gain step on OP3. The feedback network of this operational amplifier is a double T – bridge [4]. By means of the S2 switch it is possible to connect 2T-bridges aimed at certain resonant frequencies. For our specific goals we used five discrete frequencies: 6.4 Hz; 23.2 Hz; 160 Hz; 2.30 kHz and 11.00 kHz (values of elements of the bridge on 23.2 Hz are given in Fig.1)

Figure of merit Q of the entire resonance

curve is calculated by the following formula:

$$Q = f / \Delta f$$

where Δf means bandwidth and f - the center frequency. The bandwidth Δf is taken at the level 0.7 of the maximum gain of center frequency [4]. In our case, for the purpose of ensuring sufficient stability of gain the value Q was chosen as not too high. For all applied frequencies it is approximately equal 40 … 60.

The maximum gain of the device is (0.9…1.5) x 10^6. The gain is controlled by a potentiometer before the last stage (see Fig.1). The maximum output voltage of the amplifier without visible distortion sine wave on the oscilloscope is 3.3 V.

In the feedback circuit of the preamplifier wirewound resistors are used. The same applies to the resistors of the voltage dividers at the input of the operational amplifier OP3. Tantalum capasitors value of 4.7 μF and ceramic capasitors value of 0.1 μF are used in the preamplifier. Elements 2T-bridges are selected with accuracy at least 1%. Types of capacitors and resistors in these bridges must ensure temporal stability of their values.

The absolute value of input-referred voltage noise U_n is the following:

$$U_n = D\sqrt{\Delta f} = D\sqrt{f/Q}$$

From this we see that for the same Q and the spectral noise density D voltage U_n will increase proportionally to the root of frequency f.

III. Conclusion

Schematically the offered amplifier is very simple and easy to reproduce. Own noise of the whole amplifier is low. At the chosen frequencies it allows to register and measure signals with voltage of one to tens nanovolts. For example, in our case, with a frequency of 23.2 Hz and bandwidth of 0.45 Hz the measured input noise voltage is 1.1 nV. With increase in frequency, at which measurements are performed, this voltage increases.

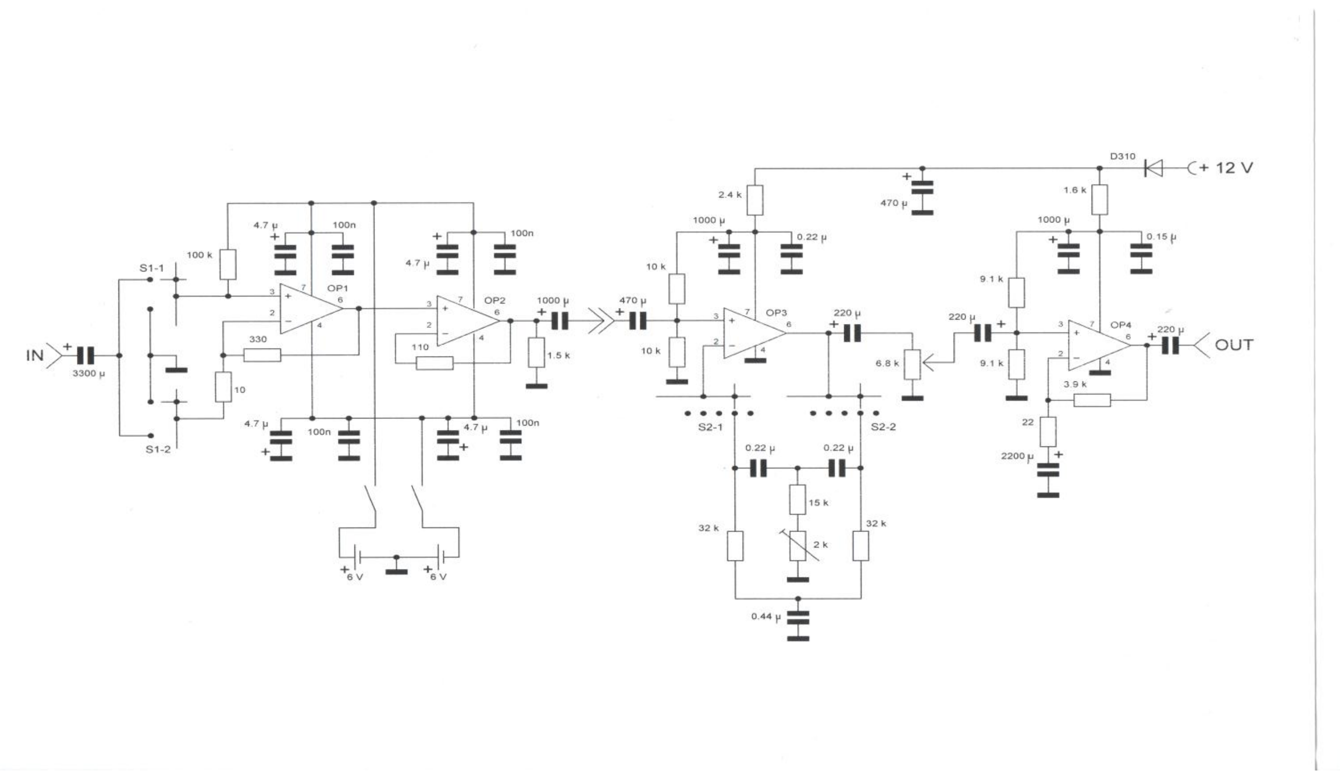

Fig.1 Electrical circuit of the amplifier

You also need to remember that it is a short-circuit input noise voltage. In practice, often need to take into account the thermal noise voltage of the resistance of the source.

References

[1] P.Lee. Low Noise Amplifier Selection Guide for Optimal Noise Performance.

www.analog.com /AN-940/.

2] Ultra low Distortion, Ultra low Noise Op Amp Data Sheet AD797. www.analog.com/static/imported files/data_sheets/AD797.pdf

[3] P.Horowitz and W. Hill. The Art of Electronics. Cambridge university press. 1980.

[4] J.E.Fisher and H.B.Gatland . Electronics – from Theory into Practice. Pergamon Press Ltd. 1976.